

How Strong Is The Repulsive Force Exerted On Two Point Charges That Each carry 1.0 E-6 C Of Negative

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Understanding the magnitude of electrostatic forces between charged particles is fundamental in physics and engineering. In particular, evaluating the repulsive force between two point charges provides insight into the behavior of charged particles in various scenarios, from atomic scale interactions to macroscopic electrical systems. This article explores how to determine the strength of the repulsive force exerted on two point charges, each carrying a charge of 1.0 microcoulomb ($1.0 \times 10^{-6} \text{ C}$), and discusses the factors influencing this force, including the distance between the charges.

Fundamentals of Electrostatic Force

Before diving into calculations, it is essential to comprehend the basic principles governing electrostatic forces.

Coulomb's Law

The force between two point charges is described by Coulomb's Law, formulated by Charles-Augustin de Coulomb in 1785. The law states:

- 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).
- The force is inversely proportional to the square of the distance (r) between the charges.
- The force acts along the straight line connecting the two charges.

Mathematically, Coulomb's Law is expressed as:

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

where:

- F = magnitude of the electrostatic force (in newtons, N)
- q_1, q_2 = magnitudes of the charges (in coulombs, C)
- r = distance between the charges (in meters, m)
- k_e = Coulomb's constant, approximately $8.9875 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$

Applying Coulomb's Law to Two Negative Charges

In our scenario, both charges are negative—each carrying (-1.0×10^{-6}) C. The magnitude of the charges is the same, but their negative signs indicate the nature of the charges. Since Coulomb's Law depends on the absolute value of the product of the charges, the force's magnitude remains unaffected by their signs; however, the nature of the force (attractive or repulsive) depends on the signs.

Repulsive Nature of Like Charges

- When both charges are of the same sign (both negative), the force is repulsive.
- The charges tend to push each other apart.

Calculating the Repulsive Force

To determine the strength of the repulsive force, we need to know:

1. The magnitude of each charge ((q_1, q_2))
2. The distance between the charges ((r))

Suppose we are given a specific separation distance; for example, 0.1 meters. We can then proceed with the calculation.

Step-by-Step Calculation

Given:

- $(q_1 = q_2 = -1.0 \times 10^{-6} \text{ C})$
- $(r = 0.1 \text{ m})$

The magnitude of the force:

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

Calculate:

$$|q_1 \times q_2| = (1.0 \times 10^{-6}) \times (1.0 \times 10^{-6}) = 1.0 \times 10^{-12} \text{ C}^2$$

Plug into Coulomb's Law:

$$F = 8.9875 \times 10^9 \times \frac{1.0 \times 10^{-12}}{(0.1)^2}$$

$$F = 8.9875 \times 10^9 \times \frac{1.0 \times 10^{-12}}{0.01}$$

$$F = 8.9875 \times 10^9 \times 1.0 \times 10^{-10}$$

$$F = 8.9875 \times 10^{-1}$$

$$F \approx 0.899 \, \text{N}$$

Therefore, the repulsive force exerted on each charge when separated by 0.1 meters is approximately 0.899 newtons.

Factors Influencing the Magnitude of the Force

While the calculation above assumes a fixed distance, several factors can influence the strength of the electrostatic force in real-world scenarios.

1. Distance Between Charges

- The force varies inversely with the square of the distance.
- Doubling the separation distance reduces the force to a quarter.

2. Magnitude of Charges

- Larger charges produce stronger forces.
- For example, increasing each charge to $(2.0 \times 10^{-6}) \, \text{C}$ would quadruple the force.

3. Medium Between Charges

- Coulomb's Law in vacuum (or air) uses (k_e) .
- In other materials, the dielectric constant (ϵ_r) reduces the force:

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

- Higher dielectric constants weaken the force.

Practical Examples and Applications

Understanding the magnitude of electrostatic forces is vital across various fields.

1. Designing Electrostatic Equipment

- Components like capacitors rely on controlled electrostatic forces.
- Ensuring precise distances between charged plates is critical.

2. Particle Physics and Atomic Interactions

- Coulomb's Law helps predict forces between charged particles at atomic levels.
- Influences how atoms bond and interact.

3. Electrical Safety Measures

- Awareness of electrostatic forces assists in designing safety protocols to prevent static discharge.

Limitations and Considerations

While Coulomb's Law provides a straightforward method for calculating electrostatic forces, it has limitations.

1. Point Charge Assumption

- The law assumes charges are point-like.
- For extended charges, integration over the charge distribution is necessary.

2. Static Charges

- The law applies to stationary charges.
- Moving charges introduce magnetic effects not accounted for here.

3. Medium Effects

- As mentioned, the medium between charges alters the force.
- In practice, accounting for dielectric properties is essential.

Conclusion

The strength of the repulsive force between two point charges each carrying 1.0 microcoulomb (1.0×10^{-6} C) is predominantly determined by their separation distance and the medium they are in. Using Coulomb's Law, at a separation of 0.1 meters, the force is approximately 0.899 newtons, illustrating a

significant repulsive interaction at microscopic distances. Understanding these principles enables scientists and engineers to design systems that harness or mitigate electrostatic forces effectively. Whether in the development of electronic components, atomic physics research, or safety protocols, comprehending the magnitude of electrostatic interactions remains fundamental to advancing technology and scientific knowledge.

Frequently Asked Questions

What is the magnitude of the repulsive force between two point charges each carrying 1.0×10^{-6} C and both negatively charged?

The magnitude of the force can be calculated using Coulomb's law: $F = k |q_1 q_2| / r^2$, where $k \approx 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$. Without the distance (r), the exact force cannot be determined, but the formula applies for any given separation.

How does the distance between the two negative point charges affect the strength of their repulsive force?

The repulsive force is inversely proportional to the square of the distance between them ($F \propto 1/r^2$). As the distance increases, the force decreases rapidly; as it decreases, the force increases significantly.

If the two charges are placed 0.05 meters apart, what is the magnitude of the repulsive force?

Using Coulomb's law: $F = (9.0 \times 10^9) (1.0 \times 10^{-6}) (1.0 \times 10^{-6}) / (0.05)^2 = 3.6 \text{ N}$. So, the repulsive force is 3.6 newtons.

Are the two charges attracting or repelling each other, and why?

They repel each other because both charges are negatively charged, and like charges repel according to Coulomb's law.

What role does Coulomb's law play in determining the force between these two charges?

Coulomb's law provides the quantitative relationship for calculating the magnitude and direction of the electrostatic force between two point charges based on their magnitudes and separation distance.

Can the repulsive force between these charges be zero? Under what circumstances?

The repulsive force can be zero only if the charges are infinitely far apart ($r \rightarrow \infty$), which is not

practical. Otherwise, as long as the charges are finite and separated by a finite distance, the force is greater than zero.

How does the magnitude of each charge influence the repulsive force between them?

The force is directly proportional to the product of the magnitudes of the charges. Doubling either charge doubles the force; halving either charge halves the force.

What is the significance of the negative sign of the charges in the context of the force magnitude?

The negative sign indicates the charges are negatively charged, but in Coulomb's law, we use the absolute values of charges to compute magnitude. The negative sign affects the direction, indicating repulsion rather than attraction.

If the charges were positive instead of negative, how would the force change?

The magnitude of the force remains the same, as Coulomb's law depends on the absolute values of the charges. However, the nature of the interaction would be attraction if the charges are opposite, or repulsion if both are positive, which in this case would still be repulsive.

What physical principles explain why like charges repel each other with a force proportional to the product of their charges?

This behavior is explained by Coulomb's law, which is a fundamental principle of electrostatics stating 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. It reflects the nature of electric charges and the electric field they generate.

Additional Resources

Repulsive Force Between Two Point Charges Carrying 1.0×10^{-6} C of Negative Charge: An In-Depth Analysis

Understanding the magnitude of the repulsive force exerted between two point charges is fundamental in electrostatics, a branch of physics that explores the interactions between electrically charged particles. When both charges are negative and carry a charge of 1.0 microcoulomb (1.0×10^{-6} C), the question arises: How strong is the repulsive force between them? This article delves into the principles governing electrostatic forces, examines the factors influencing the magnitude of the repulsive force, and provides a comprehensive analysis of the specific case where both charges are identical and negative.

Fundamentals of Electrostatic Force

What is Coulomb's Law?

Coulomb's Law is the cornerstone of electrostatics, describing the force between two point charges. Formulated by Charles-Augustin de Coulomb in the 18th century, the law states that:

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

where:

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

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

Nature of the Force: Repulsive or Attractive?

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

- Like charges (both positive or both negative) repel each other.
- Opposite charges attract each other.

In our case, both charges are negative, so they exert a repulsive force on each other.

Analyzing the Specific Scenario

Given Data:

- Charge of each point charge: $q_1 = q_2 = -1.0 \times 10^{-6} \text{ C}$
- Nature of charges: Negative
- Distance between charges: variable or specified?

Note: To compute the exact magnitude of the force, the distance r must be known. Since the problem statement does not specify r , we will analyze the force as a function of r and provide typical values for illustrative purposes.

Calculating the Force

Using Coulomb's Law:

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

Plugging in the known charges:

$$F = (8.9875 \times 10^9) \times \frac{(1.0 \times 10^{-6}) \times (1.0 \times 10^{-6})}{r^2}$$

$$F = (8.9875 \times 10^9) \times \frac{1.0 \times 10^{-12}}{r^2}$$

$$F = \frac{8.9875 \times 10^{-3}}{r^2}$$

This formula allows us to calculate the magnitude of the repulsive force for any given separation (r).

Factors Affecting the Magnitude of the Repulsive Force

1. Distance Between Charges

The most significant factor influencing the force is the separation distance (r):

- As (r) decreases, (F) increases quadratically.
- As (r) increases, (F) decreases quadratically.

Example calculations:

Distance (r) (meters)	Force (F) (Newtons)
1 mm (0.001 m)	$\frac{8.9875 \times 10^{-3}}{(0.001)^2} = 8.9875$, N
1 cm (0.01 m)	0.0899, N
10 cm (0.1 m)	0.00899, N
1 m	8.9875×10^{-3} , N

This illustrates how quickly the force diminishes with increasing separation.

Implication: Precise knowledge of the distance is crucial for accurate force calculation.

2. Magnitude of Charges

Since the force depends on the product of the charges, larger charges result in stronger forces:

- For example, doubling the charges to $(2.0 \times 10^{-6} \text{ C})$ each would quadruple the force.
- The same applies for smaller charges; halving the charges reduces the force by a quarter.

Note: The linear dependency means small variations in charge magnitude significantly impact the force magnitude.

3. Medium Between Charges

Coulomb's Law assumes a vacuum or air. When charges are in different media, the Coulomb constant (k) is replaced by the medium's permittivity:

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

where (ϵ) is the permittivity of the medium.

- In dielectric materials, the force weakens compared to vacuum.
- For example, in water $(\epsilon \approx 80 \epsilon_0)$, the force is significantly reduced.

Implication: The medium surrounding the charges influences the strength of the repulsive force.

Real-World Context and Practical Considerations

Estimating the Force at Typical Separations

In practical applications, the distance between charges varies widely:

- Microelectronic devices: Charges are separated by nanometers to micrometers, resulting in forces ranging from micro-Newtons to several Newtons.
- Atmospheric phenomena: Charges in thunderstorms are separated by meters, with forces in the order of a few Newtons, leading to lightning discharges.

Using the formula, for a separation of 1 meter, the force between two $-1.0 \mu\text{C}$ charges is approximately 8.99 millinewtons, which is relatively small but significant in precise electrostatic environments.

Limitations and Challenges

- Assumption of point charges: Real charges are often distributed over finite regions, affecting the force calculation.

- Electrostatic shielding: Conductive materials or dielectric mediums can weaken or alter the force.
- Environmental factors: Humidity, temperature, and external electric fields can influence electrostatic interactions.

Strength of the Repulsive Force: Quantitative Perspective

How Strong Is the Force?

Given the charges are each $(-1.0 \times 10^{-6} \text{ C})$, the force's strength depends on the separation:

- At 1 meter: Approximately 8.99 millinewtons.
- At 10 centimeters: About 9 millinewtons.
- At 1 millimeter: Nearly 9 newtons.

Interpretation:

- The force is quite significant at very close distances, capable of overcoming small mechanical resistances.
- At larger distances, the force diminishes rapidly, becoming negligible in many practical situations.

Implications in Design and Safety

- High electrostatic forces at close proximity can cause equipment damage or unintended discharges.
- Proper grounding and insulation are essential when working with microcoulomb-scale charges to prevent accidents.

Summary of Key Features and Considerations

Features:

- Coulomb's Law provides a straightforward way to quantify the force.
- The force is proportional to the magnitude of the charges and inversely proportional to the square of the distance.
- Both charges being negative results in a repulsive force.

Pros:

- Simplifies calculation of electrostatic interactions.
- Well-understood and experimentally verified.

Cons:

- Assumes point charges; real-world charges have finite size.
- Sensitive to environmental conditions and medium properties.
- Requires precise knowledge of distances for accuracy.

Conclusion

The repulsive force exerted on two point charges, each carrying 1.0 microcoulomb of negative charge, can be incredibly strong when the charges are in close proximity, and diminishes rapidly as the separation increases. Using Coulomb's Law, the force at a given distance can be precisely calculated, allowing engineers and scientists to predict and manage electrostatic interactions effectively.

In practical scenarios, understanding the magnitude of such forces is vital for designing electronic components, preventing static discharge hazards, and exploring fundamental physics phenomena. While the specific force depends heavily on the separation between the charges, the underlying principles remain consistent: the force is directly proportional to the product of the charges and inversely proportional to the square of the distance, with the negative charges repelling each other with a force that can range from millinewtons to several newtons depending on their separation.

Ultimately, the strength of the electrostatic repulsion illustrates the profound influence of

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