A +26.3 UC Charge Qy Is Repelled By A Forceof 0.615 N From A Second Charge 92 That Is0.750 M Away. What

A +26.3 UC Charge Qy Is Repelled By A Forceof 0.615 N From A Second Charge 92 That Is0.750 M Away. What does this scenario reveal about electrostatic forces, electric charges, and Coulomb's law? Understanding these fundamental concepts of physics is essential for students, educators, engineers, and anyone interested in the behavior of electric charges. In this comprehensive article, we will explore the principles behind electrostatic interactions, analyze the specific problem involving the charges, and discuss practical applications and related concepts.

Understanding Electrostatic Forces and Coulomb's Law

What Is Electrostatics?

Electrostatics is the branch of physics that deals with the study of forces, fields, and potentials arising from electric charges at rest. It explains how charged objects interact with each other—either attracting or repelling—based on their magnitudes and the distances between them.

The Nature of Electric Charges

Electric charges are properties of particles that cause them to exert forces on each other. There are two types:

- Positive charges (+)
- Negative charges (−)

Like charges repel, whereas unlike charges attract.

Coulomb’s Law: The Mathematical Foundation

The force F between two point charges is described by Coulomb's Law:

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

where:

- F is the magnitude of the force between the charges (in newtons, N)

- k is Coulomb's constant ($8.9875 \times 10^9\, \mathrm{Nm^2/C^2}$)
- 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 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 between them.

Analyzing the Given Scenario

The problem states:
- A positive charge $Q_y = +26.3\, \mu C$ (microcoulombs) is being repelled.
- The force of repulsion experienced by this charge is $0.615\, N$.
- The second charge Q_{92} is located $0.750\, m$ away from Q_y.

The key question is: What is the magnitude of the second charge Q_{92}?

Converting Units and Setting Up the Problem

Converting Microcoulombs to Coulombs

Since Coulomb's law uses SI units, convert the given charge:

$$
Q_y = 26.3\, \mu C = 26.3 \times 10^{-6}\, C = 2.63 \times 10^{-5}\, C
$$

Known Values

- $F = 0.615\, N$
- $r = 0.750\, m$
- $q_1 = Q_y = 2.63 \times 10^{-5}\, C$
- Coulomb's constant: $k = 8.9875 \times 10^9\, \mathrm{Nm^2/C^2}$

Calculating the Second Charge Q_{92}

Applying Coulomb's Law

Rearranged to solve for q_2:

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

Substituting Known Values

$$
q_2 = \frac{(0.615\, N) \times (0.750\, m)^2}{(8.9875 \times 10^9\, \mathrm{Nm^2/C^2}) \times (2.63 \times 10^{-5}\, C)}
$$

Calculating numerator:

$$
0.615 \times 0.75^2 = 0.615 \times 0.5625 = 0.3459375
$$

Calculating denominator:

$$
8.9875 \times 10^9 \times 2.63 \times 10^{-5} = (8.9875 \times 2.63) \times 10^{9 - 5} = 23.629125 \times 10^4 = 2.3629125 \times 10^5
$$

Now, compute q_2:

$$
q_2 = \frac{0.3459375}{2.3629125 \times 10^5} \approx 1.464 \times 10^{-6}\, C
$$

Expressed in microcoulombs:

$$
q_2 \approx 1.464\, \mu C
$$

Interpreting the Results

The calculated charge Q_{92} has a magnitude of approximately 1.464 microcoulombs and, since the force is repulsive, both charges are of the same sign—positive in this case.

Summary:
- The second charge $Q_{92} \approx +1.464\, \mu C$

- The distance between the charges is 0.75 meters
- The electrostatic force of 0.615 N is consistent with Coulomb's law

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Practical Implications and Applications

Electrostatic Force in Engineering and Technology

Understanding Coulomb's law and the behavior of electric charges is fundamental in designing electronic components, capacitors, and insulating materials. For example:

- Designing high-voltage power lines to prevent unwanted discharges
- Developing sensitive electronic sensors that rely on charge interactions
- Creating electrostatic precipitators for pollution control

Safety Considerations

Electrostatic forces can cause sparks or discharges that pose safety hazards. Proper grounding and insulation are essential in environments with high static charges.

Scientific Research

Research in atomic and molecular physics often involves precise control and measurement of charges at microscopic scales, where Coulomb's law remains a crucial principle.

Additional Related Concepts

Electric Field and Electric Potential

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

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

- Electric potential relates to the work done to bring a charge from infinity to a point in space.

Superposition Principle

- When multiple charges are present, the net force or field at a point is the vector sum of individual forces or fields.

Force Direction and Significance

- The sign of charges determines whether forces are attractive or repulsive.
- In this scenario, the positive charges repel each other, consistent with Coulomb's law.

Limitations of Coulomb’s Law

- Coulomb's law applies strictly to point charges or spherically symmetric charge distributions.
- For extended objects or charges in dielectric materials, modifications are necessary.

Conclusion

Understanding the interaction between electric charges through Coulomb's law provides critical insights into the world of electrostatics. By analyzing the problem where a positive microcoulomb charge experiences a measurable repulsive force from a second charge at a known distance, we can deduce the magnitude of that second charge. This process demonstrates the practical application of fundamental physics principles to real-world situations, from engineering design to safety protocols. Mastery of these concepts allows scientists and engineers to innovate and ensure safety in environments where electrostatic forces are significant.

References and Further Reading

- Serway, Raymond A., and Jewett, John W. Physics for Scientists and Engineers. (10th Edition)
- Halliday, David, Resnick, Robert, and Walker, Jearl. Fundamentals of Physics. (11th Edition)
- NASA's Coulomb's Law Explanation and Interactive Simulations
- Khan Academy's Electrostatics Course Modules

By understanding and applying Coulomb's law, you can analyze complex electrostatic interactions, design safer electrical systems, and deepen your appreciation for the fundamental forces that govern our universe.

Frequently Asked Questions

What is the magnitude of the electrostatic force between the two charges?

The magnitude of the force is 0.615 N, as given in the problem statement.

What is the value of the second charge, and how is it related to the force?

The second charge is 92 µC (microcoulombs), which, along with the distance, determines the electrostatic force between the charges.

How does Coulomb's Law apply to this problem?

Coulomb's Law states that the electrostatic force between two charges is proportional to the product of their magnitudes and inversely proportional to the square of the distance between them: F = k |q1 q2| / r^2.

Can we determine the magnitude of the first charge using the given data?

Yes, rearranging Coulomb's Law allows us to solve for the first charge: q1 = F r^2 / (k q2). Plugging in the values gives the magnitude of the first charge.

What is the significance of the force being repulsive in this context?

Since the force is repulsive, it indicates that both charges have the same sign (both positive or both negative), causing them to push away from each other.

Additional Resources

A +26.3 µC Charge Qy Is Repelled By A Force of 0.615 N From A Second Charge 92 That Is 0.750 M Away: An Investigative Analysis

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Introduction

In the realm of electrostatics, understanding the interactions between point charges is fundamental to grasping the behavior of charged particles in various physical systems. The scenario where a charge of +26.3 µC (microcoulombs) experiences a repulsive force of 0.615 N from a second charge separated by 0.750 meters presents an intriguing case for analysis. This article aims to dissect this configuration comprehensively, exploring the underlying physics, calculating the unknown parameters of the second charge, and contextualizing the findings within classical electrostatics principles.

Background and Significance

Electrostatics describes the forces exerted between stationary electric charges. Coulomb's Law provides the quantitative measure of these forces:

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

where:

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

Understanding such interactions is crucial in fields ranging from particle physics to electrical engineering, where charge interactions influence device operation, material properties, and fundamental phenomena.

The Physical Scenario: An Overview

The specific problem involves:

- A known charge $Q_y = +26.3\, \mu C$,
- A force $F = 0.615\, N$ acting upon it,
- A second charge Q_2,
- Separation distance $r = 0.750\, m$,
- The force is repulsive, indicating both charges have like signs (both positive or both negative).

The primary goal is to determine the magnitude and potentially the sign of the second charge Q_2, given the force and separation.

Applying Coulomb's Law: Deriving the Unknown Charge

Step 1: Expressing Coulomb's Law for the Given System

Given the force F, known charge Q_y, and separation r:

$$
F = k_e \frac{|Q_y Q_2|}{r^2}
$$

Rearranged to solve for Q_2:

$$
|Q_2| = \frac{F r^2}{k_e |Q_y|}
$$

Step 2: Substituting the Known Values

- $F = 0.615\, N$,
- $r = 0.750\, m$,
- $Q_y = +26.3\, \mu C = 26.3 \times 10^{-6}\, C$,
- $k_e = 8.9875 \times 10^9\, \mathrm{N\,m^2/C^2}$.

Calculating:

$$
|Q_2| = \frac{0.615 \times (0.750)^2}{8.9875 \times 10^9 \times 26.3 \times 10^{-6}}
$$

$$
|Q_2| = \frac{0.615 \times 0.5625}{8.9875 \times 10^9 \times 26.3 \times 10^{-6}}
$$

$$
|Q_2| = \frac{0.3453}{8.9875 \times 10^9 \times 26.3 \times 10^{-6}}
$$

Calculating the denominator:

$$
8.9875 \times 10^9 \times 26.3 \times 10^{-6} = 8.9875 \times 10^9 \times 26.3 \times 10^{-6}
$$

$$
= 8.9875 \times 26.3 \times 10^{9 - 6} = 8.9875 \times 26.3 \times 10^{3}
$$

$$
= (8.9875 \times 26.3) \times 10^{3} \approx 236.4 \times 10^{3} = 236,400
$$

Now, compute $|Q_2|$:

$$
|Q_2| = \frac{0.3453}{236,400} \approx 1.459 \times 10^{-6}\, C
$$

Expressed in microcoulombs:

$$
|Q_2| \approx 1.459\, \mu C
$$

Result:

The magnitude of the second charge Q_2 is approximately +1.46 μC.

Interpreting the Sign and Nature of the Charges

Since the force is repulsive, both charges must have the same sign. Given Q_y is positive, Q_2 must also be positive:

$$
Q_2 \approx +1.46\, \mu C
$$

This aligns with physical intuition: like charges repel each other, causing the observed force.

Deeper Insights: Verifying and Contextualizing the Results

Check for Consistency

Plugging the calculated Q_2 back into Coulomb's Law:

$$
F = k_e \frac{Q_y Q_2}{r^2}
$$

$$
F = 8.9875 \times 10^9 \times \frac{(26.3 \times 10^{-6})(1.46 \times 10^{-6})}{(0.750)^2}
$$

Calculating numerator:

$$
8.9875 \times 10^9 \times 26.3 \times 10^{-6} \times 1.46 \times 10^{-6} \approx 8.9875 \times 26.3 \times 1.46 \times 10^{9 -6 -6}
$$

$$
= 8.9875 \times 26.3 \times 1.46 \times 10^{-3}
$$

Calculating:

$$
8.9875 \times 26.3 \approx 236.4
$$
$$
236.4 \times 1.46 \approx 345.2

\]

$$
345.2 \times 10^{-3} = 0.3452
$$

Dividing by $r^2 = 0.75^2 = 0.5625$:

$$
F = \frac{0.3452}{0.5625} \approx 0.613\, N
$$

Close to the given 0.615 N, confirming consistency within rounding errors.

Implications

- The calculated charge magnitude aligns well with the observed force, confirming the validity of Coulomb's Law in this context.
- The positive sign indicates both charges are positively charged, leading to mutual repulsion.

Broader Context and Applications

Electrostatics in Engineering and Physics

Understanding such charge interactions is vital in designing:

- Capacitors and electronic components,
- Particle accelerators,
- Electrostatic precipitators in pollution control,
- Sensors and detectors relying on charge interactions.

Challenges and Limitations

While Coulomb's Law is precise for point charges, real-world systems involve:

- Charge distributions (not point charges),
- Medium effects (dielectric properties),
- External influences like electromagnetic fields.

Accurate modeling requires considering these factors for complex systems.

Summary of Key Findings

- The second charge Q_2 has an approximate magnitude of +1.46 μC.
- The charges are both positive, resulting in a repulsive force of 0.615 N.
- The spatial separation of 0.750 meters aligns with the calculated forces, confirming classical electrostatic predictions.

Concluding Remarks

This investigation underscores the predictive power of Coulomb's Law in electrostatics. By analyzing a straightforward yet illustrative charge interaction, we reaffirm fundamental principles and demonstrate how precise measurements of force and distance enable us to determine unknown charges. These insights not only deepen our understanding of electrostatic phenomena but also pave the way for practical applications across scientific and engineering disciplines.

References

- Serway, R. A., & Jewett, J. W. (2014). Physics for Scientists and Engineers. Brooks Cole.
- Griffiths, D. J. (2017). Introduction to Electrodynamics. Cambridge University Press.
- Tipler, P. A., & Mosca, G. (2008). Physics for Scientists and Engineers. W. H. Freeman and Company.

Note: This analysis assumes ideal point charges in a vacuum, neglecting external influences and medium effects. Real-world applications may require additional considerations.

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