The Figure Shows Two Charged Particles On An X Axis: Q=1.601019C At X=3.50 M And Q=1.601019C At X=3.50

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Understanding electrostatic interactions is fundamental in physics, especially when analyzing the behavior of charged particles. The given figure illustrates two charged particles positioned along the x-axis, each with a charge of Q=1.601019 C, located at the same position x=3.50 meters. This scenario provides an excellent case study to explore concepts such as Coulomb's law, electric potential, electric field, and the net force experienced by charges in a system.

In this article, we will delve deeply into the physics underlying this configuration, analyze the forces involved, compute electric fields and potentials, and discuss potential applications. Whether you're a student preparing for exams or a professional seeking a refresher, this comprehensive guide aims to clarify the principles at play and enhance your understanding of electrostatics.

Context and Significance of the Configuration

Electrostatics deals with stationary electric charges and the forces between them. The scenario presented involves two point charges placed along a single axis, a classic setup for analyzing Coulomb's law, electric field interactions, and potential energy.

Understanding such configurations is crucial in various fields:

- Physics Education: Helps students visualize charge interactions.
- Electrical Engineering: Essential for designing circuits and understanding electromagnetic compatibility.
- Chemistry & Material Science: Influences atomic and molecular interactions.
- Nanotechnology: Fundamental in manipulating particles at microscopic scales.

The particular configuration—two identical charges placed at the same position—presents interesting questions:

- What is the net force acting on each charge?
- How do their electric fields interact?
- What is the electric potential at various points along the axis?
- How does the system behave if the charges are moved or if additional

charges are introduced?

By exploring these questions, we gain insights into the fundamental laws governing electrostatic phenomena.

Details of the Charged Particles and Their Positions

The given data indicates:

- Charge (Q): 1.601019 Coulombs for each particle.
- Position (X): Both at x=3.50 meters.

However, the description appears to have a typo or omission, as both charges are said to be at the same position, which would imply an infinite force due to Coulomb’s law. Typically, such problems involve charges placed at different positions along the x-axis. For the purpose of this discussion, we'll consider a common scenario where the two charges are located at different positions but with similar magnitudes, which allows for meaningful analysis.

Suppose the corrected positions are:

- Charge Q_1: +1.601019 C at x=3.50 m.
- Charge Q_2: +1.601019 C at x=-3.50 m.

This symmetry simplifies calculations and is typical in electrostatics problems, allowing us to analyze the electric field and forces at various points along the axis.

Note: If the original statement intended both charges at x=3.50 m, then the system involves coincident charges, which is physically impossible without considering quantum effects or charge distribution over a finite area. Hence, the symmetric placement at x=±3.50 m is a reasonable assumption.

Fundamental Principles and Equations

Before proceeding with calculations, it’s essential to understand the fundamental principles:

Coulomb's Law

Coulomb's law quantifies the force between two point charges:

$$F = k_e \frac{|Q_1 Q_2|}{r^2}$$

Where:

- F is the magnitude of the force between the charges.
- k_e is Coulomb's constant, approximately $8.9875 \times 10^9\, \mathrm{Nm^2/C^2}$.
- Q_1 and Q_2 are the magnitudes of the charges.
- r is the distance between the charges.

The force is attractive if charges are opposite; repulsive if charges are like.

Electric Field Due to a Point Charge

The electric field E at a point P due to a charge Q is:

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

Direction:

- Away from positive charges.
- Toward negative charges.

Electric Potential

The electric potential V at a point due to a charge Q is:

$$V = k_e \frac{Q}{r}$$

Potential is scalar; total potential is the algebraic sum of potentials due to individual charges.

Analyzing the System: Forces, Fields, and Potentials

Given the symmetric placement, we can analyze the electric field and potential at various points along the x-axis.

Force on a Charge Due to the Other

The force between the two charges:

- Distance between charges: $r = |x_1 - x_2| = 6.99\, \mathrm{m}$ (assuming positions at x=3.50 m and x=-3.50 m).

Applying Coulomb’s law:

$$F = 8.9875 \times 10^9 \times \frac{(1.601019)^2}{(6.99)^2}$$

Calculating numerator:

$$(1.601019)^2 \approx 2.563$$

Calculating denominator:

$$(6.99)^2 \approx 48.86$$

Thus:

$$F \approx 8.9875 \times 10^9 \times \frac{2.563}{48.86}$$

$$F \approx 8.9875 \times 10^9 \times 0.05243$$

$$F \approx 471,468,000\, \mathrm{N}$$

This enormous force indicates the high magnitude of the charges involved—typical in theoretical problems, not physical reality.

Electric Field at a Point Along the Axis

To find the electric field at a point x along the axis, sum the contributions from both charges:

$$E(x) = E_1(x) + E_2(x)$$

Where:

- $E_1(x) = k_e \frac{Q}{|x - x_1|^2}$ (direction depends on the position).
- $E_2(x) = k_e \frac{Q}{|x - x_2|^2}$.

The direction:

- Away from positive charges.
- Toward negative charges.

Example: Electric Field at the Center (x=0)

At $x=0$:

- Distance to each charge: $r = 3.50\, \mathrm{m}$.

- Electric field magnitude due to each charge:

$$ E = 8.9875 \times 10^9 \times \frac{1.601019}{(3.50)^2} $$

$$ E = 8.9875 \times 10^9 \times \frac{1.601019}{12.25} $$

$$ E \approx 8.9875 \times 10^9 \times 0.13058 $$

$$ E \approx 1.174 \times 10^9\, \mathrm{N/C} $$

Direction:

- Since both charges are positive, the electric fields at the center point away from each charge, meaning they point in opposite directions along the x-axis:

- E_1 points toward negative x-direction.
- E_2 points toward positive x-direction.

Therefore, the net electric field at the center is zero, as the fields cancel out.

Example: Electric Potential at the Center

Total potential:

$$ V = V_1 + V_2 = k_e \left(\frac{Q}{r_1} + \frac{Q}{r_2} \right) $$

Since $r_1 = r_2 = 3.50\, \mathrm{m}$:

$$ V = 8.9875 \times 10^9 \times 1.601019 \times \left(\frac{1}{3.50} + \frac{1}{3.50} \right) $$

$$ V = 8.9875 \times 10^9 \times 1.601019 \times \frac{2}{3.50} $$

$$ V \approx 8.9875 \times 10^9 \times 1.601019 \times 0.5714 $$

$$ V \approx 8.9875 \times 10^9 \times 0.915 $$

$$ V \approx 8.236 \times 10^9\, \mathrm{V} $$

This high potential again indicates the theoretical nature of the calculation.

Applications and Implications of the System

Understanding such charge configurations has numerous practical implications:

Designing Capacitors

- Capacitors store electric energy via separated charges.
- Analyzing point charge interactions helps in understanding electric field distribution within capacitors.

Electrostatic Shielding

- Knowledge of electric fields allows engineers to design shields that protect sensitive circuits from external static charges.

Atomic and Molecular Inter

Frequently Asked Questions

What is the significance of the charges $Q=1.60\times10^{-19}$ C placed at x=3.50 m on the x-axis?

The charges represent point charges of equal magnitude located at the same position on the x-axis, typically used to analyze electric fields or potentials created by such charges in electrostatics problems.

How does the electric field vary at a point between the two charges placed at x=3.50 m?

The electric field at a point between the charges depends on the magnitudes and distances from each charge. Since the charges are equal and positioned symmetrically, the fields due to each charge may cancel or reinforce each other depending on the

specific point considered.

What is the force experienced by a test charge placed at the midpoint between these two charges?

If the charges are equal and placed symmetrically, the net force on a test charge at the midpoint would be zero due to equal and opposite electric field contributions, assuming no other forces are acting.

How can we calculate the potential energy of the system of these two charges?

The potential energy (U) of two point charges is given by $U = (k\ Q_1\ Q_2) / r$, where k is Coulomb's constant, Q_1 and Q_2 are the charges, and r is the distance between them. In this case, it would be $U = (8.99\times10^9\ Nm^2/C^2)\ (1.60\times10^{-19}\ C)^2 / 0$, which indicates the need to clarify the positions, as both charges are at the same point, implying zero separation and infinite potential energy.

What would happen to the electric field if both charges were moved closer together or farther apart along the x-axis?

Moving the charges closer increases the electric field strength at points between them and near their positions due to decreased separation. Conversely, moving them farther apart reduces the electric field intensity at those points, as the Coulomb force

diminishes with increasing distance.

Additional Resources

Electrostatics and Particle Interactions: An In-depth Analysis of Two Like-Charged Particles on the X-Axis

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Introduction to Coulombic Interactions

Electrostatics forms the foundation of understanding how charged particles interact within an electric field. When dealing with point charges, Coulomb's law provides a quantitative description of the force exerted between them. In this analysis, we consider a scenario involving two identical charged particles positioned along the x-axis, a fundamental setup that exemplifies core principles in electrostatics.

Scenario Description and Parameters

The problem involves:

- Two point charges (Q): Each with a magnitude of 1.601019 Coulombs.
- Positions along the x-axis: Both located at x = 3.50 meters.

At first glance, the statement suggests both charges occupy the same position, which is physically impossible for point charges without overlapping. Therefore, this likely represents either an approximate initial configuration or a typographical oversight. For the purpose of this analysis, we interpret the scenario as two charges positioned along the x-axis, possibly symmetric around a point or separated by a specific distance, which is essential for further calculations.

Understanding the Significance of the Parameters

Magnitude of the Charges

- The charges are substantial: approximately 1.6 Coulombs each.
- For context, elementary charges (electrons/protons) are on the order of 1.6×10^{-19} C.
- Implication: These are macroscopic charges,

possibly representing charged spheres or charged conductors, where classical electrostatics applies.

Positioning and Spacing

- The problem states both are at x = 3.50 m, which suggests either:

1. A typo, where the second charge is at a different position (e.g., x = -3.50 m), or
2. Both charges are coinciding at the same point (which would involve infinite repulsive force).

- Assumption for analysis: They are positioned symmetrically at x = -3.50 m and x = 3.50 m. This symmetric placement simplifies calculations and aligns with common electrostatics problems.

Electrostatic Force Between the Charges

The Coulomb's Law Formula

The force \(F \) between two point charges 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 distance between the charges.

Calculating the Force

Assuming symmetric placement at $x = -3.50 \, \text{m}$ and $x = 3.50 \, \text{m}$:

- Distance $r = 3.50\, \text{m} - (-3.50\, \text{m}) = 7.00\, \text{m}$.

Putting the knowns into the formula:

$$
F = \left(8.9875 \times 10^9\right) \times \frac{(1.601019)^2}{(7.00)^2}
$$

Calculating numerator:

$$
(1.601019)^2 \approx 2.563 \, \text{C}^2
$$

Calculating denominator:

$$
(7.00)^2 = 49 \, \text{m}^2
$$

Thus,

$$
F \approx 8.9875 \times 10^9 \times \frac{2.563}{49} \approx 8.9875 \times 10^9 \times 0.0523 \approx 470.2 \times 10^6 \, \text{N}
$$

or approximately 470.2 mega-newtons.

Note: This immense force underscores the macroscopic nature of the charges, which would be practically unmanageable in a typical experimental setup and would require specialized insulating and containment measures.

Electrostatic Potential Energy of the System

The potential energy U stored in the configuration is given by:

$$
U = k_e \frac{Q_1 Q_2}{r}
$$

Substituting the known values:

$$
U = 8.9875 \times 10^9 \times \frac{(1.601019)^2}{7.00}
$$

Calculations:

$$
U \approx 8.9875 \times 10^9 \times \frac{2.563}{7} \approx 8.9875 \times 10^9 \times 0.366 \approx 3.29 \times 10^9\, \text{J}
$$

This energy (~3.29 billion joules) further emphasizes the enormous electrostatic energy stored, which would be hazardous and is primarily of theoretical interest unless scaled down or stabilized.

Field Analysis: Electric Field Due to Each Charge

Electric Field at a Point on the X-Axis

The electric field E due to a point charge at a position x' at a point x on the x-axis is:

$$
E = k_e \frac{Q}{|x - x'|^2}
$$

Directionality:

- For a positive charge, the field points away from the charge.
- For a negative charge, the field points toward the charge.

Assuming both charges are positive:

- The total electric field at any point x is the vector sum of the individual fields.

Electric Field at a General Point x

$$
E_{total}(x) = E_1(x) + E_2(x)
$$

Where:

$$
E_1(x) = k_e \frac{Q}{|x - x_1|^2} \quad \text{(points away from Q_1)} \\
E_2(x) = k_e \frac{Q}{|x - x_2|^2} \quad \text{(points away from Q_2)}
$$

\]

Given symmetric positions, the field at the midpoint $x=0$:

$$
E_{mid} = 2 \times k_e \frac{Q}{(3.50)^2}
$$

Calculation:

$$
E_{mid} = 2 \times 8.9875 \times 10^9 \times \frac{1.601019}{12.25} \approx 2 \times 8.9875 \times 10^9 \times 0.1305 \approx 2 \times 1.173 \times 10^9 \approx 2.346 \times 10^9\, \text{V/m}
$$

This field points away from the charges along the x-axis.

Force on a Test Charge in the System

Suppose a small test charge q_t is placed somewhere along the x-axis to analyze the force experienced due to these charges.

The force:

$$
F_{test} = q_t \times E_{total}
$$

The magnitude and direction depend on the position of q_t. For instance:

- At the midpoint, the force is directed outward, away from the charges.
- Closer to one of the charges, the force magnitude increases proportionally to the local electric field.

This analysis helps in understanding how potential wells or barriers are formed in such configurations.

Potential Energy and Force Interplay

The interplay between potential energy and force governs the stability of the system:

- Repulsive Force: Since both charges are positive, they repel each other, tending to move apart.
- Potential Energy: The system's high potential energy indicates it is in a configuration with significant electrostatic stress, tending towards a lower energy state by moving apart.

In practical applications, such a configuration would require stabilization mechanisms, such as confinement or external fields, to prevent charges from flying apart or colliding.

Real-World Applications and Implications

Understanding the interaction of large charges along a linear axis has practical significance in various fields:

- Particle Accelerators: Charged particle beams are manipulated along linear paths, with electrostatic fields controlling their motion.
- Electrostatic Storage: Designing devices that contain or manipulate large charges requires understanding of force magnitudes and energy.
- Fundamental Physics Experiments: Studying the behavior of macroscopic charges helps in testing electrostatics principles and material responses.

However, the enormous forces involved imply that such systems are mostly theoretical or scaled-down versions of actual devices.

Additional Considerations and Advanced Topics

Quantum Effects and Limitations

While classical electrostatics suffices at macroscopic scales, extremely high charges can lead to:

- Air breakdown or electrical discharge.
- Material breakdown of insulators.

Energy Storage and Safety

- Large charges stored at high

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