GP Particle A Of Charge 3.00 10C Is At The Origin, Particle B Of Charge -6.00 10C Is At (4.00 M, 0) ,

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Understanding the interactions between electric charges is fundamental in physics, especially within the domain of electrostatics. The scenario involving two point charges positioned at specific coordinates provides a practical example to explore Coulomb's law, electric fields, potential energy, and forces. This article delves into the details of this situation, offering insights into the principles governing electric charges, calculations involved, and their implications.

Introduction to Electric Charges and Coulomb’s Law

What Are Electric Charges?

Electric charges are fundamental properties of matter that cause objects to experience a force when placed in an electric field. There are two types of electric charges:

- **Positive charges** – tend to repel other positive charges and attract negative charges.
- **Negative charges** – tend to attract positive charges and repel other negative charges.

Electrons carry negative charges, while protons carry positive charges. The magnitude of electric charge is quantized and measured in coulombs (C).

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 electrostatic force between the charges,
- $k_e \approx 8.99 \times 10^9\, \text{Nm}^2/\text{C}^2$ is Coulomb's constant,
- q_1 and q_2 are the magnitudes of the charges,
- r is the distance between the charges.

The direction of the force depends on the signs of the charges: like charges repel, unlike charges attract.

Scenario Description

Positions and Charges of the Particles

In our scenario:

- **Particle A** has a charge of $+3.00 \times 10^{-6}\, \text{C}$ (or 3.00 μC) located at the origin $(0, 0)$.

- **Particle B** has a charge of $-6.00 \times 10^{-6}\, \text{C}$ (or -6.00 μC) located at $(4.00\, \text{m}, 0)$.

The positions are given in Cartesian coordinates along the x-axis, with Particle A at the origin and Particle B 4 meters to the right.

Calculating the Force Between the Particles

Step 1: Determine the Distance Between Particles

Since both particles lie along the x-axis:

$$
r = |x_2 - x_1| = |4.00\, \text{m} - 0| = 4.00\, \text{m}
$$

Step 2: Apply Coulomb’s Law

Plugging in the values:

$$
F = (8.99 \times 10^9)\, \frac{|(3.00 \times 10^{-6})(-6.00 \times 10^{-6})|}{(4.00)^2}
$$

Note:
- The absolute value ensures the force magnitude is positive.
- The negative sign in the charge indicates the nature of the charge, but the magnitude is used in Coulomb’s law calculation.

Calculating numerator:

$$
| (3.00 \times 10^{-6})(-6.00 \times 10^{-6}) | = (3.00 \times 10^{-6}) \times (6.00 \times 10^{-6})
= 18.00 \times 10^{-12} = 1.80 \times 10^{-11}
$$

Calculating denominator:

$$
(4.00)^2 = 16.00
$$

Now, the force:

$$
F = 8.99 \times 10^9 \times \frac{1.80 \times 10^{-11}}{16}
$$

Simplify:

$$
F = 8.99 \times 10^9 \times 1.125 \times 10^{-12} = (8.99 \times 1.125) \times 10^{9 - 12} = 10.11 \times 10^{-3} = 0.01011\, \text{N}
$$

Result: The magnitude of the electrostatic force between Particle A and Particle B is approximately 0.01011 N.

Step 3: Direction of the Force

Since Particle A is positive and Particle B is negative, the force is attractive, meaning:
- Particle A experiences a force directed toward Particle B (to the right).
- Particle B experiences a force directed toward Particle A (to the left).

Electric Field and Potential at Various Points

The Electric Field

The electric field $\vec{E}$ at any point due to a point charge q is given by:

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

where:
- r is the distance from the charge to the point of interest,
- $\hat{r}$ is the unit vector pointing from the charge to the point.

For multiple charges, the net electric field at a point is the vector sum of the fields due to each charge.

Calculating Electric Field at a Specific Point

Suppose we want to find the electric field at a point P located at $(x, 0)$ along the x-axis:
- Distance from Particle A:

$$
r_A = |x - 0| = |x|
$$
- Distance from Particle B:

$$
r_B = |x - 4.00\, \text{m}|
$$

The electric field contributions:

$$
E_A = k_e \frac{q_A}{r_A^2}
$$
$$
E_B = k_e \frac{q_B}{r_B^2}
$$

The net electric field depends on the positions:
- For $x < 0$, both fields point to the left.
- For $0 < x < 4$, the fields may oppose each other depending on the magnitude.
- For $x > 4$, both fields point to the right.

Electric Potential Energy and Potential

Potential Energy of the System

The electric potential energy U between two point charges:

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

Calculating:

$$
U = 8.99 \times 10^9 \times \frac{(3.00 \times 10^{-6})(-6.00 \times 10^{-6})}{4.00}
$$

$$
U = 8.99 \times 10^9 \times (-18.00 \times 10^{-12}) / 4.00
$$

$$
U = -8.99 \times 10^9 \times 4.50 \times 10^{-12} = -40.45 \times 10^{-3} = -0.04045\, \text{J}
$$

The negative sign indicates that the system’s potential energy is lower due to attraction, and energy must be supplied to separate the charges.

Electric Potential at a Point

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

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

The total potential is the algebraic sum of potentials due to each charge.

Implications and Applications

Electrostatic Forces in Real-World Applications

Understanding such interactions is crucial in:

- Designing electronic components, like capacitors and sensors.
- Studying atomic and molecular interactions.
- Developing technologies in electrostatic precipitators for pollution control.
- Exploring fundamental physics concepts related to forces and fields.

Safety Precautions When Handling Charges

Electrostatic forces can be powerful; high voltages and charges can cause electrical shocks or damage sensitive equipment. Proper grounding and insulation are essential.

Conclusion

The scenario involving GP Particle A of charge $+3.00\, \mu C$ at the origin and Particle B of charge $-6.00\, \mu C$ at (4 meters, 0) offers a vivid example of electrostatic principles. Calculating the force between them using Coulomb's law reveals a force magnitude of approximately 0.01011 N, directed attractively. Understanding electric fields, potential energy, and the influence of charge magnitudes and positions provides foundational insights into electrostatics, underpinning many modern technological advancements and scientific explorations.

Further Reading and

Frequently Asked Questions

What is the electric potential at the origin due to particles A and B?

The electric potential at the origin is the sum of potentials from both particles: V = k (q_A / r_A + q_B / r_B). Since q_A is at the origin, its potential is infinite there, but considering the contribution from B at (4.00 m, 0), the potential due to B is V_B = (8.99 × 10^9 N·m²/C²) (-6.00 × 10^-6 C) / 4.00 m ≈ -13,485 V. The potential from A at its own position is undefined (infinite), but for practical purposes, the potential at the origin is dominated by A's own charge.

What is the magnitude and direction of the electric field at point (2.00 m, 0)?

The electric field at (2.00 m, 0) is the vector sum of fields due to both particles. The field from A (charge +3.00 × 10^-6 C) at (2.00 m, 0): E_A = k q_A / r_A² directed away from A. Since A is at the origin, r_A = 2.00 m, and E_A = (8.99 × 10^9) (3.00 × 10^-6) / (2.00)^2 ≈ 6,743 N/C, directed to the right. The field

from B at (2.00 m, 0): r_B = 2.00 m, q_B negative, so the field points toward B (to the right). Its magnitude: $E_B = (8.99 \times 10^9)\ 6.00 \times 10^{-6} / (2.00)^2 \approx 13{,}485$ N/C. Both fields point right, so total E ≈ 6,743 + 13,485 ≈ 20,228 N/C to the right.

Calculate the force exerted on particle B by particle A.

Force on B due to A: $F = k\,|q_A q_B| / r^2$. With $q_A = 3.00 \times 10^{-6}$ C, $q_B = -6.00 \times 10^{-6}$ C, r = 4.00 m: $F = (8.99 \times 10^9)(3.00 \times 10^{-6})(6.00 \times 10^{-6}) / (4.00)^2 \approx 10.11$ N. The force is attractive (since charges are opposite), directed from B toward A, along the x-axis.

What is the potential energy of the system consisting of particles A and B?

The electrostatic potential energy: $U = k\, q_A q_B / r$. Using $q_A = 3.00 \times 10^{-6}$ C, $q_B = -6.00 \times 10^{-6}$ C, r = 4.00 m: $U = (8.99 \times 10^9)(3.00 \times 10^{-6})(-6.00 \times 10^{-6}) / 4.00 \approx -40.4$ Joules. The negative sign indicates a bound, attractive interaction.

If particle A is moved to a position (x, 0), how does the electric potential at that point change?

The potential at position (x, 0) due to A (at origin) is $V_A = k\, q_A / |x|$. Due to B at (4.00 m, 0), $V_B = k\, q_B /$

$|x - 4.00|$. The total potential is $V_{total} = V_A + V_B = (8.99 \times 10^9) [3.00 \times 10^{-6} / |x| - 6.00 \times 10^{-6} / |x - 4.00|]$. As A moves, the potential depends inversely on its distance from the point.

What is the electric field at a point (x, y) in the plane due to these two particles?

The electric field at (x, y) is the vector sum of fields due to both particles. Each field is calculated as $E = k |q| / r^2$, with direction along the line connecting the charge to (x, y). For A at (0, 0), E_A points radially away (for positive charge). For B at (4.00 m, 0), E_B points toward B (since charge is negative). The total electric field is obtained by vector addition of these components.

How does the force on particle B change if its charge magnitude doubles?

If q_B doubles from -6.00 μC to -12.00 μC, the force exerted by A on B doubles as well: F_{new} = 2 10.11 N = 20.22 N, maintaining the same attractive direction along the x-axis.

What is the work done in moving particle B from (4.00 m, 0) to (6.00 m, 0)?

The work done is equal to the change in potential energy: W = U_final - U_initial. Initial U = (8.99 × 10^9) 3.00 × 10^-6 (-6.00 × 10^-6) / 4.00 ≈ -40.4 J. Final U at 6.00 m: U = (8.99 × 10^9) 3.00 × 10^-6 (-6.00 × 10^-6) / 6.00 ≈ -22.6 J. Therefore, W ≈ -22.6 J - (-40.4 J) = 17.8 J. The positive work indicates energy input needed to move B outward.

What is the electric potential at a point midway between the two charges?

Midpoint between A at (0,0) and B at (4.00 m, 0) is at (2.00 m, 0). The potential due to A: V_A = (8.99 × 10^9) 3.00 × 10^-6 / 2.00 ≈ 13,485 V. Due to B: V_B = (8.99 × 10^9) (-6.00 × 10^-6) / 2.00 ≈ -26,970 V. Total potential: V_total ≈ -13,485 V.

Additional Resources

GP Particle A of Charge 3.00 × 10^{-6} C Is At The Origin, Particle B of Charge -6.00 × 10^{-6} C Is At (4.00 m, 0)

Understanding the behavior of point charges in an electric field is fundamental in electrostatics, and analyzing the specific setup of two particles with known charges and positions provides a concrete example of Coulomb's law in action. In this scenario, Particle A with a positive charge of 3.00 µC is located at the origin, while Particle B with a negative charge of -6.00 µC is positioned at (4.00 m, 0). This configuration allows us to explore the forces between the particles, the electric field they produce, and the potential energy of the system. Such analysis is crucial in understanding the interactions in more complex electrostatic systems and has practical applications ranging from atomic physics to electrical engineering.

Overview of the System

The setup involves two point charges aligned along the x-axis:

- Particle A: charge $q_A = +3.00 \times 10^{-6} \, C$, located at $(0, 0)$.
- Particle B: charge $q_B = -6.00 \times 10^{-6} \, C$, located at $(4.00 \, m, 0)$.

The primary objectives in analyzing this system include calculating the force exerted between the charges, determining the electric field at various points, and understanding the potential energy stored in this configuration.

Fundamental Principles and Coulomb's Law

Coulomb's law states that the magnitude of the electrostatic force F between two point charges is given by:

$$
F = k_e \frac{|q_A q_B|}{r^2}
$$

where:

- $k_e \approx 8.99 \times 10^9 \, N \cdot m^2 / C^2$ is Coulomb's constant,
- q_A and q_B are the magnitudes of the charges,
- r is the distance between the charges.

The force is attractive if the charges are of opposite sign and repulsive if they are of the same sign.

Calculating the Force Between the Particles

Step 1: Determine the Distance r

Given the positions:

- **Particle A at $(0, 0)$,**
- **Particle B at $(4.00\, m, 0)$.**

The distance between them:

$$
r = \sqrt{(4.00 - 0)^2 + (0 - 0)^2} = 4.00\, m
$$

Step 2: Apply Coulomb's Law

Calculate the magnitude of the force:

$$
F = (8.99 \times 10^9) \times \frac{(3.00 \times 10^{-6})(6.00 \times 10^{-6})}{(4.00)^2}
$$

$$
F = 8.99 \times 10^9 \times \frac{18.00 \times 10^{-12}}{16}
$$

$$
F = 8.99 \times 10^9 \times 1.125 \times 10^{-12}
$$

$$
F \approx 10.12 \, N
$$

The force magnitude is approximately 10.12 N.

Step 3: Determine Force Direction

Since q_A is positive and q_B is negative, the force on each particle is attractive. The force on Particle A points towards Particle B, along the positive x-axis (from A to B). Conversely, the force on B points towards A, along the negative x-axis.

Electric Field Analysis

Electric Field Due to Particle A at B's Location

Electric field $\vec{E}$ created by a point charge:

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

where $\hat{r}$ is a unit vector pointing from the charge to the point where the field is measured.

At $(4.00\, m, 0)$, the field due to Particle A (located at the origin):

$$
E_A = k_e \frac{|q_A|}{r^2} = 8.99 \times 10^9 \times \frac{3.00 \times 10^{-6}}{(4.00)^2}
$$

$$
E_A = 8.99 \times 10^9 \times 1.875 \times 10^{-7} \approx 1686\, \text{V/m}
$$

Direction: from A to B, along the positive x-axis, since q_A is positive.

Electric Field Due to Particle B at A's Location

Similarly, at $(0, 0)$, the field due to q_B:

$$
E_B = k_e \frac{|q_B|}{r^2} = 8.99 \times 10^9 \times \frac{6.00 \times 10^{-6}}{(4.00)^2}
$$

$$
E_B = 8.99 \times 10^9 \times 3.75 \times 10^{-7} \approx 3372\, \text{V/m}
$$

Direction: from B to A, along the negative x-axis, since q_B is negative and the field points toward negative charges.

Potential Energy of the System

The electrostatic potential energy U between two point charges:

$$
U = k_e \frac{q_A q_B}{r}
$$

Calculating:

$$
U = 8.99 \times 10^9 \times \frac{(3.00 \times 10^{-6})(-6.00 \times 10^{-6})}{4.00}
$$

$$
U = 8.99 \times 10^9 \times \frac{-18.00 \times 10^{-12}}{4} = -8.99 \times 10^9 \times 4.5 \times 10^{-12}
$$

$$
U \approx -40.45\, \text{J}
$$

The negative sign indicates an attractive interaction, and the system's potential energy is approximately -40.45 Joules.

Visualizing the System

Creating a visual diagram of the charges and their fields can significantly aid in understanding the interactions:

- Charges: Marked distinctly with positive and negative

signs.
- Force vectors: Arrows indicating attractive forces along the x-axis.
- Electric field lines: Lines emanating from the positive charge and terminating at the negative charge, illustrating the direction of the electric field.

Features and Key Observations

- Asymmetry of Charges: The negative charge magnitude is twice that of the positive charge, leading to a stronger electric field and force exerted by the negative charge.
- Force Magnitude: Approximately 10.12 N, indicating a significant electrostatic attraction at 4 meters apart.
- Electric Fields: The electric field due to the negative charge at Particle A's position is twice as strong as the field from the positive charge at Particle B's position.
- Potential Energy: Negative value reflects the bound state tendency of oppositely charged particles.

Pros and Cons of the Setup

Pros:

- Clear analysis of Coulomb's law: The setup provides straightforward calculations for force, field, and potential energy.
- Educational value: Demonstrates fundamental electrostatic principles in a simple, one-dimensional context.
- Applicability: Can be used as a basis for more complex systems involving multiple charges or charge distributions.

Cons:

- Idealized conditions: Assumes point charges without considering effects like charge distribution or medium effects.
- Static analysis: Does not account for dynamic interactions or movement due to forces.
- Limited scope: Only considers a linear arrangement, whereas real systems can be more complex spatially.

Extensions and Further Considerations

- Force Equilibrium and Motion: If these particles are free to move, analyzing their acceleration and

trajectories would require applying Newton's second law $F = ma$.

- Potential Energy Changes: Bringing charges from infinity to their positions involves work equal to the potential energy calculated.
- Influence of Medium: The presence of a dielectric medium would reduce the force and field magnitudes proportionally via the dielectric constant.

Conclusion

The analysis of the system where a positively charged particle A at the origin interacts with a negatively charged particle B at (4.00 m, 0) vividly illustrates the core principles of electrostatics. The forces are attractive and substantial, with a force magnitude of about 10.12 N, and the electric fields produced by each charge influence each other significantly. The potential energy of the system, being negative, confirms the bound state characteristic of opposite charges. Such detailed examination underscores the importance of Coulomb

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