A +4.75 UC And A -3.55 AC Charge Is Placed 18.5 Cm Apart: Where Can Third Charge Be Placed So That It

A +4.75 UC And A -3.55 AC Charge Is Placed 18.5 Cm Apart: Where Can Third Charge Be Placed So That It is a fundamental question in electrostatics and charge interaction studies. Understanding the placement of a third charge relative to existing charges is essential for various applications, including electronic circuit design, electrostatic shielding, and charge manipulation techniques. This article explores the principles governing the placement of a third charge between two existing charges, analyzes the factors influencing optimal position, and provides practical methods to determine the ideal location. Whether you're an engineering student, a physicist, or a hobbyist, this comprehensive guide will equip you with the knowledge to solve similar electrostatic placement problems effectively.

Understanding the Basics of Electrostatic Charges

What Are Electric Charges?

Electric charges are fundamental properties of particles that cause them to experience a force when placed in an electric field. They are classified as positive (+) or negative (−). Like charges repel each other, while opposite charges attract.

Types of Charges in This Scenario

In the given scenario:
- One charge has a magnitude of +4.75 UC (microcoulombs), which is positive.
- The other has a magnitude of -3.55 AC (the unit AC is uncommon; it may be a typo or meant as microcoulombs, but assuming it is similar to UC, it likely signifies a negative charge of 3.55 μC).
- The charges are separated by a distance of 18.5 cm.

Electrostatic Forces and Potential Energy

Coulomb’s Law

Coulomb's law quantifies the force between two point charges:
$$ F = k \frac{|q_1 q_2|}{r^2} $$
where:
- F is the magnitude of the force,
- $k \approx 8.99 \times 10^9 \, \mathrm{Nm^2/C^2}$ is Coulomb's constant,
- q_1 and q_2 are the magnitudes of the charges,
- r is the separation distance.

Potential Energy in a Charge System

The electrostatic potential energy between two charges is given by:
$$ U = k \frac{q_1 q_2}{r} $$
This energy indicates the work needed to assemble the charges from infinity to their current positions.

Problem Statement and Objective

Given the two fixed charges:
- $q_1 = +4.75\, \mathrm{μC}$,
- $q_2 = -3.55\, \mathrm{μC}$,

separated by 18.5 cm, determine where a third charge q_3 can be placed along the line connecting or outside these charges so that the net force on q_3 is zero or the potential energy configuration satisfies specific criteria.

Analyzing the Placement of the Third Charge

Potential Placement Regions

The third charge can potentially be placed:
- Between the two charges (the segment between q_1 and q_2),
- Outside the two charges (beyond q_1 or beyond q_2).

Conditions for Equilibrium

- The net electrostatic force on q_3 is zero when the attractive and repulsive forces from the existing charges balance.
- For stable equilibrium, the second derivative of potential energy should be positive (local minimum).

Calculating the Position of the Third Charge

Assumptions and Simplifications

- The charges are aligned linearly.
- The third charge q_3 is placed along the same line.
- The magnitude and sign of q_3 are to be determined based on the placement.

Step-by-Step Approach

1. Define coordinate system:
- Place q_1 at $x = 0$.
- Place q_2 at $x = 18.5\, \mathrm{cm}$.

2. Identify potential positions:
- Between q_1 and q_2: $0 < x < 18.5\, \mathrm{cm}$.
- Left of q_1: $x < 0$.
- Right of q_2: $x > 18.5\, \mathrm{cm}$.

3. Force balance equation:
For a candidate position x, the net force F_{net} on q_3 is:
$$F_{net} = F_{q_1, q_3} + F_{q_2, q_3}$$
where
$$F_{q_i, q_3} = k \frac{q_i q_3}{(r_i)^2}$$
and r_i is the distance from q_3 to q_i.

4. Determine q_3 sign and magnitude:
- To achieve equilibrium, the forces must cancel out, which depends on the signs of q_3.
- For example, if q_3 is positive, it will be repelled by positive charges and attracted by negative charges.

Practical Methods to Find Optimal Placement

Analytical Solution

- Set the net force to zero and solve for x:
$$k \frac{q_1 q_3}{x^2} + k \frac{q_2 q_3}{(d - x)^2} = 0$$
Simplifying:
$$\frac{q_1}{x^2} + \frac{q_2}{(d - x)^2} = 0$$

- Solve this equation for x given specific q_3 values.

Numerical Methods

- Use computational tools (like a graphing calculator or software) to plot the net force as a function of x.
- Find the point(s) where the net force crosses zero.

Simulation Tools

- Use electrostatics simulation software (e.g., COMSOL, PhET) to visualize the electric field and potential energy landscape.
- Adjust the position of q_3 until the equilibrium condition is visually confirmed.

Key Factors Influencing the Placement of the Third Charge

1. Magnitudes of Existing Charges

- Larger magnitudes create stronger electric fields, influencing where the third charge can be stably placed.

2. Sign of the Third Charge

- The polarity of q_3 determines whether it is attracted or repelled by existing charges.

3. Distance Between Existing Charges

- The separation distance affects the potential energy landscape and force balance points.

4. Relative Positions

- Whether the third charge is placed between the charges or outside affects stability and force balance.

Applications and Real-World Relevance

Understanding the placement of a third charge has practical implications:
- Electronics Design: Precise control of charge placement in microelectronic components.
- Electrostatic Shielding: Designing shields to protect sensitive components.
- Particle Trapping: Manipulating charged particles in lab environments.
- Educational Demonstrations: Visualizing electrostatic principles for students.

Conclusion

Determining where to place a third charge relative to two fixed charges involves analyzing electrostatic forces, potential energy, and stability conditions. By applying Coulomb’s law, setting force balance equations, and utilizing analytical or numerical methods, one can identify the optimal position for the third charge. This process underscores fundamental principles of electrostatics and highlights their importance in both theoretical and practical domains. Whether for academic purposes, engineering applications, or scientific research, mastering the concepts of charge placement enhances our ability to manipulate and understand electric fields effectively.

Summary of Key Points

- Charges: +4.75 μC and -3.55 μC placed 18.5 cm apart.
- Coulomb’s law governs force calculations.
- The third charge can be positioned between or outside the existing charges.
- Equilibrium occurs where net force on the third charge is zero.
- Analytical solutions involve solving force balance equations.
- Numerical and simulation tools assist in complex scenarios.
- Factors such as charge magnitudes, signs, and distances influence placement.
- Practical applications span electronics, particle physics, and educational demonstrations.

By understanding these principles, you can confidently approach similar electrostatic placement problems and optimize charge configurations for desired outcomes.

Frequently Asked Questions

How do I determine the position to place a third charge so that the net force on it is zero when two charges are

fixed at a certain distance?

You need to set up the equations for the electrostatic forces exerted by the two fixed charges on the third charge and solve for the position where their vector sum equals zero. This typically involves equating the magnitudes and considering the directions, based on Coulomb's law.

Given charges A (+4.75 μC) and B (-3.55 μC) are 18.5 cm apart, where can a third charge be placed so that it experiences no net force?

The third charge can be placed along the line joining the two charges, either outside the segment or between them, at a position where the attractive and repulsive forces balance out. Solving the force equations will give the exact position.

What is the significance of the relative magnitudes and signs of the charges when placing a third charge for equilibrium?

The signs determine whether the forces are attractive or repulsive, affecting the possible positions for equilibrium. Larger charge magnitudes exert stronger forces, and the third charge's position must be chosen to balance these forces accordingly.

Can the third charge be placed exactly midway between the two charges to achieve equilibrium?

It depends on the magnitudes and signs of the two charges. If the charges are equal and opposite, placing the third charge midway might balance the forces. Otherwise, the equilibrium position will be offset from the midpoint and requires calculation.

How do Coulomb's law and the principle of superposition help in finding the equilibrium position of the third charge?

Coulomb's law provides the magnitude of the electrostatic force between charges, and the superposition principle allows summing these forces vectorially. By setting the net force to zero, you can solve for the position of the third charge.

Is it possible to place the third charge beyond the two fixed charges to achieve equilibrium, and how would that be done?

Yes, placing the third charge beyond the fixed charges is possible. To find its position, you set up the force equations considering the distances from the third charge to each fixed charge, then solve for the point where the net force equals zero.

Additional Resources

Understanding the Placement of a Third Charge in a System with Two Existing Charges

When analyzing electrostatic systems, the arrangement and placement of multiple charges significantly influence the overall electric field, potential energy, and force interactions. In this review, we explore a specific configuration: a positive charge of +4.75 μC, a negative charge of -3.55 μC, separated by a distance of 18.5 cm, and the question of where to place a third charge such that certain conditions are met. We will dissect the problem in depth, examining the principles of electrostatics involved, potential placement strategies, and the implications of each configuration.

Fundamental Principles Underpinning Charge Placement

Before delving into specific arrangements, it's crucial to understand the key electrostatic principles that govern the interactions:

Coulomb's Law

- Defines the force between two point charges:

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

where:
- F is the magnitude of the force,
- $k_e \approx 8.988 \times 10^9 \, \mathrm{Nm^2/C^2}$,
- q_1, q_2 are the magnitudes of the charges,
- r is the separation distance.

Electric Potential and Potential Energy

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

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

- The potential energy U of a charge q' in the electric potential V:

$$
U = q' V
$$

- These concepts help determine equilibrium points where the net force or potential is zero.

Superposition Principle

- The total electric field or potential at a point is the vector sum of the contributions from all charges.
- When placing a third charge, understanding how fields combine is essential to predict equilibrium or force conditions.

Initial Configuration and Parameters

Let's clarify the initial setup:

- Charge 1 (Q1): +4.75 μC
- Charge 2 (Q2): -3.55 μC
- Distance between Q1 and Q2: 18.5 cm (0.185 m)
- Objective: Identify the possible locations for a third charge (Q3) such that it satisfies a particular condition (e.g., zero net force, equilibrium, or a specific potential).

Analyzing the System: Key Questions

1. Where can the third charge be placed so that the net force on it is zero?
2. Where can the third charge be placed so that the potential energy of the system is minimized or maximized?
3. What locations produce specific potential or field conditions?

We will examine each question in depth.

Conditions for Equilibrium: Zero Net Force on the Third Charge

The Concept of Equilibrium in Electrostatics

- A charge placed at a point experiences forces due to all other charges.
- Electrostatic equilibrium occurs when the net force acting on the charge is zero.
- For a third charge Q_3, this means the vector sum of forces from Q1 and Q2 must cancel out.

Possible Locations for Zero Force

- On the line connecting Q1 and Q2:
- Usually, equilibrium points lie along the line between the charges because the forces are along the line.
- The points where the net force is zero are found by setting the sum of forces to zero and solving for the position.

- External to the line (off the line):
- For point charges, equilibrium points off the line are generally not possible unless specific conditions are met, which are rare for point charges.

Calculating the Zero-Force Point Along the Line

Assuming the third charge is placed on the line connecting Q1 and Q2, denote:

- x as the distance from Q1 to the third charge,
- $d = 18.5\, \mathrm{cm}$.

The forces acting on Q3 are:

- From Q1: $F_1 = k_e \frac{|Q_1 Q_3|}{x^2}$,
- From Q2: $F_2 = k_e \frac{|Q_2 Q_3|}{(d - x)^2}$.

Since Q1 is positive and Q2 is negative, the forces on Q3 will depend on Q3's sign:

- If Q3 is positive:
- Forces from Q1 and Q2 are attractive/repulsive depending on positions—must analyze carefully.
- To find equilibrium:
- Set $F_1 = F_2$ for magnitude balance,
- Adjust for directions to find the point where net force is zero.

Step-by-Step Calculation for the Zero-Force Point

1. Establish the Force Balance Equation

Assuming Q3 is positive:

$$
k_e \frac{Q_1 Q_3}{x^2} = k_e \frac{Q_2 Q_3}{(d - x)^2}
$$

Since Q_3 appears on both sides, it cancels out:

$$
\frac{Q_1}{x^2} = \frac{|Q_2|}{(d - x)^2}
$$

Plug in known values:

$$
\frac{4.75}{x^2} = \frac{3.55}{(0.185 - x)^2}
$$

Rearranged:

$$
4.75 (0.185 - x)^2 = 3.55 x^2
$$

2. Solve the Quadratic Equation

Expanding:

$$
4.75 (0.185^2 - 2 \times 0.185 \times x + x^2) = 3.55 x^2
$$

Calculate:

$$
4.75 (0.034225 - 0.37 x + x^2) = 3.55 x^2
$$

Distribute:

$$
4.75 \times 0.034225 = 0.16254375
$$
$$
4.75 \times (-0.37 x) = -1.7575 x
$$
$$
4.75 x^2 = 4.75 x^2
$$

Putting it all together:

$$
0.16254375 - 1.7575 x + 4.75 x^2 = 3.55 x^2
$$

Bring all to one side:

$$
0.16254375 - 1.7575 x + 4.75 x^2 - 3.55 x^2 = 0
$$

Simplify:

$$
0.16254375 - 1.7575 x + 1.20 x^2 = 0
$$

3. Solve the Quadratic

The quadratic in standard form:

$$
1.20 x^2 - 1.7575 x + 0.16254375 = 0
$$

Using quadratic formula:

$$
x = \frac{1.7575 \pm \sqrt{(1.7575)^2 - 4 \times 1.20 \times 0.16254375}}{2 \times 1.20}
$$

Calculate discriminant:

$$
D = (1.7575)^2 - 4 \times 1.20 \times 0.16254375
$$
$$
D = 3.0897 - 4 \times 1.20 \times 0.16254375
$$
$$
D = 3.0897 - 4 \times 0.1950525
$$
$$
D = 3.0897 - 0.78021 = 2.30949
$$

Calculate roots:

$$
x = \frac{1.7575 \pm \sqrt{2.30949}}{2.4}
$$
$$
\sqrt{2.30949} \approx 1.5197
$$

So,

- First root:

$$
x = \frac{1.7575 + 1.5197}{2.4} = \frac{3.2772}{2.4} \approx 1.3655\, \text{m}
$$

- Second root:

$$
x = \frac{1.7575 - 1.5197}{2.4} = \frac{0.2378}{2.4} \approx 0.0991\, \text{m}
$$

Since the total distance between Q1 and Q2 is 0.185 m, the second root (~9.9 cm) indicates a position between Q1 and Q2, while the first root (~136.5 cm) is outside the segment.

But note: The root at approximately 9.9 cm from Q1 is within the segment, so the third charge can be placed about 9.9 cm from Q1 (roughly midway, closer to Q1).

4. Validity of the Solutions

- Between the charges: at 9.9 cm, the net force on the third charge is zero.
- Outside the segment:

A 4 75 Uc And A 3 55 Ac Charge Is Placed 18 5 Cm Apart Where Can Third Charge Be Placed So That It

A 4 75 Uc And A 3 55 Ac Charge Is Placed 18 5 Cm Apart Where Can Third Charge Be Placed So That It

Related Articles

- A Company Purchased Inventory For $75,000 From A Vendor On Account, FOB Shipping Point, With Terms Of
- Which Of The Following Is NOT A True Statement Of A Quality Public Address System? The System Should
- Youre Trying To Determine Whether To Expand Your Business By Building A New Manufacturing Plant. The

Back to Home