Three Point Charges Of Q, = 6uC, Q2 =2uc, Q3= -4C Are Located At (0, 0), (3,0), And (3,3) Respectively.

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This configuration of point charges presents an interesting scenario in electrostatics, illustrating fundamental principles such as Coulomb’s law, electric field calculation, and potential energy. Understanding the interactions among these charges is essential for grasping how electric forces operate in multi-charge systems. In this article, we will explore the detailed analysis of these three charges, including calculating the electric forces between them, determining the net electric field at various points, and evaluating the potential energy stored within this system.

Introduction to Point Charges and Coulomb’s Law

Before delving into the specific problem, it is important to review some foundational concepts in electrostatics.

What are Point Charges?

Point charges are idealized charges that have negligible size but possess a certain electric charge. They serve as simplified models to analyze electric interactions without considering the effects of charge distribution or physical dimensions. These charges exert forces on each other according to Coulomb’s law, which is fundamental in electrostatics.

Coulomb’s Law

Coulomb’s law states that the magnitude of the electrostatic force F between two point charges q_1 and q_2 separated by a distance r is given by:

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

where:
- F is the magnitude of the force (in newtons),
- k_e 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),
- r is the distance between the charges (in meters).

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

System Description and Coordinates

Given the charges and their positions, we can visualize the system as follows:

Charge	Magnitude	Coordinates (x, y)	Sign
Q_1	6 μC	(0, 0)	Positive
Q_2	2 μC	(3, 0)	Positive
Q_3	-4 μC	(3, 3)	Negative

Note: The charges are given in microcoulombs (μC) and coulombs (C). To maintain consistency, convert all charges to coulombs:
- $Q_1 = 6 \times 10^{-6} \, \mathrm{C}$
- $Q_2 = 2 \times 10^{-6} \, \mathrm{C}$
- $Q_3 = -4 \times 10^{-6} \, \mathrm{C}$

This coordinate setup allows us to analyze the forces and fields systematically.

Calculating Electric Forces Between Charges

The first step in understanding the system is to compute the forces acting between each pair of charges.

Force Between Q_1 and Q_2

- Distance r_{12}: The two charges are located at (0,0) and (3,0), so
$$
r_{12} = 3 \, \mathrm{m}
$$
- Magnitudes: $|Q_1| = 6 \times 10^{-6} \, \mathrm{C}$, $|Q_2| = 2 \times 10^{-6} \, \mathrm{C}$
- Applying Coulomb's law:
$$
F_{12} = k_e \frac{|Q_1 Q_2|}{r_{12}^2} = (8.9875 \times 10^9) \times \frac{(6 \times 10^{-6})(2 \times 10^{-6})}{3^2}
$$
$$
F_{12} \approx 8.9875 \times 10^9 \times \frac{12 \times 10^{-12}}{9} \approx 8.9875 \times 10^9 \times 1.333 \times 10^{-12} \approx 0.012 \, \mathrm{N}
$$

Since both are positive, they repel each other along the x-axis, with Q_1 experiencing a force to the right and Q_2 to the left.

Force Between Q_1 and Q_3

- Distance r_{13}: Between (0,0) and (3,3),
\[

$$
r_{13} = \sqrt{(3-0)^2 + (3-0)^2} = \sqrt{9 + 9} = \sqrt{18} \approx 4.24 \, \mathrm{m}
$$

- Coulomb force:

$$
F_{13} = k_e \frac{|Q_1 Q_3|}{r_{13}^2} = 8.9875 \times 10^9 \times \frac{(6 \times 10^{-6})(4 \times 10^{-6})}{(4.24)^2}
$$

$$
F_{13} \approx 8.9875 \times 10^9 \times \frac{24 \times 10^{-12}}{18} \approx 8.9875 \times 10^9 \times 1.333 \times 10^{-12} \approx 0.012 \, \mathrm{N}
$$

Because Q_3 is negative and Q_1 is positive, they attract each other. The force on Q_1 points toward Q_3.

Force Between Q_2 and Q_3

- Distance r_{23}: Between (3,0) and (3,3),

$$
r_{23} = 3 \, \mathrm{m}
$$

- Coulomb force:

$$
F_{23} = 8.9875 \times 10^9 \times \frac{(2 \times 10^{-6})(4 \times 10^{-6})}{3^2} \approx 8.9875 \times 10^9 \times \frac{8 \times 10^{-12}}{9} \approx 8.9875 \times 10^9 \times 0.888 \times 10^{-12} \approx 0.008 \, \mathrm{N}
$$

Since Q_2 is positive and Q_3 negative, they attract each other, with the force on Q_2 directed toward Q_3.

Net Electric Field and Force on Each Charge

To understand how each charge experiences net forces, we need to calculate the electric field vectors at their locations.

Electric Field Due to a Single Charge

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

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

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

Electric Field at Q_1’s Position

- Due to Q_2:

$$
\vec{E}_{Q_2} = k_e \frac{Q_2}{r_{Q_2}^2} \hat{r}_{Q_2}
$$

- Due to Q_3:

$$
\vec{E}_{Q_3} = k_e \frac{Q_3}{r_{Q_3}^2} \hat{r}_{Q_3}
$$

Calculations involve vector addition of these fields to find the net electric field at Q_1’s position, which determines the force experienced by Q_1.

Similarly, the electric fields at Q_2 and Q_3’s positions can be calculated considering the contributions from the other charges.

Potential Energy of the System

The electrostatic potential energy U stored in a system of point charges is given by:

$$
U = \frac{1}{4\pi \varepsilon_0} \left(\frac{Q_1 Q_2}{r_{12}} + \frac{Q_1 Q_3}{r_{13}} + \frac{Q_2 Q_3}{r_{23}} \right)
$$

where ε_0

Frequently Asked Questions

What is the net electric field at the origin (0,0) due to the three charges Q1, Q2, and Q3?

The net electric field at (0,0) is found by calculating the individual electric fields from each charge at that point and vectorially adding them. Q1 is at (0,0), so it creates an undefined field at its own location, typically considered as infinite or zero depending on context. Q2 at (3,0) produces a field pointing away from Q2 since it is positive, while Q3 at (3,3) produces a field pointing away from Q3 if positive or toward if negative. The combined field results from vector addition of these contributions.

How do the signs and magnitudes of the charges affect the direction of the electric field at a specific point?

The magnitude of each charge determines the strength of its electric field, while the sign indicates the direction: positive charges produce fields radiating outward, and negative charges produce fields directed inward. Therefore, at any point, the net electric field is the vector sum of all individual fields, with directions influenced by each charge's sign and position.

What is the potential energy of the system of three charges?

The total electrostatic potential energy of the system is given by the sum of potential energies between each pair of charges: $U = k(Q1Q2/r12 + Q1Q3/r13 + Q2Q3/r23)$, where r12, r13, and r23 are the distances between the respective charges. Calculating these distances and substituting the values yields the total potential energy.

How do you calculate the electric potential at a point due to multiple point charges?

The electric potential at a point is the algebraic sum of the potentials due to each individual charge. For each charge, the potential is $V = kQ/r$, where Q is the charge and r is the distance from the charge to the point. Summing these for all charges gives the total potential at that point.

What is the significance of the distances between charges in determining the electric field and potential?

Distances between charges determine the magnitude of their mutual electrostatic interactions. The electric field strength and potential at a point depend inversely on the distance from each charge (1/r dependence). Closer charges exert stronger influence, so understanding their positions is essential for accurate calculations.

How would the electric field change if the charge Q3 were positive instead of negative?

If Q3 were positive, it would produce an electric field radiating outward, similar to Q1 and Q2. This change would alter the vector sum of the fields at various points, potentially increasing the net field in some regions or changing the direction of the resultant field, especially near Q3.

Additional Resources

Three Point Charges Of Q, = 6μC, Q2 = 2μC, Q3= -4μC Are Located At (0, 0), (3,0), And (3,3) Respectively. This scenario provides a classic example of electrostatic interactions among multiple point charges in a two-dimensional plane. Understanding how these charges influence each other's electric fields, potentials, and forces is fundamental in electrostatics. In this detailed guide, we will break down the problem step-by-step, exploring the principles involved, calculating the electric field and potential at various points, and analyzing the net forces acting on each charge. Whether you're a student preparing for an exam or a professional reviewing electrostatic principles, this comprehensive analysis will deepen your understanding of multi-charge systems.

Introduction to the System

In electrostatics, point charges are idealized particles with electric charges concentrated at a single point in space. The system under consideration involves three such charges:

- $Q_1 = 6\ \mu C$ located at (0, 0)
- $Q_2 = 2\ \mu C$ located at (3, 0)
- $Q_3 = -4\ \mu C$ located at (3, 3)

Here, microcoulombs (μC) are used as units of charge, where $1\ \mu C = 10^{-6}$ C.

The spatial arrangement forms a right-angled triangle with the following sides:

- Distance between Q1 and Q2: 3 units along the x-axis
- Distance between Q2 and Q3: 3 units along a vertical line
- Distance between Q1 and Q3: calculated via the Pythagorean theorem, $\sqrt{3^2 + 3^2} = \sqrt{18} \approx 4.24$ units

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Fundamental Principles Involved

Coulomb’s Law

Coulomb's Law describes the electrostatic force between two point charges:

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

where:
- F is the magnitude of the force
- $k \approx 8.99 \times 10^9 \, \mathrm{N\,m^2/C^2}$ is Coulomb's constant
- Q_1, Q_2 are the magnitudes of the charges
- r is the distance between the charges

The direction of force depends on the signs:
- Like charges repel
- Opposite charges attract

Electric Field

The electric field $\mathbf{E}$ at a point due to a point charge:

$$\mathbf{E} = k \frac{Q}{r^2} \hat{\mathbf{r}}$$

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

Electric Potential

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

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

The total potential at a point is the algebraic sum of potentials due to all charges.

Step-by-Step Analysis

1. Coordinate System Setup

Plot the positions:

- Q1 at (0, 0)
- Q2 at (3, 0)
- Q3 at (3, 3)

This setup allows us to analyze electric fields and potentials at various points, such as midpoints, on axes, or specific locations of interest.

2. Calculating Distances Between Charges

- Q1 to Q2: $r_{12} = 3\, \mathrm{units}$
- Q2 to Q3: $r_{23} = 3\, \mathrm{units}$
- Q1 to Q3: $r_{13} = \sqrt{(3-0)^2 + (3-0)^2} = \sqrt{18} \approx 4.24\, \mathrm{units}$

Electric Field Analysis

3. Electric Field at a Point Due to Each Charge

Suppose we want to find the electric field at a particular point $P (x, y)$. The total electric field at P is the vector sum:

$$\mathbf{E}_{total} = \mathbf{E}_1 + \mathbf{E}_2 + \mathbf{E}_3$$

where each $\mathbf{E}_i$ is due to charge Q_i:

$$\mathbf{E}_i = k \frac{Q_i}{r_i^2} \hat{\mathbf{r}}_i$$

and r_i is the distance from Q_i to P.

4. Example: Electric Field at the Origin (0,0)

- Contribution from Q1: At its own location, the field is undefined, but we can consider the effect of other charges.
- Contribution from Q2: Located at (3, 0)

- Distance: $r_{2} = 3\, \mathrm{units}$
- Direction: from Q2 to origin: pointing left (negative x-direction)
- Magnitude:

$$E_{2} = k \frac{Q_2}{r_{2}^2} = 8.99 \times 10^9 \times \frac{2 \times 10^{-6}}{3^2}$$

$$E_{2} \approx 8.99 \times 10^9 \times \frac{2 \times 10^{-6}}{9}$$

$$E_{2} \approx 8.99 \times 10^9 \times 2.22 \times 10^{-7}$$

$$ E_{2} \approx 199.8 \, \mathrm{N/C} $$

- Direction: along the negative x-axis

- Contribution from Q3: Located at (3, 3)

- Distance:

$$ r_{3} = \sqrt{(3-0)^2 + (3-0)^2} = 4.24\, \mathrm{units} $$

- Direction: from Q3 to origin:

$$ \hat{\mathbf{r}}_{3} = \frac{(0-3, 0-3)}{r_{3}} = \left(-\frac{3}{4.24}, -\frac{3}{4.24} \right) $$

- Magnitude:

$$ E_{3} = k \frac{|Q_3|}{r_{3}^2} = 8.99 \times 10^9 \times \frac{4 \times 10^{-6}}{(4.24)^2} $$

$$ E_{3} \approx 8.99 \times 10^9 \times \frac{4 \times 10^{-6}}{17.98} $$

$$ E_{3} \approx 8.99 \times 10^9 \times 2.22 \times 10^{-7} $$

$$ E_{3} \approx 199.8\, \mathrm{N/C} $$

- Direction: diagonally down-left (since the charge is negative, the field points towards the charge)

The vector sum of these fields provides the net electric field at the origin.

Electric Potential at a Point

5. Calculating Electric Potential at (0,0)

- Contribution from Q1: Zero, since at the location of the charge, potential tends to infinity, but in practical calculations, the potential due to the charge at its own position is considered as a reference or can be omitted.

- Contribution from Q2:

$$ V_{2} = k \frac{Q_2}{r_{2}} = 8.99 \times 10^9 \times \frac{2 \times 10^{-6}}{3} $$

$$ V_{2} \approx 8.99 \times 10^9 \times 0.6667 \times 10^{-6} $$

$$ V_{2} \approx 5993\, \mathrm{V} $$

- Contribution from Q3:

$$ V_{3} = k \frac{|Q_3|}{r_{3}} = 8.99 \times 10^9 \times \frac{4 \times 10^{-6}}{4.24} $$

$$ V_{3} \approx 8.99 \times 10^9 \times 0.943 \times 10^{-6} $$

$$ V_{3} \approx 8470\, \mathrm{V} $$

- Total Potential:

Since Q3 is negative, its potential contribution is negative:

$$ V_{total} = V_{2} - V_{3} \approx 5993 - 8470 = -2477\, \mathrm{V} $$

This negative potential indicates a net attractive or binding potential at that point.

Force Analysis

6. Calculating the Force on Each Charge

Using Coulomb's Law, the force on a charge due to others:

- Force on Q

Three Point Charges Of Q 6uc Q2 2uc Q3 4c Are Located At 0 0 3 0 And 3 3 Respectively

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