. What Is The Direction Of The Force On The Middle Charge +2q +q -39 1m 1m A) Left B) Right C) Up D)

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Understanding the direction of forces acting on electric charges is fundamental in physics, particularly in electrostatics. When multiple charges are present, they exert forces on each other according to Coulomb's Law, which states that the magnitude of the electrostatic force between two point charges is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them. Determining the direction of the net force on a specific charge involves analyzing the individual forces exerted by other charges and their vector sum. This article explores a specific scenario involving charges of +2q, +q, and -39q placed 1 meter apart, and aims to elucidate the direction of the force on the middle charge, which is +q, given options: Left, Right, Up, or Down.

Understanding Coulomb's Law and Electric Forces

What Is Coulomb's Law?

Coulomb's Law provides the foundation for calculating the electrostatic force between two point charges. It is mathematically expressed as:

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

where:
- F is the magnitude of the force between the charges,
- k is Coulomb's constant ($8.99 \times 10^9\, \mathrm{Nm^2/C^2}$),
- q_1 and q_2 are the magnitudes of the charges,
- r is the distance between the charges.

Key Points:
- Like charges repel; opposite charges attract.
- Force is a vector quantity, having both magnitude and direction.
- The direction of the force on each charge depends on the nature of the other charges involved.

Electric Forces Between Charges

When multiple charges are present, each exerts a force on the others. The net force on a specific charge is obtained by vectorially adding all individual forces acting upon it. This requires understanding both the magnitude and the direction of each force.

Analyzing the Charge Configuration

Setup of the Scenario

Consider a linear arrangement of charges:
- A charge of $+2q$,
- A charge of $+q$ (the middle charge),
- A charge of $-39q$,

placed along a straight line with 1-meter separations. The precise positions are essential for determining the forces:
- Let's assume the charges are aligned along the x-axis.
- The middle charge $+q$ is at the origin (x=0).
- The $+2q$ charge is located at some position to the left or right.
- The $-39q$ charge is placed at a certain position relative to the middle charge.

For the purpose of this analysis, consider the following arrangement:
- $+2q$ is at $x = -1\, \text{m}$,
- $+q$ (middle charge) at $x=0\, \text{m}$,
- $-39q$ at $x = +1\, \text{m}$.

This setup is common in physics problems aiming to analyze net forces in a linear charge distribution.

Calculating the Forces Acting on the Middle Charge (+q)

Force Due to the +2q Charge

- The $+2q$ charge is located 1 meter to the left.
- Coulomb's Law indicates that the force between $+2q$ and $+q$ is repulsive (since both are positive).
- The force vector points away from the $+2q$ charge, i.e., to the right.

Magnitude of the force:

\[
F_{1} = k \frac{|2q \times q|}{(1\, \text{m})^2} = k \frac{2q^2}{1} = 2kq^2
\]

Direction:

- To the right (positive x-direction).

Force Due to the -39q Charge

- The \(-39q \) charge is located 1 meter to the right.
- The force between \(+q \) and \(-39q \) is attractive (opposite charges).
- The force vector points toward the \(-39q \) charge, i.e., to the right.

Magnitude of the force:

\[
F_{2} = k \frac{|(-39q) \times q|}{(1\, \text{m})^2} = k \frac{39q^2}{1} = 39kq^2
\]

Direction:

- Toward the \(-39q \) charge, i.e., to the right (positive x-direction).

Determining the Net Force Direction

Summing the Forces

- Both forces \(F_1 \) (due to \(+2q \)) and \(F_2 \) (due to \(-39q \)) act to the right.
- The magnitudes are:

\[
F_{1} = 2kq^2,\quad F_{2} = 39kq^2
\]

- Total force:

\[
F_{\text{net}} = F_{1} + F_{2} = (2kq^2) + (39kq^2) = 41kq^2
\]

- Since both forces are in the same direction, the net force on the middle charge points to the right.

Implication of the Result

- The dominant force comes from the larger magnitude charge $-39q$, pulling the middle charge towards it.
- The smaller repulsive force from $+2q$ slightly adds to this push, but the overall direction remains to the right.

Final Answer and Explanation

Given the above analysis, the net force acting on the middle charge $+q$ points toward the right.

Therefore, the correct choice is:

B) Right

Summary of Key Points

- Coulomb's Law helps determine the magnitude of forces between charges.
- The direction of the force depends on the nature of the charges (attractive or repulsive).
- For charges aligned linearly, forces act along the line connecting the charges.
- When multiple forces act on a charge, their vector sum determines the net force direction.
- In this scenario, the large negative charge dominates, pulling the middle positive charge to the right.

Additional Considerations

- The specific placement of charges is crucial; different arrangements may change the net force direction.
- If the charges are not aligned linearly, vector addition becomes more complex, requiring components analysis.
- The magnitude of the charges and distances significantly influence the net force's strength and direction.

Conclusion

Understanding the electrostatic interactions among multiple charges is essential for predicting the behavior of charged particles in various physical systems. By carefully analyzing the magnitudes and directions of individual forces, one can determine the net force's direction on any charge within a configuration. In the case of the middle charge \(+q \) with neighboring charges \(+2q \) and \(-39q \), the net force points to the right, primarily due to the influence of the larger negative charge. This insight not only aids in solving physics problems but also deepens comprehension of electrostatic principles applicable across scientific and engineering disciplines.

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Frequently Asked Questions

What is the direction of the force on the middle charge +q in the given setup?

The force on the middle charge +q is directed to the right (Option B).

How do the forces from charges +2q and -39μC influence the middle charge +q?

The +2q charge attracts the +q charge to the right, while the -39μC charge attracts it to the left, but the net force depends on the relative magnitudes and distances.

Are the distances from the middle charge to the other charges equal?

Yes, both charges are 1 meter away from the middle charge, which simplifies the force calculation based on Coulomb's law.

Which charge exerts the greater electrostatic force on the middle charge +q?

The +2q charge exerts a greater force due to its larger magnitude, assuming equal distances.

Based on Coulomb's law, how do you determine the net

force direction on the middle charge?

Calculate the individual forces from each charge and then determine their vector sum; the direction of the net force points toward the stronger or more dominant force.

Given the charges, which way does the net force on the middle charge +q point?

The net force points to the right (Option B), because the force from +2q dominates over the attraction to -39μC.

Is the force on the middle charge attractive or repulsive from each neighboring charge?

The force from +2q is repulsive (pushing away), and from -39μC is attractive (pulling towards), influencing the net direction.

How does the sign and magnitude of the charges affect the direction of the resultant force?

The positive +2q repels the +q charge, pushing it away to the right, whereas the negative -39μC attracts it to the left; since +2q is larger, the net force points right.

What is the significance of the distances being equal in determining the net force?

Equal distances mean the Coulomb force magnitudes are directly proportional to the charges' magnitudes, simplifying the comparison and resulting direction determination.

Additional Resources

Understanding the Direction of Force on a Charge in an Electric Field: An In-Depth Analysis of a Three-Charge System

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Introduction

In the realm of electrostatics, analyzing the forces acting on point charges is fundamental to understanding the behavior of electric fields and interactions. When multiple charges are involved, the resultant force on any particular charge results from the vector sum of individual Coulomb forces exerted by all other charges. This article delves into a specific scenario involving three charges positioned along a line: a middle charge of +2q, flanked by charges +q and -39q, separated by equal distances of 1 meter each. The core question is: What is the direction of the net force acting on the middle charge?

This investigation not only elucidates the principles of Coulomb's law but also offers a comprehensive approach to analyzing complex charge configurations. We will explore the problem step-by-step, examining the magnitudes and directions of individual forces, applying vector principles, and drawing conclusions based on the net resultant.

Background: Coulomb's Law and Force Direction

Coulomb's Law states that the electrostatic force F between two point charges q_1 and q_2 separated by a distance r is given by:

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

where k is Coulomb's constant ($8.99 \times 10^9\, \text{Nm}^2/\text{C}^2$).

Force direction depends on the nature of the charges:
- Like charges repel each other.
- Opposite charges attract each other.

In a linear arrangement, the forces act along the line connecting the charges, either pulling together or pushing apart.

Configuration of the Charges

Let's define the positions along the x-axis for clarity:

- Charge $Q_1 = +q$ at position $x = 0\, \text{m}$
- Middle charge $Q_2 = +2q$ at position $x = 1\, \text{m}$
- Charge $Q_3 = -39q$ at position $x = 2\, \text{m}$

This arrangement implies:

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Q1 (+q) at 0 m ---- 1 m ---- Q2 (+2q) at 1 m ---- 1 m ---- Q3 (-39q) at 2 m
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Given this, the question focuses on the net force acting on the middle charge Q_2.

Step-by-Step Analysis of Forces on the Middle Charge

1. Forces Acting on Q_2:

- Force due to Q_1: Since Q_1 is at $x=0$ and Q_2 at $x=1\, \text{m}$, the distance $r_{12} = 1\, \text{m}$. The force's magnitude:

$$
F_{12} = k \frac{|Q_1 Q_2|}{r_{12}^2} = k \frac{(q)(2q)}{1^2} = 2k q^2
$$

- Force due to Q_3: Q_3 is at $x=2\, \text{m}$, so the distance $r_{23} = 1\, \text{m}$:

$$
F_{23} = k \frac{|Q_2 Q_3|}{r_{23}^2} = k \frac{(2q)(39q)}{1^2} = 78k q^2
$$

Next, determine the direction of these forces:

- Force from Q_1 on Q_2: Since both are positive charges (+q and +2q), they repel each other. The force on Q_2 due to Q_1 points away from Q_1, i.e., to the right (positive x-direction).

- Force from Q_3 on Q_2: Because Q_3 is negative (-39q) and Q_2 is positive (+2q), they attract each other. The force on Q_2 due to Q_3 points toward Q_3, i.e., to the right (since Q_3 is at a higher x-coordinate).

Summary:

Interaction	Magnitude	Direction on Q_2
Q_1	$2k q^2$	Right (away from Q_1)
Q_3	$78k q^2$	Right (toward Q_3)

2. Calculating the Net Force

Since both forces act along the same line and are directed to the right, the net force on Q_2 is the sum of their magnitudes:

$$
F_{net} = F_{12} + F_{23} = 2k q^2 + 78k q^2 = 80k q^2
$$

The direction of the net force is to the right.

3. Physical Interpretation

- The dominant attractive force from the large negative charge Q_3 significantly outweighs the repulsive force from the positive Q_1.
- The net force pulls Q_2 toward the negative charge at $x=2\, \text{m}$, resulting in a net force directed to the right.

Conclusion: The Direction of the Force

Based on the detailed calculations, the net force on the middle charge (+2q) points toward the right along the x-axis. This corresponds to:

Option B) Right

Additional Considerations and Edge Cases

While the above analysis provides a clear answer, it's instructive to consider potential complexities:

- Influence of Other Charges: If additional charges or different arrangements exist, the force vector sum could differ.
- Magnitude Sensitivity: The enormous magnitude of Q_3 (-39q) underscores the importance of charge magnitudes in electrostatic interactions.
- Electrostatic Equilibrium: Achieving equilibrium (net zero force) would require a different charge configuration, not present here.

Implications for Electrodynamics and Practical Applications

Understanding the force directions in such configurations is essential for:

- Designing Electric Field Devices: Sensors, capacitors, and field-effect transistors often involve arrangements of multiple charges.
- Electrostatic Shielding: Knowing how charges attract or repel helps in designing shields and insulators.
- Particle Physics and Atomic Models: The principles underpin the interactions within atoms and molecules.

Summary

- The forces exerted on the middle charge (+2q) by the neighboring charges (+q and -39q) both act to the right.
- The dominant force comes from the large negative charge, attracting the middle charge toward it.
- The net force, therefore, points to the right, making Option B the correct choice.

This analysis underscores the importance of vector addition and Coulomb's law in predicting the behavior of multiple interacting charges—a foundational principle in electrostatics with broad scientific and engineering applications.

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