Three Source Charges Are Used To Create An Electric Field At A Point P In Space Located At X=9.0 M, Y=7.0

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Introduction to Electric Fields and Source Charges

Electric fields are fundamental concepts in physics and electromagnetism, describing the influence that electric charges exert on their surroundings. When multiple charges are present in space, they collectively produce a combined electric field at any given point. Understanding how individual source charges contribute to the total electric field is essential for analyzing complex electrostatic systems. In this article, we explore a scenario involving three source charges and their combined effect at a specific point in space, located at coordinates X=9.0 meters and Y=7.0 meters.

Understanding Electric Fields and Coulomb's Law

What Is an Electric Field?

An electric field is a vector field around charged particles that represents the force exerted on other charges placed within the field. The strength and direction of this force depend on the magnitude and sign of the source charge and the position where the field is evaluated.

Coulomb’s Law and Electric Field Calculation

The electric field $\vec{E}$ created by a point charge q at a position $\vec{r}$ relative to the charge is given by Coulomb’s Law:

$$
\vec{E} = \frac{k \, |q|}{r^2} \hat{r}
$$

where:
- $k \approx 8.99 \times 10^9 \, \mathrm{N\,m^2/C^2}$ (Coulomb's constant),
- q is the magnitude of the source charge,
- r is the distance between the source charge and the point of interest,
- $\hat{r}$ is the unit vector pointing from the source charge to the point.

The direction of $\vec{E}$ depends on the sign of q:
- Positive charge: electric field points away from the charge.

- Negative charge: electric field points toward the charge.

Scenario Setup: Three Source Charges and Point P

Coordinates of the Charges and Point P

Suppose we have three charges, labeled Q_1, Q_2, and Q_3, located at different positions in the plane:

- Q_1 at (x_1, y_1),
- Q_2 at (x_2, y_2),
- Q_3 at (x_3, y_3).

The point P where we want to find the resultant electric field is at:

$$
X_P = 9.0\, \text{m}, \quad Y_P = 7.0\, \text{m}
$$

To proceed, the exact positions and magnitudes of the source charges are necessary. For illustration, assume:

- $Q_1 = +2\, \mu C$ at $(0, 0)$,
- $Q_2 = -3\, \mu C$ at $(10, 0)$,
- $Q_3 = +1\, \mu C$ at $(5, 10)$.

Assumption for Simulation:
- All distances are measured in meters.
- Charges are in microcoulombs (μC), converted to Coulombs when necessary.

Calculating the Electric Field at Point P

Step 1: Determine Distance Vectors

Calculate the vector from each source charge to point P:

$$
\vec{r}_i = (x_P - x_i, y_P - y_i)
$$

and its magnitude:

$$
r_i = |\vec{r}_i| = \sqrt{(x_P - x_i)^2 + (y_P - y_i)^2}
$$

For each charge:
- Q_1:
$$
\vec{r}_1 = (9.0 - 0, 7.0 - 0) = (9.0, 7.0)
$$
$$
r_1 = \sqrt{9.0^2 + 7.0^2} = \sqrt{81 + 49} = \sqrt{130} \approx 11.4\, \text{m}
$$
- Q_2:
$$
\vec{r}_2 = (9.0 - 10, 7.0 - 0) = (-1.0, 7.0)
$$
$$
r_2 = \sqrt{(-1.0)^2 + 7.0^2} = \sqrt{1 + 49} = \sqrt{50} \approx 7.07\, \text{m}
$$
- Q_3:
$$
\vec{r}_3 = (9.0 - 5, 7.0 - 10) = (4.0, -3.0)
$$
$$
r_3 = \sqrt{4.0^2 + (-3.0)^2} = \sqrt{16 + 9} = \sqrt{25} = 5.0\, \text{m}
$$

Step 2: Calculate Electric Field Contributions

Calculate the electric field vector contribution from each charge using Coulomb's Law:

$$
\vec{E}_i = \frac{k \, q_i}{r_i^2} \hat{r}_i
$$

where $\hat{r}_i = \frac{\vec{r}_i}{r_i}$.

Convert charges to Coulombs:
- $Q_1 = +2\, \mu C = 2 \times 10^{-6}\, C$,
- $Q_2 = -3\, \mu C = -3 \times 10^{-6}\, C$,
- $Q_3 = +1\, \mu C = 1 \times 10^{-6}\, C$.

Compute each:

- For Q_1:
$$
\vec{E}_1 = \frac{8.99 \times 10^9 \times 2 \times 10^{-6}}{(11.4)^2} \times \frac{(9.0, 7.0)}{11.4}
$$
$$
|\vec{E}_1| \approx \frac{8.99 \times 10^9 \times 2 \times 10^{-6}}{130} \approx \frac{17.98 \times 10^{3}}{130} \approx 138.4\, \text{kV/m}
$$
The unit vector:

$$
\hat{r}_1 = \left(\frac{9.0}{11.4}, \frac{7.0}{11.4}\right) \approx (0.789, 0.614)
$$
Therefore:
$$
\vec{E}_1 \approx 138.4 \times 10^3 \times (0.789, 0.614) \approx (109, 85) \, \text{kV/m}
$$

- For Q_2:
$$
|\vec{E}_2| = \frac{8.99 \times 10^9 \times 3 \times 10^{-6}}{(7.07)^2} \approx \frac{26.97 \times 10^{3}}{50} \approx 539.4\, \text{kV/m}
$$
Unit vector:
$$
\hat{r}_2 = \left(\frac{-1.0}{7.07}, \frac{7.0}{7.07}\right) \approx (-0.141, 0.99)
$$
Electric field:
$$
\vec{E}_2 \approx 539.4 \times 10^3 \times (-0.141, 0.99) \approx (-76, 534) \, \text{kV/m}
$$

- For Q_3:
$$
|\vec{E}_3| = \frac{8.99 \times 10^9 \times 1 \times 10^{-6}}{(5.0)^2} = \frac{8.99 \times 10^{3}}{25} \approx 359.6\, \text{kV/m}
$$
Unit vector:
$$
\hat{r}_3 = \left(\frac{4.0}{5.0}, \frac{-3.0}{5.0}\right) = (0.8, -0.6)
$$
Electric field:
$$
\vec{E}_3 \approx 359.6 \times 10^3 \times (0.8, -0.6) \approx (287, -215) \, \text{kV/m}
$$

Step 3: Summing the Electric Fields

Total electric

Frequently Asked Questions

What is the significance of the three source charges in creating an electric field at point P?

The three source charges serve as the sources of the electric field, each contributing a vector component to the total electric field at point P based on their magnitudes and positions, allowing for the calculation of the net electric field at that point.

How do you determine the net electric field at point P due to three point charges?

You calculate the individual electric field vectors produced by each charge at point P using Coulomb's law, then vectorially add these fields to find the resultant electric field at P.

What is the importance of the coordinates X=9.0 M and Y=7.0 M in the analysis of the electric field?

The coordinates specify the exact location of point P in space where the electric field is being evaluated, allowing for precise calculation of distances and directions from each charge to point P.

How does the relative position of the charges affect the electric field at point P?

The position of each charge relative to point P determines the magnitude and direction of the individual electric fields; closer charges exert a stronger influence, and their relative placement affects the overall resultant field.

What factors must be considered when calculating the electric field at point P from multiple charges?

Factors include the magnitudes of the charges, their positions relative to point P, the distances from each charge to P, and the vector directions of their individual electric fields.

Can the electric field at point P be zero with three charges present? Under what circumstances?

Yes, the electric field at P can be zero if the vector sum of the electric fields produced by all three charges cancels out, which depends on their magnitudes and positions relative to P.

Additional Resources

Three Source Charges Are Used To Create An Electric Field At A Point P In Space Located At X=9.0 M, Y=7.0

Creating and understanding electric fields generated by multiple point charges is a fundamental concept in electrostatics, bridging theoretical physics and practical applications such as sensors, electronic devices, and electrostatic shielding. When three source charges are involved, the complexity increases significantly compared to a single charge scenario, necessitating a systematic approach to analyze their combined effects at a specific point in space. This detailed review explores the principles, mathematical formulations, and implications of using three source charges to generate an electric field at a point P located at coordinates (X=9.0 m, Y=7.0 m).

Understanding Electric Fields and Point Charges

Fundamentals of Electric Fields

An electric field ($\vec{E}$) represents the force per unit charge experienced by a positive test charge placed at a point in space. It is a vector field, meaning it has both magnitude and direction. The electric field due to a point charge is given by Coulomb's law:

$$
\vec{E} = \frac{1}{4\pi \varepsilon_0} \frac{q}{r^2} \hat{r}
$$

where:
- q is the magnitude of the source charge,
- 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,
- ε_0 is the permittivity of free space ($8.854 \times 10^{-12} \, \text{F/m}$).

Superposition Principle

The total electric field at a point due to multiple charges is the vector sum of the individual fields:

$$
\vec{E}_{\text{total}} = \sum_{i=1}^{n} \vec{E}_i
$$

where each $\vec{E}_i$ is the electric field due to the i^{th} charge.

This superposition principle is crucial when analyzing multiple source charges, as it allows a complex configuration to be broken down into simpler, individual contributions.

Configuration of the Three Source Charges

Positioning the Charges in Space

For a practical and comprehensive analysis, we assume specific positions for the three charges, which could be arbitrary but are often chosen for symmetry or simplicity:

- Charge q_1 at position (x_1, y_1)
- Charge q_2 at position (x_2, y_2)

- Charge q_3 at position (x_3, y_3)

The coordinates of point P are fixed at $(9.0\, \text{m}, 7.0\, \text{m})$. To proceed, we need to assign plausible positions to the charges, for example:

- q_1 at $(x_1, y_1) = (0, 0)$
- q_2 at $(x_2, y_2) = (10, 0)$
- q_3 at $(x_3, y_3) = (5, 10)$

Alternatively, the charges could be positioned based on the problem's context. The key is to understand that their locations significantly influence the resulting electric field at P.

Charge Magnitudes and Signs

The nature (positive or negative) and magnitude of each charge determine the direction and strength of the electric field contributions:

- Positive charges produce fields radiating outward.
- Negative charges produce fields directed inward.

For example:

- $q_1 = +5\, \mu C$
- $q_2 = -3\, \mu C$
- $q_3 = +2\, \mu C$

These values are illustrative; actual calculations depend on specified magnitudes.

Calculating the Electric Field at Point P

Step-by-Step Methodology

Calculating the electric field at point P due to three charges involves several steps:

1. Determine the position vectors:
Calculate the vectors from each charge to point P:

$$
\vec{r}_i = \vec{r}_P - \vec{r}_i
$$

2. Calculate the magnitude of each displacement vector:

$$
r_i = |\vec{r}_i| = \sqrt{(x_P - x_i)^2 + (y_P - y_i)^2}
$$

\]

3. Find the unit vectors:

$$
\hat{r}_i = \frac{\vec{r}_i}{r_i}
$$

4. Compute the electric field contribution from each charge:

$$
\vec{E}_i = \frac{1}{4 \pi \varepsilon_0} \frac{q_i}{r_i^2} \hat{r}_i
$$

5. Sum the vector contributions:

$$
\vec{E}_{\text{total}} = \sum_{i=1}^3 \vec{E}_i
$$

6. Determine magnitude and direction:

$$
|\vec{E}_{\text{total}}| = \sqrt{E_x^2 + E_y^2}
$$

and the angle:

$$
\theta = \arctan \left(\frac{E_y}{E_x} \right)
$$

Numerical Example (Hypothetical)

Suppose:

- $q_1 = +5\, \mu C$ at $(0,0)$,
- $q_2 = -3\, \mu C$ at $(10,0)$,
- $q_3 = +2\, \mu C$ at $(5,10)$,

and point P at $(9,7)$.

Calculations would involve:

- Finding $\vec{r}_i$ for each charge,
- Computing r_i,
- Calculating $\hat{r}_i$,
- Using Coulomb’s law to find each $\vec{E}_i$,
- Summing all vectors component-wise.

This process, while straightforward in principle, can be computationally intensive but is perfectly suited for programming or calculator use.

Influence of Charge Magnitudes and Positions

Effect of Charge Magnitudes

The magnitude of each charge directly impacts the strength of its contribution to the electric field:

- Larger positive or negative charges produce stronger fields.
- The field magnitude scales proportionally with the charge size.

For example, doubling a charge doubles its contribution to the electric field at P.

Effect of Spatial Arrangement

The positions of the charges relative to point P influence both the magnitude and the direction of the resultant field:

- Proximity: Closer charges exert stronger influences due to the $1/r^2$ dependence.
- Symmetry: Symmetrical arrangements can lead to partial field cancelation or reinforcement.
- Configuration: Linear versus triangular arrangements change the vector sum outcome.

Understanding these spatial effects is critical when designing systems that rely on precise electric field manipulations, such as sensors or electrostatic precipitators.

Graphical Representation and Visualization

Vector Diagrams

Visualizing the electric field vectors helps in comprehending their combined effect:

- Draw individual vectors from each charge to point P.
- Show the direction of each $\vec{E}_i$, pointing away from positive charges and toward negative charges.
- Sum vectors tip-to-tail to find the resultant.

Field Lines

Electric field lines provide a qualitative view:

- Lines emanate outward from positive charges.
- Lines terminate on negative charges.
- The density of lines indicates field strength.
- At point P, the direction of the resultant field aligns tangent to the field lines passing through that point.

Applications and Practical Implications

Design of Electrostatic Devices

Understanding how multiple charges influence fields allows engineers to:

- Create targeted electric fields for particle manipulation.
- Design electrostatic shieldings and enclosures.
- Optimize the placement of charges or electrodes in sensors.

Educational Demonstrations

Simulating three-source charge configurations helps students grasp:

- Superposition principles,
- Vector addition,
- Field visualization.

Research and Development

In advanced physics and engineering:

- Precise control of electric fields at micro and nanoscale is vital.
- Electric field modeling informs the development of sensors, actuators, and other electronic components.

Limitations and Advanced Considerations

Assumptions in Point Charge Model

The calculations assume:

- Charges are point-like with no spatial extent.
- The medium is vacuum or air with permittivity \(\varepsilon_0

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