What Is The Potential Difference Between Yi =4cm And Yf =4cm In The Uniform Electric Field E =(20,000i^75,000j^)v/m?

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Understanding the potential difference in a uniform electric field is fundamental in physics and electrical engineering. When analyzing electric fields and their effects on charged particles or conductors, calculating the potential difference between two points provides critical insights into energy transfer, device operation, and electric circuit design. In this article, we will explore the calculation of the potential difference between two points, specifically at positions Yi = 4 cm and Yf = 4 cm, within a uniform electric field characterized by the vector E = (20,000î + 75,000ĵ) V/m.

Introduction to Electric Fields and Potential Difference

Electric Field Concept

An electric field (E) is a vector field surrounding electric charges that exerts force on other charges within the field. Its units are volts per meter (V/m), indicating the potential energy change per unit charge in the field.

Mathematically, the electric field vector E indicates the direction and magnitude of the force experienced by a positive test charge placed in the field. The components of E along the x and y axes describe how the electric field varies in space.

Potential Difference (Voltage)

The potential difference, often called voltage (V), between two points in an electric field is the work done (per unit charge) to move a test charge from one point to the other. It is calculated using the electric field and the path taken between the two points. In a uniform electric field, this calculation simplifies considerably.

Understanding the Given Electric Field and Points

Given Electric Field

The electric field is given as:

$E = (20{,}000\hat{i} + 75{,}000\hat{j})$ V/m

This means:
- The x-component of the electric field, $E_x = 20{,}000$ V/m
- The y-component of the electric field, $E_y = 75{,}000$ V/m

Both components are uniform across space, characteristic of a uniform electric field.

Points of Interest

The initial and final points are specified by their y-coordinates:
- Initial point: $Y_i = 4$ cm $= 0.04$ m
- Final point: $Y_f = 4$ cm $= 0.04$ m

Note that both points share the same y-coordinate, implying they are horizontally aligned at $y = 0.04$ m. The x-coordinates are not specified, but for the purpose of this calculation, we assume movement occurs along a certain displacement in the x-direction or along the path between these points.

Important: Since both points have the same y-coordinate, the vertical component of the electric field does not contribute to the potential difference when moving horizontally at constant y, but if movement occurs along x or y, the calculation must consider the path.

However, the problem as posed emphasizes potential difference between points at the same y-coordinate. Let's clarify the typical scenario:

- If the movement is purely horizontal (along x), then the potential difference depends only on the electric field's x-component.
- If movement is along y, then the y-component matters.
- If movement is along an arbitrary path, the potential difference involves integrating the electric field along that path.

Given the points have the same y-coordinate, and assuming movement along the x-axis, the potential difference simplifies to considering only the x-component.

Calculating Potential Difference in a Uniform Electric Field

General Formula

The potential difference (ΔV) between two points in a uniform electric field is given by:

$$
\Delta V = - \int_{A}^{B} \vec{E} \cdot d\vec{r}
$$

Where:
- A and B are the initial and final points.
- $d\vec{r}$ is an infinitesimal displacement vector along the path.

In a uniform field, this becomes:

$$
\Delta V = - \vec{E} \cdot \vec{d}
$$

Where:
- $\vec{d}$ is the displacement vector from point A to point B.

Applying to Our Scenario

Suppose the initial point is at coordinates:

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

and the final point at:

$$
\vec{r}_f = (x_f, y_f)
$$

Given both points are at y = 0.04 m, and movement occurs along x, then:

$$
\vec{d} = (x_f - x_i, 0)
$$

The potential difference becomes:

$$
\Delta V = - \left(E_x \cdot (x_f - x_i) + E_y \cdot 0 \right) = - E_x \cdot (x_f - x_i)
$$

Note: If movement is purely along x, only the x-component of the electric field contributes.

Calculating the Potential Difference for the Given Values

Assumptions and Clarifications

Since the problem states $Y_i = 4$ cm and $Y_f = 4$ cm, and the electric field components are given, but no explicit x-coordinates, we need to consider typical assumptions:

- The points are at the same y-coordinate, meaning the displacement is purely horizontal.
- The initial and final x-coordinates are x_i and x_f, respectively.

If the problem intends to analyze the potential difference between two points at different x-coordinates but same y, then:

$$
\Delta V = - E_x \cdot (x_f - x_i)
$$

Similarly, if movement occurs vertically (along y), then:

$$
\Delta V = - E_y \cdot (y_f - y_i)
$$

Given both y-coordinates are identical, vertical displacement is zero, so no potential difference arises from y-component in this case.

Calculating with Specific Coordinates

Suppose the initial point is at:

$$
\vec{r}_i = (x_i, 0.04\,m)
$$

and the final point at:

$$
\vec{r}_f = (x_f, 0.04\,m)
$$

then,

$$
\Delta V = - E_x \cdot (x_f - x_i)
$$

Without explicit x-values, we can't compute a numeric value. However, if the problem assumes movement from $x_i = 0$ m to $x_f = d$ m, then:

$$
\Delta V = - 20,000\, V/m \times (x_f - x_i) = - 20,000\, V/m \times d
$$

Where d is the displacement in meters.

For example, if the displacement is 1 meter in the x-direction:

$$
\Delta V = - 20,000\, V/m \times 1\, m = - 20,000\, V
$$

This indicates a potential drop of 20,000 volts when moving 1 meter along the positive x-direction.

Special Cases and Additional Considerations

Movement Along Both x and y

If the movement occurs along a path with both x and y components, the potential difference is:

$$
\Delta V = - (E_x \cdot \Delta x + E_y \cdot \Delta y)
$$

Where:
- $\Delta x = x_f - x_i$
- $\Delta y = y_f - y_i$

In our case, since $\Delta y = 0$, the potential difference simplifies to the x-component.

Impact of the Electric Field Components

The electric field's components influence the potential difference as follows:

- The x-component (E_x = 20,000 V/m) causes potential changes along the x-axis.
- The y-component (E_y = 75,000 V/m) causes potential changes along the y-axis.

However, because both points share the same y-coordinate, the y-component does not contribute to the potential difference in this particular scenario unless the path involves vertical displacement.

Significance of Sign in Potential Difference

The negative sign indicates the direction of potential change relative to the electric field:

- Moving along the electric field (in the same direction as E) results in a decrease in electric potential.
- Moving against the electric field (opposite to E) results in an increase in electric potential.

Implications in Practical Applications

Electrical Devices and Circuits

Understanding potential differences in electric fields is crucial for designing circuits, capacitors, and other electronic components where voltage levels determine device operation.

Electrostatics and Particle Motion

In electrostatic applications, knowing the potential difference helps predict the motion of charged particles, such as electrons moving in a vacuum tube or ions in a plasma.

Field Manipulation and Control

Engineers utilize electric field calculations to control particle beams, manipulate charges in sensors, and develop electrostatic shielding.

Summary of Key Points

- The potential difference in a uniform electric field depends on the electric field components and the displacement vector between two

Frequently Asked Questions

What is the potential difference between Yi = 4 cm and Yf = 4 cm in a uniform electric field E = (20,000î + 75,000ĵ) V/m?

Since Yi and Yf are both 4 cm (or 0.04 m), and they are at the same position in the field, the potential difference is zero because there is no displacement in the direction of the electric field.

How do you calculate the potential difference between two points in a uniform electric field?

The potential difference ΔV is calculated by ΔV = -E · Δr, where E is the electric field vector and Δr is the displacement vector between the two points.

Given the electric field E = (20,000î + 75,000ĵ) V/m, what is the potential difference between points at the same Y-coordinate (Y=4cm)?

If both points are at the same Y-coordinate, the vertical displacement is zero, so the potential difference depends only on the horizontal displacement. If the horizontal displacement is also zero, then the potential difference is zero.

If the initial point is at (x_i, y_i) and the final point at (x_f, y_f) both with y=4cm, how does the electric field influence the potential difference?

Since the points are at the same y-coordinate, the vertical component does not contribute; the potential difference is determined solely by the horizontal component of the field and the difference in x-coordinates.

Why is the potential difference zero if both initial and final points are at the same position in a

uniform electric field?

Because there is no displacement between the points, the work done by the electric field is zero, resulting in zero potential difference.

Additional Resources

Potential Difference Between Yi = 4cm And Yf = 4cm In The Uniform Electric Field E = (20,000î + 75,000ĵ) V/m

Understanding the potential difference between two points in an electric field is fundamental in electromagnetism, as it relates directly to the work done in moving a charge within that field. When examining the potential difference between two points with the same y-coordinate but different positions along the x-axis in a uniform electric field, it becomes essential to analyze both the field's nature and the geometrical configuration. In this context, the question about the potential difference between points where Yi = 4 cm and Yf = 4 cm in the uniform electric field E = (20,000î + 75,000ĵ) V/m provides a valuable example of how vector fields influence electrical potential.

Understanding the Electric Field: E = (20,000î + 75,000ĵ) V/m

Before calculating the potential difference, it is crucial to understand the characteristics of the electric field in question.

Nature and Components of the Electric Field

- The electric field E is given as a vector with components:
- $E_x = 20,000 \, V/m$ along the x-axis.
- $E_y = 75,000 \, V/m$ along the y-axis.
- This indicates a uniform electric field with a significant component along the y-direction and a moderate component along the x-direction.

Implication of the Field Components

- The field's magnitude can be computed as:

$$
|\mathbf{E}| = \sqrt{(20,000)^2 + (75,000)^2} \approx \sqrt{4 \times 10^8 + 5.625 \times 10^9} \approx \sqrt{6.025 \times 10^9} \approx 77,600\, V/m
$$

- The field points in a direction that is inclined from the x-axis toward the y-axis, with an angle θ given by:

$$
\theta = \arctan{\left(\frac{75,000}{20,000}\right)} \approx \arctan{(3.75)} \approx 75.96^\circ
$$

- This high inclination indicates that movement along the y-direction contributes significantly to the potential difference, compared to movement along the x-direction.

Potential Difference in a Uniform Electric Field

Fundamental Concept

The potential difference between two points in an electric field is calculated via the line integral of the electric field:

$$
\Delta V = V_{final} - V_{initial} = - \int_{initial}^{final} \mathbf{E} \cdot d\mathbf{r}
$$

- For a uniform field, this simplifies to:

$$
\Delta V = - \mathbf{E} \cdot \Delta \mathbf{r}
$$

- Where $\Delta \mathbf{r}$ is the displacement vector from the initial to the final point.

Application to the Given Points

- The problem specifies initial and final points with the same y-coordinate, both at $y = 4\,cm$, but different x-coordinates, say:

$$
\mathbf{r}_i = (x_i, 4\,cm), \quad \mathbf{r}_f = (x_f, 4\,cm)
$$

- Since $y_i = y_f = 4\,cm$, the displacement vector is:

$$
\Delta \mathbf{r} = (x_f - x_i) \hat{i} + (0) \hat{j}
$$

- If x_i and x_f are given or known, the potential difference can be directly calculated.

Calculating the Potential Difference: Step-by-Step

Step 1: Convert Coordinates to SI Units

- Because the problem specifies distances in centimeters, convert to meters:

$$
1\,cm = 0.01\,m
$$

- So, $y = 4\,cm = 0.04\,m$.

- Let:

$$
x_i = x_{initial} \quad (\text{in meters}), \quad x_f = x_{final}
$$

For example, if $x_i = 0\,m$ and $x_f = 4\,cm = 0.04\,m$, this makes calculations straightforward.

Step 2: Express Displacement Vector

- The displacement:

$$
\Delta \mathbf{r} = (x_f - x_i) \hat{i} + 0 \hat{j}
$$

- Since the y-component remains constant, only the x-component contributes to the change.

Step 3: Dot Product of E and $\Delta \mathbf{r}$

- The potential difference:

$$
\Delta V = - \mathbf{E} \cdot \Delta \mathbf{r} = - (E_x \Delta x + E_y \Delta y)
$$

- But because $\Delta y = 0$:

$$
\Delta V = - E_x \Delta x
$$

- Substituting:

$$
\Delta V = - (20,000\, V/m) \times (x_f - x_i)
$$

- Therefore, the potential difference depends solely on the change in x-position when y remains constant.

Numerical Example and Interpretation

Suppose:

- Initial point: $ \mathbf{r}_i = (0\,m, 0.04\,m) $
- Final point: $ \mathbf{r}_f = (0.04\,m, 0.04\,m) $

Then:

$$
\Delta x = 0.04\,m - 0 = 0.04\,m
$$

Calculating the potential difference:

$$
\Delta V = - (20,000\, V/m) \times 0.04\,m = -800\,V
$$

This indicates:

- Moving from the initial to final point along the x-direction at $y = 4\,cm$ results in a potential change of -800 volts.
- The negative sign indicates a decrease in potential when moving along the direction of the electric field component in x.

Key Takeaways:

- Moving along the electric field vector decreases potential.
- Moving opposite to the electric field vector increases potential.

Influence of the y-Coordinate: Why It Matters

Since the points are at the same y-coordinate, the y-component of the electric field does not directly influence the potential difference between these two points, assuming movement strictly along x. However:

- If the path involves movement in y, or if initial and final positions differ in y, the y-component would contribute to the potential difference.
- For points at the same y, the potential difference simplifies primarily to the x-component.

General Case: Potential Difference between Yi and Yf at Different x-Positions

If the points are at different y-coordinates:

$$
\Delta V = - (E_x \Delta x + E_y \Delta y)
$$

- For example, moving from (x_i, y_i) to (x_f, y_f):

$$
\Delta V = - E_x (x_f - x_i) - E_y (y_f - y_i)
$$

This allows for more comprehensive analysis when the path is not parallel to axes.

Features, Pros, and Cons of the Approach

Features:

- Simplifies calculations for uniform fields and straight-line paths.
- Highlights the importance of field components and spatial orientation in potential difference calculations.
- Demonstrates the vector nature of electric fields and potentials.

Pros:

- Straightforward computation using dot products.
- Can be extended to complex paths with line integrals if needed.
- Applicable in designing circuits, understanding dielectric materials, and electric field mapping.

Cons:

- Assumes the electric field is uniform; non-uniform fields require more complex calculus.
- Assumes a straight path; curved paths necessitate integral calculus.
- Potential difference alone does not specify the work done without considering charge magnitude.

Conclusion

The potential difference between two points at the same y-coordinate (Yi = 4cm and Yf = 4cm) in a uniform electric field E = $(20{,}000\hat{i} + 75{,}000\hat{j})$ V/m fundamentally depends on the x-coordinate difference. When movement occurs solely along the x-direction at a fixed y, the potential difference simplifies to $\Delta V = - E_x \Delta x$. This underscores the vector nature of electric fields and their influence on electrical potential. Understanding this relationship is essential in numerous applications, including electrical engineering, physics experiments, and the design of devices involving electric fields. When extending the analysis to points with different y-coordinates or more complex paths, the general line integral approach becomes necessary, providing a

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