

The Figure(Figure 1) Shows Four Sides Of A 6.0cm6.0cm6.0cm Cube.Part AWhat Is The Electric Flux 1 Through

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Understanding electric flux is fundamental in electromagnetism, especially when analyzing how electric fields interact with objects such as cubes. In this article, we will explore the concept of electric flux through a cube, with particular emphasis on a cube measuring 6.0 cm on each side, as depicted in the referenced figure. We will dissect the problem systematically, provide step-by-step solutions, and clarify the underlying physics principles involved.

What Is Electric Flux?

Electric flux is a measure of the electric field passing through a given surface. It quantifies how much electric field "flows" through that surface, serving as a vital concept in Gauss's Law and other areas of electromagnetism.

Definition of Electric Flux

Electric flux (denoted as Φ_E) through a surface is mathematically expressed as:

- $\Phi_E = \int \mathbf{E} \cdot d\mathbf{A}$

where:

- $\mathbf{E}$ is the electric field vector.
- $d\mathbf{A}$ is an infinitesimal area vector perpendicular to the surface.

The dot product signifies that only the component of $\mathbf{E}$ perpendicular to the surface contributes to the flux.

Significance of Electric Flux

This quantity helps determine how electric fields interact with objects, such as whether they induce charges or cause forces. It also forms the basis for Gauss's Law, which relates the electric flux through a closed surface to the

enclosed charge.

Understanding the Cube and Its Geometry

In the problem, a cube with sides measuring 6.0 cm (0.06 meters) is considered. The figure shows four sides of this cube, and the goal is to compute the electric flux passing through one of these sides.

Dimensions and Surface Area

Given:

- Side length of the cube, $s = 6.0 \text{ cm} = 0.06 \text{ m}$

The surface area of each side is:

- Area, $A = s^2 = (0.06 \text{ m})^2 = 0.0036 \text{ m}^2$

Orientation of the Cube and Electric Field

While the figure depicts four sides, it's essential to understand the orientation of the electric field relative to these faces. The electric flux calculation depends on whether the electric field is uniform, its direction, and whether it's perpendicular or at an angle to the surface.

Part A: Calculating the Electric Flux Through One Side of the Cube

To determine the electric flux through a particular face of the cube, we need to analyze the electric field's properties and the face's orientation. We'll consider common scenarios and calculations.

Scenario 1: Electric Field Perpendicular to the Face

Suppose the electric field E is uniform and directed perpendicular to the face of interest.

Given:

- The magnitude of the electric field, E
- The face area, A

Calculation:

The electric flux Φ_E through one face is:

$$\Phi_E = E A \cos\theta$$

where θ is the angle between E and the normal to the surface. If E is perpendicular to the face, $\theta = 0^\circ$, and $\cos\theta = 1$.

Thus:

$$\Phi_E = E A$$

Example:

If $E = 3.0 \times 10^3 \text{ N/C}$ (assuming the problem provides this value):

- Calculate:

$$\Phi_E = (3.0 \times 10^3 \text{ N/C}) \quad 0.0036 \text{ m}^2 = 10.8 \text{ N}\cdot\text{m}^2/\text{C}$$

Conclusion:

The electric flux through that side would be $10.8 \text{ N}\cdot\text{m}^2/\text{C}$.

Scenario 2: Electric Field at an Angle to the Face

If the electric field makes an angle θ with the normal to the surface:

$$\Phi_E = E A \cos\theta$$

This accounts for the component of the electric field perpendicular to the surface.

Example:

If $\theta = 45^\circ$, then:

$$\Phi_E = E A \cos 45^\circ = E A \left(\frac{\sqrt{2}}{2}\right)$$

This reduces the flux proportionally to the cosine of the angle.

Scenario 3: Electric Field Parallel to the Face

If E is parallel to the face ($\theta = 90^\circ$), then:

$$\Phi_E = 0$$

since no electric field passes through the surface in this orientation.

Applying Gauss's Law to the Cube

Gauss's Law states:

$$\oint \mathbf{E} \cdot d\mathbf{A} = Q_{\text{enclosed}} / \epsilon_0$$

where:

- Q_{enclosed} is the total charge within the surface.
- ϵ_0 is the permittivity of free space ($\approx 8.854 \times 10^{-12} \text{ C}^2/(\text{N}\cdot\text{m}^2)$).

This law is instrumental when analyzing the total flux through all six faces of the cube or specific subsets.

Flux Through Multiple Sides

If the electric field is uniform and symmetric:

- The flux through faces parallel to the field is maximized.
- The flux through faces perpendicular to the field depends on the orientation.

Summary of Key Calculations and Concepts

- Electric flux measures how much electric field passes through a surface.
- For a cube of side 6.0 cm, each face has an area of 0.0036 m^2 .
- The flux through a face depends on the electric field's magnitude and its orientation relative to that face.
- When the field is perpendicular to the face, $\text{flux} = E A$.
- When the field is at an angle θ , $\text{flux} = E A \cos\theta$.
- If the electric field is known, calculating flux is straightforward; otherwise, the problem might involve using Gauss's Law to find enclosed charges or field strengths.

Conclusion

Understanding the electric flux through a cube's face involves combining geometric considerations with the properties of the electric field. Whether the field is uniform, at an angle, or variable, the fundamental formula remains $\Phi_E = E A \cos\theta$, adapted as needed based on the scenario.

As demonstrated, the problem of calculating electric flux through a cube's side is approachable with a clear grasp of the underlying physics principles,

the geometry of the object, and the orientation of the electric field. This analysis provides a foundation for solving more complex electromagnetism problems involving flux, electric fields, and charge distributions.

Remember: Always consider the direction of the electric field relative to the surface when calculating flux, and use Gauss's Law as a powerful tool for relating flux to enclosed charge in symmetric situations.

Frequently Asked Questions

What is the formula for calculating electric flux through a surface?

The electric flux (Φ) through a surface is given by $\Phi = E \times A \times \cos(\theta)$, where E is the electric field strength, A is the area of the surface, and θ is the angle between the electric field and the normal to the surface.

How do you determine the electric flux through one face of the cube in the given figure?

To determine the electric flux through one face, identify the electric field's magnitude and direction relative to that face, then use $\Phi = E \times A \times \cos(\theta)$. If the field is perpendicular to the face, $\cos(\theta) = 1$; if parallel, flux is zero.

What is the area of one side of a 6.0 cm cube?

The area of one face of the cube is $A = (6.0 \text{ cm}) \times (6.0 \text{ cm}) = 36.0 \text{ cm}^2$, which is $36.0 \times 10^{-4} \text{ m}^2$ or $3.6 \times 10^{-3} \text{ m}^2$.

If the electric field is uniform and perpendicular to one face of the cube, how do you calculate the flux through that face?

If the electric field is perpendicular to the face, the flux $\Phi = E \times A$, since $\cos(0^\circ) = 1$. Simply multiply the electric field magnitude by the area.

What is the significance of the direction of the electric field when calculating flux through the cube's sides?

The direction determines the angle θ between the electric field and the normal to each face, which affects the flux calculation via the cosine term. Flux is maximum when the field is perpendicular and zero when parallel.

How does the symmetry of the cube affect the calculation of total electric flux through all sides?

Due to symmetry, if the electric field is uniform and symmetrical, the total flux through the entire cube can be summed by considering the flux through each face, often simplifying to the net flux based on the field's orientation and magnitude.

What additional information is needed to accurately compute the electric flux through the given side of the cube?

You need to know the magnitude and direction of the electric field, as well as whether the field is uniform and perpendicular or at an angle to the face in question to correctly apply the flux formula.

Additional Resources

The Figure (Figure 1) Shows Four Sides Of A $6.0\text{cm} \times 6.0\text{cm} \times 6.0\text{cm}$ Cube. Part A: What Is The Electric Flux Through?

Introduction

Understanding electric flux is fundamental to grasping the principles of electromagnetism, a cornerstone of physics that explains how electric fields interact with charged objects and surfaces. In the context of the given problem – involving a cube with specified dimensions and certain electric field orientations – calculating the electric flux through its sides is an essential step in analyzing the behavior of electric fields in bounded regions.

This article provides a comprehensive investigation into the concept of electric flux, focusing on the specific scenario depicted in the figure, which displays four sides of a cube measuring 6.0 cm on each edge. We will explore the principles underpinning electric flux, the role of Gauss's law, and the detailed calculation process for the flux through the specified faces, illustrating the physics concepts with mathematical rigor.

Background and Fundamental Concepts

What Is Electric Flux?

Electric flux, denoted by Φ_E , measures the number of electric field lines passing through a given surface area. Mathematically, it is defined as:

$$\Phi_E = \int \vec{E} \cdot d\vec{A}$$

where:

- $\vec{E}$ is the electric field vector at a point on the surface,
- $d\vec{A}$ is an infinitesimal area element vector, perpendicular to the surface.

In simpler terms, the flux quantifies how much of the electric field "flows" through a surface. It is scalar and measured in units called volt-meters (V·m) or newton-meters squared per coulomb (N·m²/C), commonly expressed as N·m²/C.

The Physical Significance of Electric Flux

Electric flux offers insight into the distribution and strength of electric fields relative to surfaces. For example:

- Zero flux indicates that the electric field lines are tangential to the surface (no flow through),
- Positive flux indicates field lines passing outward through the surface,
- Negative flux indicates lines passing inward.

In the context of closed surfaces, Gauss's law relates total electric flux to the net enclosed charge:

$$\Phi_{\text{total}} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

where:

- Q_{enc} is the total charge enclosed,
- ϵ_0 is the permittivity of free space ($8.854 \times 10^{-12} \text{ F/m}$).

The Geometry of the Cube: Dimensions and Orientation

The cube in Figure 1 measures 6.0 cm along each edge, which converts to meters as:

Φ_E

6.0\, \text{cm} = 0.06\, \text{m} \\

The problem involves calculating the electric flux through four sides of this cube. The orientation of the electric field relative to these sides determines the flux values. The figure, while not visually provided here, suggests a scenario where a uniform electric field interacts with the cube's faces, possibly aligned along one axis.

Investigating the Electric Field Configuration

Assumptions Based on Typical Scenarios

In standard introductory physics problems, configurations often involve:

- A uniform electric field $(\vec{E})$ oriented along a specific axis (say, the x-axis),
- The cube positioned so that some of its faces are parallel or perpendicular to $(\vec{E})$.

Given that four sides are involved, it's likely that:

- Two sides are perpendicular to the electric field (parallel faces),
- The remaining two sides are either parallel or perpendicular, depending on the problem's specifics.

Without the figure, we infer a typical setup:

- The electric field $(\vec{E})$ is uniform and points along one axis (say, the x-axis),
- The cube's faces are aligned with the coordinate axes.

Step-by-Step Calculation of Electric Flux

1. Identifying the Relevant Faces

Suppose the electric field $(\vec{E})$ is directed along the x-axis. The faces of the cube perpendicular to the x-axis are:

- The "left" face at $(x=0)$,
- The "right" face at $(x=0.06\, \text{m})$.

The other four faces are parallel to the electric field (i.e., the four sides perpendicular to the x-axis).

Note: The problem asks about four sides, which probably refers to the four vertical and horizontal faces excluding the two faces aligned with the field

direction.

2. Calculating Flux Through Each Face

The electric flux through a face depends on:

$$\Phi_E = \vec{E} \cdot \vec{A} = E A \cos \theta$$

where:

- E is the magnitude of the electric field,
- A is the area of the face,
- θ is the angle between $\vec{E}$ and the normal to the surface.

Assuming:

- The electric field is uniform,
- The faces considered are perpendicular to the field (normal vector aligned or anti-aligned with $\vec{E}$),

then:

$$\Phi_E = E \times A \times (\pm 1)$$

depending on whether the normal vector points in the same or opposite direction as $\vec{E}$.

3. Computing the Area of Each Side

Each side of the cube has an area:

$$A = (0.06 \text{ m}) \times (0.06 \text{ m}) = 0.0036 \text{ m}^2$$

4. Considering the Electric Field Magnitude

Suppose the electric field magnitude E is given or needs to be determined from additional data (for example, from the figure or problem statement). For demonstration, assume:

$$\begin{aligned} & \backslash[\\ & E = E_0 \\ & \backslash] \end{aligned}$$

where (E_0) is a known constant.

Calculating the Flux for Each Side

Suppose the electric field points along the positive x-axis:

- For the face at $(x=0)$, normal vector points outward in the positive x-direction:

$$\begin{aligned} & \backslash[\\ & \Phi_{x=0} = E \times A \\ & \backslash] \end{aligned}$$

- For the face at $(x=0.06\text{ m})$, normal vector points outward in the negative x-direction:

$$\begin{aligned} & \backslash[\\ & \Phi_{x=0.06} = -E \times A \\ & \backslash] \end{aligned}$$

If the four sides in question are those perpendicular to the y and z axes, then:

- For faces perpendicular to y or z axes, if $(\vec{E})$ is along x, the flux through those faces is zero because:

$$\begin{aligned} & \backslash[\\ & \cos 90^\circ = 0 \\ & \backslash] \end{aligned}$$

Total Electric Flux Through the Four Sides

- Sides parallel to the electric field (faces at $(y=0)$ and $(y=0.06\text{ m})$, and similarly for z):

$$\begin{aligned} & \backslash[\\ & \Phi = 0 \\ & \backslash] \end{aligned}$$

- Sides perpendicular to the electric field (at $(x=0)$ and $(x=0.06\text{ m})$):

$$\begin{aligned} & \backslash[\end{aligned}$$

$$\begin{aligned} \Phi_{x=0} &= E \times A \\ \Phi_{x=0.06} &= -E \times A \end{aligned}$$

Total flux through these two sides:

$$\Phi_{\text{total}} = \Phi_{x=0} + \Phi_{x=0.06} = E \times A - E \times A = 0$$

This aligns with the principle that the net flux through a closed surface is related to enclosed charge (Gauss's law). For open surfaces, the flux depends on the field direction and surface orientation.

Deeper Analysis: Net Flux and Charge Enclosure

If the cube encloses no charge, the total flux through all six faces sums to zero, consistent with Gauss's law. The problem's focus on four sides suggests an interest in partial flux, which can be positive, negative, or zero depending on the field and face orientations.

Practical Implications and Applications

Understanding the flux through specific surfaces of a cube has significant applications:

- Electrostatic shielding: Designing enclosures that prevent external electric fields from penetrating sensitive equipment.
- Capacitor design: Knowing flux distribution helps optimize electric field strength and uniformity.
- Electromagnetic compatibility (EMC): Ensuring that devices do not unintentionally interfere through electric field leakage.

Concluding Remarks

This investigation underscores the importance of vector calculus and physical intuition in analyzing electric flux. The key takeaways include:

- The calculation of flux depends critically on the electric field's magnitude and direction, as well as the orientation of the surface.
- For a uniform field and planar surfaces, the flux calculation simplifies to a product of field strength, area, and the cosine of the angle between them.
- The net flux through a closed surface relates directly to enclosed charge,

as per Gauss's law.

In the specific scenario depicted by the figure, understanding which sides are involved and their orientation relative to the electric field is crucial. Such detailed analysis not only aids in solving the problem at hand but also enhances comprehension of broader electromagnetic principles applicable in various engineering and physics contexts

The Figure Figure 1 Shows Four Sides Of A 6 0cm6 0cm6 0cm Cube Part Awhat Is The Electric Flux 1 Through

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