UT DALLAS

PHYS2326
Lecture #6

Prof. Fabiano Rodrigues

Department of Physics
The University of Texas at Dallas

Reminder / Announcement

TA office Hours:

Hasan Jahanandish

PHY 1.102 Desk 10

Tue.: 2pm - 4pm

Fri.: 10am - noon

Goals for this lecture (Ch. 22)

- Quick review (Ch. 21)
- Understand electric flux
- Introduce Gauss's Law

Review

$$\vec{F}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$$

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$$\vec{\tau} = \vec{p}\times\vec{E}$$

Charge from Electric Field

Charge from Electric Field

- We saw that one can determine the electric field from a distribution of charges

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\sum\frac{q}{r^2}\hat{r} \qquad \vec{E} = \frac{1}{4\pi\epsilon_0}\int\frac{dq}{r^2}\hat{r}$$

Charge from Electric Field

- We saw that one can determine the electric field from a distribution of charges

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- But… can we say anything about charge sources if the electric vector field (**E**) is known?

Charge from Electric Field

- It turns out the flux of electric field through a closed surface is proportional to the net charge inside the surface.

Charge from Electric Field

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$$\Phi_E = \oint \vec{E} \cdot d\vec{S} = \frac{Q_{enclosed}}{\epsilon_0}$$

Gauss's Law

American Institute of Physics

Karl Friedrich Gauss

German mathematician and astronomer (1777–1855)

Gauss received a doctoral degree in mathematics from the University of Helmstedt in 1799. In addition to his work in electromagnetism, he made contributions to mathematics and science in number theory, statistics, non-Euclidean geometry, and cometary orbital mechanics. He was a founder of the German Magnetic Union, which studies the Earth's magnetic field on a continual basis.

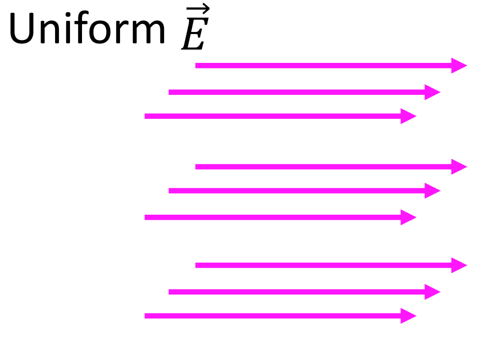
$$\Phi_E = \oint \vec{E} \cdot d\vec{S} = \frac{Q_{enclosed}}{\epsilon_0}$$

The net electric flux through any closed surface is proportional to the net charge enclosed by that surface.

Electric Flux

Electric Flux

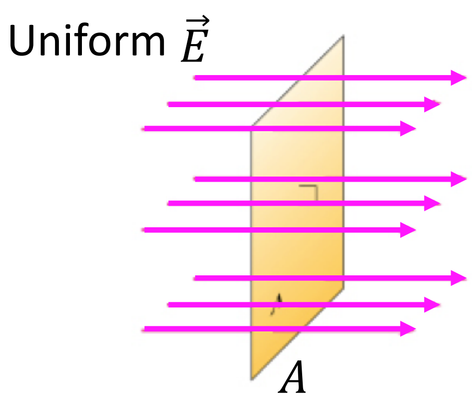
- The density (proximity) of electric field lines represent the magnitude of the electric field.



Electric Flux

- The density (proximity) of electric field lines represent the magnitude of the electric field.

- The electric flux Φ represents the amount of electric field E passing through a surface A.



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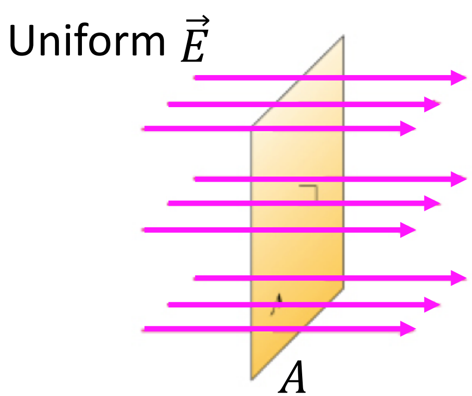
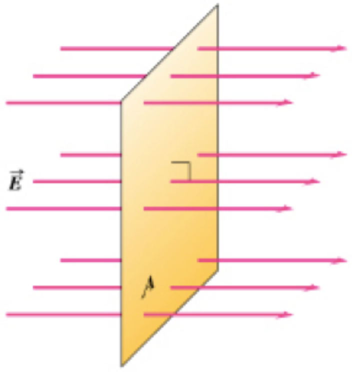


$$\Phi_{\mathrm{E}} = EA$$

Electric Flux

Uniform **E**



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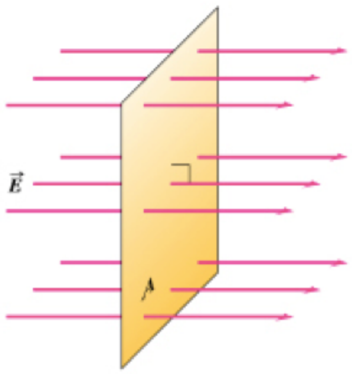

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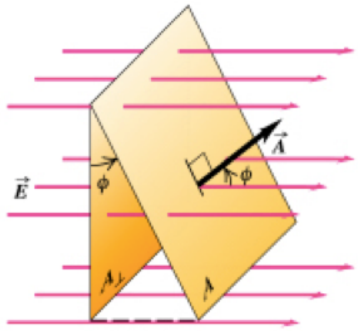

$$\Phi_{\mathrm{E}} = ?$$

$$\Phi_{\mathrm{E}} = EAcos(\phi)$$

$$Where: \vec{A} = A\hat{\mathrm{n}}$$

Electric Flux

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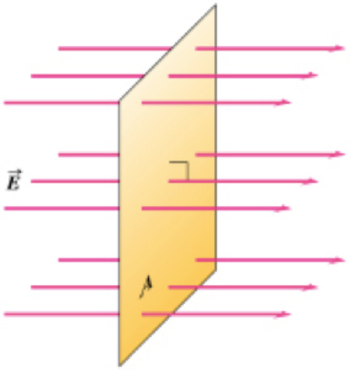

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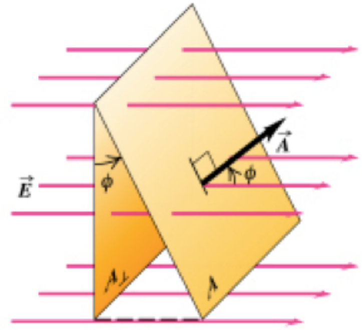

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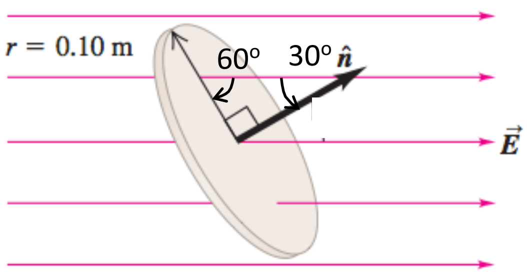
Example: What is the electric flux through the disk shown in the figure if the magnitude of the electric field is 1.0×10^3 N/C?



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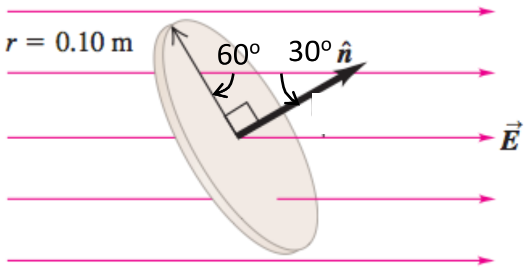

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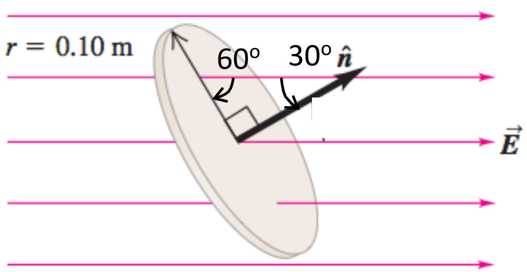
Example: What is the electric flux through the disk shown in the figure if the magnitude of the electric field is $1.0 \text{x} 10^3$ N/C?



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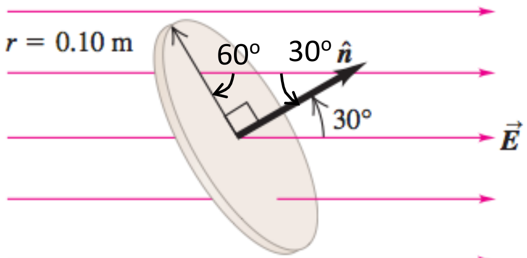

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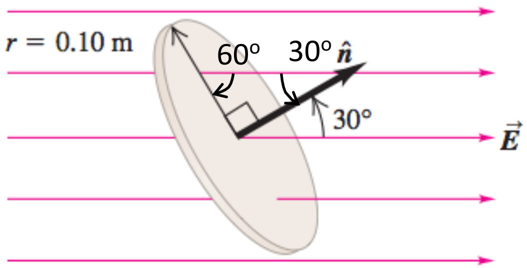

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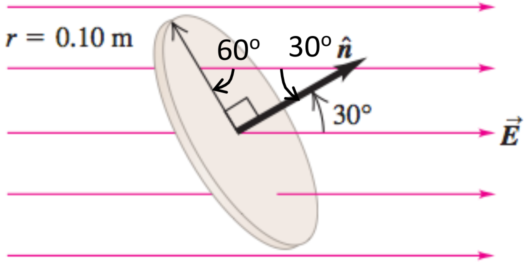

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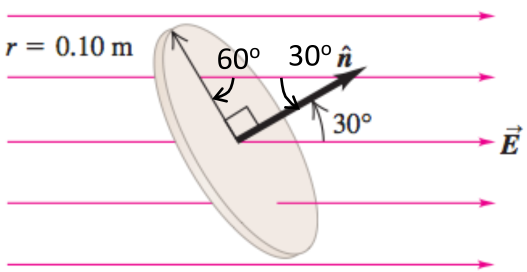

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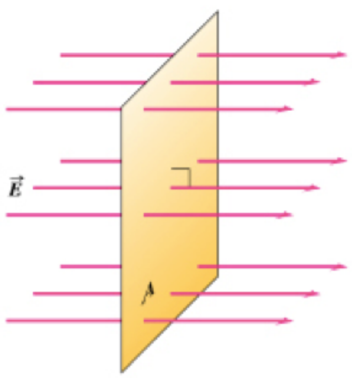
$$\Phi_E = (1.0 \times 10^3)(0.01\pi)\cos(30°)$$

$$\Phi_E = 27 \ Nm^2/C$$

Electric Flux

Uniform **E**



$\Phi_{\mathrm{E}} = EA$

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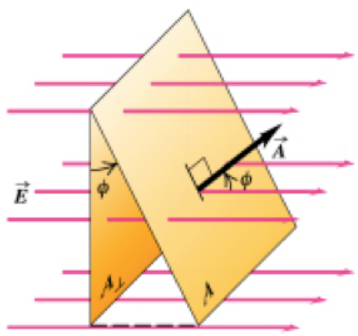
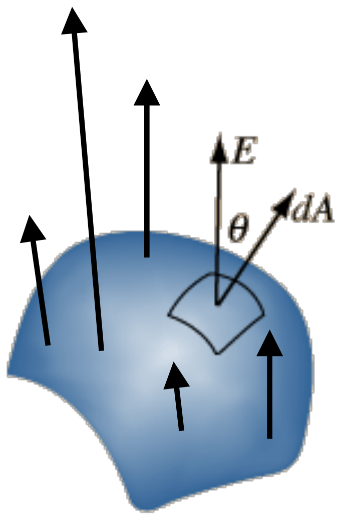


$\Phi_{\mathrm{E}} = ?$



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$\Phi_{\mathrm{E}} = EAcos(\phi)$

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$Where\text{: } \vec{A} = A\hat{\mathrm{n}}$

Electric Flux

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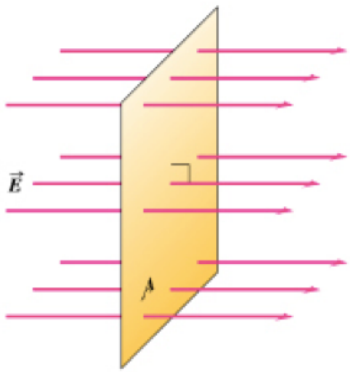

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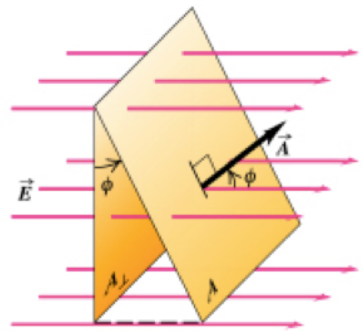

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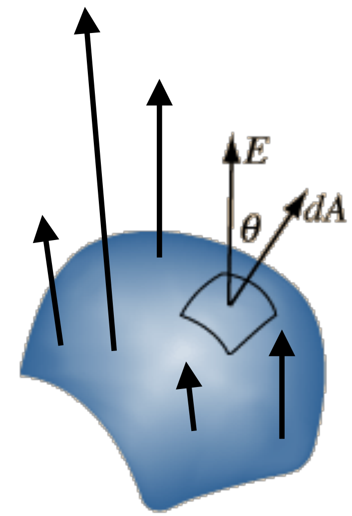
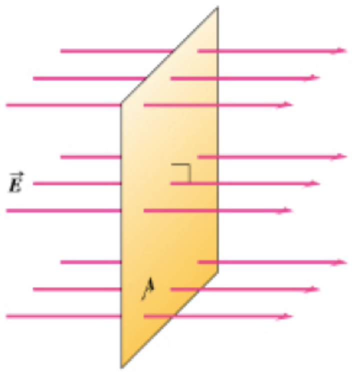


$$\Phi_E = ?$$

$$\Phi_E = \int EdAcos(\theta)$$

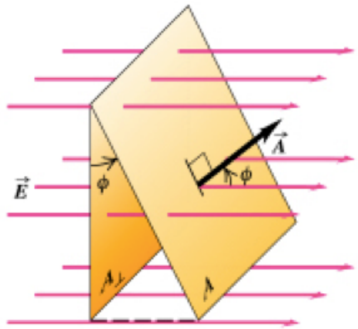
Electric Flux

Uniform **E**



$\Phi_E = EA$

Uniform **E**



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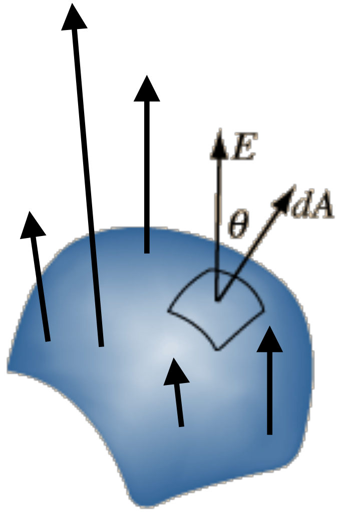

$\Phi_E = ?$

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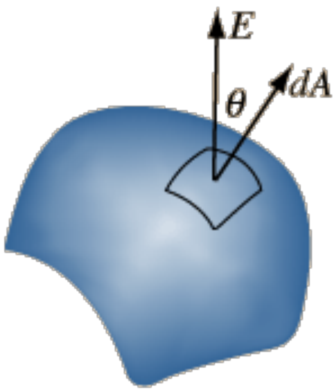
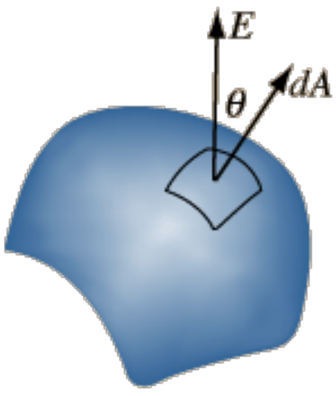
$\Phi_E = \int \vec{E} \cdot d\vec{A}$

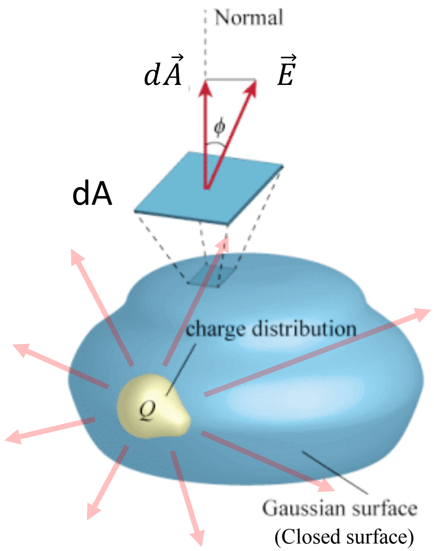
Electric Flux



$$\Phi_{\mathrm{E}} = \int \vec{E} \cdot d\vec{A}$$

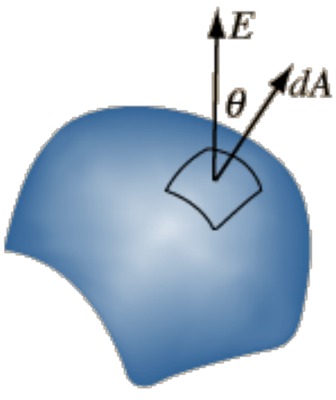
Electric Flux





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

Electric Flux



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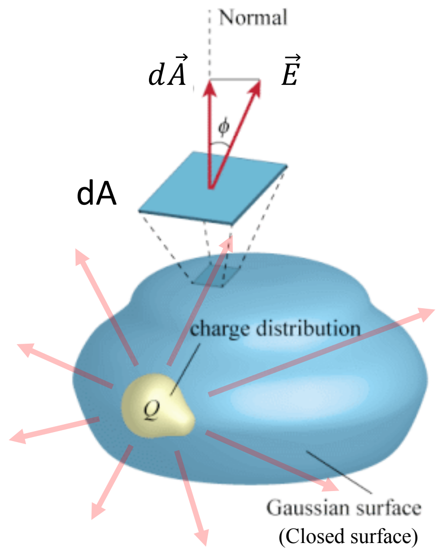

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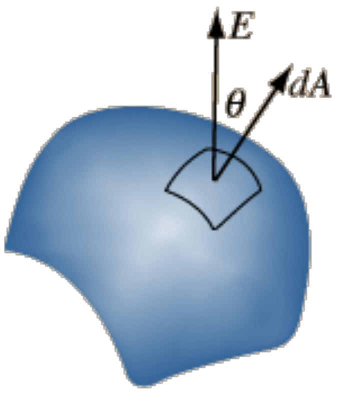
Electric Flux



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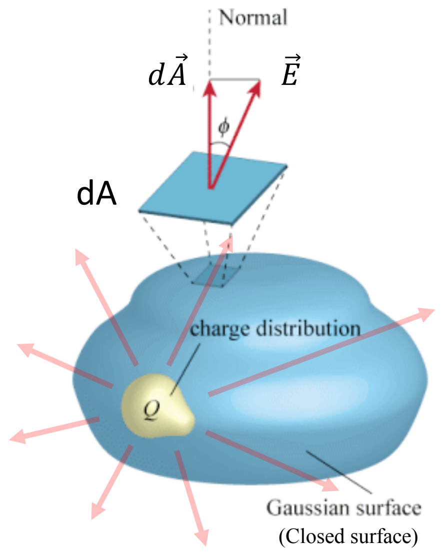

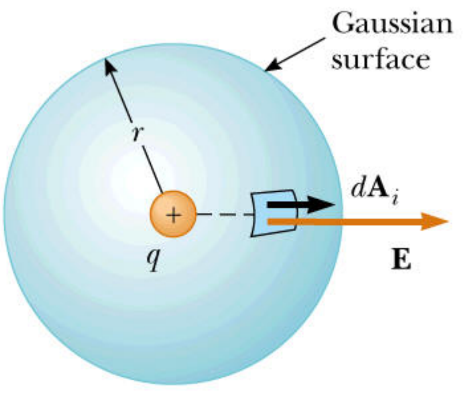

$$\Phi_E = \oint \vec{E} \cdot d\vec{A}$$

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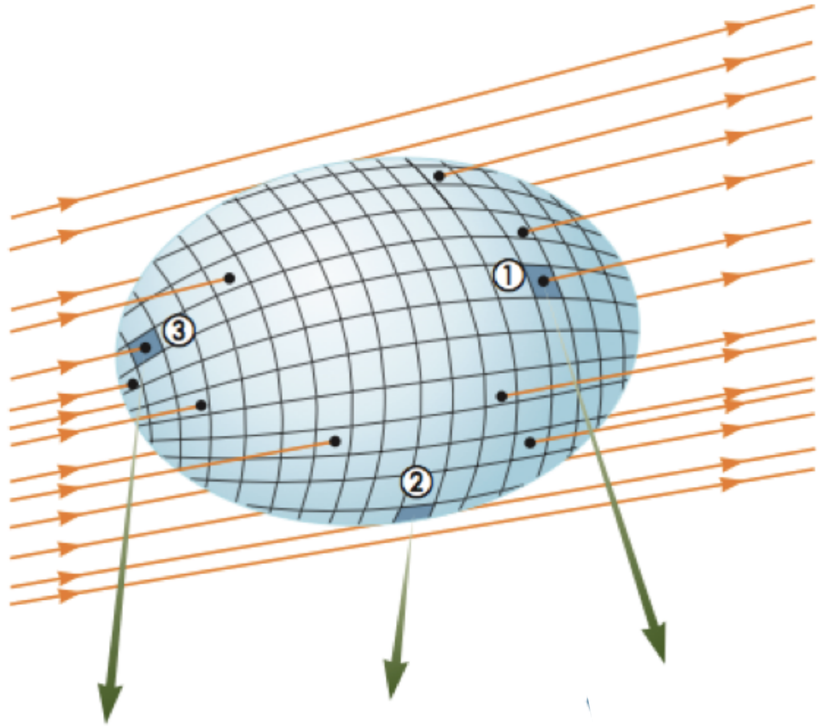
Electric Flux: Positive or Negative?

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



Electric Flux: Positive or Negative?

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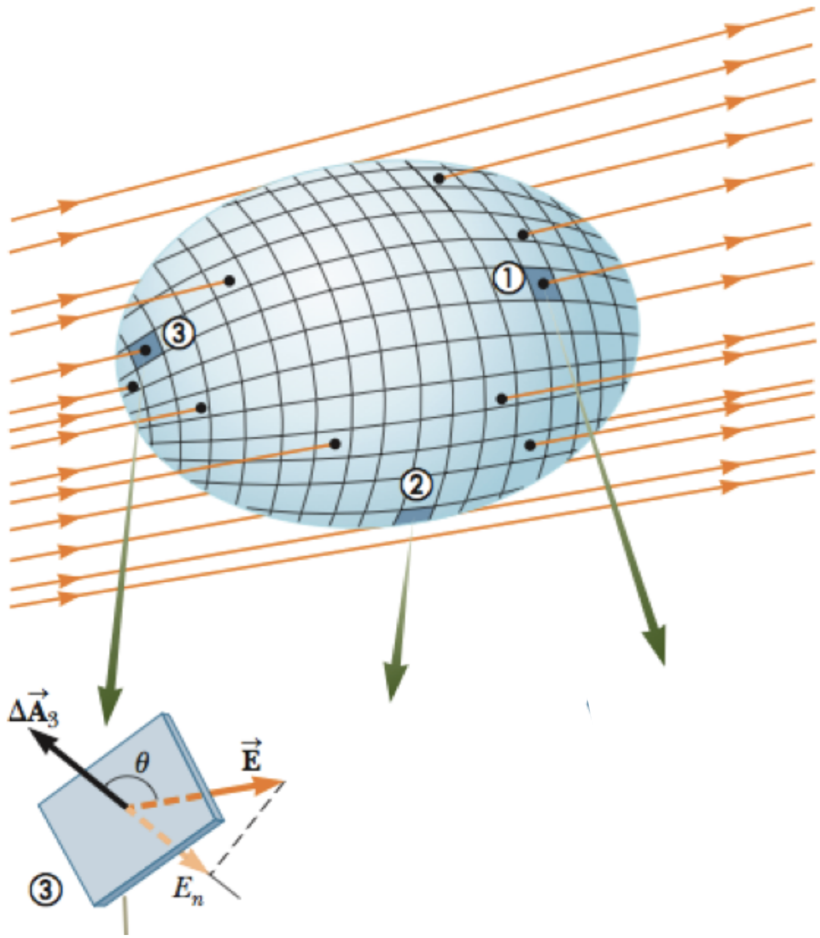

$-\Phi_E$

Electric Flux: Positive or Negative?

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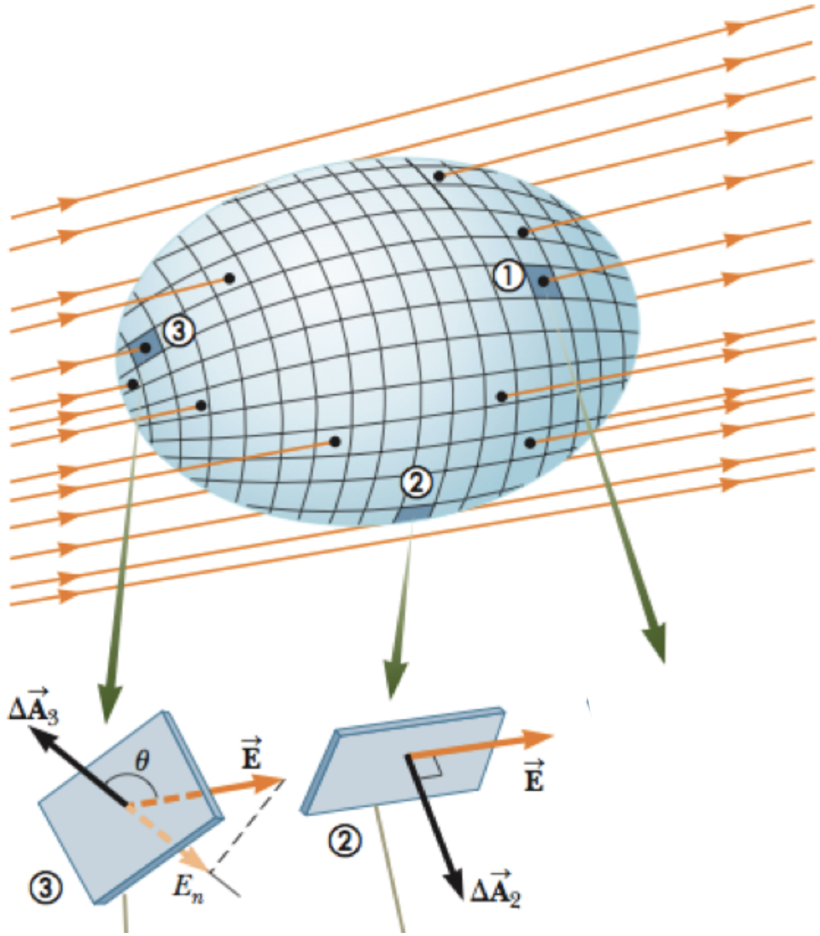
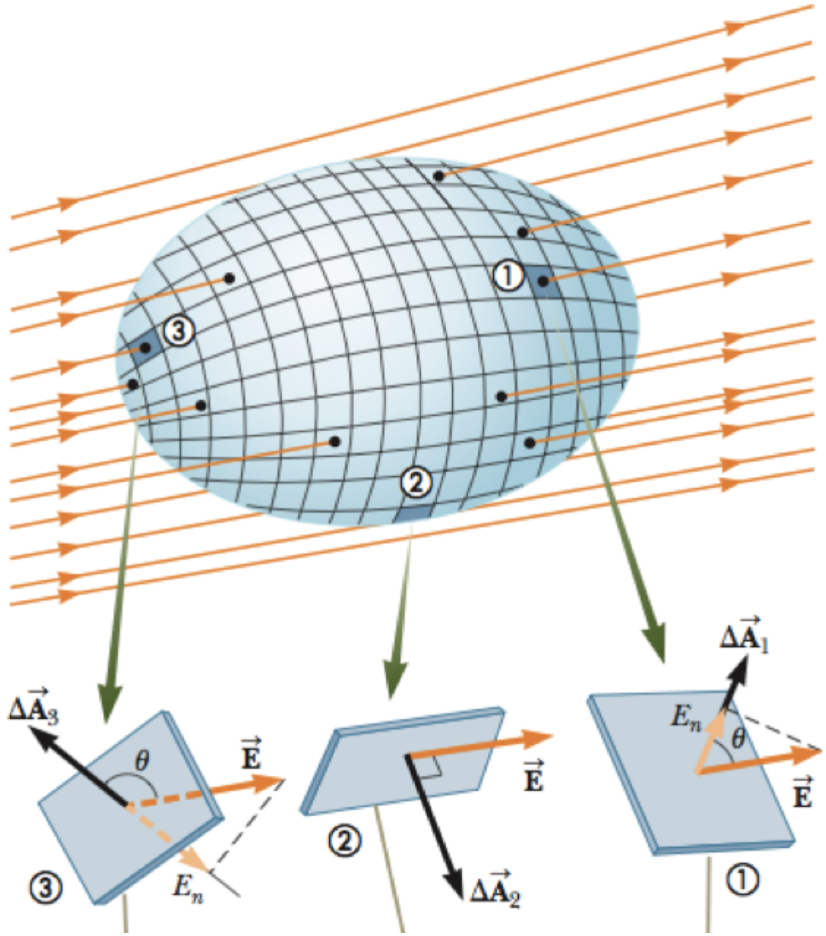


$-\Phi_E$ $\Phi_E = 0$

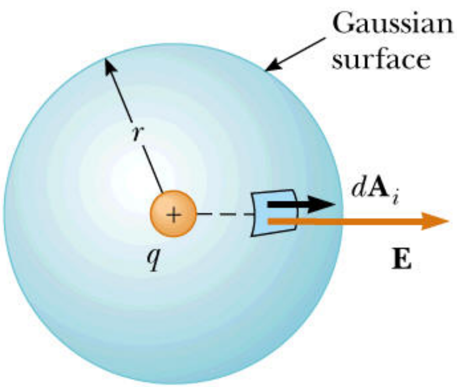
Electric Flux: Positive or Negative?

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



$-\Phi_E$ $\qquad$ $\Phi_E = 0$ $\qquad$ $+\Phi_E$

Example: Compute the electric flux due to a positive charge q through an spherical Gaussian surface.



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

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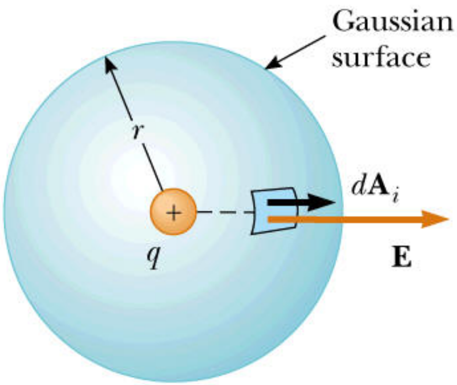

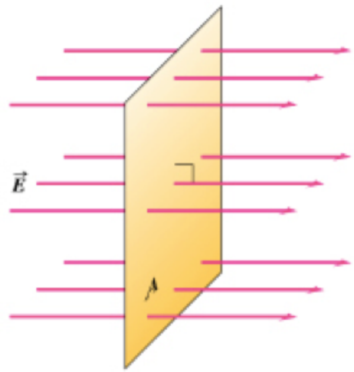

$$\Phi_E = \oint \vec{E} \cdot d\vec{A}$$

$$\Phi_E = EA$$

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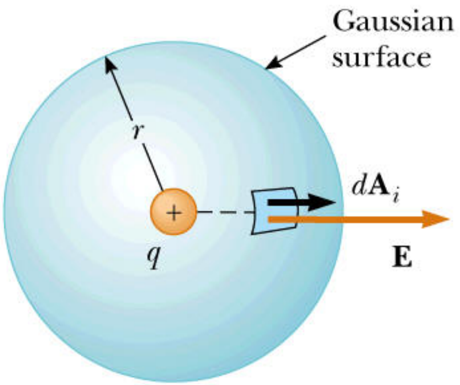
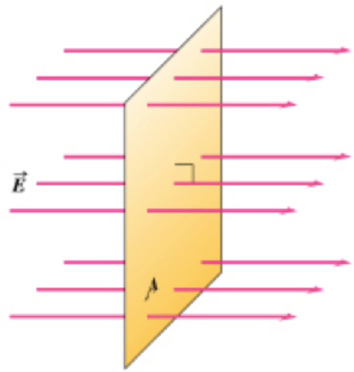




$$\Phi_E = \oint \vec{E} \cdot d\vec{A}$$

$$\Phi_E = EA$$

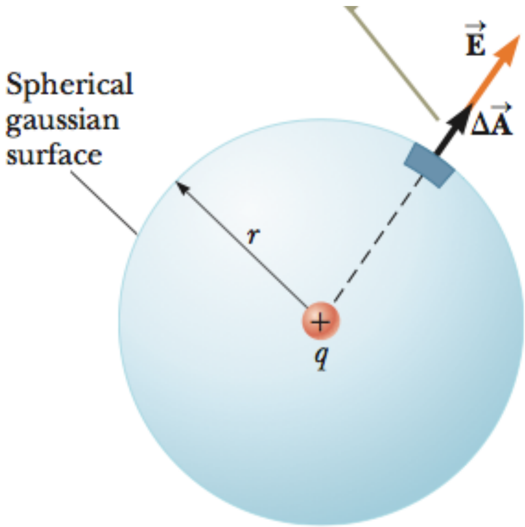
$$\Phi_E = \int E dA = E \int dA$$

$$\Phi_E = \left(\frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\right)(4\pi r^2)$$

$$\Phi_E = \frac{q}{\epsilon_0}$$

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$$

Electric Flux: non-spherical surface



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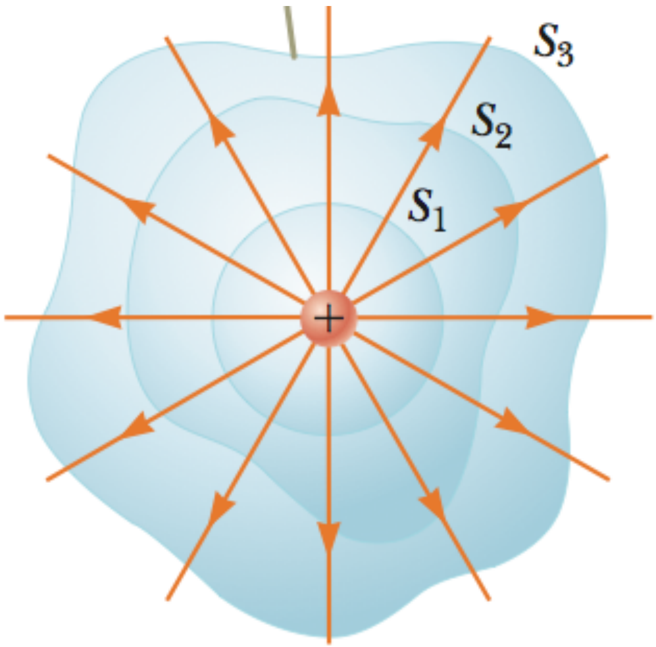
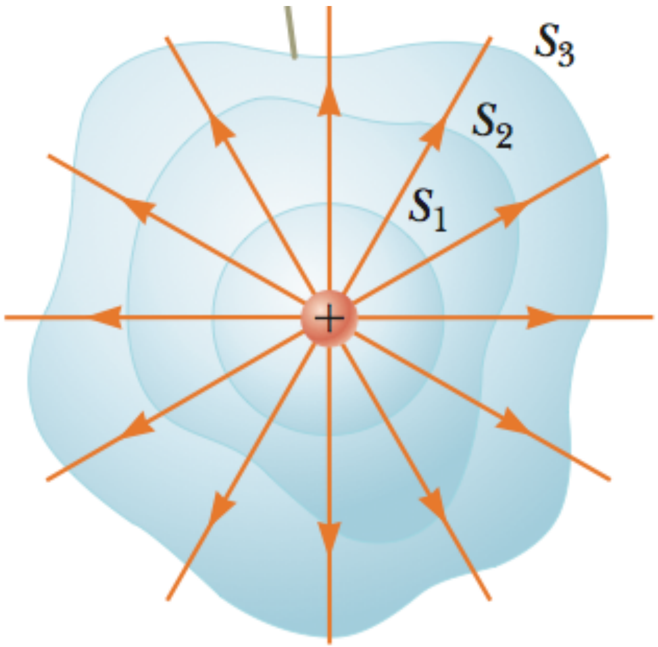


Still true?

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$$

Electric Flux: non-spherical surface



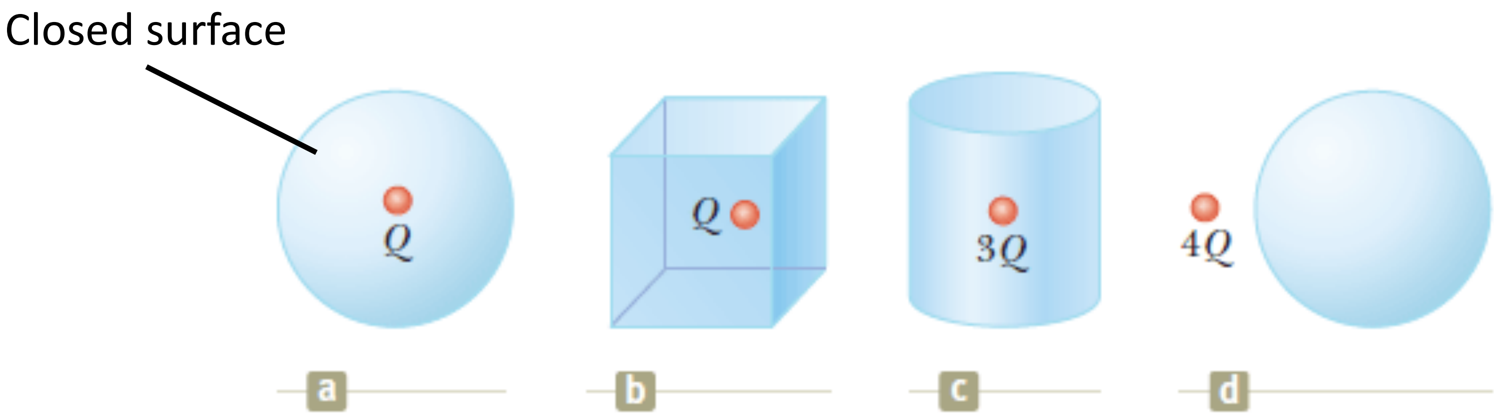
Still true? YES!

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$$

$$\Phi_{\mathrm{E}} = \oint \vec{E} \cdot d\vec{S}_1 = \oint \vec{E} \cdot d\vec{S}_2 = \oint \vec{E} \cdot d\vec{S}_3 = \frac{Q_{enclosed}}{\epsilon_0}$$

Gauss's Law

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$$

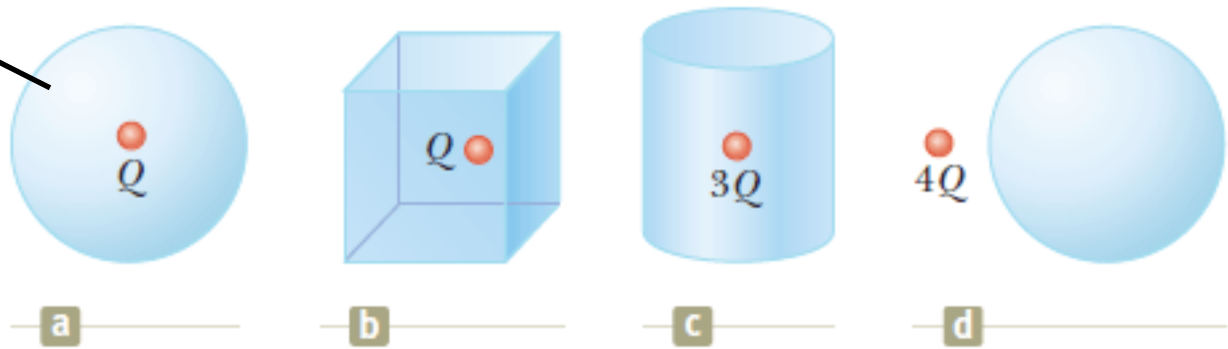


Rank the electric flux through those closed (Gaussian) surfaces:

Gauss's Law

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$$

Closed surface



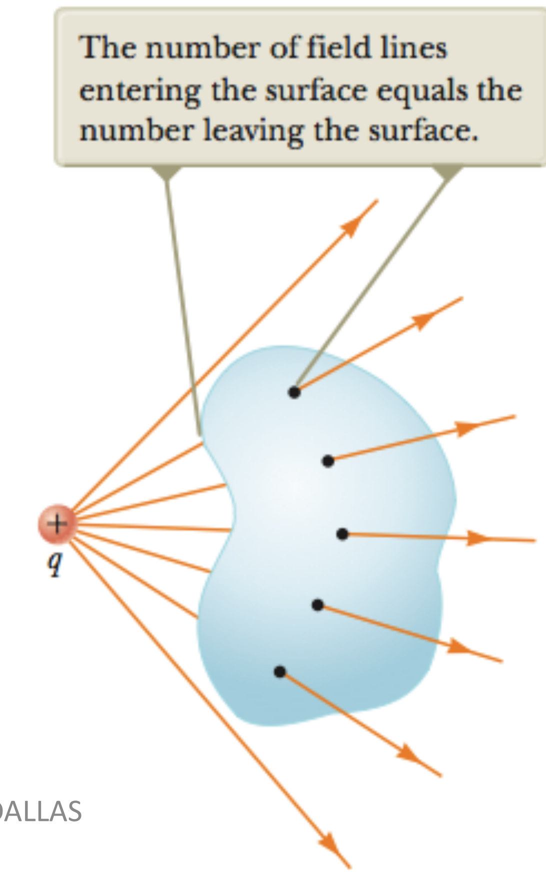
Rank the electric flux through those closed (Gaussian) surfaces:

1. d
2. a=b
3. c

Electric Flux

- To remember: Net electric flux is zero through closed surface unless there is net charge inside!

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$$



Electric Flux

- Zero net charge does not mean the E-field through the closed surface is zero.
- Zero net charge means the electric flux through the closed surface is zero.

Electric Flux

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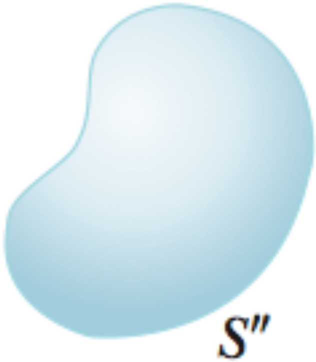
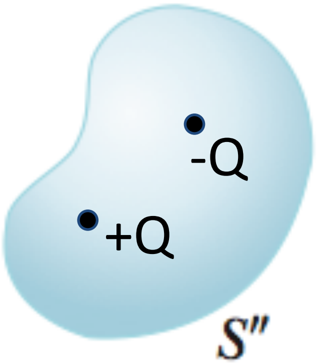
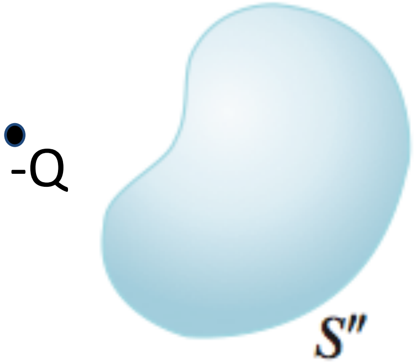
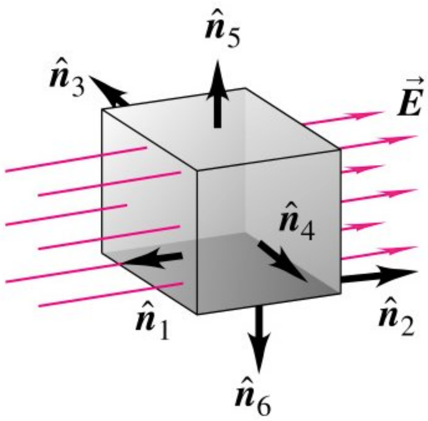






Example: Consider a uniform electric field "E" of magnitude $2.0\text{x}10^3$ N/ C and oriented in the x direction. A cube of side a = 10 cm is placed in the field as shown in the figure. What is the net electric flux through the surface of the cube?



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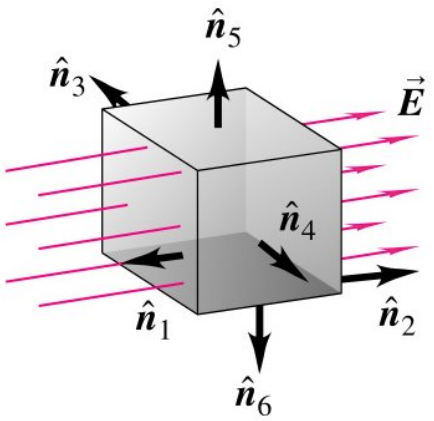

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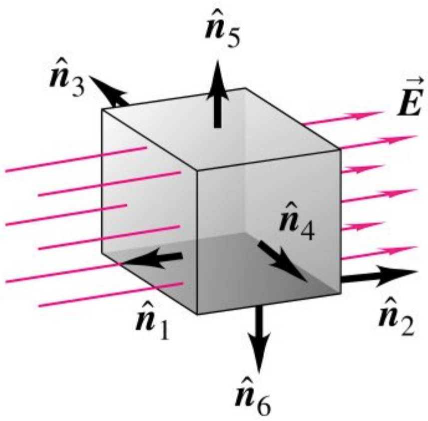

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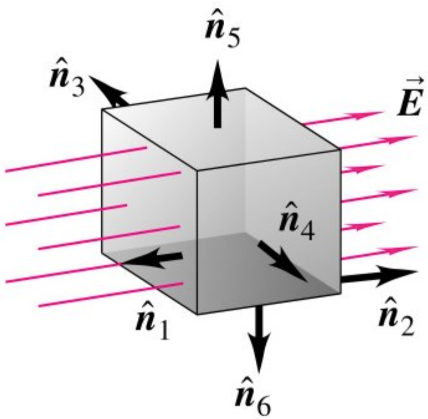

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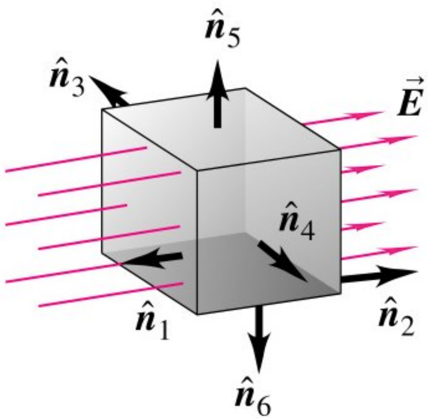

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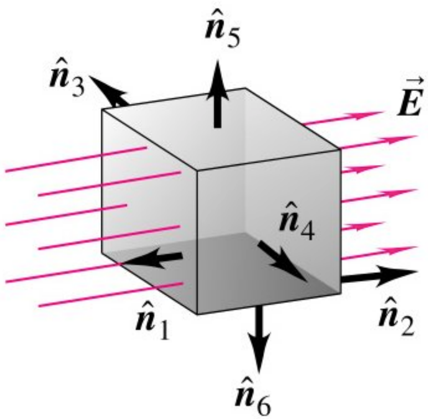

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