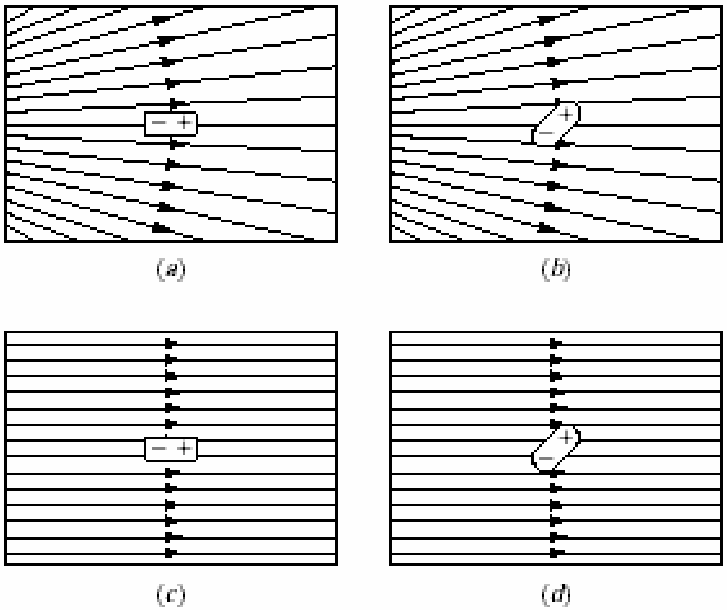
PHYS102 - Field Lines and Gauss's Law.

Dr. Suess

January 29, 2007

Question #1

An electrically neutral dipole is placed in an external field. In which situation(s) is the net force on the dipole zero?



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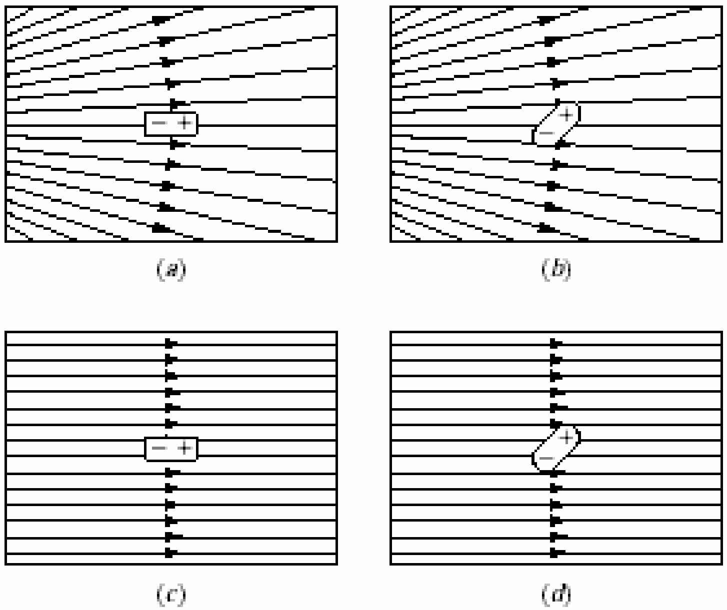

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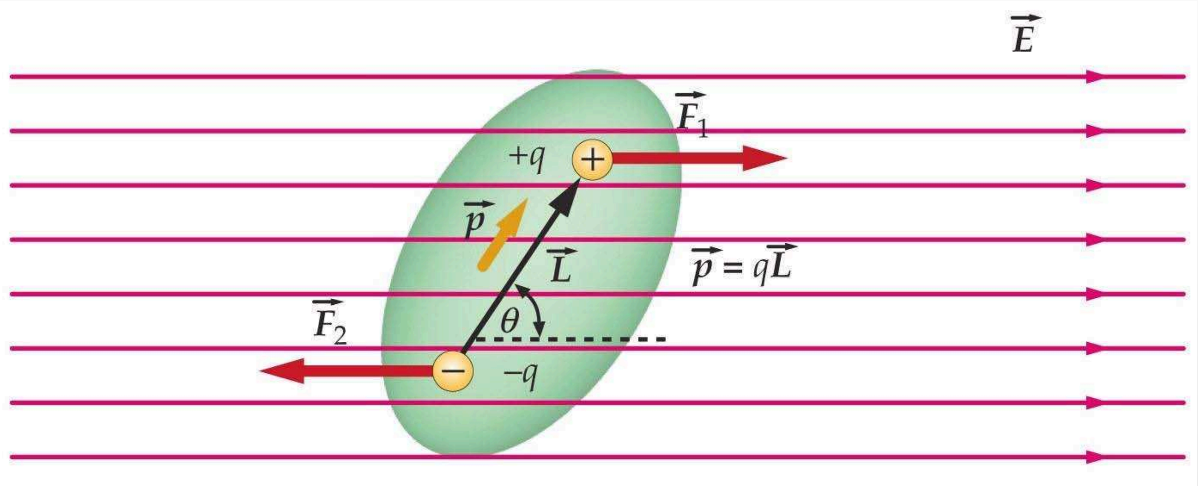
Dipole Moments and Electric Fields



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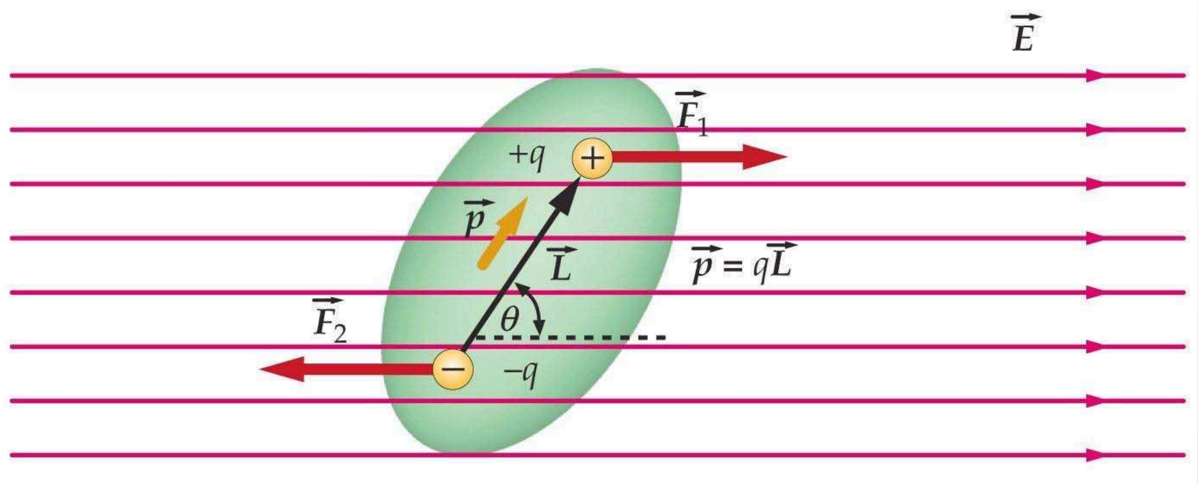

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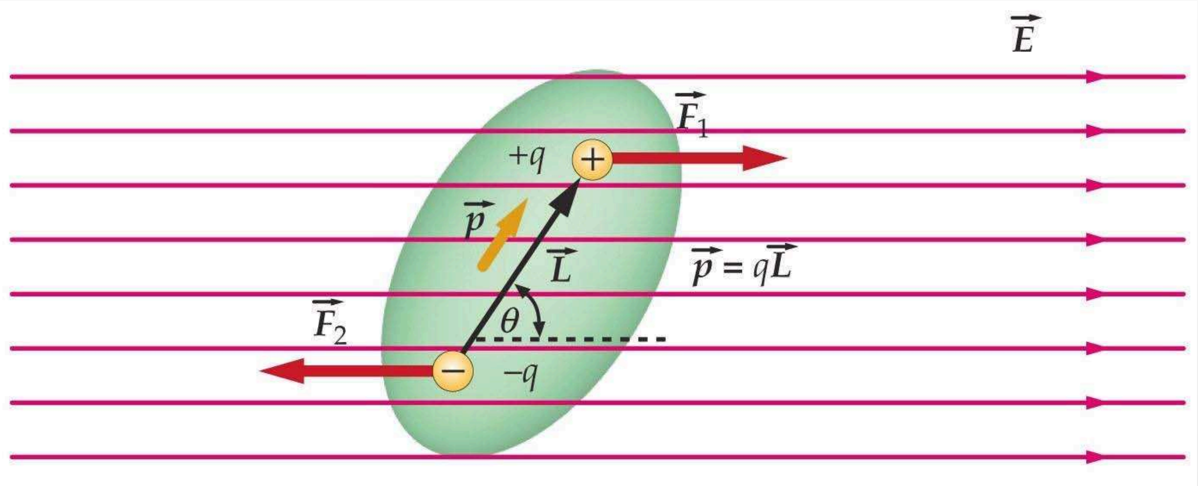

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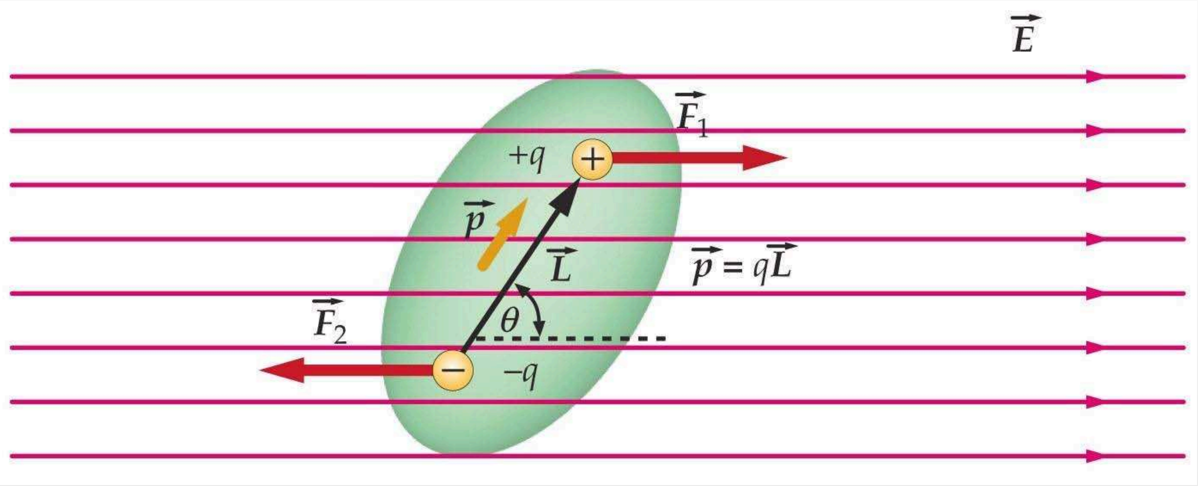

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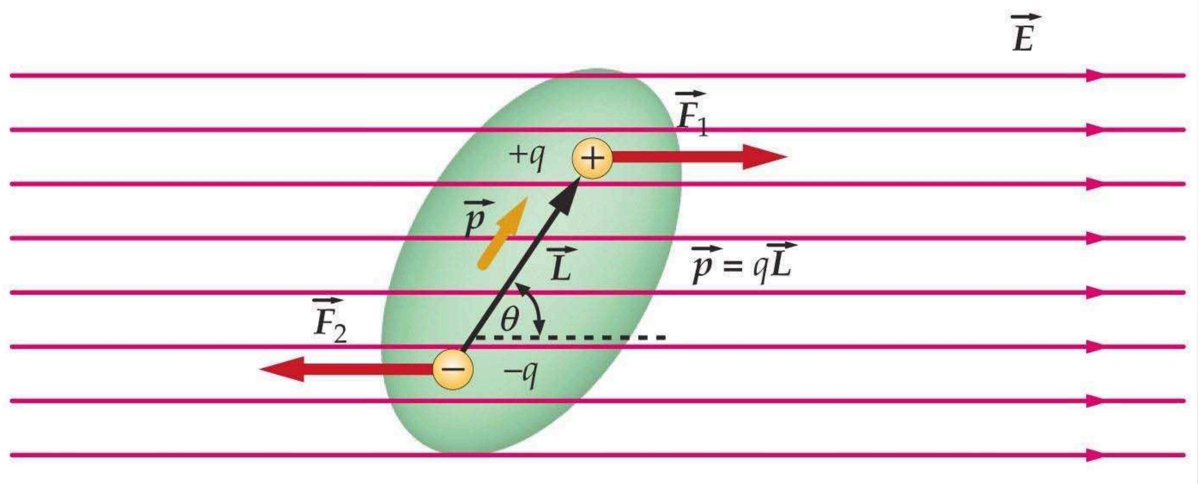

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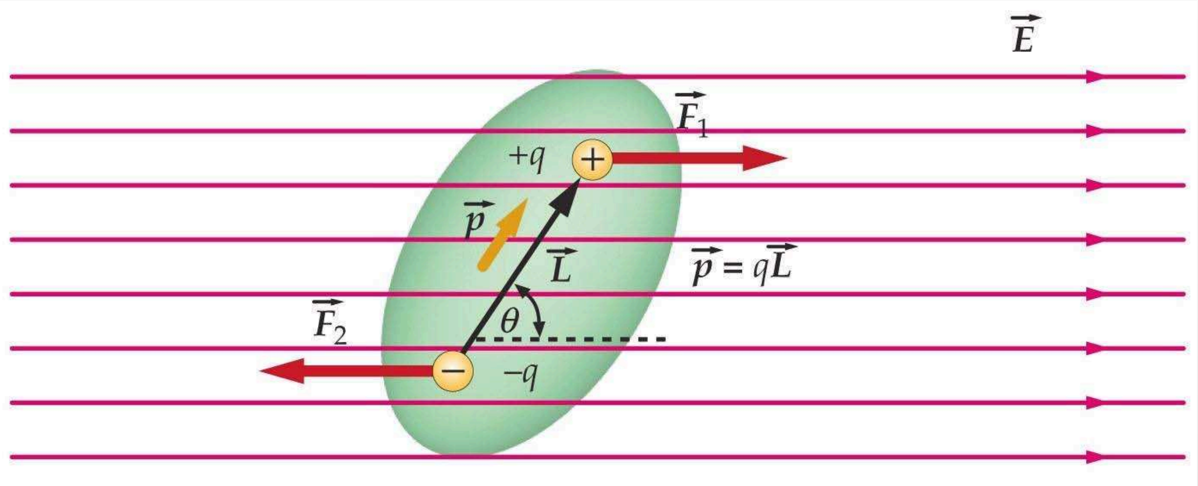

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If identical charged particles are placed at points A and B in the figure below, what can be said about the magnitude of the electric force experienced by the charged particles?

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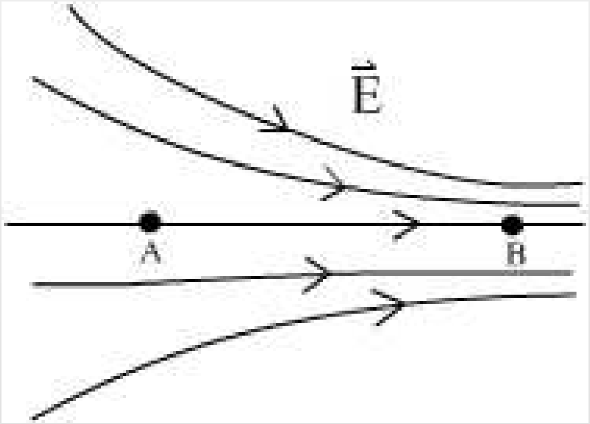

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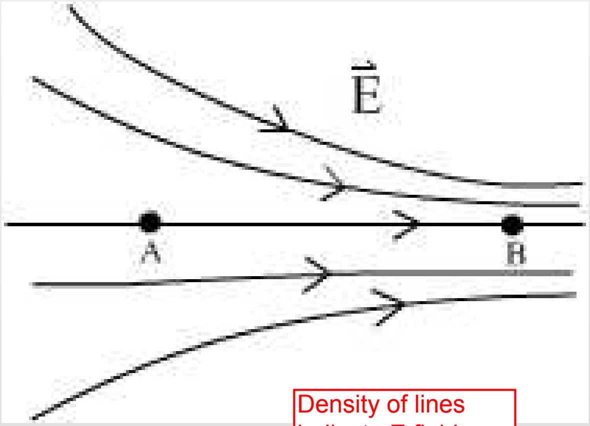

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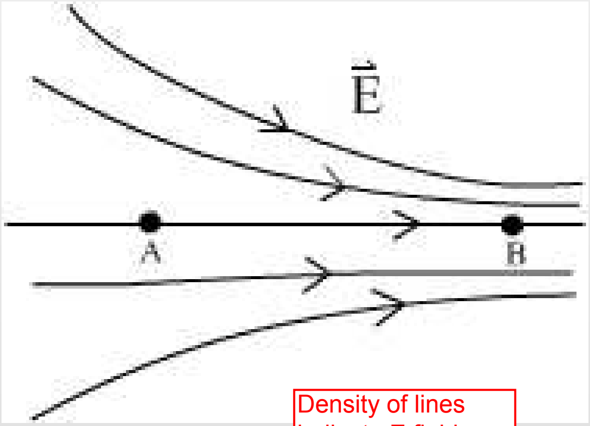

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$$\Rightarrow [\Phi] = N\,m^2\,C^{-1}$$

This implies $\Phi \propto$ the number of field lines passing through the area.

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    - $\Phi = \vec{E} \cdot \vec{A}$
- What if the electric field varies in space or the surface area which the electric field penetrates is not constant?

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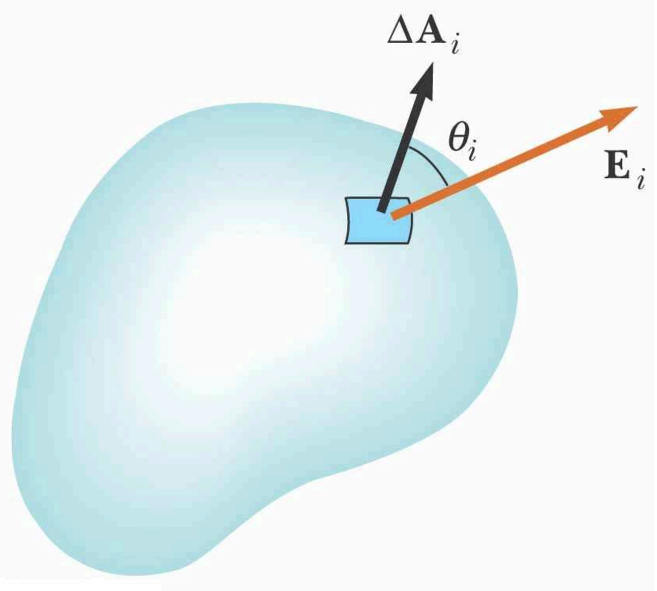

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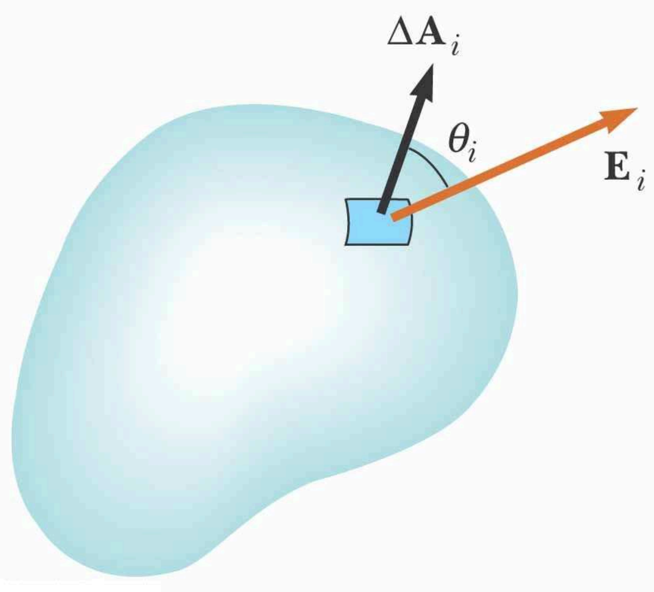

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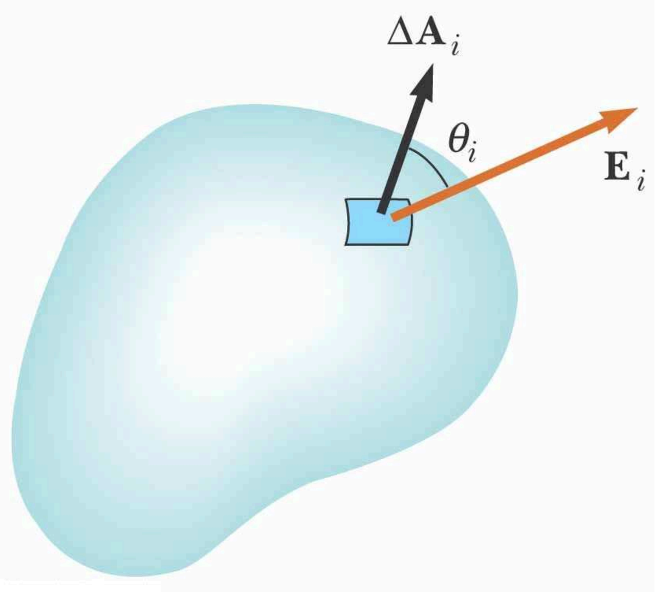

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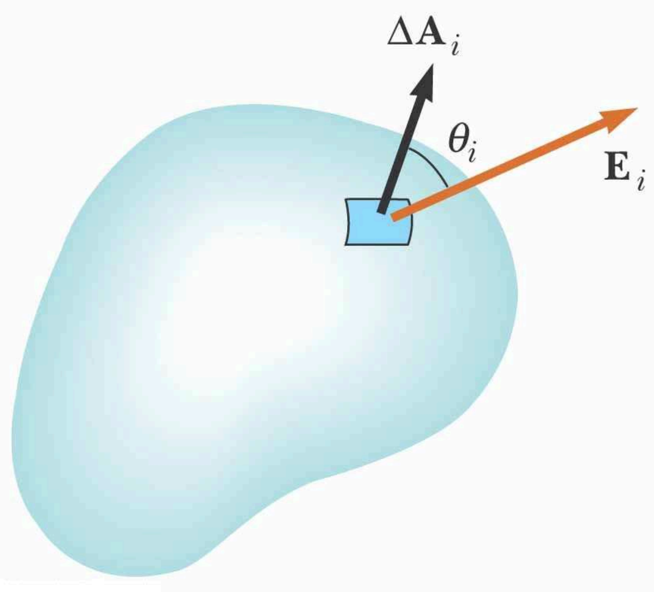

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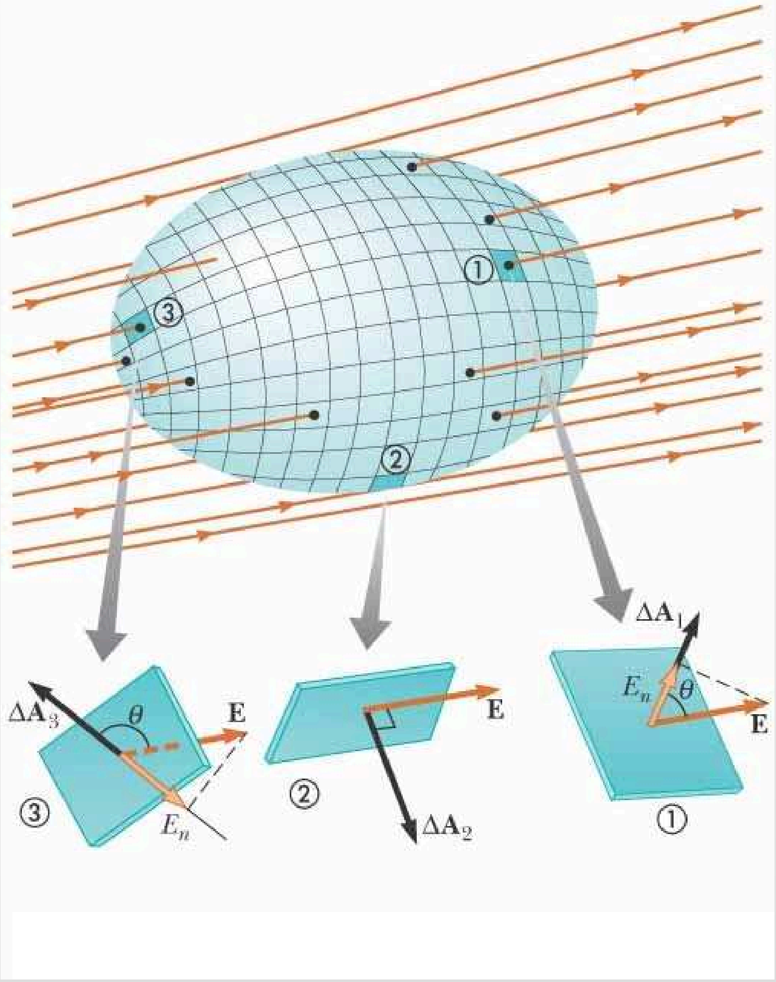
Electric Flux - General Graphical

One would have to sum the electric flux over all the smaller pieces shown in the figure to the right in order to find the net flux through the surface.



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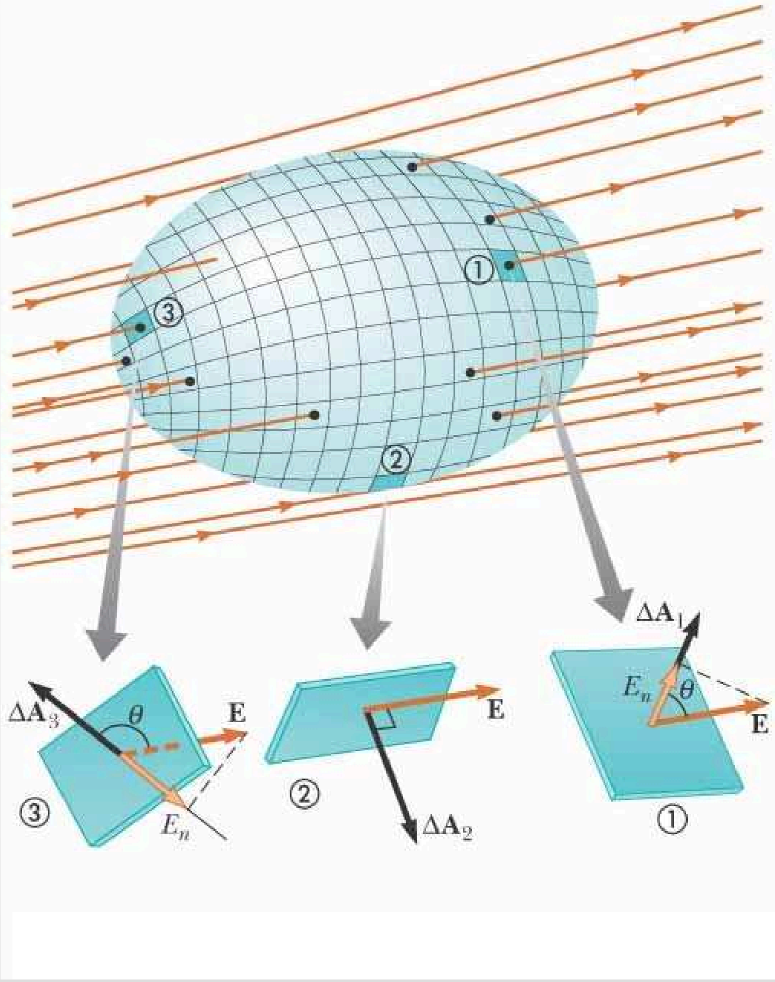

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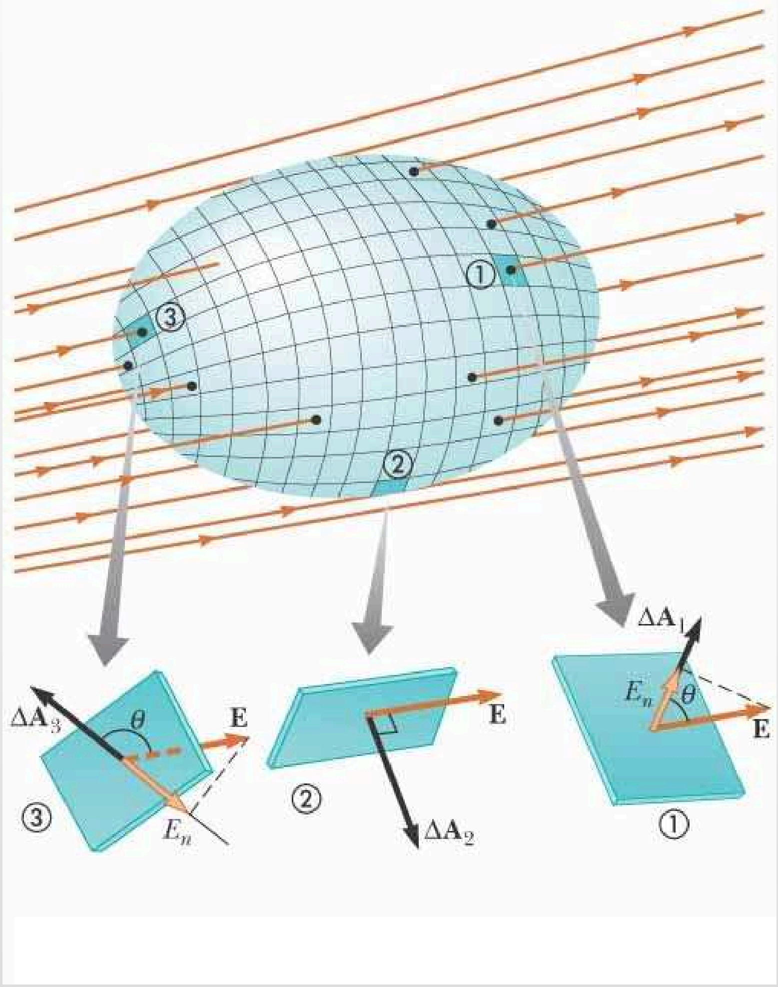
- I hope the graphic helps illustrate the surface area integral. Integrating (from the last slide) is essentially gluing all the small patches together to recreate the surface.



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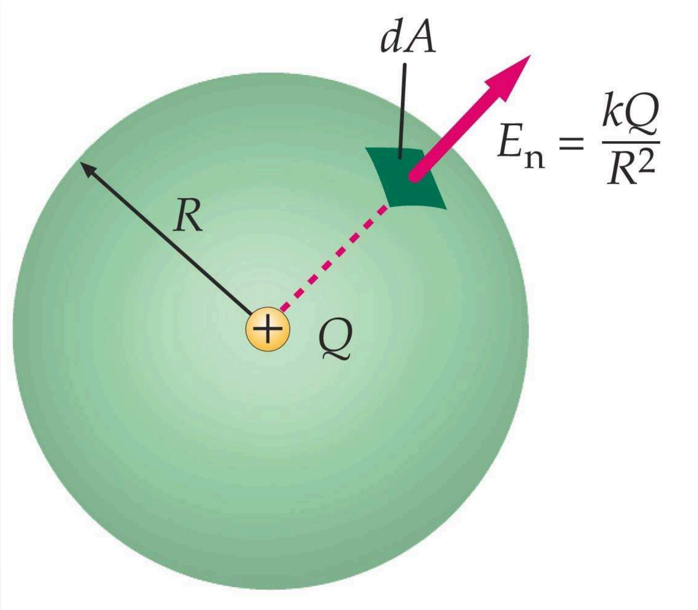

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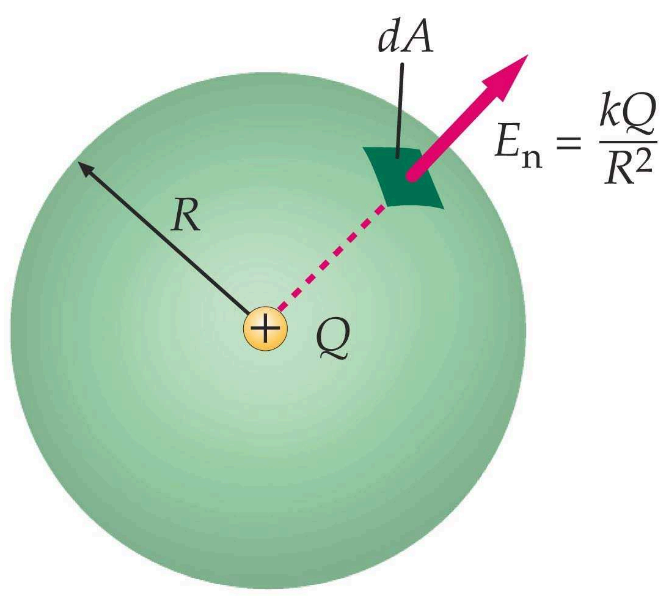

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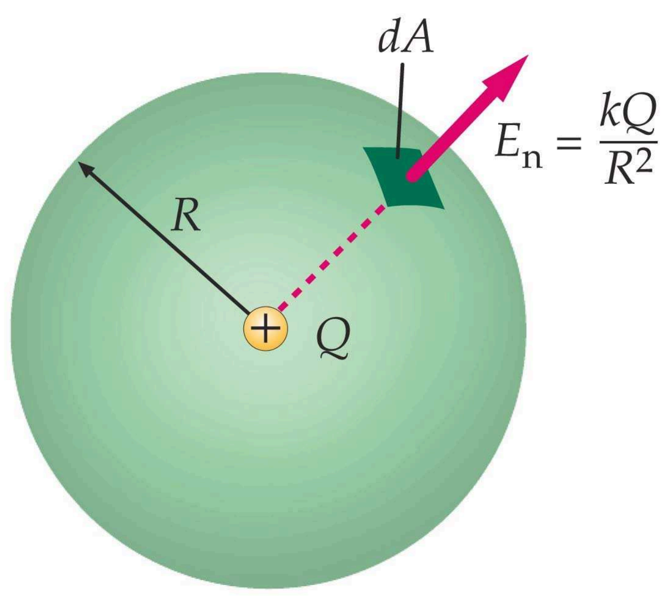

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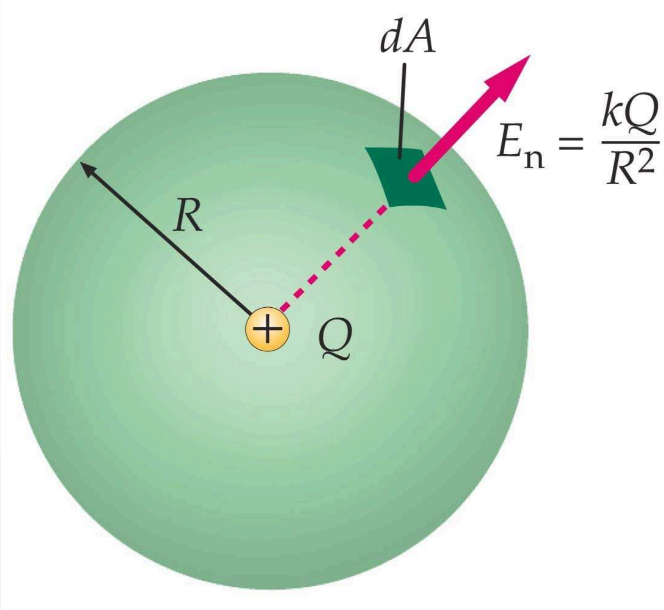
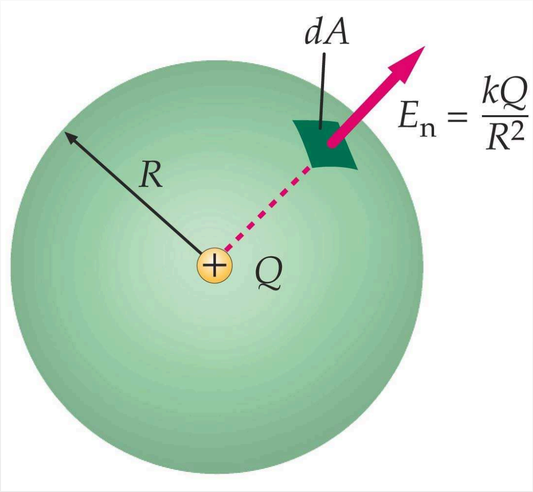
$$E = \frac{k\,Q}{R^2}$$



Quantification - Gauss's Law



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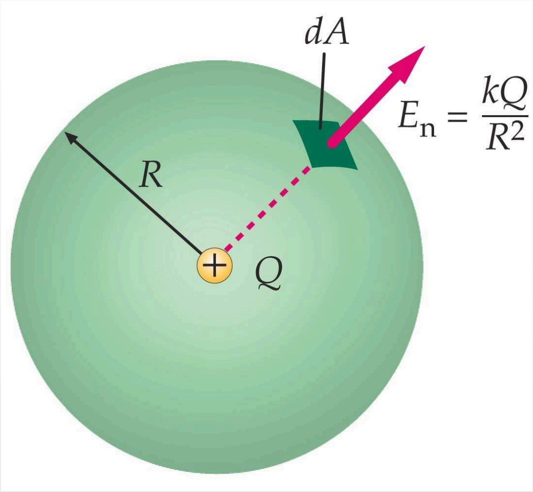

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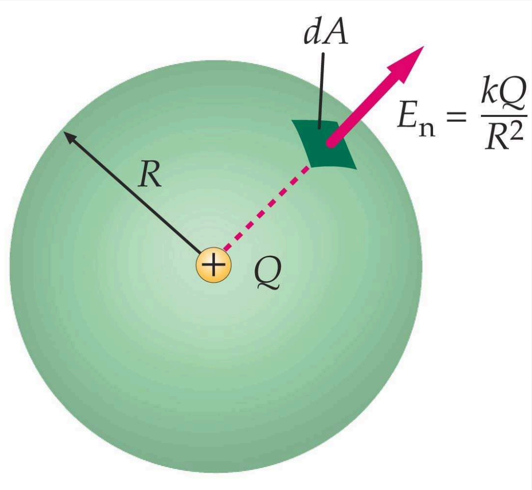

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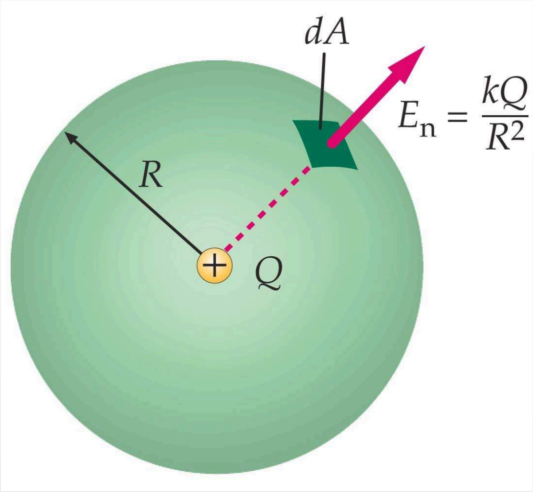

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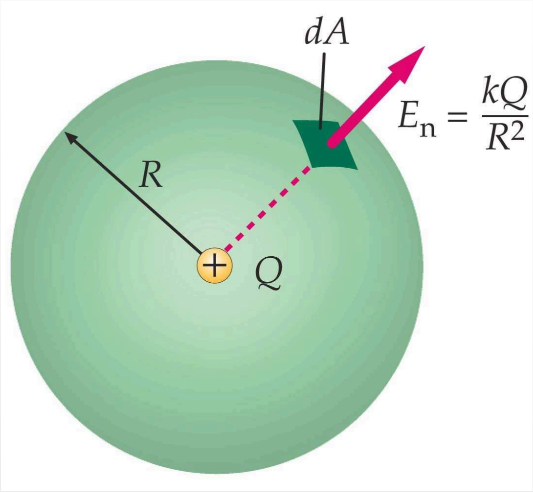

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Gauss's Law - Final Version

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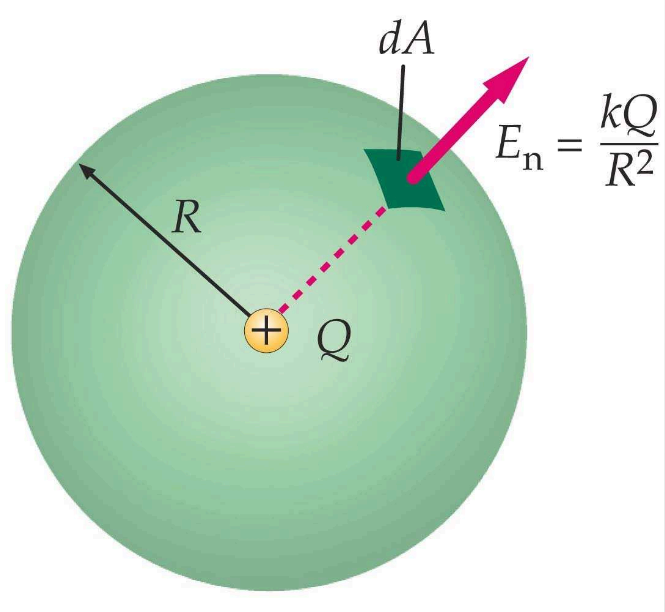

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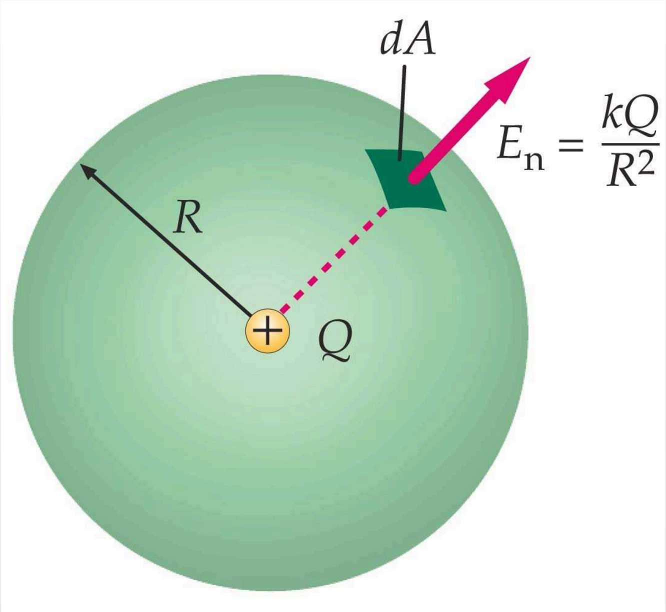
$$\oint_S \vec{E} \cdot \hat{n}\, dA = E\, A_{\text{surface}}$$

- Using this and substituting kQ/R^2 for E we obtain:



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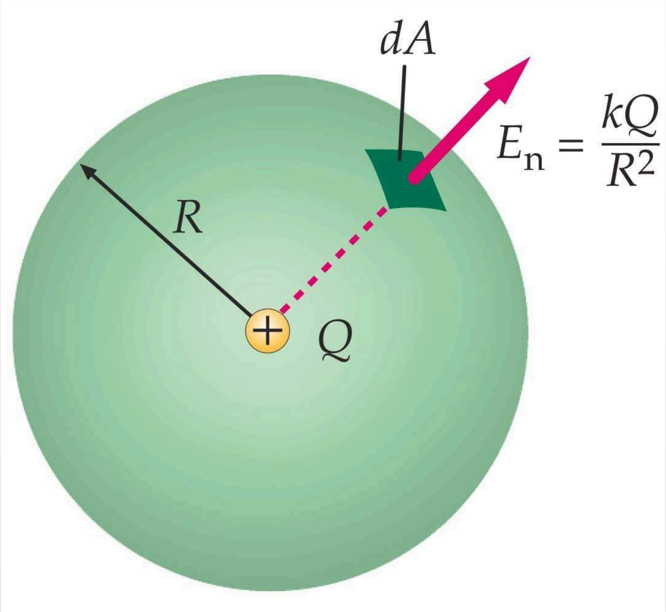

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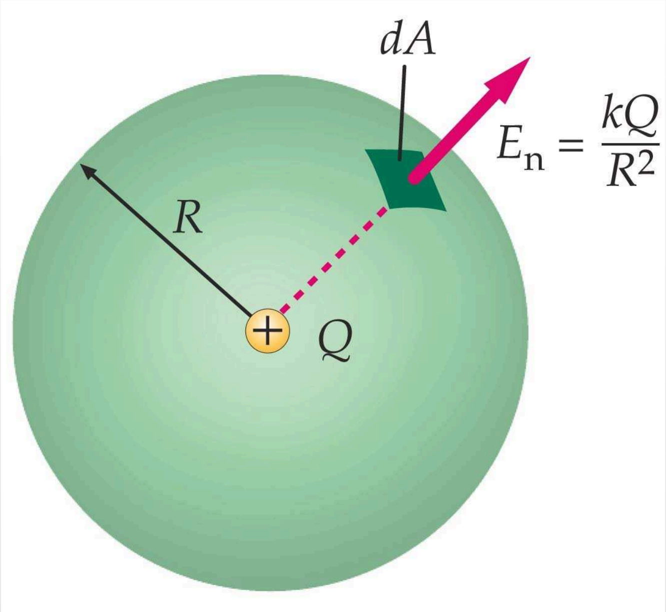

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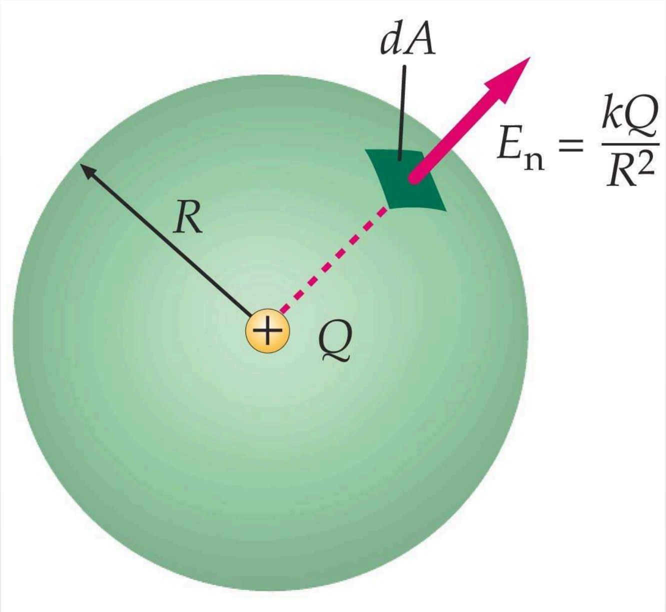

- This result was obtained using a very symmetric surface because it was the easiest geometry considering the behavior of the electric field for a point particle.

Gauss's Law - General

$$\Phi = \oint_S \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$

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- This is an electric flux law - NOT AN ELECTRIC FIELD LAW.
  - Gauss's Law is always true, but the law is NOT always useful in determining electric fields from charge distributions.
  - We will examine the only THREE cases where the law is useful in determining the electric field.

Applying Gauss's Law

Consider the figure on the right:

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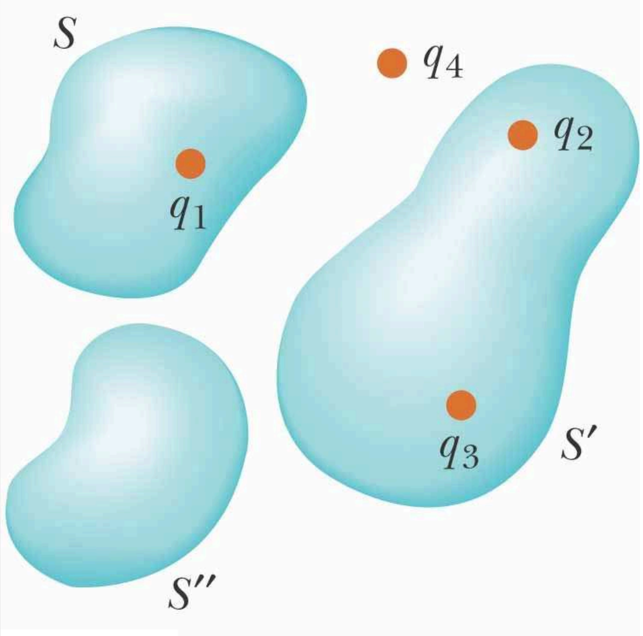
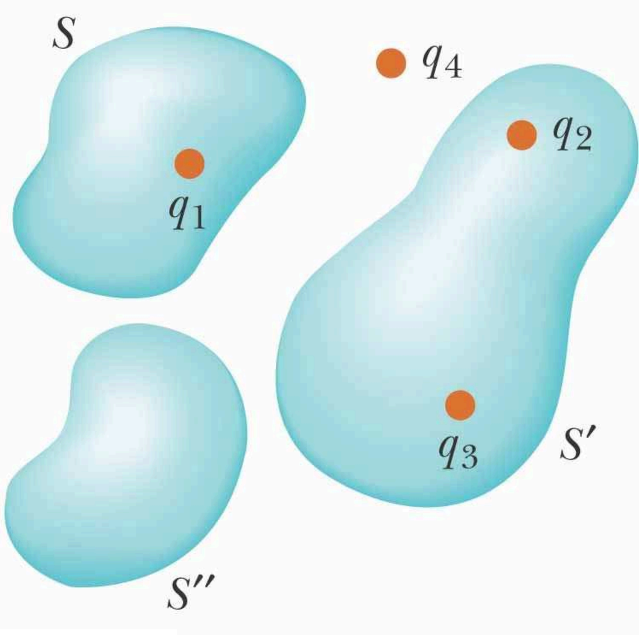


Applying Gauss's Law

Consider the figure on the right:

- For the arbitrarily shaped surfaces:



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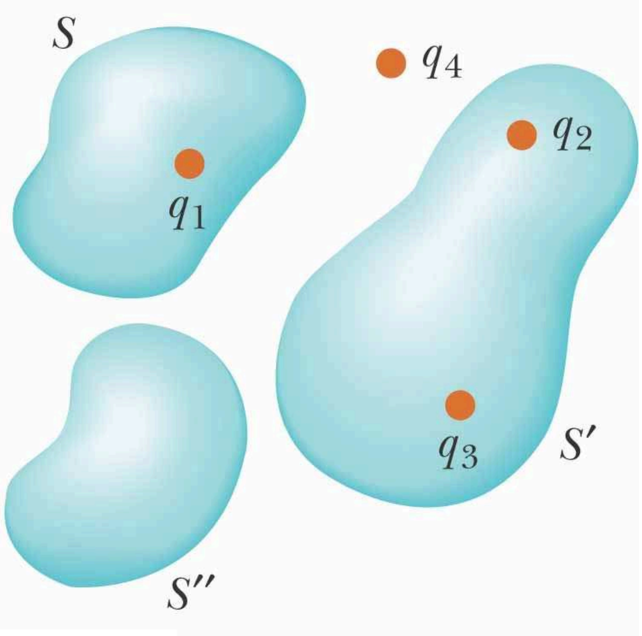
$$\Phi_S = \frac{Q_{enclosed}}{\varepsilon_0} = \frac{q_1}{\varepsilon_0}$$



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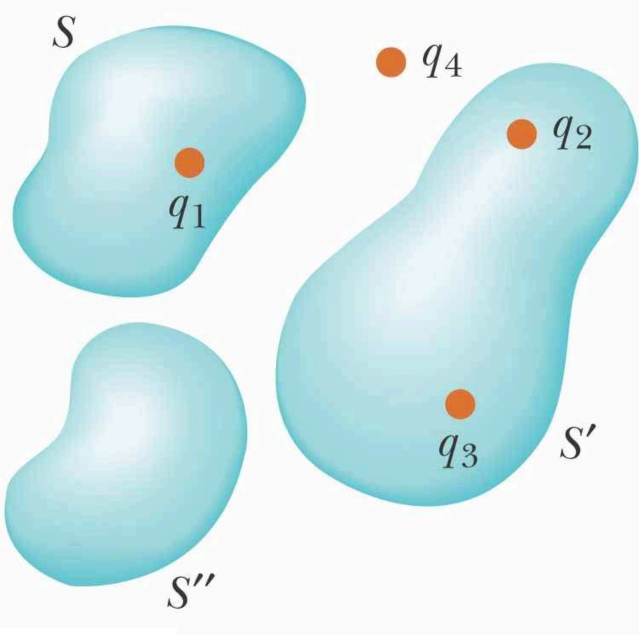

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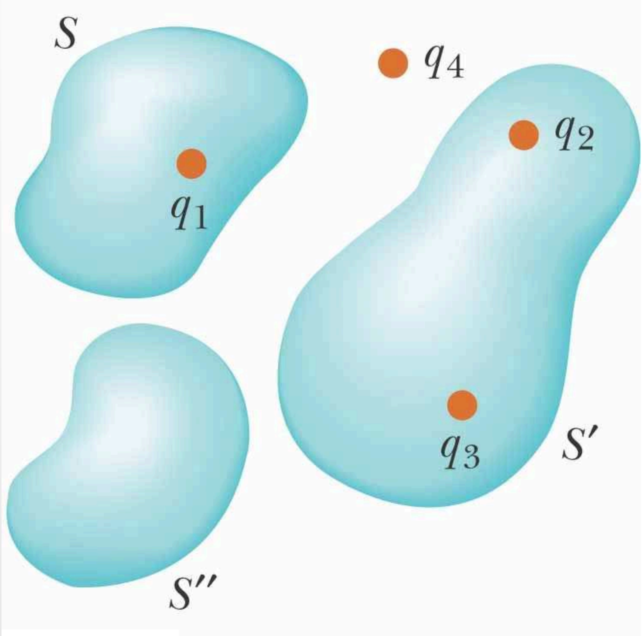

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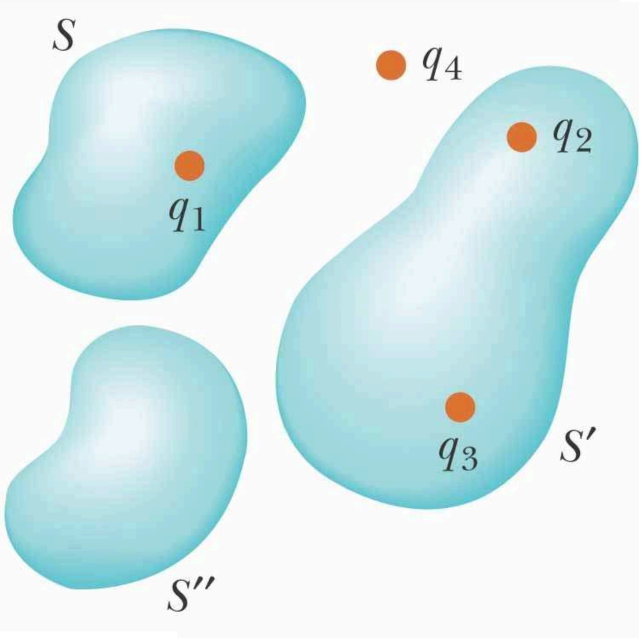
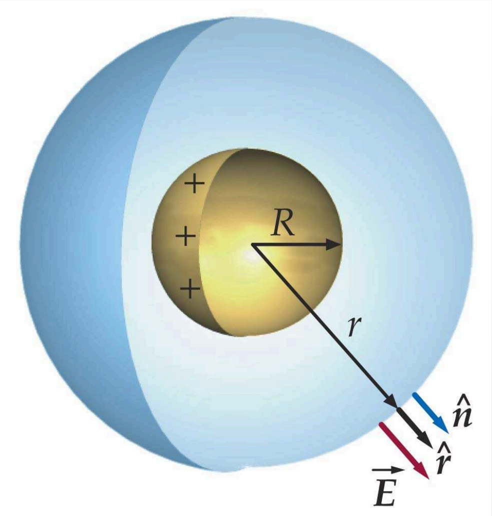
- One CANNOT use Gauss's Law to find the electric field due to the charge configuration.

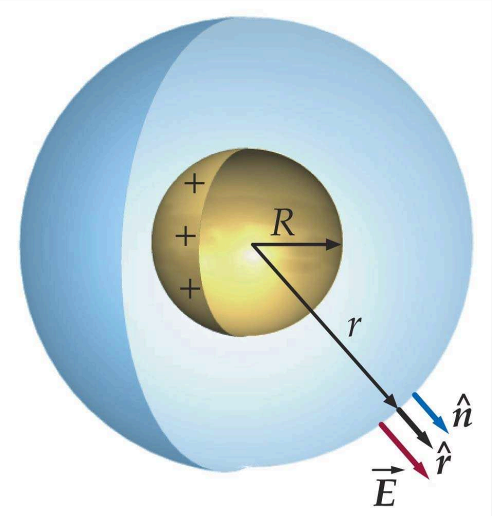


Spherical Symmetry



1. Spherical Symmetry.

Spherical Symmetry



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   - A charge distribution has *spherical symmetry* if the views of it from all points on the spherical surface are the same.

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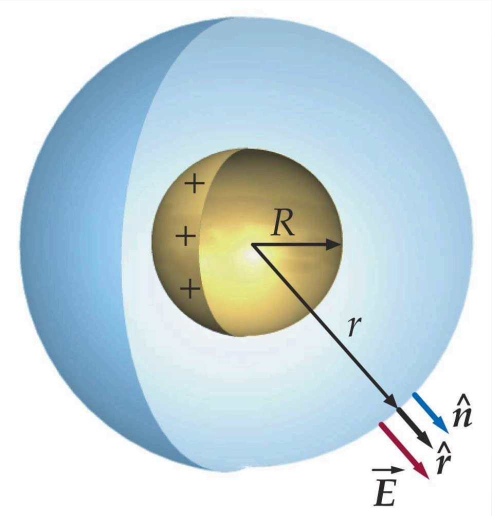

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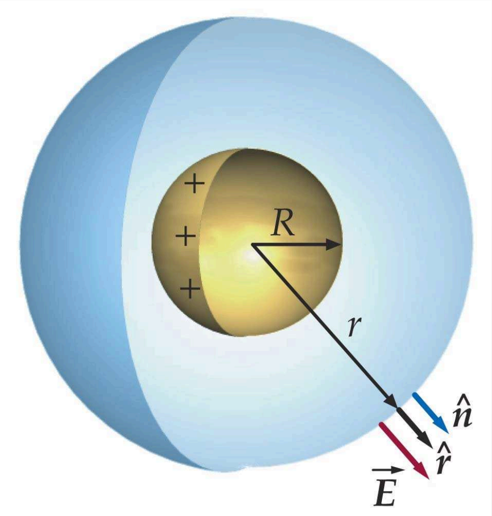
- A charge distribution has *spherical symmetry* if the views of it from all points on the spherical surface are the same.
  - Choose a spherical surface of radius r, centered at the charge distribution - such surfaces are called "Gaussian surfaces"

Spherical Symmetry



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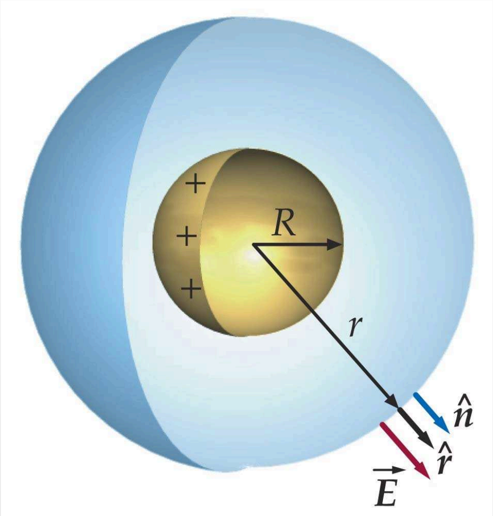

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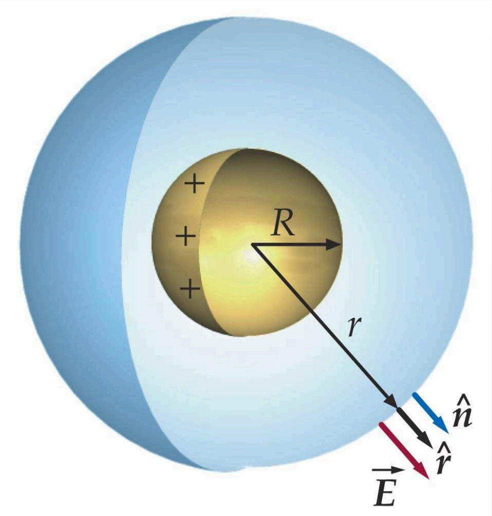

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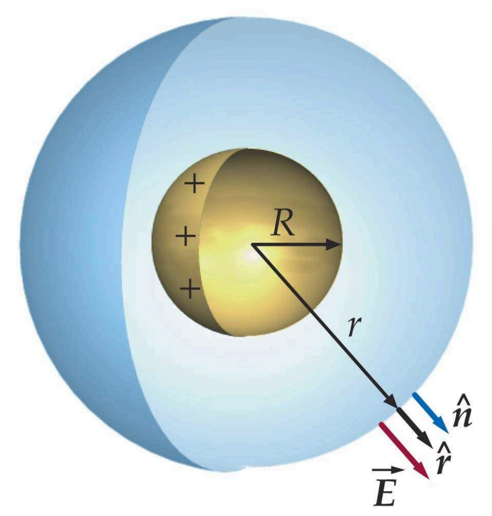
   - By symmetry, the electric field is directed radially (inward if charge distribution is negative or outward if charge distribution is positive).

Spherical Symmetry



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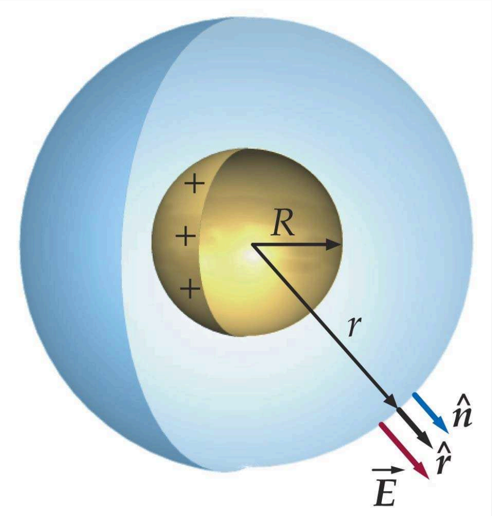

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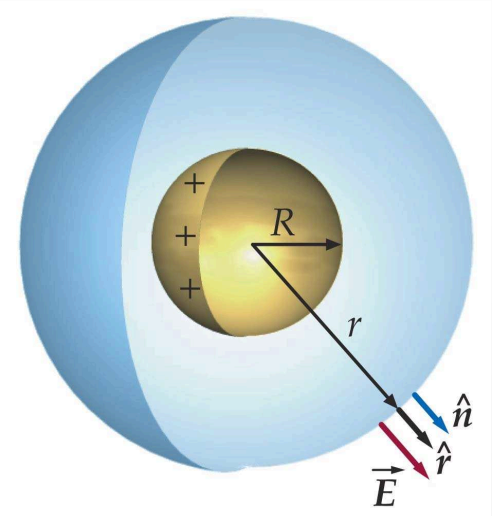

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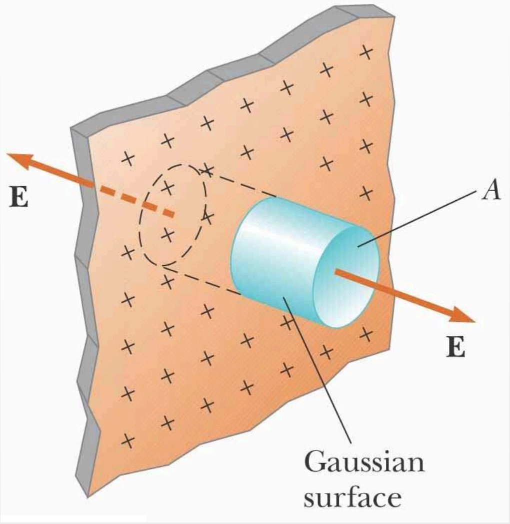
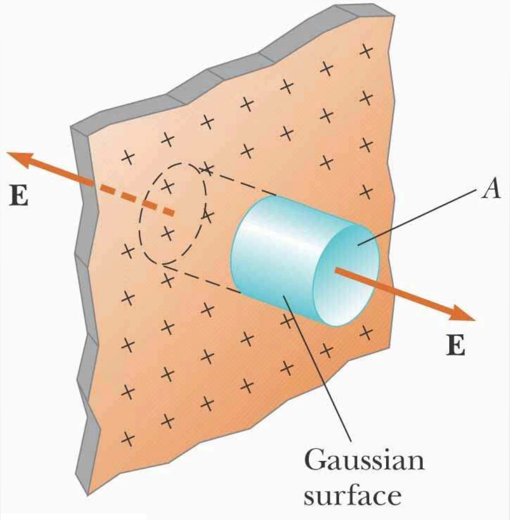
Plane Symmetry



2. Plane Symmetry.

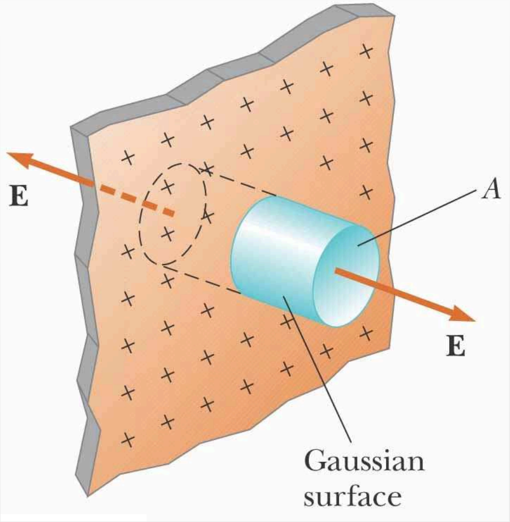
Plane Symmetry



2. Plane Symmetry.

- A charge distribution has *plane symmetry* if the views of it from all points on an infinite (or very long) plain surface are the same.

Plane Symmetry



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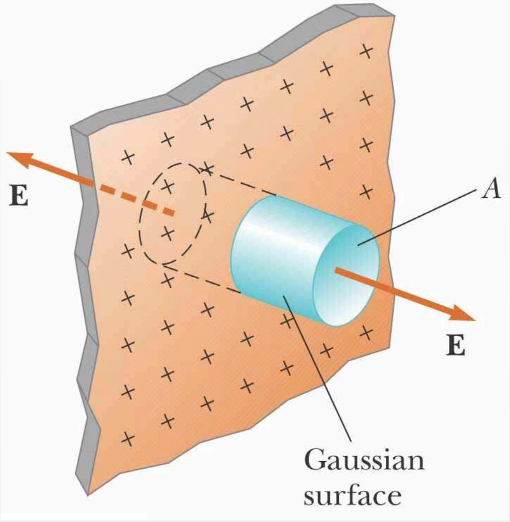
- A charge distribution has *plane symmetry* if the views of it from all points on an infinite (or very long) plain surface are the same.
  - Choose a soup-can shaped cylinder, with the charged plane bisecting the cylinder.

Plane Symmetry



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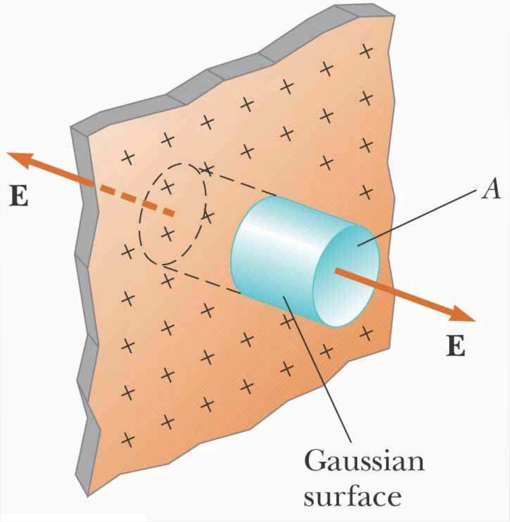
- A charge distribution has *plane symmetry* if the views of it from all points on an infinite (or very long) plain surface are the same.
  - Choose a soup-can shaped cylinder, with the charged plane bisecting the cylinder.
  - The only contributing flux is that due to the flat ends.

Plane Symmetry



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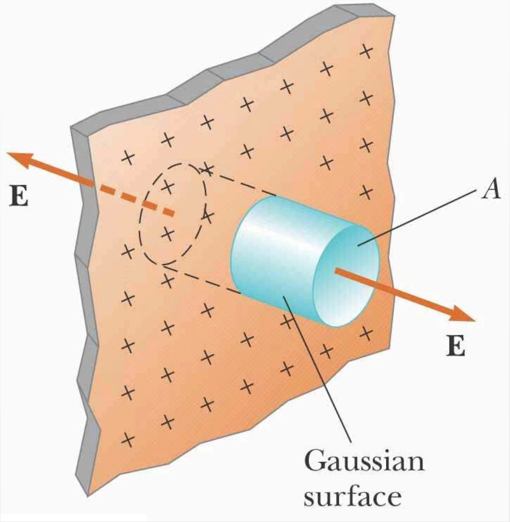
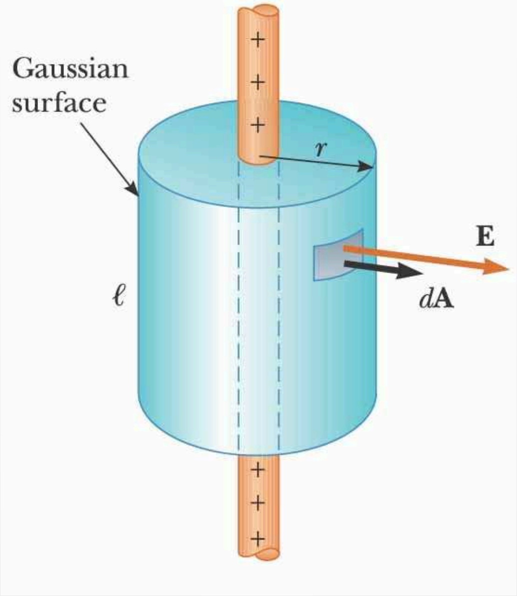


2. Plane Symmetry.

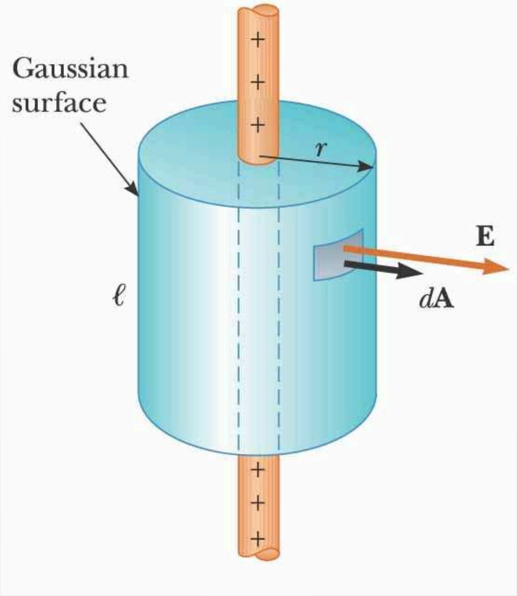
   - By symmetry, the electric field is directed perpendicular (away for positive and toward for negative) to the plane.

Cylindrical Symmetry



3. Cylindrical Symmetry.

Cylindrical Symmetry



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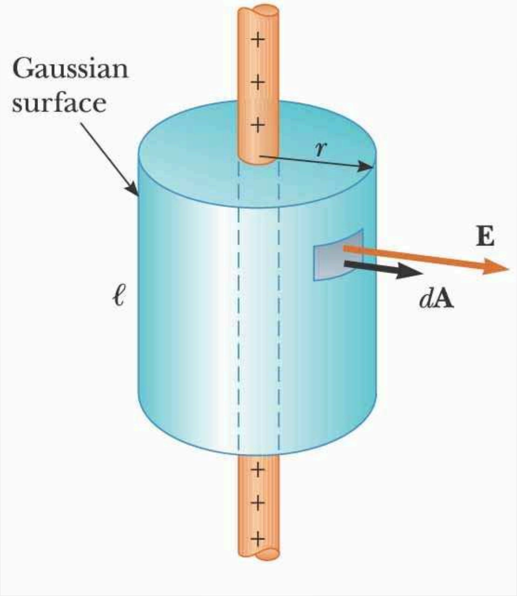
   - A charge distribution has *cylindrical symmetry* if the views of it from all points on a cylindrical surface of infinite (or very long) length are the same.

Cylindrical Symmetry



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- A charge distribution has *cylindrical symmetry* if the views of it from all points on a cylindrical surface of infinite (or very long) length are the same.
  - Choose a cylindrical Gaussian surface with the center of the Gaussian cylinder coincident with the cylindrical charge distribution.

Cylindrical Symmetry

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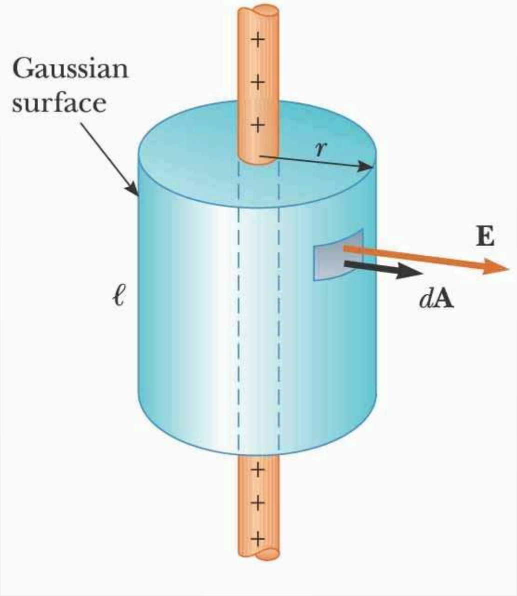

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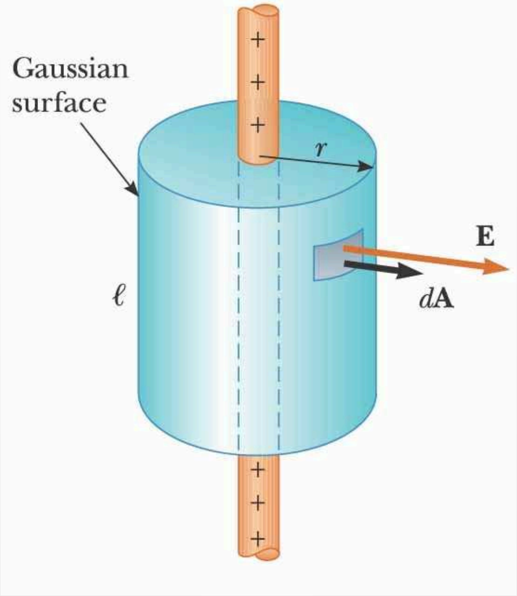

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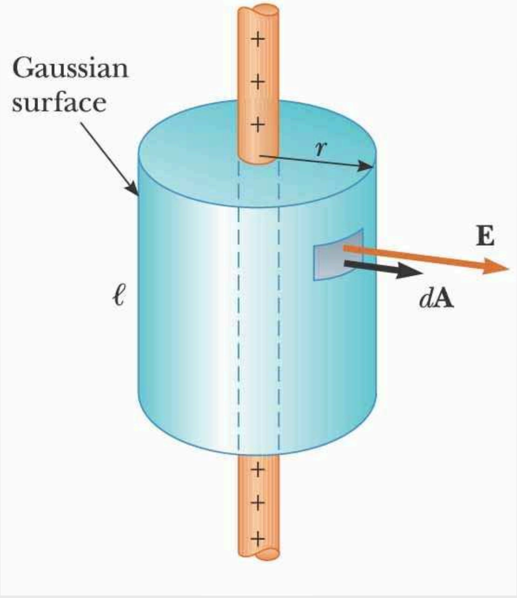
   - The only contributing flux is along the curved piece of the cylinder.

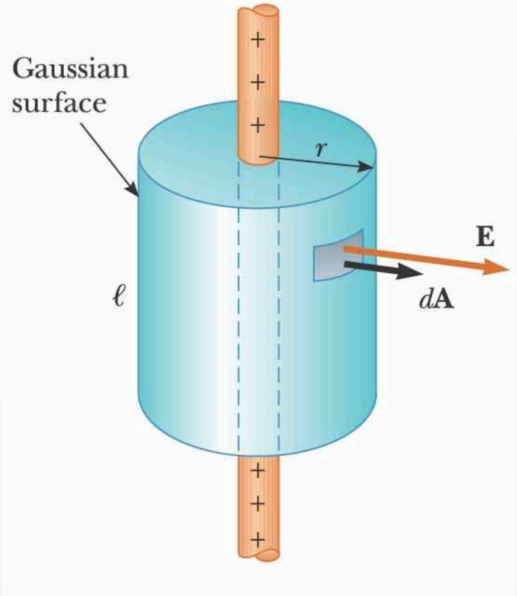
Cylindrical Symmetry



3. Cylindrical Symmetry.

- The only contributing flux is along the curved piece of the cylinder.
- By symmetry, the electric field is directed (away for positive or toward for negative) from the line charge.

Cylindrical Symmetry



3. Cylindrical Symmetry.

   - The only contributing flux is along the curved piece of the cylinder.
   - By symmetry, the electric field is directed (away for positive or toward for negative) from the line charge.
   - The magnitude of E depends only on the radial distance from the line charge.