JYOTHISHMATHI INSTITUTE OF TECHNOLOGY AND SCIENCE

ELECTROMAGNETIC FIELDS

II B.TECH – EEE

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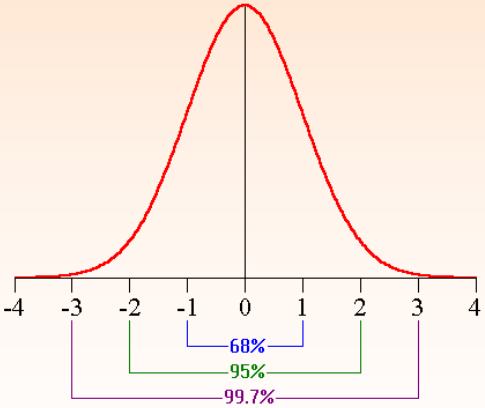
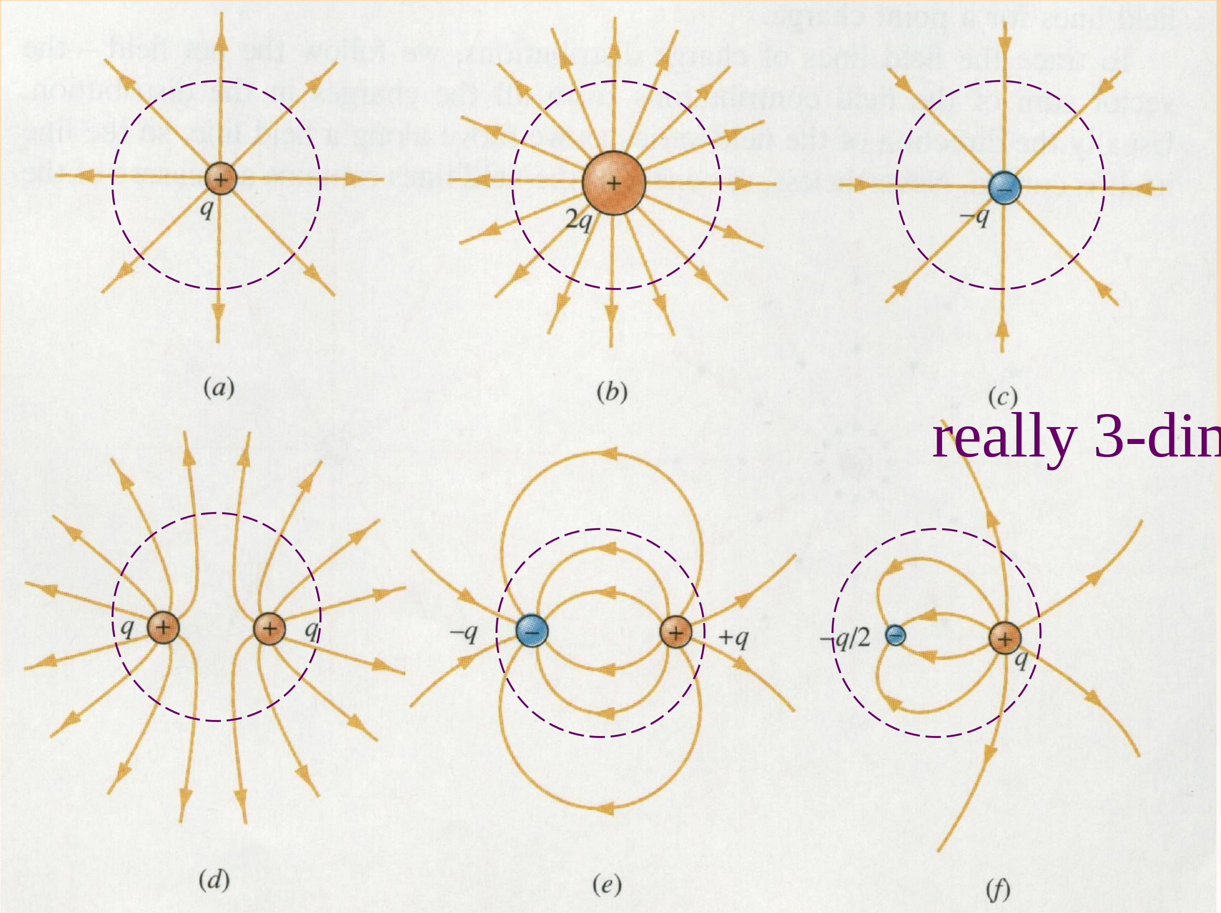
Gauss' Law

- Electric Flux
- Gauss's Law
- Applications of Gauss' Law



Gauss' Law

- Here are a number of charge arrangements.



really 3-dimensional

•Is there any connection between the number of field lines through a surface and the charge enclosed.

Gauss' Law

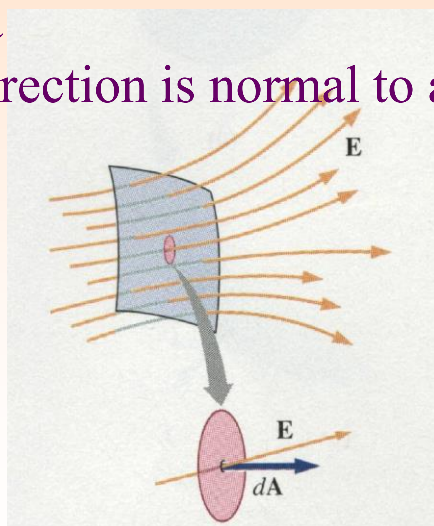
- Electrical Flux

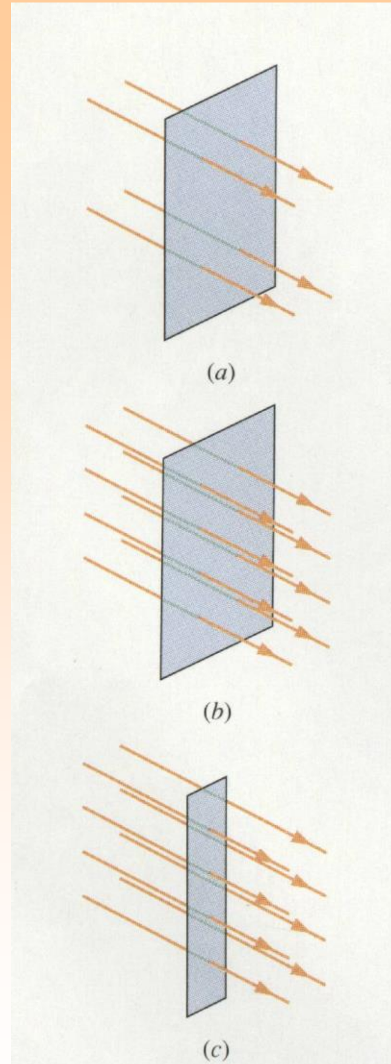
electric field

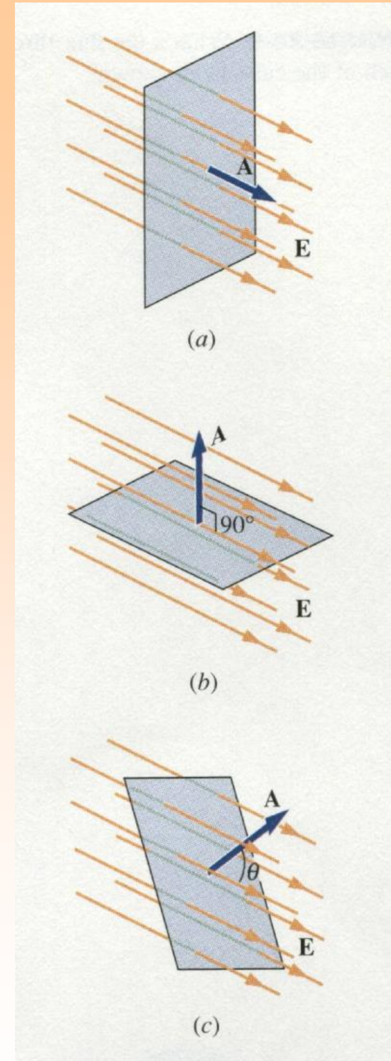
$$\phi = \int_{surface} \vec{E} \cdot d\vec{A}$$

vector area

- Magnitude is common old area
- Direction is normal to area







Gauss's Law

- **What about the flux through a closed surface?**

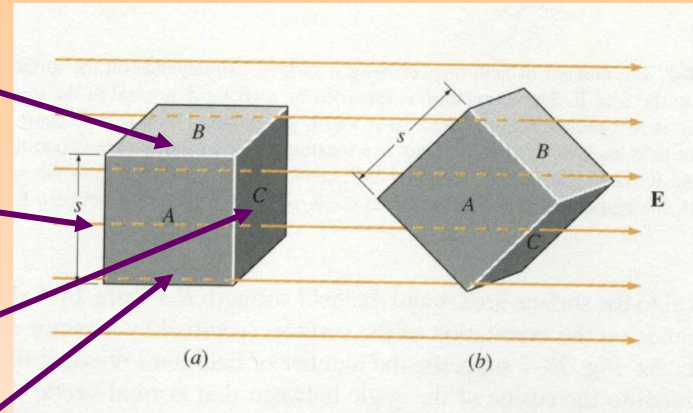
$\phi = 0$

$\phi = 0$

$\phi = -\phi_0$

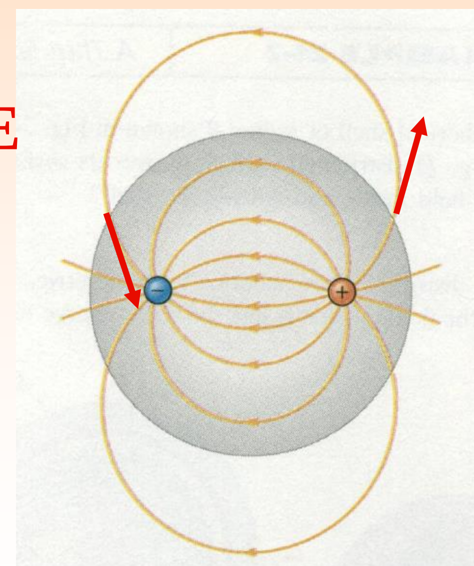
$\phi = \phi_0$

$\phi = 0$



- What about this surface?

E



$\phi = 0$ yes

Gauss' Law

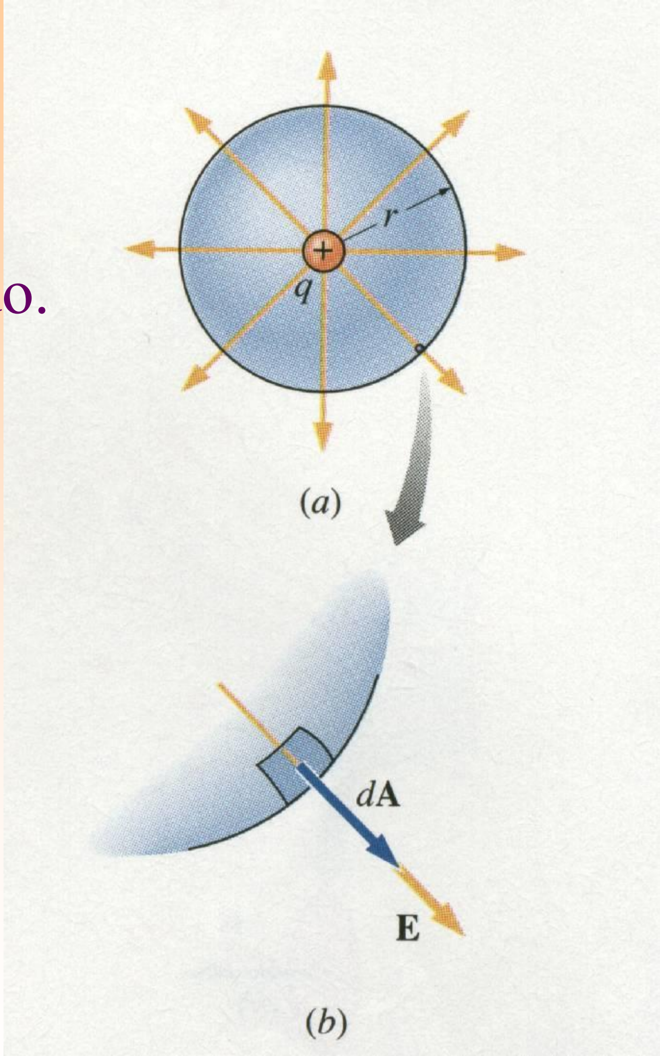
- **Gauss's law**

$$\phi = \int_{surface} \vec{E} \cdot d\vec{A} = \frac{q_{enclosed}}{\varepsilon_0}$$

In general this is a hard integral to do.

There are some simple cases where symmetry helps us perform the integral.

Let's look at the point charge!



Gauss' Law

- **Gauss' law for a point charge**

$$\phi = \oint_{surface} \vec{E} \cdot d\vec{A} = \frac{q_{enclosed}}{\varepsilon_0}$$

What can we say about **E** and d**A**?

They are in the same direction

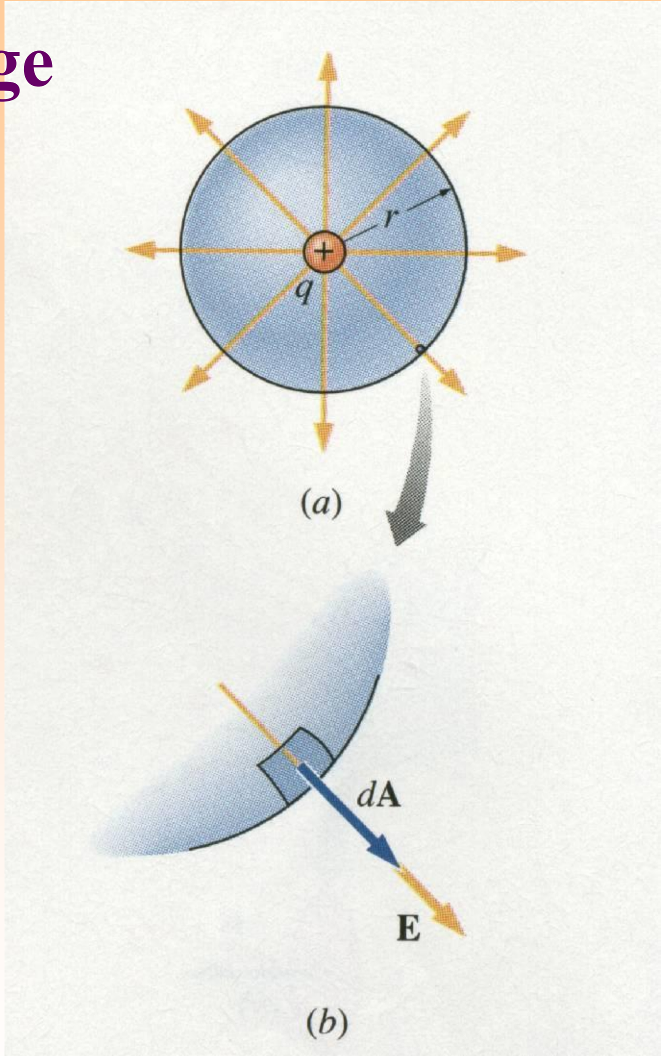
so cos q = cos 0 = 1

$$\phi = \oint_{surface} E dA = \frac{q_{enclosed}}{\varepsilon_0}$$

What can you say about the magnitude of E on the surface?

E depends only on r so constant

$$\phi = E \oint_{surface} dA = \frac{q_{enclosed}}{\varepsilon_0}$$



Gauss' Law

$$\phi = E \int_{surface} dA = \frac{q_{enclosed}}{\varepsilon_0}$$

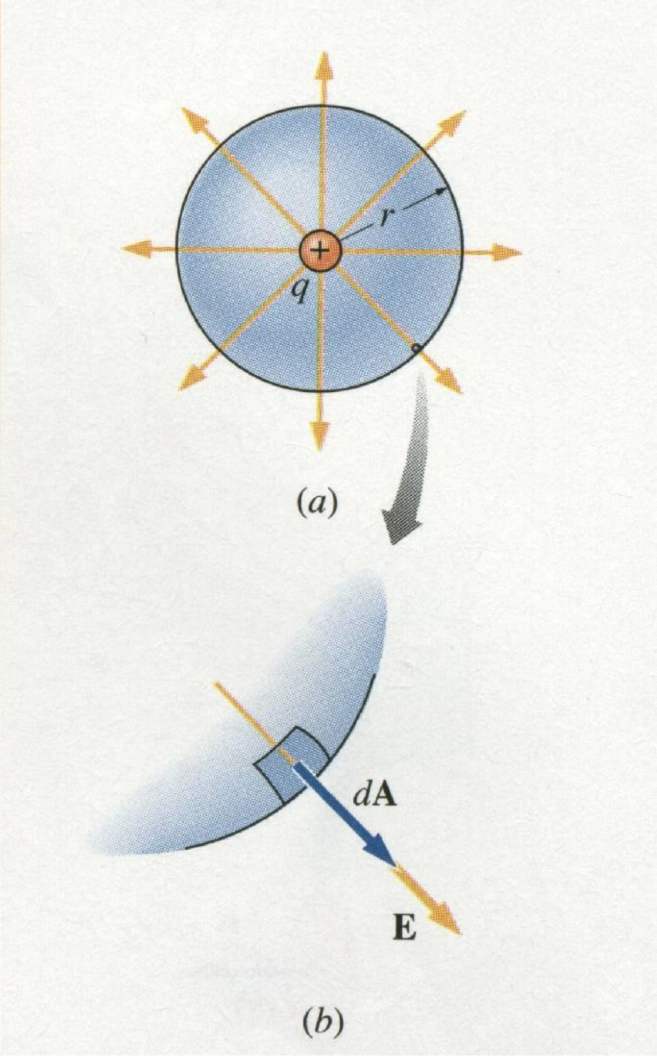
What is $\int_{sphere} dA$?

$$\int_{sphere} dA = 4\pi r^2$$

$$\phi = E\,4\pi r^2 = \frac{q_{enclosed}}{\varepsilon_0}$$

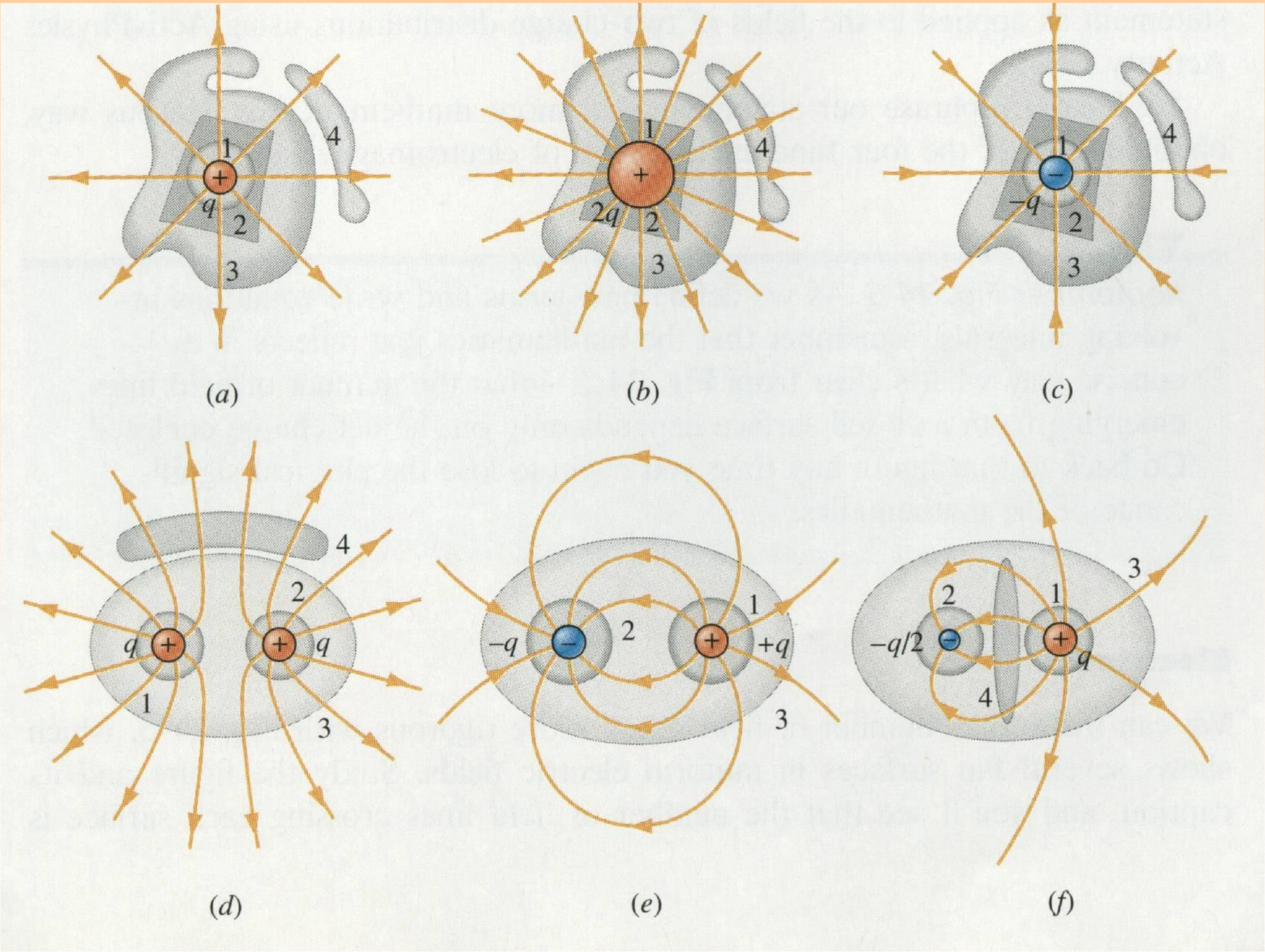
$$q_{enclosed} = q$$

$$E(r) = \frac{q}{4\pi\varepsilon_0 r^2} = k\frac{q}{r^2}$$



Gauss' Law

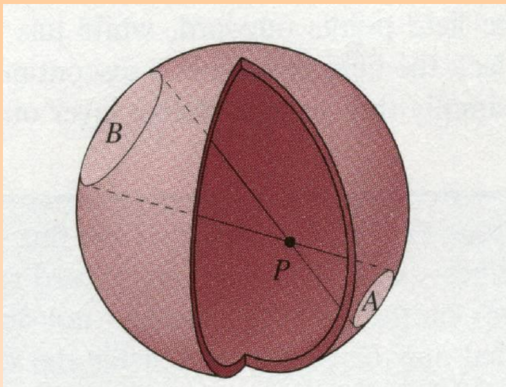
- **Electric Flux**

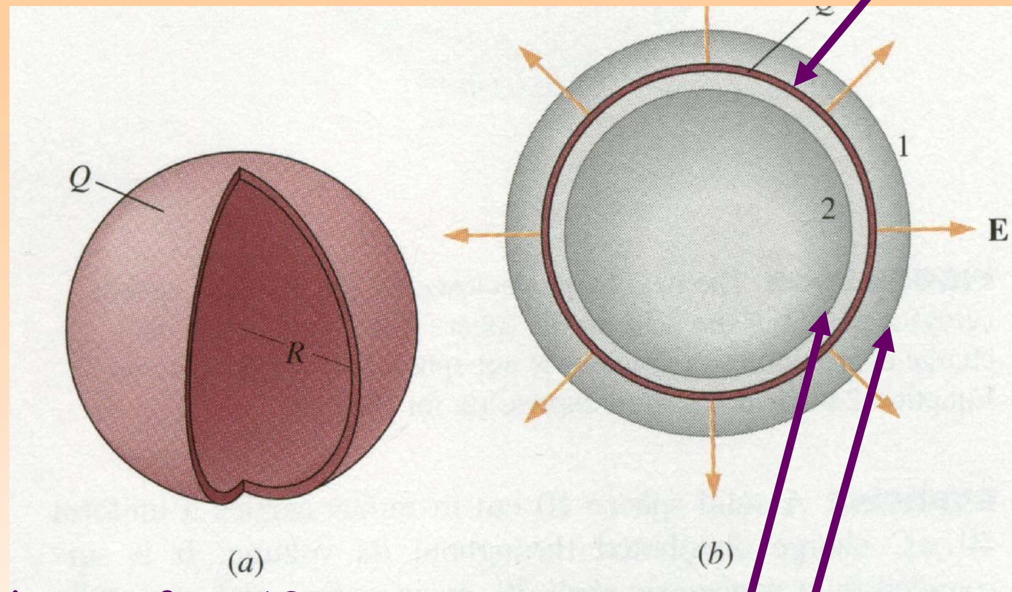


Gauss's Law

- **What is the electric field for a charged shell**

Q





Gaussian surfaces 1 and 2

What is charge inside Gaussian surface 1?

Q = 0

What is flux through the surface?

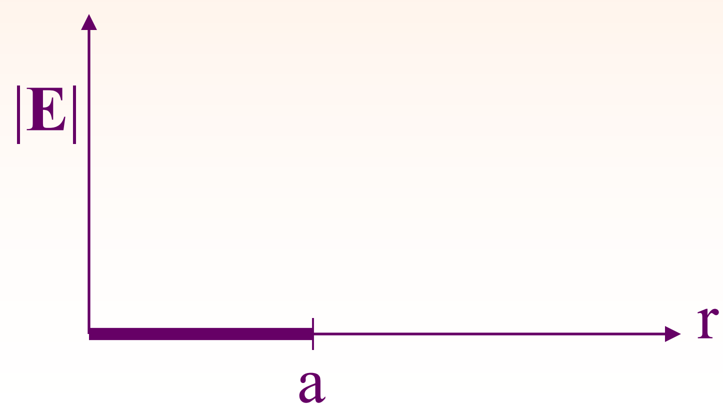
ϕ = 0 from Gauss's law

What is the electric field on the surface?

E = 0 from Gauss's law

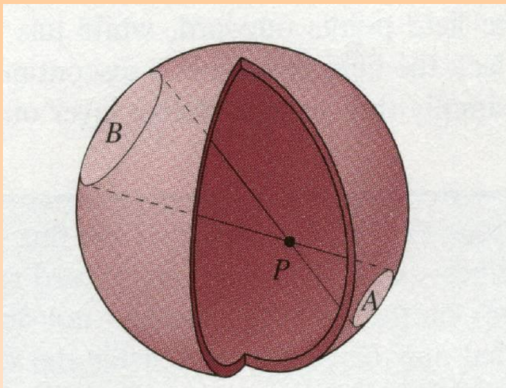
What is electric field inside surface?

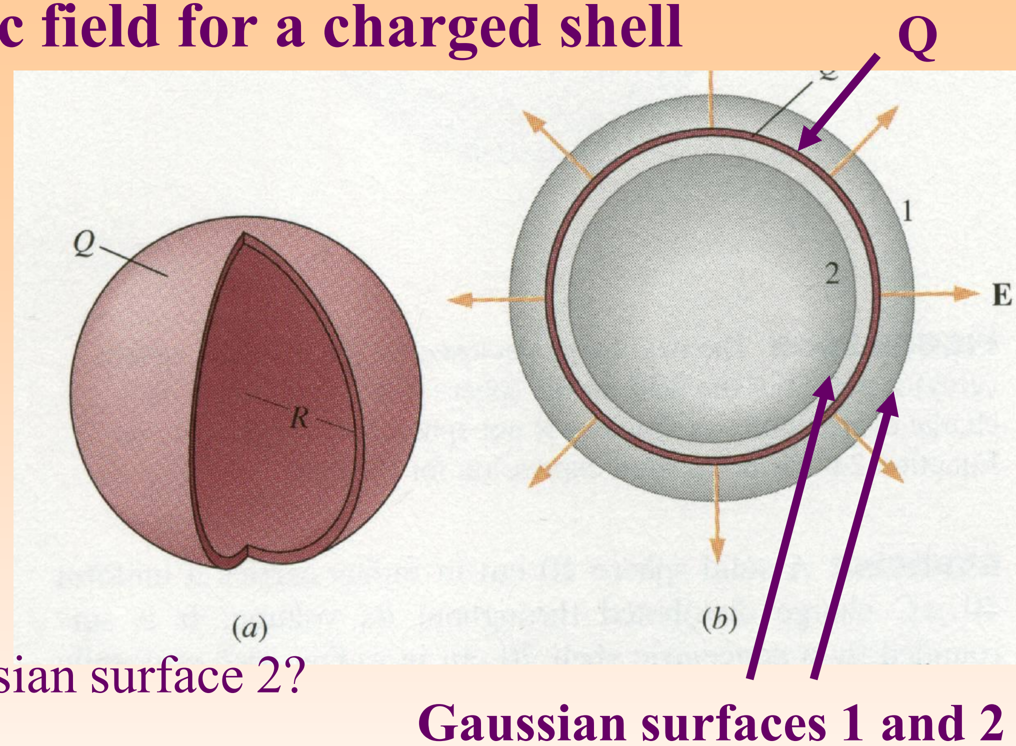
E = 0 from symmetry



Gauss' Law

- **What is the electric field for a charged shell**





What is charge inside Gaussian surface 2?

Q

What is flux through the surface?

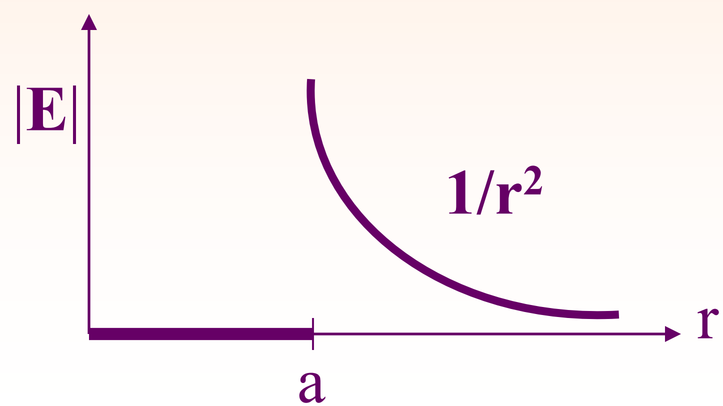
$\phi = Q/\varepsilon_0$ from Gauss's law

What is the electric field on the surface?

$E = kQ/a^2$ from Gauss's law

What is electric field outside surface?

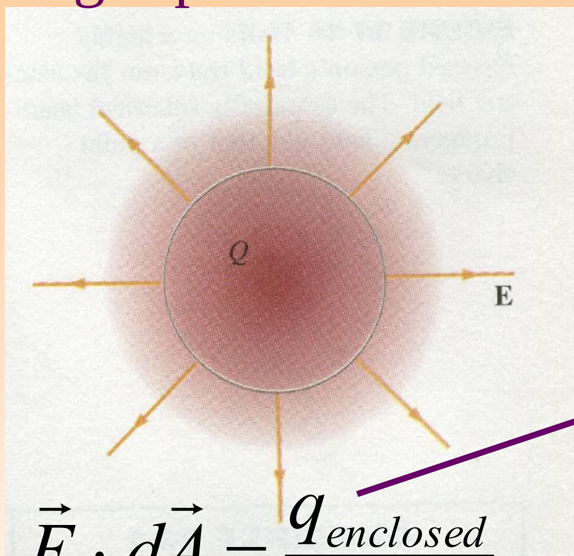
$E = kQ/r^2$ from symmetry

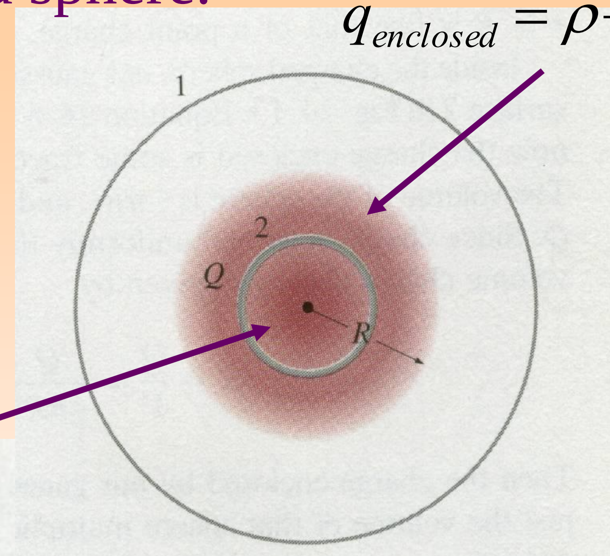


Gauss’ Law

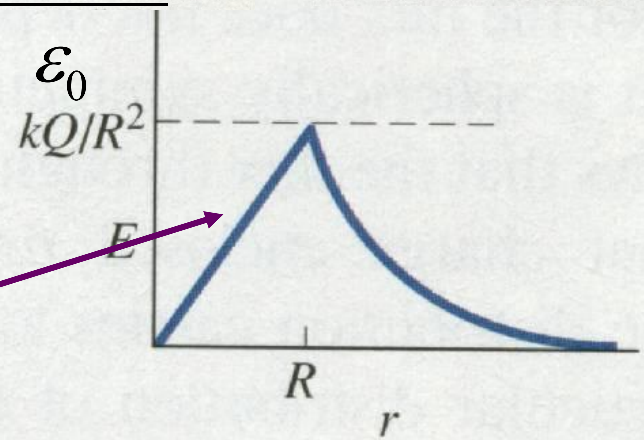
• We can also use Gauss’s Law to find the electric field for a charge spread out inside a sphere.

$$q_{enclosed} = \rho \frac{4}{3}\pi r^3$$





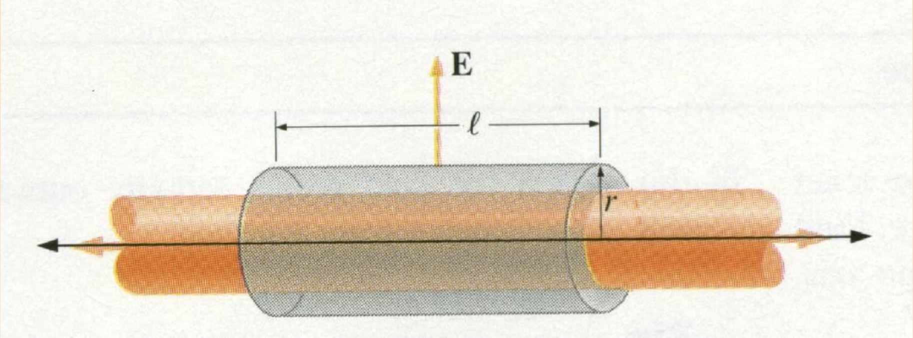
$$\phi = \int_{Surface} \vec{E} \cdot d\vec{A} = \frac{q_{enclosed}}{\varepsilon_0}$$

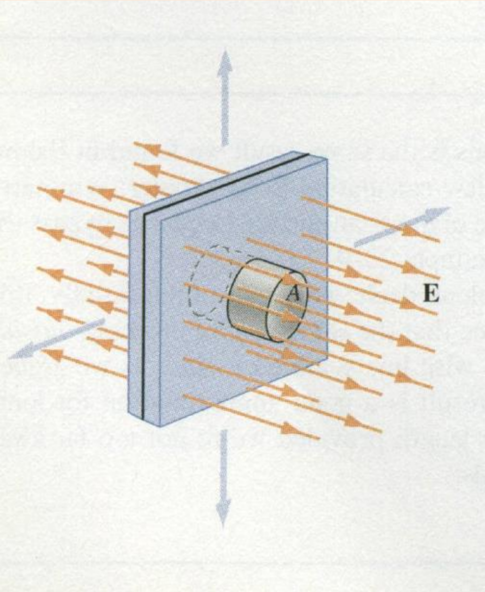


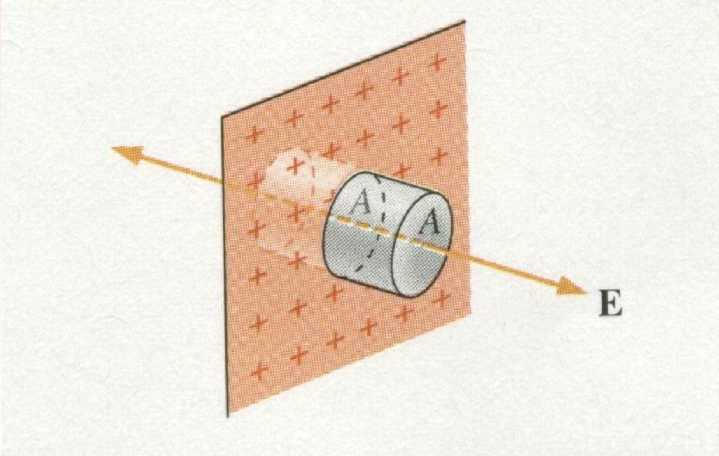
$$\left|\vec{E}\right| \propto \frac{q}{dA} \propto \frac{r^3}{r^2} \propto r$$

Gauss' Law

• Gauss's Law can be used with different surfaces like a cylinder or cap, but we do not have time to explore these.







Gauss' Law

- What about a conductor?

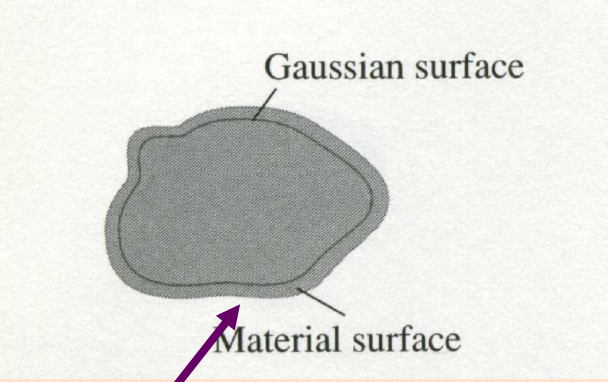
The electric field is zero inside a conductor in electrostatic equilibrium.

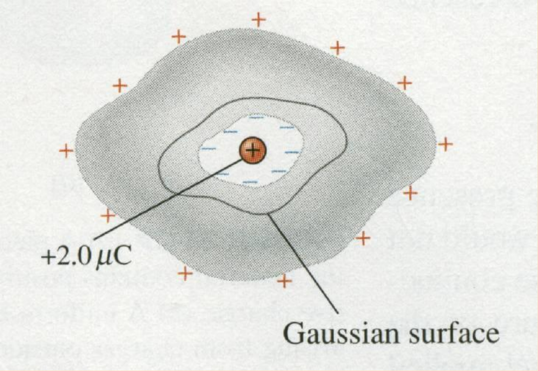
Near the surface of a conductor in electrostatic equilibrium and with a net charge the electric field is perpendicular to the surface.

If a conductor in electrostatic equilibrium carries a net charge, all excess charge resides on the conductor surface.

Gauss' Law

- **What about a conductor.**





Since all the charge is on the surface the electric field is zero inside a conductor.

The electric field is perpendicular to the surface of a conductor.