Mon Jan 30, 2017

Last time

- The electric field: demonstration
- Calculating electric field: Group Activity

This time

- Electric field visualization applet - reminder
- Introduction to Gauss' Law: the first of the four Maxwell equations of electromagnetism
- Electric Flux, calculating flux

Electric Fields

www.falstad.com/vector3de

shows electric field vectors, electric field lines, equipotential surfaces, etc. for a large number of objects we have been considering

Electric Flux; Gauss' Law

Gauss' Law is equivalent to Coulomb's law. It will provide us:

(i) an **easier way to calculate the electric field** in specific circumstances (especially situations with a high degree of symmetry)

(ii) a better understanding of the properties of conductors in electrostatic equilibrium (more on this as we go)

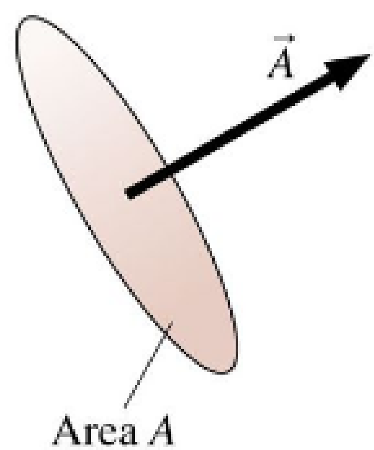
(iii) It is valid for moving charges – not limited to electrostatics.

Electric flux, passing through a **closed** Gaussian surface

$$\boxed{\Phi_E = \oiint \vec{E} \cdot d\vec{A}} = \frac{Q_{enc}}{\varepsilon_0}$$

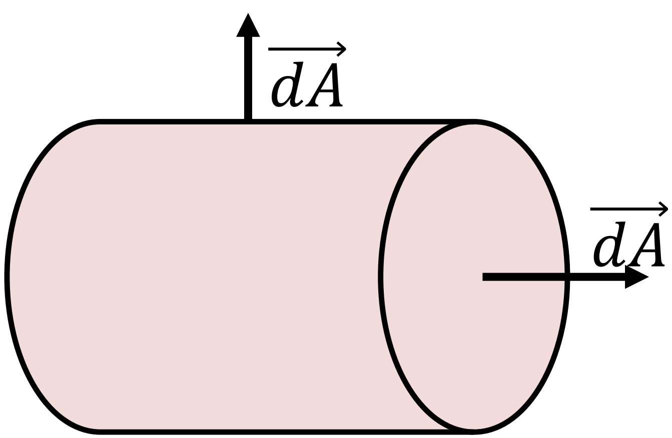
Area vector

- Area vector, $\vec{A}$:
  - magnitude is equal to the surface area
  - direction normal to the plane of the area (unit vector, $\vec{n}$)



Area vector

- Area vector, $\overrightarrow{dA}$:
  - area vector for infinitesimally small surface segment (small enough to be considered flat)
  - on closed surfaces we choose $\overrightarrow{dA}$ to point outwards



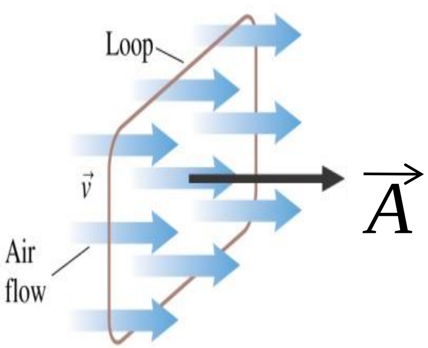
Electric flux passing through a **closed** Gaussian surface

$$\oiint \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\varepsilon_0}$$

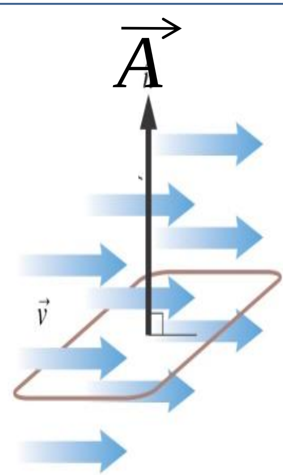
$$\boxed{\Phi_E = Q_{encl} / \varepsilon_0}$$

Gauss's law: the **net flux** passing through a closed surface (Gaussian surface) is **proportional to the net charge inside** the surface. **It does NOT depend on the shape of the surface.**

Flux : amount of 'something' (air, water……) flowing through an area

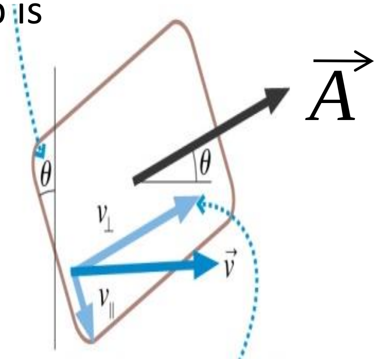


The air flowing through the loop is maximum when $\theta = 0^o$



No air flows through the loop when $\theta = 90^o$

The loop is tilted by angle θ

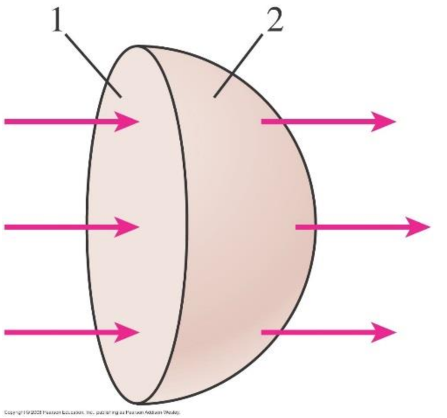


$v_\perp = v \cos\theta$ is the component of the air velocity perpendicular to the loop.

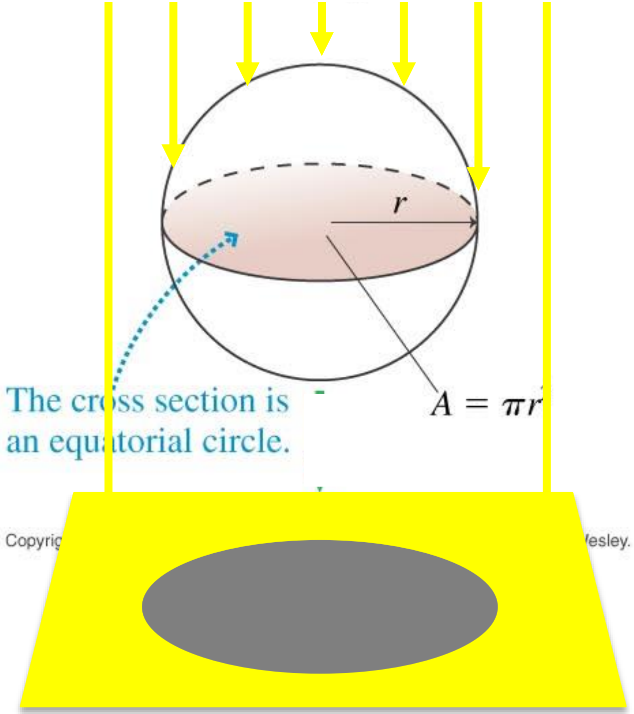
Cross-sectional area

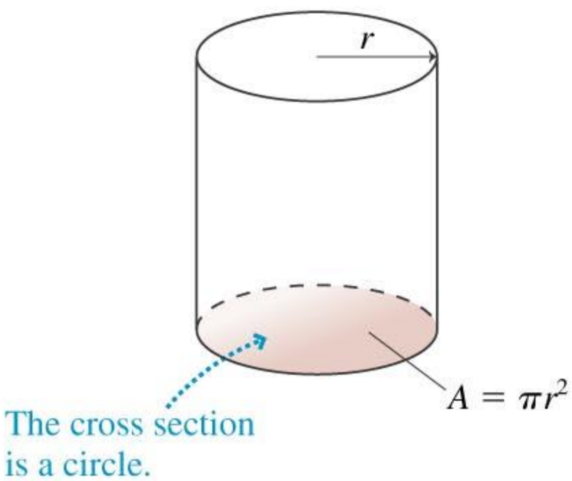
Area measured in a plane ⊥ to the direction of flow.

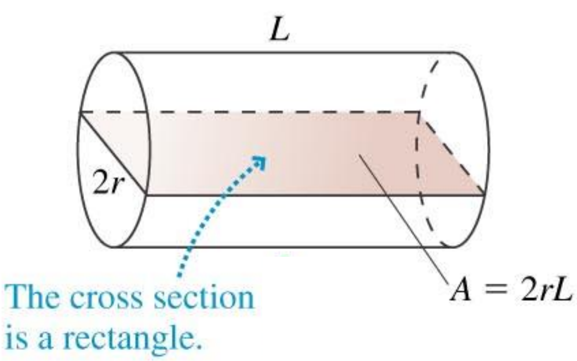
Area of shadow cast by || light rays



Flux through 1 = Flux through 2





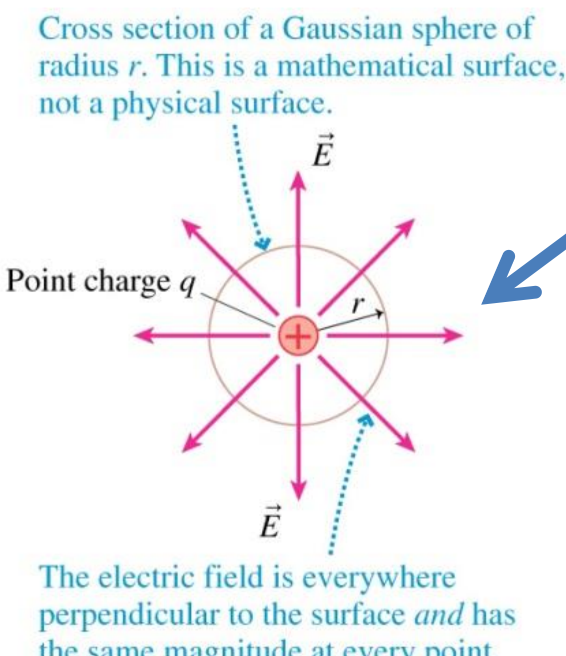


Electric flux passing through a **closed** Gaussian surface

$$\oint \vec{E} \cdot \overrightarrow{da} = \frac{Q_{enclosed}}{\epsilon_0}$$

$$\boxed{\Phi_E = Q_{encl} / \epsilon_0}$$

Flux : amount of ‘something’ (air, water……) flowing through an area

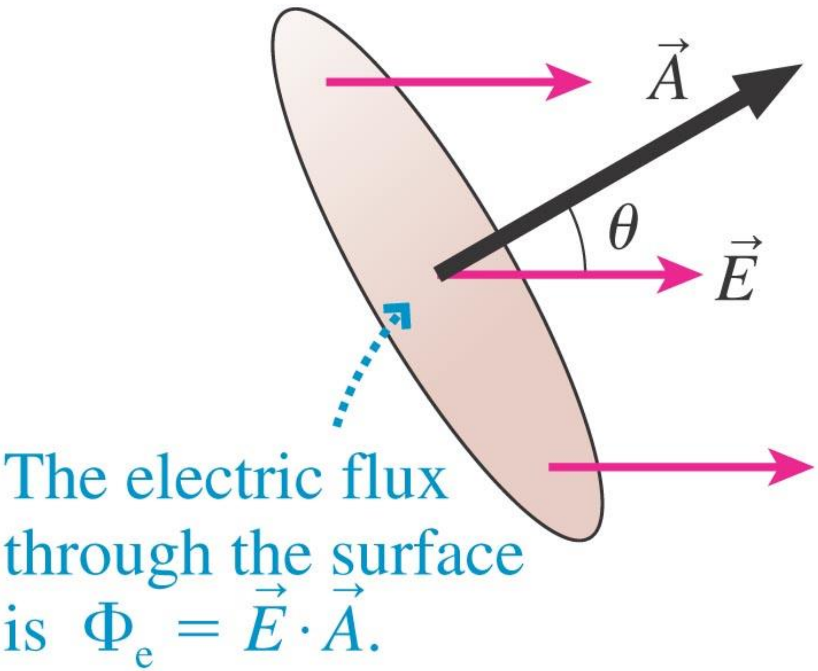


The flux passing **out** of the closed Gaussian surface is **positive**. The flux is: $\boxed{\Phi_E = +q / \epsilon_0}$

If the positive charge is replaced by a negative charge, the flux would be:

$$\boxed{\Phi_E = -q / \epsilon_0}$$

<u>Electric flux</u> through a surface with area A



$$\Phi_E = EA\cos\theta$$

How to evaluate $\Phi_E = \oiint \vec{E} \cdot d\vec{A}$

- If the electric field is tangent to the surface:

$$\Phi = 0$$

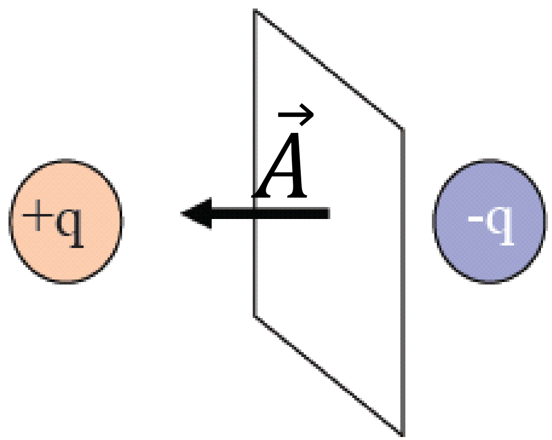
- If the electric field is normal to the surface and is constant at every point:

$$\Phi = EA$$

TopHat Questions

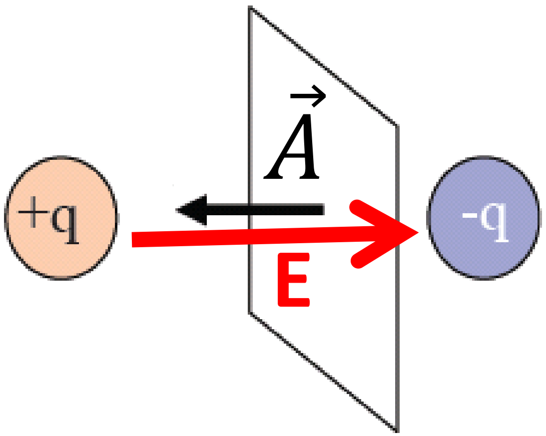
TopHat Question

The flux through the planar surface below (surface vector pointing to the left)



A: is positive.
B: is negative.
C: is zero.
D: not enough information

The flux through the planar surface below (surface vector pointing to the left)



A: is positive.

B: is negative.

C: is zero.

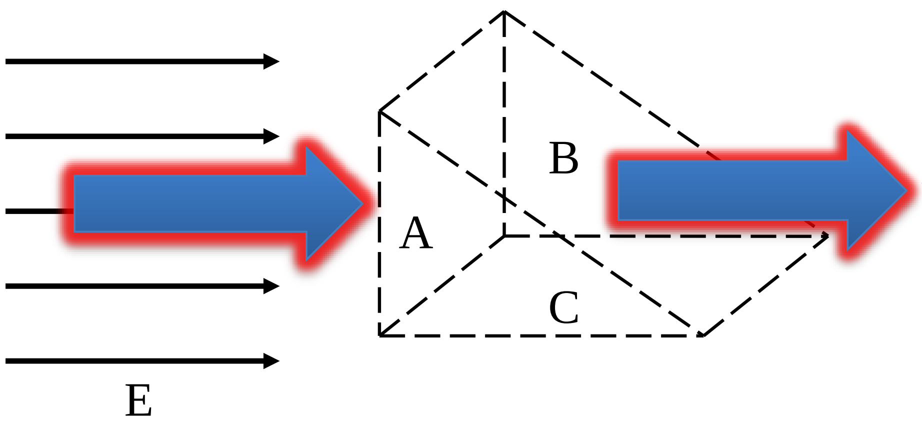
D: not enough info

Here we choose the outward direction to be to the left. That is completely arbitrary. Since the E field is flowing inward (negative), the flux is negative.

E always points from + to - charges

TopHat Question

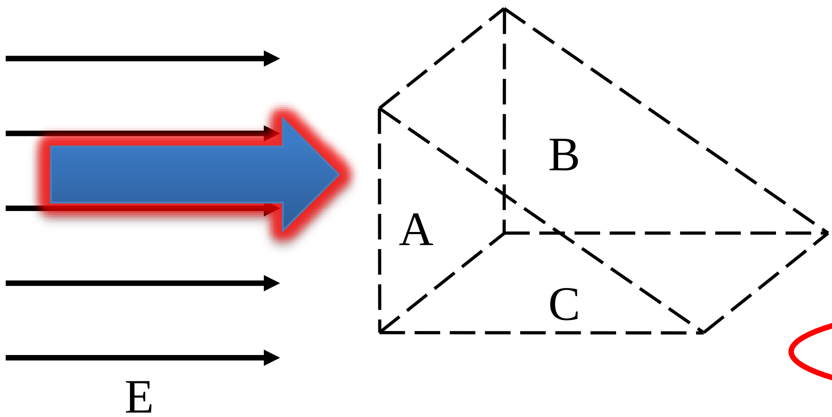
A prism-shaped closed surface is in a constant, uniform electric field **E**, filling all space, pointing to the right. The 3 rectangular faces of the prism are labeled A, B, and C. Face A is perpendicular to the E-field. The bottom face C is parallel to **E**. Face B is the leaning face.



Which face has the largest magnitude electric flux passing through it?

A) side A
B) side B
C) side C
D) sides A and B have the same Electric flux

A prism-shaped closed surface is in a constant, uniform electric field **E**, filling all space, pointing to the right. The 3 rectangular faces of the prism are labeled A, B, and C. Face A is perpendicular to the E-field. The bottom face C is parallel to **E**. Face B is the leaning face.



Which face has the largest magnitude electric flux passing through it?

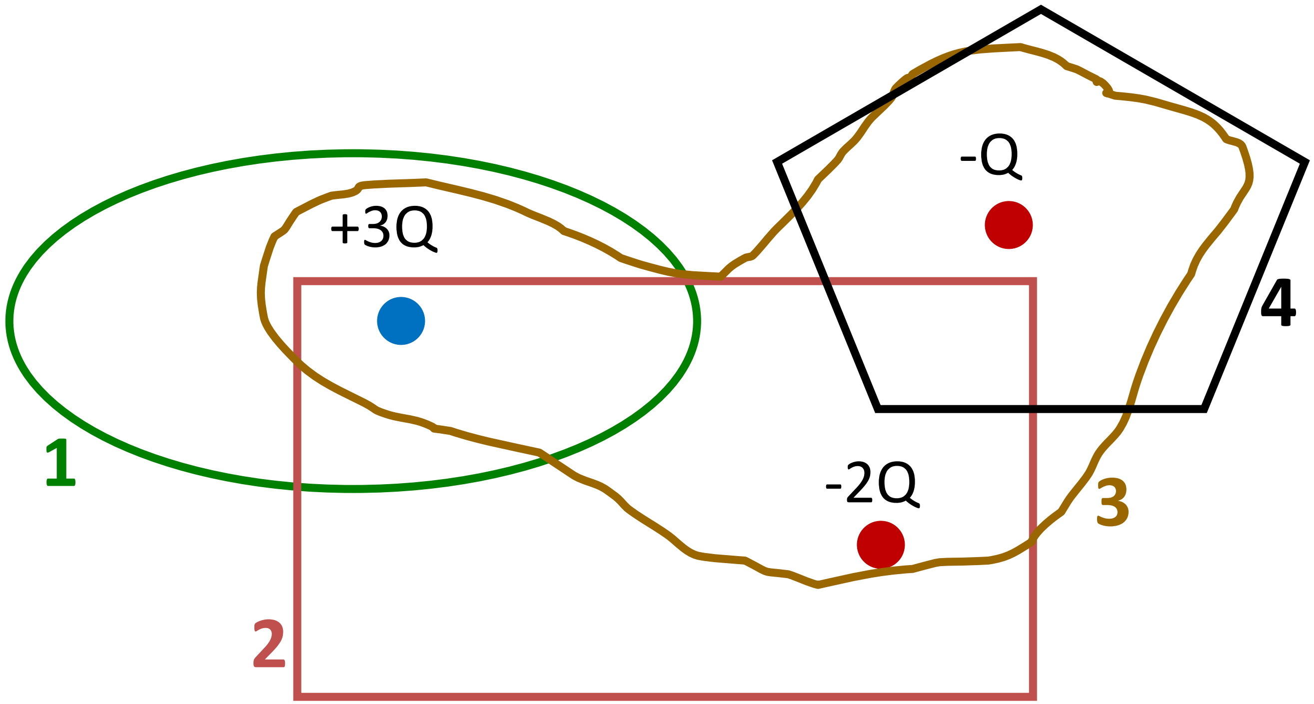
A) A B) B C) C

D) A and B have the same E flux

The same amount of E flux flows through the perpendicular face A and the slanted face B. The amount of **E**-flux flowing through the bottom face C is 0. Remember, although the slanted face B has larger surface area, the cos(θ) term keeps the flux equal to the flux through the perpendicular face A. Recall, θ is the angle between E and the normal to the slanted surface B.

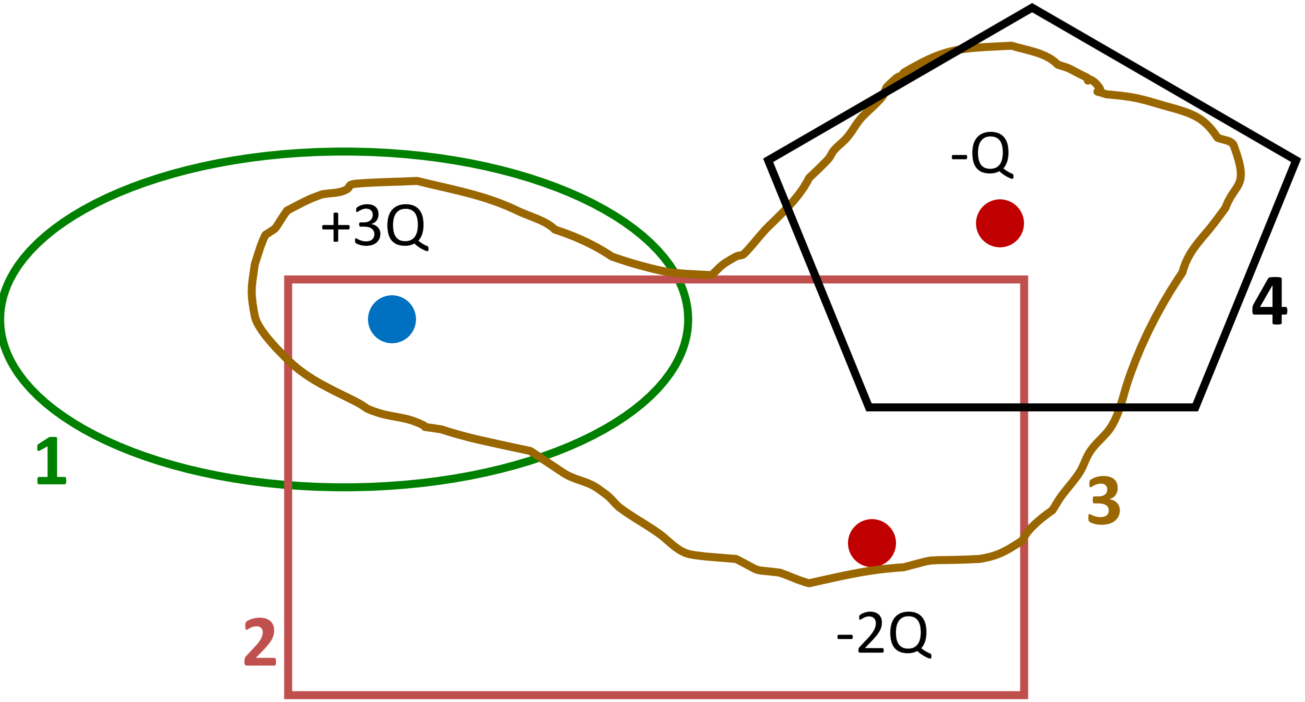
TopHat Question

Which surface has the largest **magnitude** electric flux?



A) 1 = 2 = 3 = 4
B) 1 > 2 = 4 > 3
C) 3 > 2 > 1 > 4
D) 3 > 2 > 1 = 4
E) None of the above

Which surface has the largest <u>magnitude</u> electric flux?



A) 1 = 2 = 3 = 4

B) 1 > 2 = 4 > 3

C) 3 > 2 > 1 > 4

D) 3 > 2 > 1 = 4

E) None of the above

Region 1: Net charge is +3Q

Region 2: Net charge is +Q

Region 3: Net charge is 0

Region 4: Net charge is -Q

Here, we are interested in the **magnitude** of the flux, so the flux through regions 2 & 4 is the same. The flux through region 2 is outward (**+**), while the flux through region 4 is inward (**-**).

Again, electric flux is equal to "$Q_{enclosed}/\varepsilon_0$"