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PY212

# Problem Set 2 Worksheet

Please begin working immediately with your partners on this first page of tutorials.

## I. Electric flux through closed surfaces

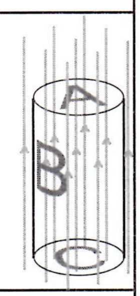
In the tutorial *Electric field and flux* and in the homework, we found that the electric flux through a set of imaginary surfaces, $d\vec{A}_i$, each with a uniform electric field, $\vec{E}_i$, can be written as:

$$\Phi_{\text{net}} = \vec{E}_1 \bullet d\vec{A}_1 + \vec{E}_2 \bullet d\vec{A}_2 + \vec{E}_3 \bullet d\vec{A}_3 + \ldots$$

The area vectors at each point on a *closed surface* (*i.e.*, a surface that surrounds a region so that the only way out of the region is through the surface) are chosen by convention to point *out of* the enclosed region. A closed imaginary surface is called a *Gaussian surface*.

In the following questions, a Gaussian cylinder with radius $a$ and length $l$ is placed in various electric fields. The end caps are labeled A and C and the side surface is labeled B. In each case, *base your answer about the net flux only on qualitative arguments about the magnitude of the flux through the end caps and side surface*.

A. The Gaussian cylinder is in a uniform electric field of magnitude $E_o$ aligned with the cylinder axis.

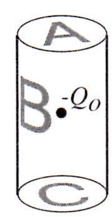



- Find the sign and magnitude of the flux through:

  Surface A: Surface B: Surface C:

- Is the net flux through the Gaussian surface *positive, negative,* or *zero?*

B. The Gaussian cylinder encloses a negative charge. (The field from part A is removed.)

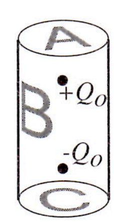



- Find the sign of the flux through:

  Surface A: Surface B: Surface C:

- Is the net flux through the Gaussian surface *positive, negative,* or *zero?*

C. The Gaussian cylinder encloses opposite charges of equal magnitude. (The charges are on the axis of the cylinder and equidistant from the center.)

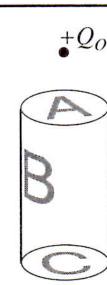



- Find the sign of the flux through:

  Surface A: Surface B: Surface C:

- Is the net flux through the Gaussian surface *positive, negative,* or *zero?*

D. A positive charge is located above the Gaussian cylinder.




- Find the sign of the flux through:

  Surface A: Surface B: Surface C:

- Can you tell whether the net flux through the Gaussian surface is *positive, negative,* or *zero?* Explain.

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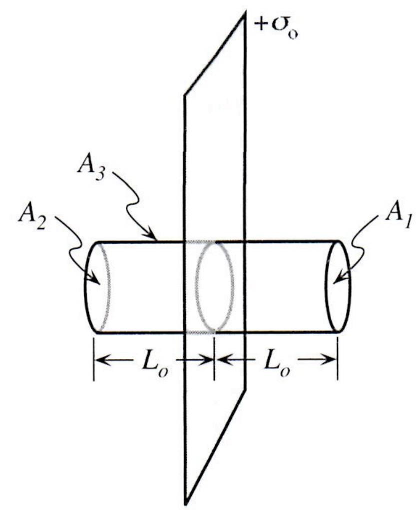
## II. Application of Gauss' law

A large sheet has charge density $+\sigma_o$. A cylindrical Gaussian surface encloses a portion of the sheet and extends a distance $L_o$ on either side of the sheet. $A_1$, $A_2$, and $A_3$ are the areas of the ends and curved side, respectively. Only a small portion of the sheet is shown.

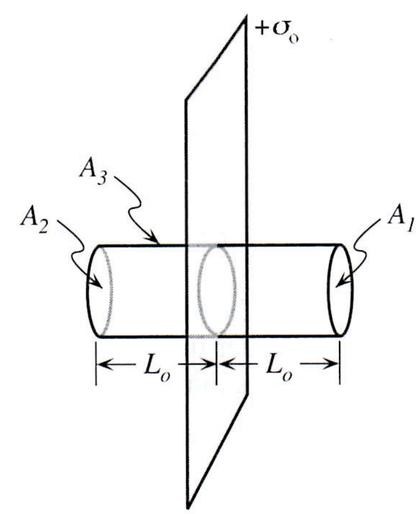



1. On the diagram at right indicate the location of the charge enclosed by the Gaussian cylinder.

   In terms of $\sigma_o$ and other relevant quantities, what is the net charge enclosed by the Gaussian cylinder?

2. Sketch the electric field lines on both sides of the sheet.

   Does the Gaussian cylinder affect the field lines or the charge distribution? Explain.




3. Let $E_L$ and $E_R$ represent the magnitude of the electric field on the left and right ends of the Gaussian surface.

   How do the magnitudes of $E_L$ and $E_R$ compare? Explain.

4. Through which of the surfaces $(A_1, A_2, A_3)$ is there a net flux? Explain using a sketch showing the relative orientation of the electric field vector and the area vectors.

   Write an expression for the net electric flux $\Phi_{net}$ through the cylinder in terms of the three areas $(A_1, A_2,$ and $A_3)$, $E_L$, and $E_R$.

   Use the relationships between the electric fields $E_L$ and $E_R$ and between the areas $A_1$ and $A_2$ to simplify your equation for the net flux.

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5.

Instead of a large thin sheet, suppose we had a large thick slab of insulating material with thickness 2d. Instead of a surface charge density $\sigma$, the slab has a uniform positive volume charge density $\rho$. In comparison to the thickness 2d, the other dimensions of the slab are large and can thus be treated as essentially infinite.

Please draw a diagram of the slab in the space to the right. Is there any symmetry in the problem?

Is Gauss's law useful in this situation? Explain.

If so, what Gaussian surface can be used? Draw it.

Indicate (by shading) the precise location of the charge enclosed by your Gaussian surface. In terms of $\rho$ and other relevant quantities, what is the charge enclosed by this surface?

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Please draw another diagram of the slab in the space to the right. Consider the region **inside** the slab.

Is there a net electric field **at the center** of the slab? Why or why not?

Is there a net electric field at a point inside the slab but not at the exact center? Why or why not?

Is Gauss's Law useful for calculating the electric field inside the slab? Explain.

If so, what Gaussian surface can be used? Draw it.

Indicate (by shading) the precise location of the charge enclosed by your Gaussian surface. In terms of $\rho$ and other relevant quantities, what is the charge enclosed by this surface?

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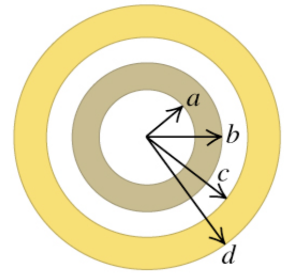
### III. Conductors and Induced Charge




A small conducting spherical shell with inner radius a and outer radius b is concentric with a larger conducting spherical shell with inner radius c and outer radius d (see the figure). The inner and outer shells have total charges as given below.

Given the total charges as follows, what is the charge on **each surface**?
Case 1: +2q (on inner shell) and +4q (on outer shell)

| | |
|---|---|
| Inner sphere (r=a) | |
| Inner sphere (r=b) | |
| Outer sphere (r=c) | |
| Outer sphere (r=d) | |

What is the relationship between the charge at r=a and the charge at r=b?

Between the charge at r=b and at r=c?

Between the charge at r=c and r=d?

Now consider two other cases. Specify the charge.

Case 2: +2q and 0

| | |
|---|---|
| Inner sphere (r=a) | |
| Inner sphere (r=b) | |
| Outer sphere (r=c) | |
| Outer sphere (r=d) | |

Case 3: +2q and -4q

| | |
|---|---|
| Inner sphere (r=a) | |
| Inner sphere (r=b) | |
| Outer sphere (r=c) | |
| Outer sphere (r=d) | |

Consider now Case 3. Is Gauss's Law useful in this situation for calculating **E**? Explain.

In calculating the electric field, how many different "regions" are there for this problem? Are there any regions for which the electric field is zero? Please draw a rough sketch of the field $E$ as a function of position $r$. Be sure to label your axes and important values.

Given the charges listed in your table, calculate the **charge density** on each of the surfaces for Case 3. What units would your answers have?