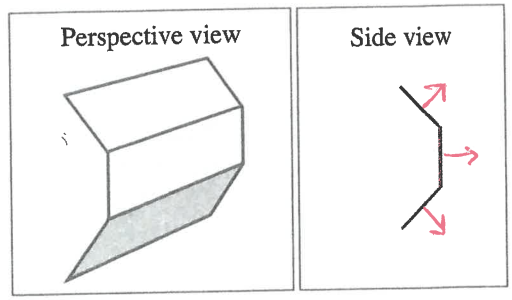
ELECTRIC FIELD AND FLUX

Name ______________________

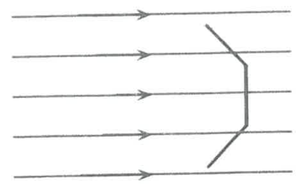
1. A piece of paper is folded into three equal parts as shown.



   a. How many area vectors are needed to describe the surface of the paper? Sketch the area vectors on the side view diagram and label them $\vec{A}_1$, $\vec{A}_2$, *etc.*

   3

   b. Consider an imaginary surface in a uniform electric field $\vec{E}$ as shown. The surface has the same size and shape as the paper above. Is the flux through the top third of the surface *greater than*, *less than*, or *equal to* the flux through the middle third? Explain.



   cosine of angle between $\vec{E}$ and surface normal is less than 1

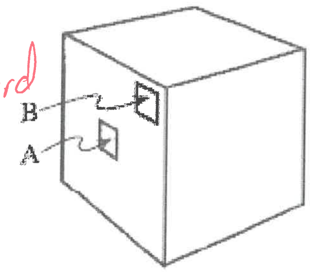
   c. Write an expression for the net electric flux Φ_{net} through the entire surface in terms of the area vectors and the electric field $\vec{E}$. (*Hint:* Use the vector definition for electric flux found in tutorial to first write expressions for the flux through each of the flat surfaces.)

$$\Phi_{net} = \Phi_1 + \Phi_2 + \Phi_3 = \int \vec{E} \cdot d\vec{A}_1 + \int \vec{E} \cdot d\vec{A}_2 + \int \vec{E} \cdot d\vec{A}_3$$

2. A positive charge is located at the center of a cube.

   a. Are the intersections of the field lines with a side of the box uniformly distributed across that side? Explain.

   no, they are increasingly oblique toward the edges



   b. We can consider the left side of the box as composed of many small surface elements of equal area.

      i. Is the number of field lines through surface element A *greater than*, *less than*, or *equal to* the number of field lines through surface element B? Explain.

      $\#_A > \#_B$

      ii. Is the flux through surface element A *greater than*, *less than*, or *equal to* the flux through surface element B? Explain.

      $\phi_A > \Theta_B$

   c. Consider the surface element A itself as composed of many even smaller pieces. Would the number of field lines through each of those new small surface elements vary much from one to another? Explain.

   no

   Describe how the field lines for the positive point charge appear to be distributed when the region over which you look becomes sufficiently small.

   uniform

   d. Consider the left side of the box as consisting of N small pieces. Let $d\vec{A}_i$ represent the area of the i^{th} small surface element on the left side of the box, and let $\vec{E}_i$ represent the electric field on that surface element.

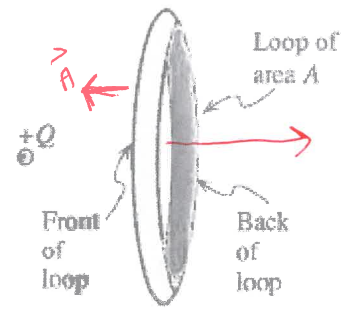
   Write an expression for the net electric flux Φ_{net} through the left side of the box in terms of $d\vec{A}_i$ and $\vec{E}_i$.

   $$\Phi_{net_{left}} = \int \vec{E}_i \cdot d\vec{A}_i$$

ELECTRIC FIELD AND FLUX

Name ______________________ EM HW–81

3. The loop shown at right has an area A.



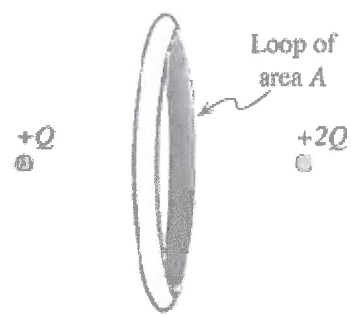
a. The loop is held to the right of a positive point charge as shown.

i. Draw and label an area vector for the surface bounded by the loop.

ii. Sketch electric field lines to represent the electric field due to the charge.

iii Is the electric flux through the loop due to the charge *positive*, *negative*, or *zero?* Explain your reasoning.

negative $\cos 180° = -1$



b. A positive charge with twice the value of the initial charge is now placed to the right of the loop as shown. Both charges are the same distance from the loop and are placed along the axis of the loop.

Is the net electric flux through the loop due to the charges *positive*, *negative*, or *zero?* Explain your reasoning. (*Note:* Use the same area vector you used in part a.)

positive

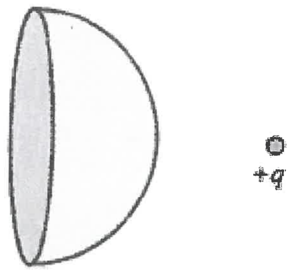
c. Suppose that the new charge located to the right of the loop had been negative instead of positive. How would your answer to part b change, if at all? Explain.

it would then remain a negative E flux

GAUSS' LAW

Name ________________ EM HW-83

1. The *closed* Gaussian surface shown at right consists of a hemispherical surface and a flat plane. A point charge $+q$ is outside the surface, and no charge is enclosed by the surface.



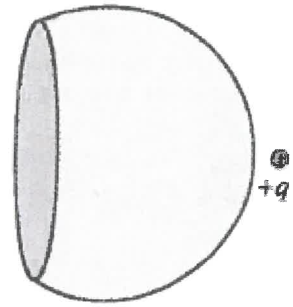
   a. What is the flux through the *entire* closed surface? Explain.

   zero $q_{inside} = 0$

   Let Φ_L represent the flux through the flat left-hand portion of the surface. Write an expression in terms of Φ_L for the flux through the curved portion of the surface, Φ_C.

   $\Phi_c = -\Phi_L$

   b. Suppose that the curved portion of the Gaussian surface in part a is replaced by the larger curved surface as shown. The flat left-hand portion of the surface is unchanged.



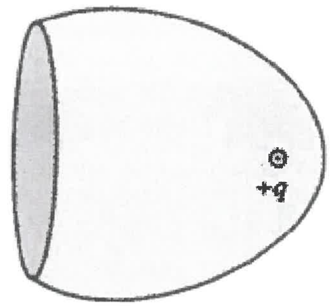
      i. Does the value of Φ_L change? Explain.

      no

      ii. How does the flux through the new curved portion of the surface compare to the flux through the original curved portion of the surface? Explain.

      same More area now, but different vector dot products

   c. Suppose that the curved portion of the Gaussian surface is replaced by the larger curved surface that encloses the charge as shown. The flat left-hand portion of the surface is still unchanged.



      i. Does the value of Φ_L change? Explain.

      no

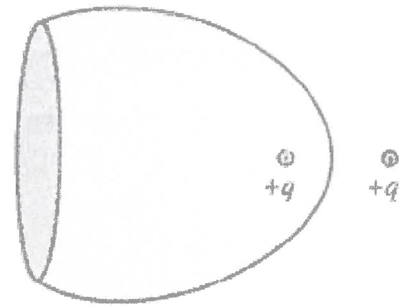
      ii. How does the flux through the new curved portion of the surface compare to the flux through the original curved portion of the surface? Explain.

      $\Phi_{curved\ new} > \Phi_{curved\ old}$ $\Phi_{curved\ new} > 0$ $\Phi_{curved\ old} < 0$

      iii. Use Gauss' law to write an expression in terms of Φ_L and q for the flux through the curved portion of the surface.

      $\Phi_{total} = \frac{q}{\epsilon_0} = \Phi_L + \Phi_c \rightarrow \Phi_c = \frac{q}{\epsilon_0} - \Phi_L$

d. A second point charge $+q$ is placed to the right of the Gaussian surface as shown.



i. Is the value of Φ_L *greater than, less than,* or *equal to* the value of Φ_L in part c? Explain.

$\Phi_{L_d} > \Phi_{L_c}$

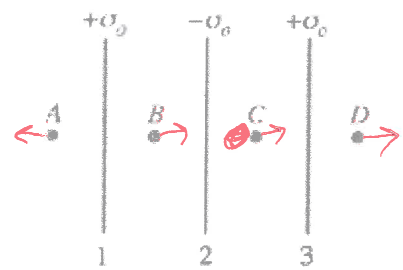
ii. Is the value of the flux through the entire Gaussian surface *greater than, less than,* or *equal to* the value of the flux through the entire Gaussian surface in part c? Explain.

$\Phi_{net_d} = \Phi_{net_c}$

2. Consider three sheets of charge with the charge densities shown. The sheets are very large and extend beyond the top and bottom of the side view diagram at right.

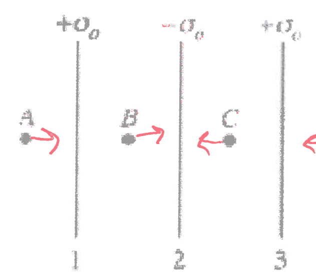
a. Sketch a vector at each of points *A–D* to represent the electric field at that point due to sheet 1. Draw your vectors to scale and state how they compare in magnitude.

same in magnitude



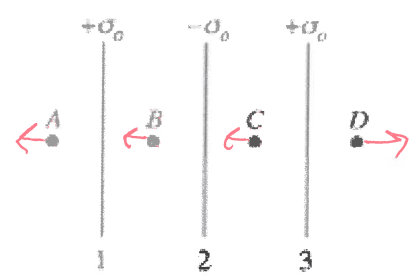
b. Sketch a vector at each of points *A–D* to represent the electric field at that point due to sheet 2. Draw your vectors to scale and state how they compare in magnitude.

Same



c. Sketch a vector at each of points *A–D* to represent the electric field at that point due to sheet 3. Draw your vectors to scale and state how they compare in magnitude.

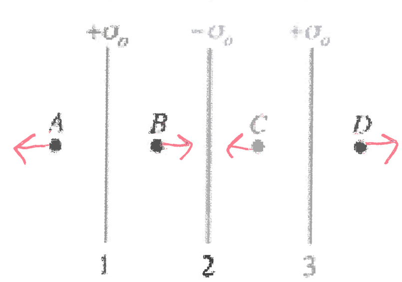
same



d. Sketch the net electric field at each of points *A–D*.

e. Calculate the magnitude of the electric field at each point *A–D*. Use superposition to answer this question.

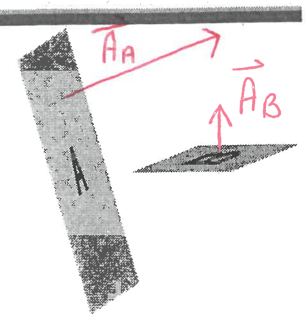
$\frac{\sigma_0}{2\epsilon_0}$



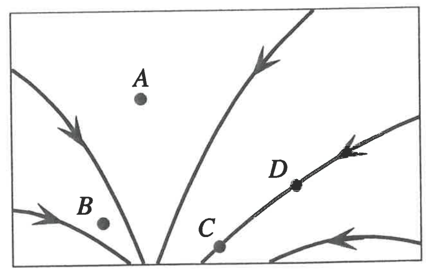
Pretest: Electric field and flux

Name ____________________

1. Shown at right are two sheets of paper. Sheet A has three times the area of sheet B. Describe how you could use a vector for each sheet to specify the orientation and area of that sheet. Draw these vectors on the diagram.

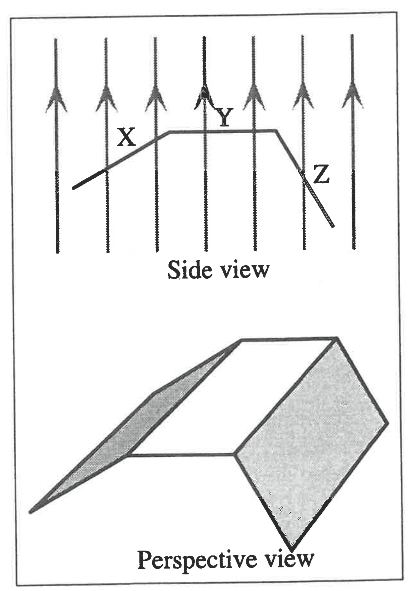


2. Electric field lines for an unknown charge distribution are shown at right. Rank the magnitude of the electric field at the four points *A*, *B*, *C*, *D*. Explain.



$|E_B| > |E_C| > |E_D| > |E_A|$

3. An imaginary surface made of three flat pieces is shown. The entire surface is placed in a uniform electric field *E* pointing toward the top of the page, as shown in the side view.



a. The areas of the three flat sides X, Y, and Z are identical. Rank the magnitude of the electric flux through sides X, Y, and Z. Explain.

$|\Phi_Y| > |\Phi_X| > |\Phi_Z|$

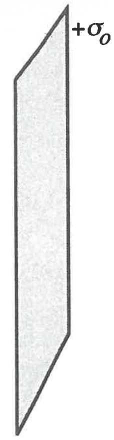
b. Is the electric flux through the entire surface *positive*, *negative*, or *zero?* Explain. If you cannot tell, explain why not.

area vectors point in the same general direction as $\vec{E}$

Pretest: Gauss' law Name ________________

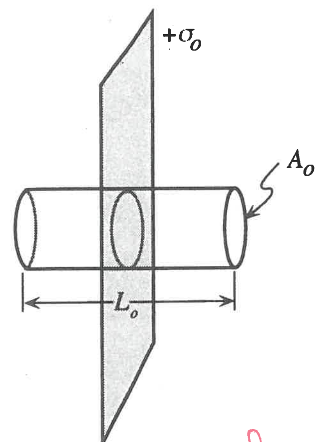
1. Shown at right is a small portion near the center of a *very large* nonconducting sheet. The sheet has a uniform positive charge per unit area $+\sigma_o$.

   If the entire sheet has a width W and a height H, how much charge is distributed over the entire sheet?



$Q_{total} = +\sigma_o A = \sigma_o W H$

2. An imaginary cylindrical surface encloses a small portion of the sheet near the center. The cylinder has a length L_o, and the area of each end cap is A_o.



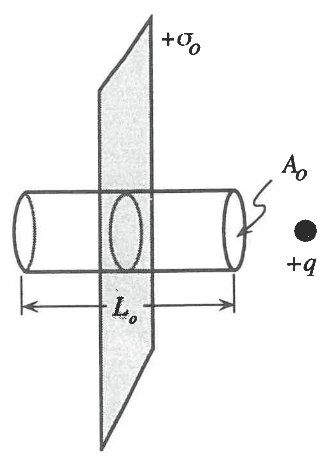
   a. What is the net charge enclosed by the cylinder? Explain.

   $Q = \sigma_o \pi R^2 = \sigma_o A_o$

   b. Is the electric flux through the curved side wall of the cylinder *positive, negative,* or *zero?* Explain.

   electric field is perpendicular to the surface normal

3. A positive point charge is now placed to the right of the imaginary cylinder, as shown.



   a. Does the electric flux through the left-hand end cap of the cylinder *increase, decrease,* or *remain the same?* Explain.

   electric field due to +q points in same direction as the surface normal

   b. Does the net electric flux through the entire imaginary cylinder *increase, decrease,* or *remain the same?* Explain.

   The charge is outside the cylinder, so no new enclosed charge → no change to ϕ