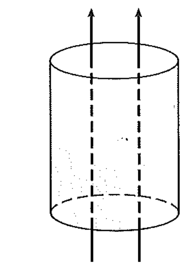
28.4 Gauss's Law

28.5 Using Gauss's Law

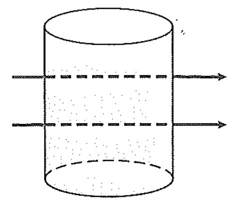
11. For each of the closed cylinders shown below, are the electric fluxes through the top, the wall, and the bottom positive (+), negative (−), or zero (0)? Is the net flux positive, negative, or zero?

a.



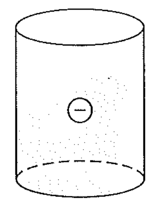
$\Phi_{top} =$ +
$\Phi_{wall} =$ 0
$\Phi_{bot} =$ −
$\Phi_{net} =$ 0

b.



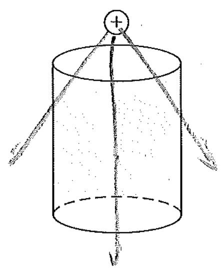
$\Phi_{top} =$ 0
$\Phi_{wall} =$ 0
$\Phi_{bot} =$ 0
$\Phi_{net} =$ 0

c.



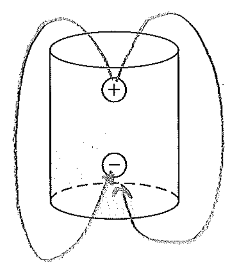
$\Phi_{top} =$ −
$\Phi_{wall} =$ −
$\Phi_{bot} =$ −
$\Phi_{net} =$ −

d.



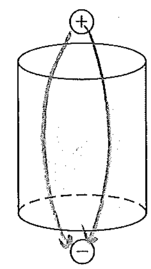
$\Phi_{top} =$ −
$\Phi_{wall} =$ +
$\Phi_{bot} =$ +
$\Phi_{net} =$ 0

e.



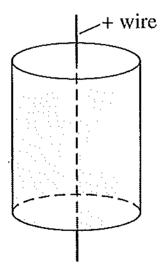
$\Phi_{top} =$ +
$\Phi_{wall} =$ 0
$\Phi_{bot} =$ −
$\Phi_{net} =$ 0

f.



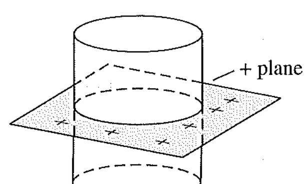
$\Phi_{top} =$ −
$\Phi_{wall} =$ 0
$\Phi_{bot} =$ +
$\Phi_{net} =$ 0

g.



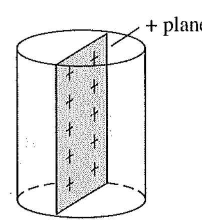
$\Phi_{top} =$ 0
$\Phi_{wall} =$ +
$\Phi_{bot} =$ 0
$\Phi_{net} =$ 0

h.



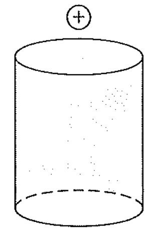
$\Phi_{top} =$ +
$\Phi_{wall} =$ 0
$\Phi_{bot} =$ +
$\Phi_{net} =$ +

i.



$\Phi_{top} =$ 0
$\Phi_{wall} =$ +
$\Phi_{bot} =$ 0
$\Phi_{net} =$ +

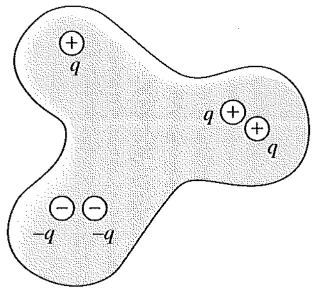
12. For this closed cylinder, $\Phi_{top} = -15\ \text{Nm}^2/\text{C}$ and $\Phi_{bot} = 5\ \text{Nm}^2/\text{C}$. What is Φ_{wall}?



10 Nm²/C

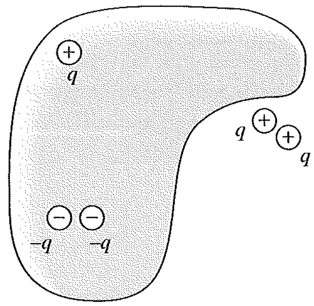
13. What is the electric flux through each of these surfaces? Give your answers as multiples of q/ε_0.

a.



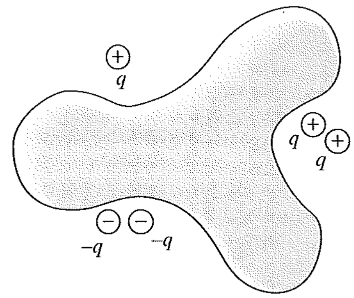
$\Phi_e =$ 1

b.



$\Phi_e =$ −1

c.



$\Phi_e =$ 0

14. What is the electric flux through each of these surfaces? Give your answers as multiples of q/ε_0.

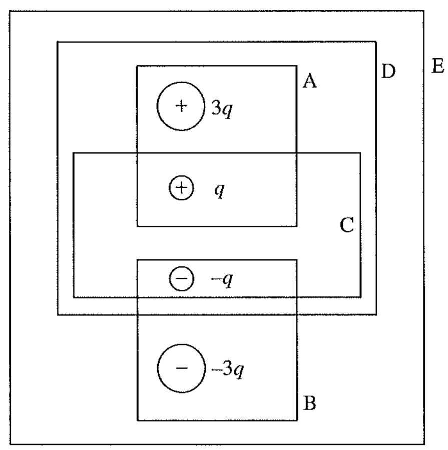
$\Phi_A =$ 4

$\Phi_B =$ −4

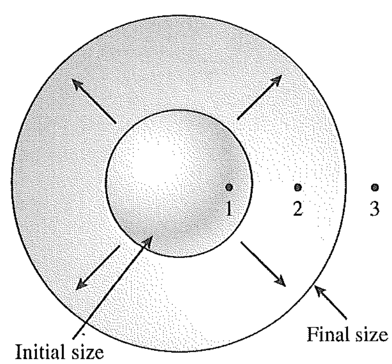
$\Phi_C =$ 0

$\Phi_D =$ 3

$\Phi_E =$ 0



15. A charged balloon expands as it is blown up, increasing in size from the initial to final diameters shown. Do the electric fields at points 1, 2, and 3 increase, decrease, or stay the same? Explain your reasoning for each.

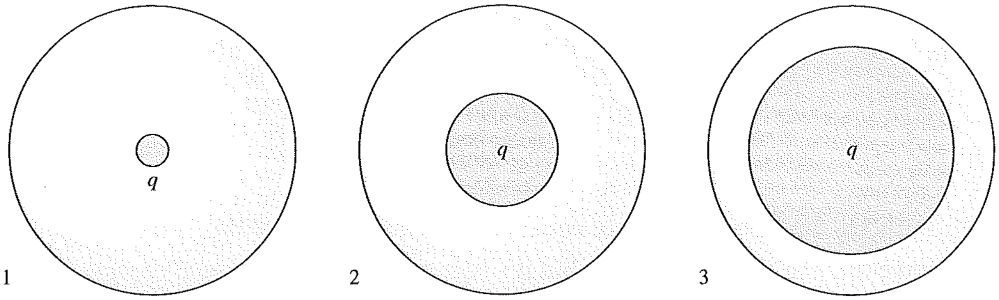


Point 1: E = 0 always by Gauss' law no change.

Point 2: E drops to zero as r > r₂.

Point 3: remains same.

16. Three charges, all the same charge q, are surrounded by three spheres of equal radii.



a. Rank in order, from largest to smallest, the fluxes Φ_1, Φ_2, and Φ_3 through the spheres.

Order: all same

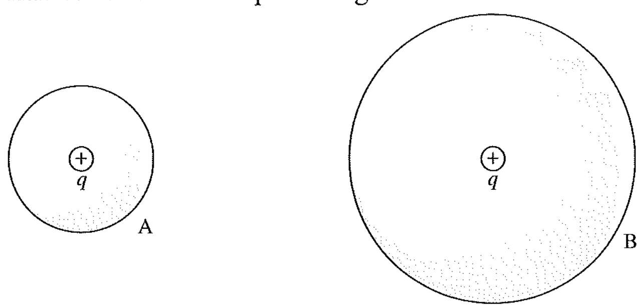
Explanation: Gauss' law

b. Rank in order, from largest to smallest, the electric field strengths E_1, E_2, and E_3 on the surfaces of the spheres.

Order: all same

Explanation:

17. Two spheres of different diameters surround equal charges. Three students are discussing the situation.



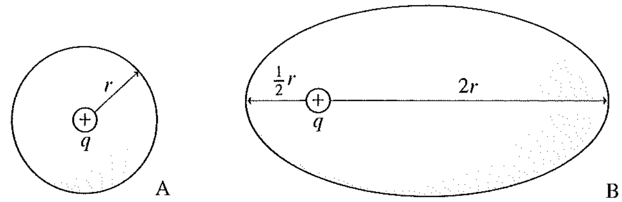
Student 1: The flux through spheres A and B are equal because they enclose equal charges.

Student 2: But the electric field on sphere B is weaker than the electric field on sphere A. The flux depends on the electric field strength, so the flux through A is larger than the flux through B.

Student 3: I thought we learned that flux was about surface area. Sphere B is larger than sphere A, so I think the flux through B is larger than the flux through A.

Which of these students, if any, do you agree with? Explain.

18. A sphere and an ellipsoid surround equal charges. Four students are discussing the situation.



Student 1: The fluxes through A and B are equal because the average radius is the same.

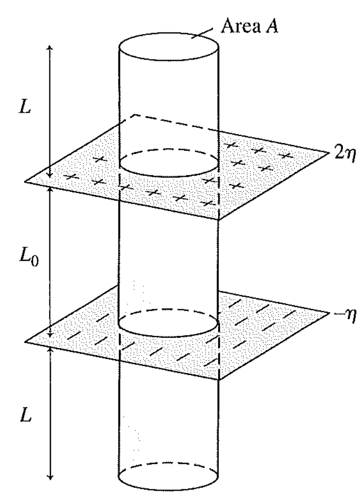
Student 2: I agree that the fluxes are equal, but it's because they enclose equal charges.

Student 3: The electric field is not perpendicular to the surface for B, and that makes the flux through B less than the flux through A.

Student 4: I don't think that Gauss's law even applies to a situation like B, so we can't compare the fluxes through A and B.

Which of these students, if any, do you agree with? Explain.

19. Two parallel, infinite planes of charge have charge densities 2η and $-\eta$. A Gaussian cylinder with cross section A extends distance L to either side.



a. Is $\vec{E}$ perpendicular or parallel to the surface at the:

Top ⊥ Bottom ⊥ Wall ||

b. Is the electric field E_{top} emerging from the top surface stronger than, weaker than, or equal in strength to the field E_{bot} emerging from the bottom? Explain.

Same.

c. By inspection, write the electric fluxes through the three surfaces in terms of E_{top}, E_{bot}, E_{wall}, L, L_0, and A. (You may not need all of these.)

Φ_{top} = $E_{top} A$ Φ_{bot} = $E_{bot} A$ Φ_{wall} = 0

d. How much charge is enclosed within the cylinder? Write Q_{in} in terms of η, L, L_0, and A.

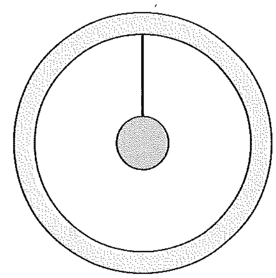
Q_{in} = η

e. By combining your answers from parts b, c, and d, use Gauss's law to determine the electric field strength above the top plane. Show your work.

$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0} = \frac{\eta A}{\epsilon_0} = E \cdot 2A \quad E = \frac{\eta}{2\epsilon_0}$

28.6 Conductors in Electrostatic Equilibrium

20. A small metal sphere hangs by a thread within a larger, hollow conducting sphere. A charged rod is used to transfer positive charge to the outer surface of the hollow sphere.



a. Suppose the thread is an insulator. After the charged rod touches the outer sphere and is removed, are the following surfaces positive, negative, or not charged?

The small sphere: 0

The inner surface of the hollow sphere: 0

The outer surface of the hollow sphere: +

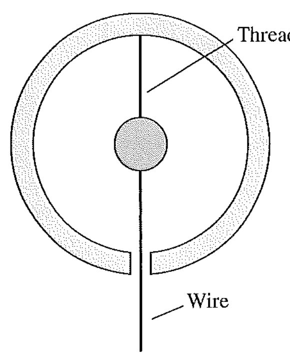
b. Suppose the thread is a conductor. After the charged rod touches the outer sphere and is removed, are the following surfaces positive, negative, or not charged?

The small sphere: 0

The inner surface of the hollow sphere: 0

The outer surface of the hollow sphere: +

21. A small metal sphere hangs by an insulating thread within a larger, hollow conducting sphere. A conducting wire extends from the small sphere through, but not touching, a small hole in the hollow sphere. A charged rod is used to transfer positive charge to the wire. After the charged rod has touched the wire and been removed, are the following surfaces positive, negative, or not charged?

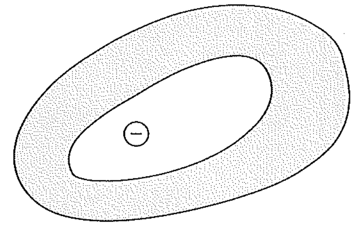


The small sphere: +

The inner surface of the hollow sphere: −

The outer surface of the hollow sphere: +

22. A −10 nC point charge is inside a hole in a conductor. The conductor has no net charge.



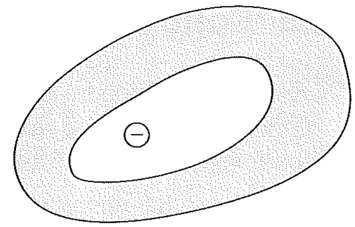
a. What is the total charge on the inside surface of the conductor?

+10 nC

b. What is the total charge on the outside surface of the conductor?

−10 nC

23. A −10 nC point charge is inside a hole in a conductor. The conductor has a net charge of +10 nC.



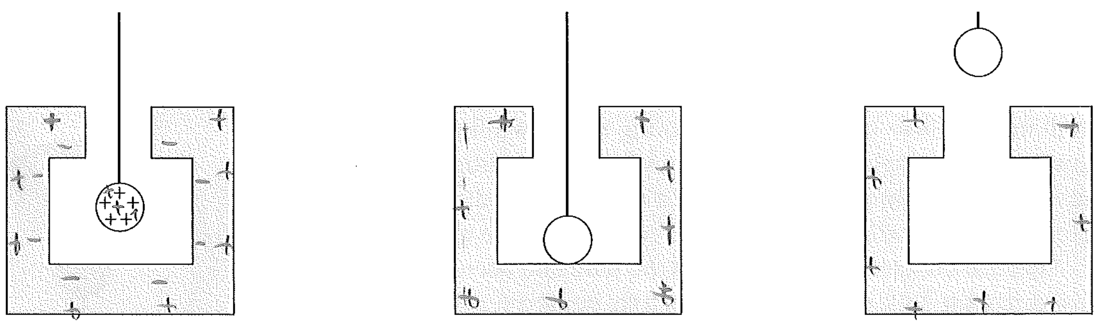
a. What is the total charge on the inside surface of the conductor?

+10 nC

b. What is the total charge on the outside surface of the conductor?

0

24. An insulating thread is used to lower a positively charged metal ball into a metal container. Initially, the container has no net charge. Use plus and minus signs to show the charge distribution on the ball at the times shown in the figure. (The ball's charge is already shown in the first frame.)

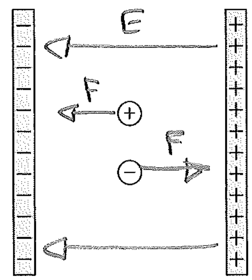


Ball hasn't touched — Ball has touched — Ball has been withdrawn

29 The Electric Potential

29.1 Electric Potential Energy

29.2 The Potential Energy of Point Charges



1. A positive point charge and a negative point charge are inside a parallel-plate capacitor. The point charges interact only with the capacitor, not with each other. Let the negative capacitor plate be the zero of potential energy for both charges.
   a. Use a **black** pen or pencil to draw the electric field vectors inside the capacitor.
   b. Use a **red** pen or pencil to draw the forces acting on the two charges.
   c. Is the potential energy of the *positive* point charge positive, negative, or zero? Explain.

   Depends on choice of U=0!

   d. In which direction (right, left, up, or down) does the potential energy of the positive charge decrease? Explain.

   To left. "Downhill"

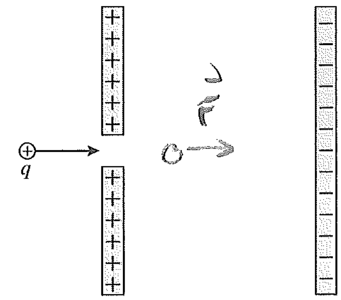
   e. In which direction will the positive charge move if released from rest? Use the concept of energy to explain your answer.

   To left.

   f. Does your answer to part e agree with the force vector you drew in part b? Yes
   g. Repeat steps c to f for the *negative* point charge.

   Right

2. A positive charge q is fired through a small hole in the positive plate of a capacitor. Does q speed up or slow down inside the capacitor? Answer this question twice:



a. First using the concept of force.

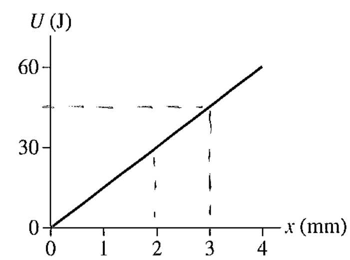
$F = ma$, to right, Speed up

b. Second using the concept of energy.

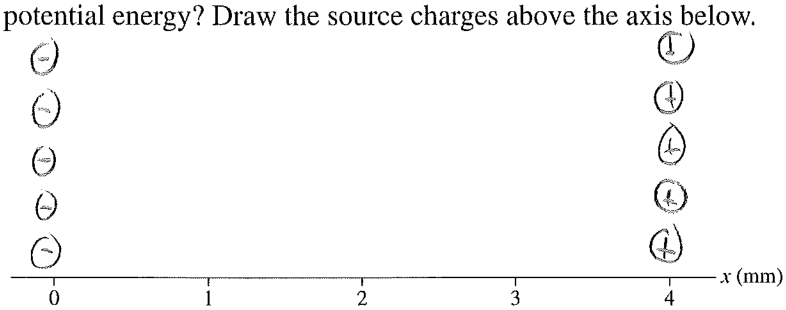
3. Charge $q_1 = 3$ nC is distance r from a positive point charge Q. Charge $q_2 = 1$ nC is distance $2r$ from Q. What is the ratio U_1/U_2 of their potential energies due to their interactions with Q?

$$\frac{U_1}{U_2} = \frac{kq_1/r_1}{kq_2/r_2} = \frac{3/r}{1/2r} = 6.$$

4. The figure shows the potential energy of a positively charged particle in a region of space.



a. What possible arrangement of source charges is responsible for this potential energy? Draw the source charges above the axis below.



b. With what kinetic energy should the charged particle be launched from $x = 0$ mm to have a turning point at $x = 3$ mm? Explain.

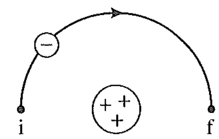
45 J.

c. How much kinetic energy does this charged particle of part b have as it passes $x = 2$ mm?

15 J = 45 J − 30 J.

$K_f = K_i - U$

5. An electron ($q = -e$) completes half of a circular orbit of radius r around a nucleus with $Q = +3e$.



a. How much work is done on the electron as it moves from i to f? Give either a numerical value or an expression from which you could calculate the value if you knew the radius. Justify your answer.

0

b. By how much does the electric potential energy change as the electron moves from i to f?

0

c. Is the electron's speed at f greater than, less than, or equal to its speed at i?

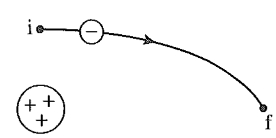
same.

d. Are your answers to parts a and c consistent with each other?

yes.

6. An electron moves along the trajectory from i to f.

a. Does the electric potential energy increase, decrease, or stay the same? Explain.

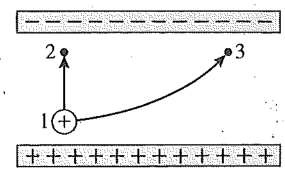


increase.

b. Is the electron's speed at f greater than, less than, or equal to its speed at i? Explain.

less

7. Inside a parallel-plate capacitor, two protons are launched with the same speed from point 1. One proton moves along the path from 1 to 2, the other from 1 to 3. Points 2 and 3 are the same distance from the positive plate.



   a. Is $\Delta U_{1\to 2}$, the change in potential energy along the path $1 \to 2$, larger than, smaller than, or equal to $\Delta U_{1\to 3}$? Explain.

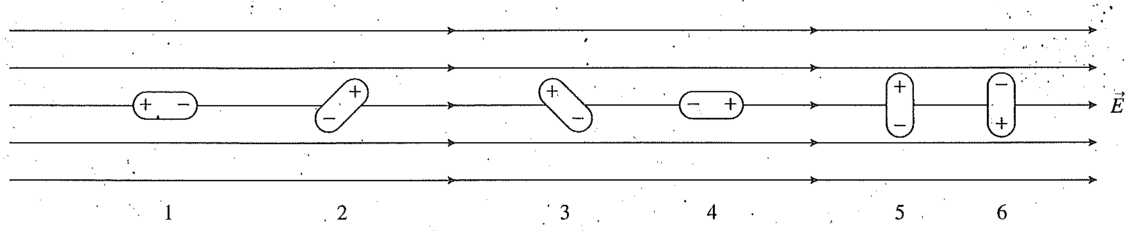
Same.

   b. Is the proton's speed v_2 at point 2 larger than, smaller than, or equal to v_3? Explain.

Same.

29.3 The Potential Energy of a Dipole

8. Rank in order, from most positive to most negative, the potential energies U_1 to U_6 of these six electric dipoles in a uniform electric field.



Order: 1 2 (5 6) 3 4

Explanation:

Highest potential energy is opposite to how dipole "wants to go."