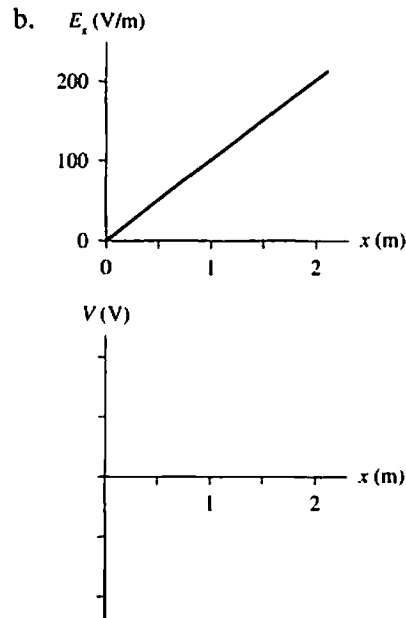
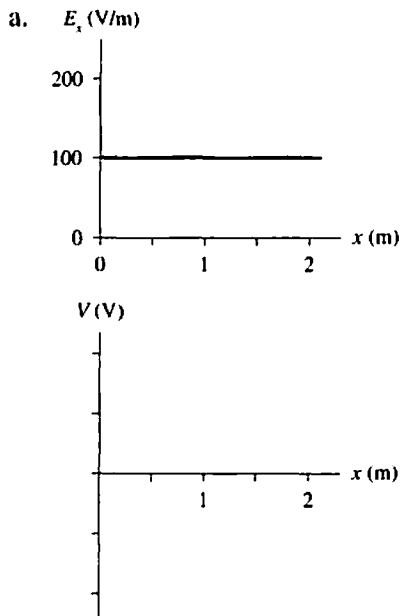


# 30 Potential and Field

## 30.1 Connecting Potential and Field

1. The top graph shows the  $x$ -component of  $\vec{E}$  as a function of  $x$ . On the axes below the graph, draw the graph of  $V$  versus  $x$  in this same region of space. Let  $V = 0$  V at  $x = 0$  m. Include an appropriate vertical scale. (Hint: Integration is the area under the curve.)



## 30.2 Sources of Electric Potential

2. What is  $\Delta V_{\text{series}}$  for each group of 1.5 V batteries?

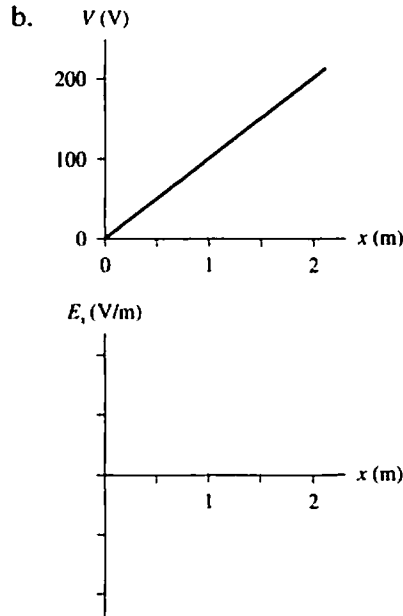
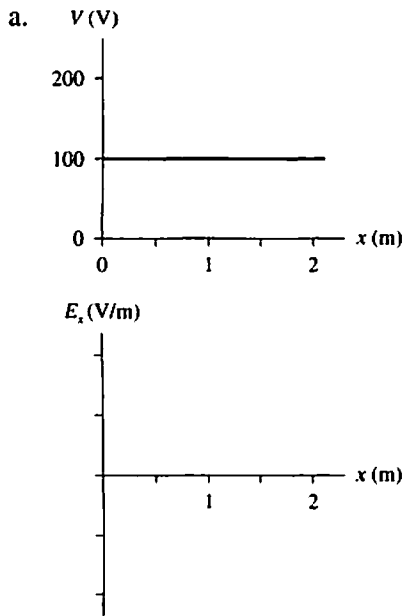
a.   $\Delta V_{\text{series}} =$  \_\_\_\_\_

b.   $\Delta V_{\text{series}} =$  \_\_\_\_\_

c.   $\Delta V_{\text{series}} =$  \_\_\_\_\_

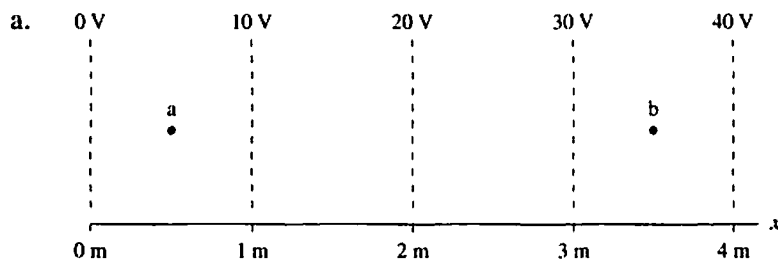
### 30.3 Finding the Electric Field from the Potential

3. The top graph shows the electric potential as a function of  $x$ . On the axes below the graph, draw the graph of  $E_x$  versus  $x$  in this same region of space. Add an appropriate scale on the vertical axis.

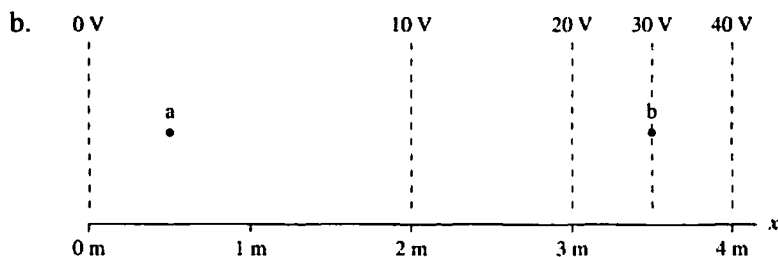


4. For each contour map:

- Estimate the electric fields  $\vec{E}_a$  and  $\vec{E}_b$  at points a and b. Don't forget that  $\vec{E}$  is a vector. Show how you made your estimate.
- On the contour map, draw the electric field vectors at points a and b.

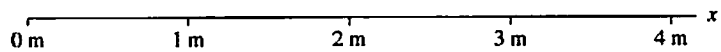
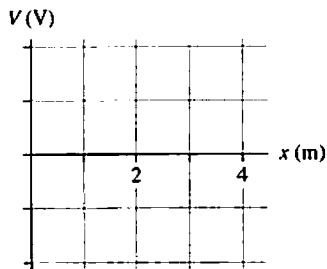
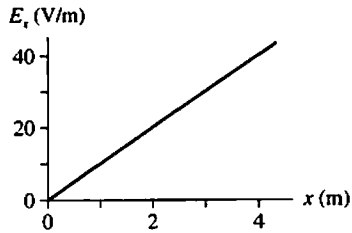


$\vec{E}_a =$  \_\_\_\_\_  
 $\vec{E}_b =$  \_\_\_\_\_

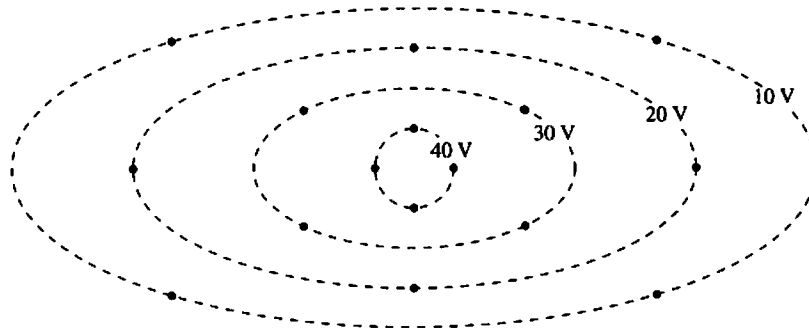


$\vec{E}_a =$  \_\_\_\_\_  
 $\vec{E}_b =$  \_\_\_\_\_

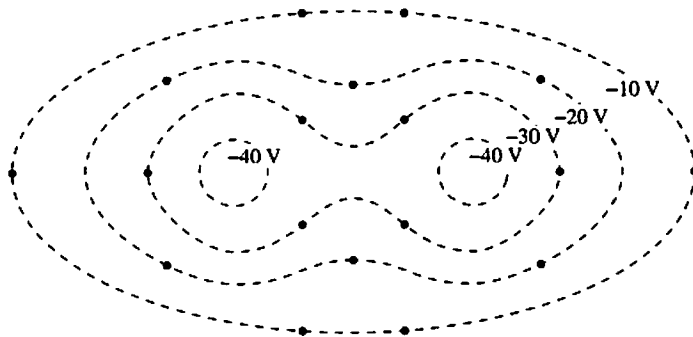
5. The top graph shows  $E_x$  versus  $x$  for an electric field that is parallel to the  $x$ -axis.
- Draw the graph of  $V$  versus  $x$  in this region of space. Let  $V = 0$  V at  $x = 0$  m. Add an appropriate scale on the vertical axis. (Hint: Integration is the area under the curve.)
  - Use dashed lines to draw a contour map above the  $x$ -axis on the right. Space your equipotential lines every 20 volts and label each equipotential line.
  - Draw electric field vectors on top of the contour map.



6. Draw the electric field vectors at the dots on this contour map. The length of each vector should be proportional to the field strength at that point.



7. Draw the electric field vectors at the dots on this contour map. The length of each vector should be proportional to the field strength at that point.

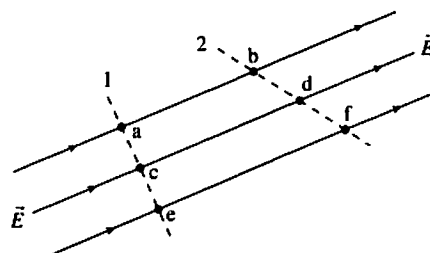


8. a. Suppose  $\vec{E} = \vec{0}$  V/m throughout some region of space. Is  $V = 0$  V in this region? Explain.

b. Suppose  $V = 0$  V throughout some region of space. Is  $\vec{E} = \vec{0}$  V/m in this region? Explain.

9. The figure shows an electric field diagram. Dashed lines 1 and 2 are two surfaces in space, not physical objects.

a. Is the electric potential at point a higher than, lower than, or equal to the electric potential at point b? Explain.



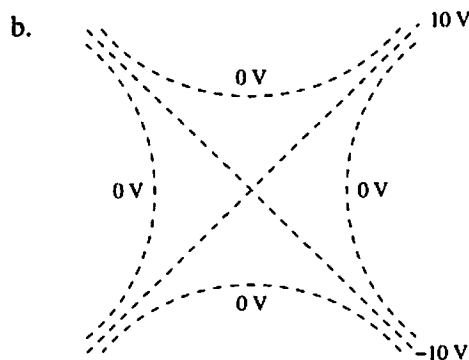
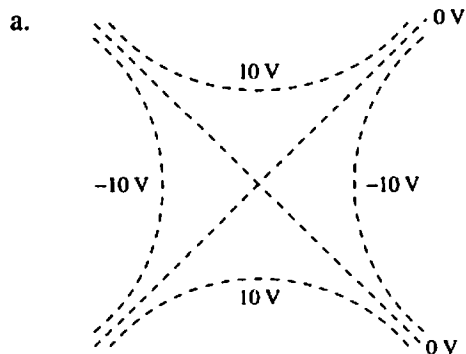
b. Rank in order, from largest to smallest, the potential differences  $\Delta V_{ab}$ ,  $\Delta V_{cd}$ , and  $\Delta V_{ef}$ .

Order:

Explanation:

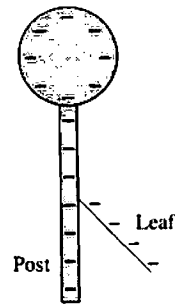
c. Is surface 1 an equipotential surface? What about surface 2? Explain why or why not.

10. For each of the figures below, is this a physically possible potential map if there are no free charges in this region of space? If so, draw an electric field line diagram on top of the potential map. If not, why not?

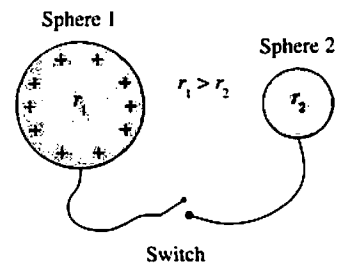


### 30.4 A Conductor in Electrostatic Equilibrium

11. The figure shows a negatively charged electroscope. The gold leaf stands away from the rigid metal post. Is the electric potential of the leaf higher than, lower than, or equal to the potential of the post? Explain.



12. Two metal spheres are connected by a metal wire that has a switch in the middle. Initially the switch is open. Sphere 1, with the larger radius, is given a positive charge. Sphere 2, with the smaller radius, is neutral. Then the switch is closed. Afterward, sphere 1 has charge  $Q_1$ , is at potential  $V_1$ , and the electric field strength at its surface is  $E_1$ . The values for sphere 2 are  $Q_2$ ,  $V_2$ , and  $E_2$ .

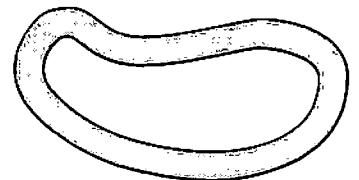


- a. Is  $V_1$  larger than, smaller than, or equal to  $V_2$ ? Explain.

- b. Is  $Q_1$  larger than, smaller than, or equal to  $Q_2$ ? Explain.

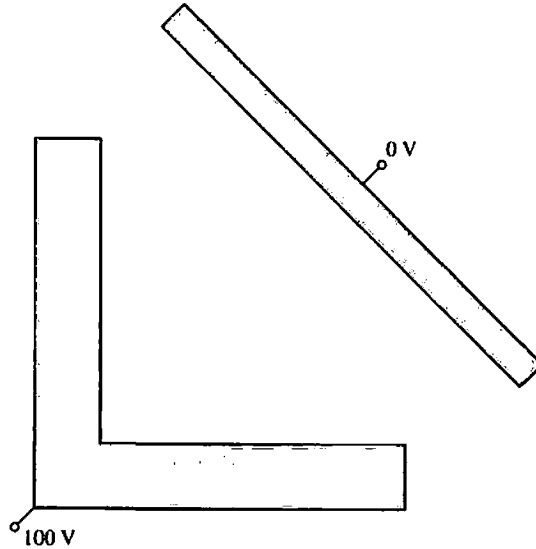
- c. Is  $E_1$  larger than, smaller than, or equal to  $E_2$ ? Explain.

13. The figure shows a hollow metal shell. A negatively charged rod touches the top of the sphere, transferring charge to the shell. Then the rod is removed.



- a. Show on the figure the equilibrium distribution of charge.  
b. Draw the electric field diagram.

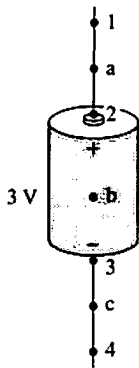
14. The figure shows two flat metal electrodes that are held at potentials of 100 V and 0 V.
- Used dashed lines to sketch a reasonable approximation of the 20 V, 40 V, 60 V, and 80 V equipotential lines.
  - Draw enough electric field lines to indicate the shape of the electric field. Use solid lines with arrowheads.



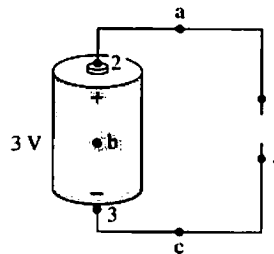
15. The figure shows two 3 V batteries with metal wires attached to each end. Points a and c are *inside* the wire. Point b is inside the battery. For each figure:

- What are the potential differences  $\Delta V_{12}$ ,  $\Delta V_{23}$ ,  $\Delta V_{34}$ , and  $\Delta V_{14}$ ?
- Does the electric field at a, b, and c point left, right, up, or down? Or is  $\vec{E} = \vec{0}$ ?

a.



b.



$\Delta V_{12} = \text{_____}$      $\Delta V_{23} = \text{_____}$

$\Delta V_{34} = \text{_____}$      $\Delta V_{14} = \text{_____}$

$\vec{E}_a \text{ _____}$      $\vec{E}_b \text{ _____}$      $\vec{E}_c \text{ _____}$

$\Delta V_{12} = \text{_____}$      $\Delta V_{23} = \text{_____}$

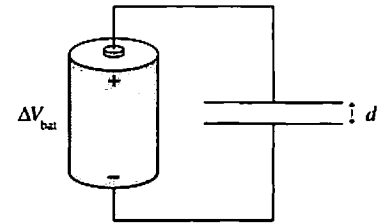
$\Delta V_{34} = \text{_____}$      $\Delta V_{14} = \text{_____}$

$\vec{E}_a \text{ _____}$      $\vec{E}_b \text{ _____}$      $\vec{E}_c \text{ _____}$

### 30.5 Capacitance and Capacitors

### 30.6 The Energy Stored in a Capacitor

16. A parallel-plate capacitor with plate separation  $d$  is connected to a battery that has potential difference  $\Delta V_{\text{bat}}$ . Without breaking any of the connections, insulating handles are used to increase the plate separation to  $2d$ .



a. Does the potential difference  $\Delta V_C$  change as the separation increases? If so, by what factor? If not, why not?

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b. Does the capacitance change? If so, by what factor? If not, why not?

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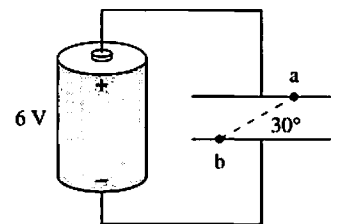
c. Does the capacitor charge  $Q$  change? If so, by what factor? If not, why not?

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17. For the capacitor shown, the potential difference  $\Delta V_{ab}$  between points a and b is

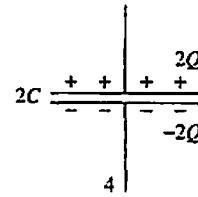
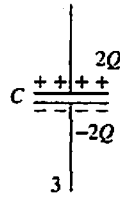
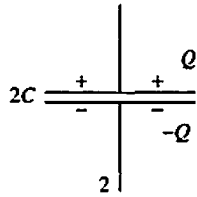
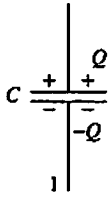
- |                              |                              |                        |
|------------------------------|------------------------------|------------------------|
| a. 6 V                       | b. $6 \cdot \sin 30^\circ$ V | c. $6/\sin 30^\circ$ V |
| d. $6 \cdot \tan 30^\circ$ V | e. $6 \cdot \cos 30^\circ$ V | f. $6/\cos 30^\circ$ V |

Explain your choice.




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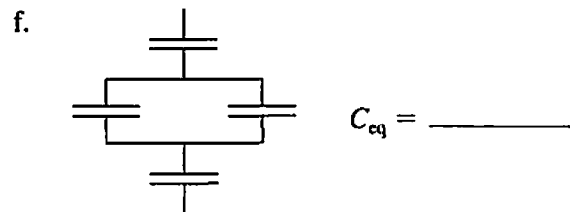
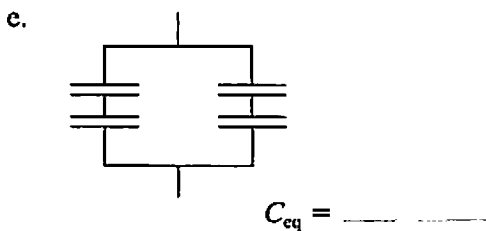
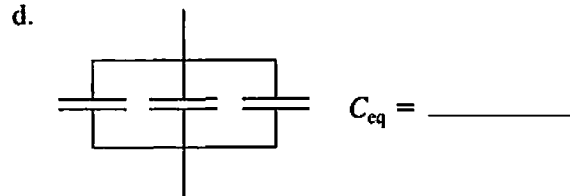
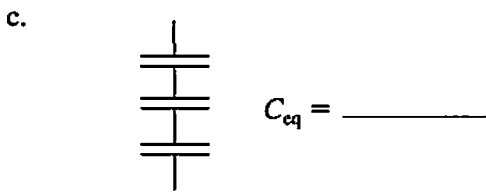
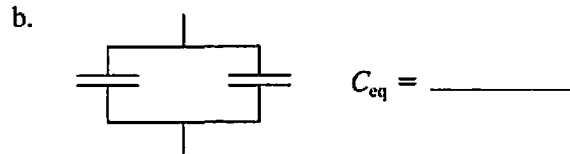
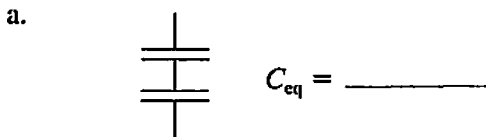
18. Rank in order, from largest to smallest, the potential differences  $(\Delta V_C)_1$  to  $(\Delta V_C)_4$  of these four capacitors.



Order:

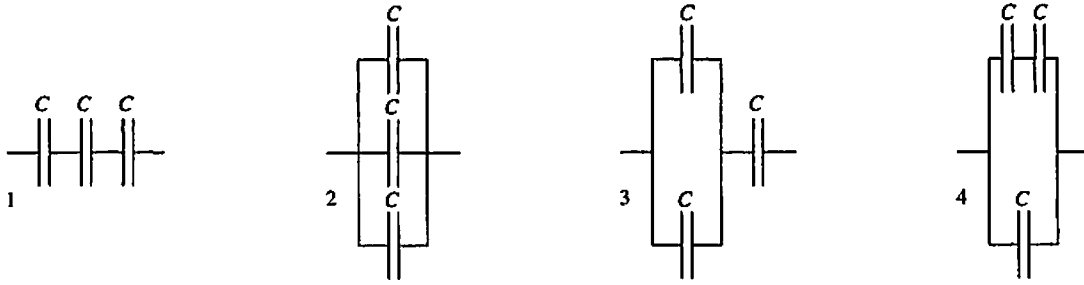
Explanation:

19. Each capacitor in the circuits below has capacitance  $C$ . What is the equivalent capacitance of the group of capacitors?





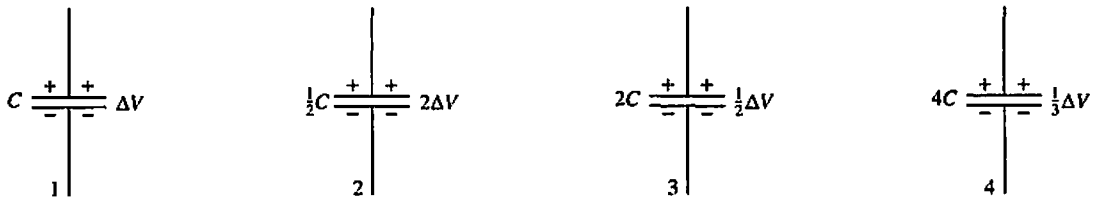
20. Rank in order, from largest to smallest, the equivalent capacitances  $(C_{eq})_1$  to  $(C_{eq})_4$  of these four groups of capacitors.



Order:

Explanation:

21. Rank in order, from largest to smallest, the energies  $(U_C)_1$  to  $(U_C)_4$  stored in each of these capacitors.



Order:

Explanation:

### 30.7 Dielectrics

22. An air-insulated capacitor is charged until the electric field strength inside is 10,000 V/m, then disconnected from the battery. When a dielectric is inserted between the capacitor plates, the electric field strength is reduced to 2000 V/m.

a. Does the amount of charge on the capacitor plates increase, decrease, or stay the same when the dielectric is inserted? If it increases or decreases, by what factor?

b. Does the potential difference between the capacitor plates increase, decrease, or stay the same when the dielectric is inserted? If it increases or decreases, by what factor?

23. The plates of an air-insulated capacitor are charged to  $\pm 100$  nC, then left connected to the battery. When a dielectric is inserted between the plates, the charge on the plates increases to  $\pm 500$  nC.

a. Does the potential difference across the capacitor increase, decrease, or stay the same when the dielectric is inserted? If it increases, by what factor?

b. Does the electric field strength inside the capacitor increase, decrease, or stay the same when the dielectric is inserted? If it increases, by what factor?

24. The gap between two capacitor plates is *partially* filled with a dielectric. Rank in order, from largest to smallest, the electric field strengths  $E_1$ ,  $E_2$ , and  $E_3$  at points 1, 2, and 3.

Order:

Explanation:

