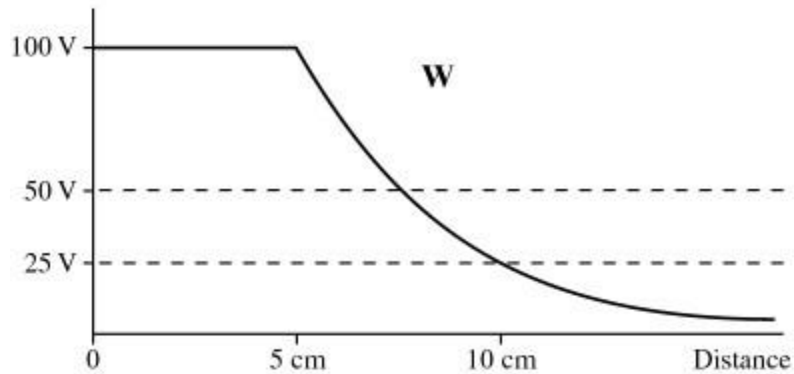
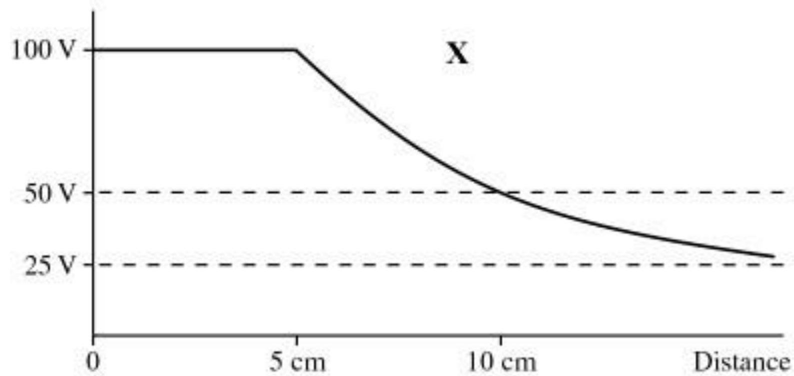
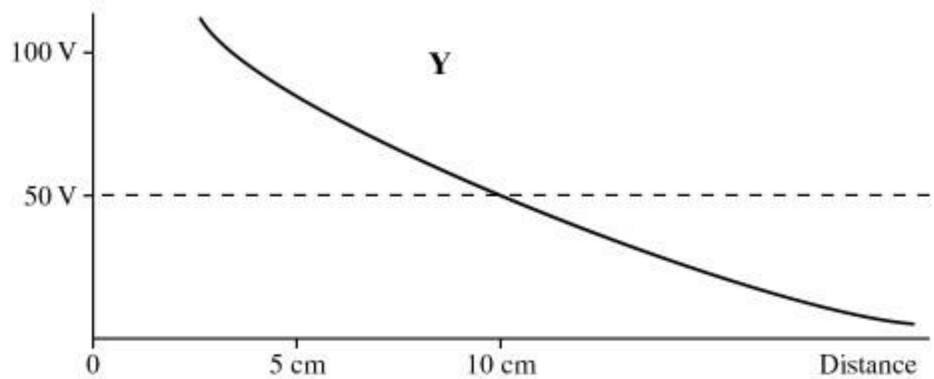
***Physics for Scientists and Engineers, 4e* (Knight)**
Chapter 26   Potential and Field

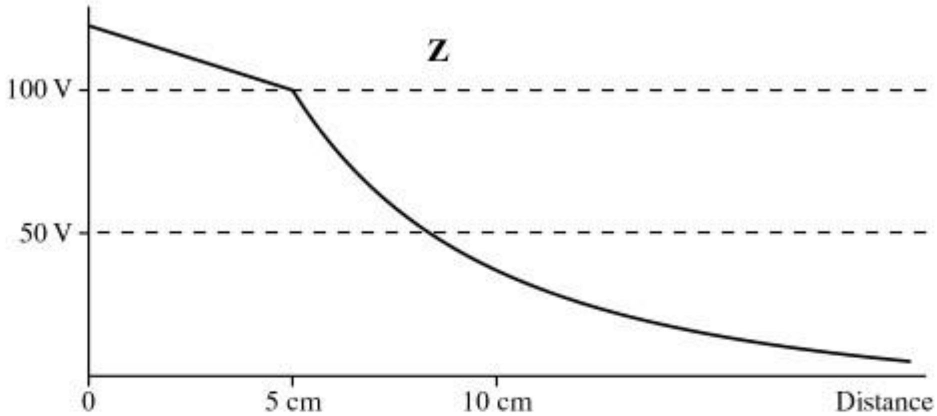
26.1   Conceptual Questions

1) A metallic sphere of radius 5 cm is charged such that the potential of its surface is 100 V (relative to infinity). Which of the following plots correctly shows the potential as a function of distance from the center of the sphere?





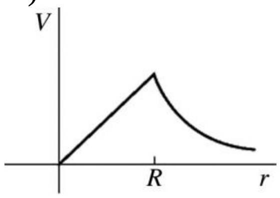




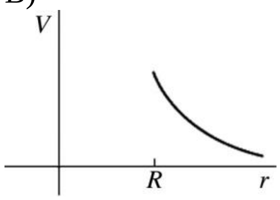
A) plot W
B) plot X
C) plot Y
D) plot Z
Answer: B
Var: 1

2) A conducting sphere of radius *R* carries an excess positive charge and is very far from any other charges. Which one of the following graphs best illustrates the potential (relative to infinity) produced by this sphere as a function of the distance *r* from the center of the sphere?

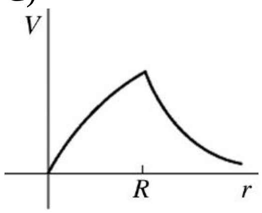
A)



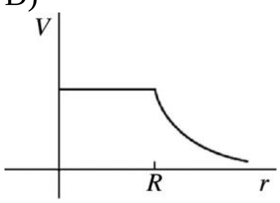
B)



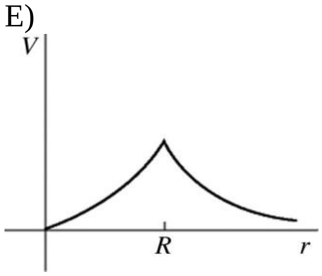
C)



D)



E)

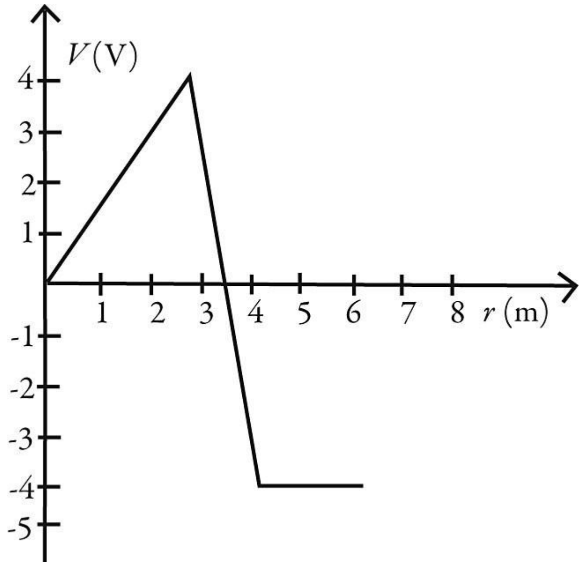


Answer: D
Var: 1

3) A nonconducting sphere contains positive charge distributed uniformly throughout its volume. Which statements about the potential due to this sphere are true? All potentials are measured relative to infinity. (There may be more than one correct choice.)
A) The potential is highest at the center of the sphere.
B) The potential at the center of the sphere is zero.
C) The potential at the center of the sphere is the same as the potential at the surface.
D) The potential at the surface is higher than the potential at the center.
E) The potential at the center is the same as the potential at infinity.
Answer: A
Var: 1

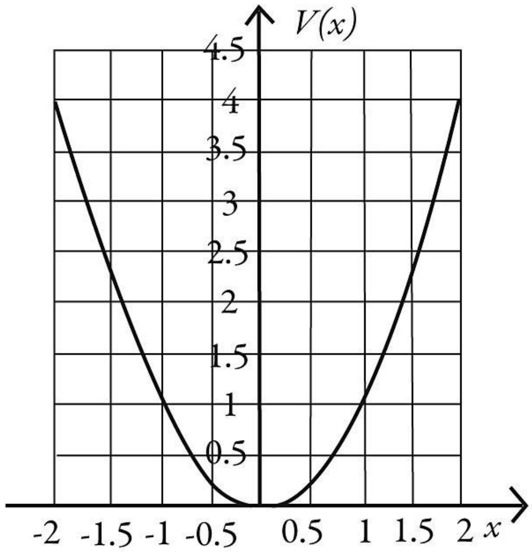
4) A conducting sphere contains positive charge distributed uniformly over its surface. Which statements about the potential due to this sphere are true? All potentials are measured relative to infinity. (There may be more than one correct choice.)
A) The potential is lowest, but not zero, at the center of the sphere.
B) The potential at the center of the sphere is zero.
C) The potential at the center of the sphere is the same as the potential at the surface.
D) The potential at the surface is higher than the potential at the center.
E) The potential at the center is the same as the potential at infinity.
Answer: C
Var: 1

5) The graph in the figure shows the variation of the electric potential V (measured in volts) as a function of the radial direction r (measured in meters). For which range or value of r is the magnitude of the electric field the largest?



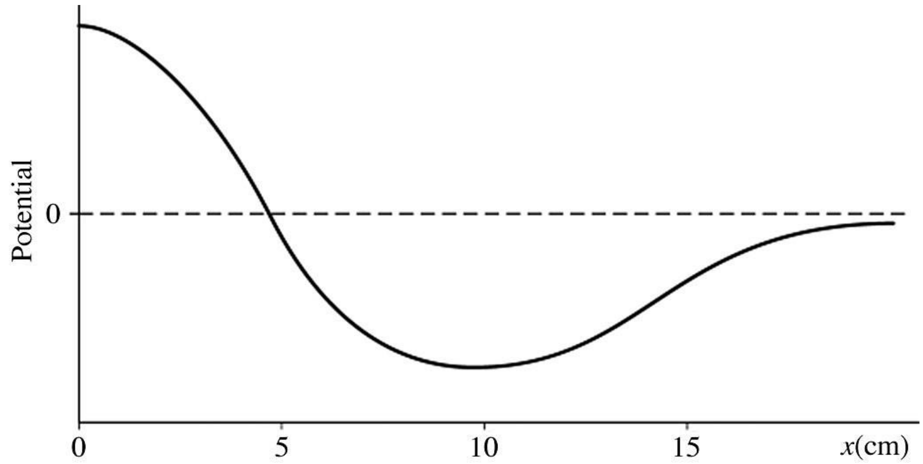
A) from r = 0 m to r = 3 m
B) from r = 3 m to r = 4 m
C) from r = 4 m to r = 6 m
D) at r = 3 m
E) at r = 4 m
Answer: B
Var: 1

6) The graph in the figure shows the variation of the electric potential $V(x)$ (in arbitrary units) as a function of the position x (also in arbitrary units). Which of the choices below correctly describes the orientation of the x-component of the electric field along the x-axis?



A) E_x is positive from x = -2 to x = 2.
B) E_x is positive from x = -2 to x = 0, and negative from x = 0 to x = 2.
C) E_x is negative from x = -2 to x = 0, and positive from x = 0 to x = 2.
D) E_x is negative from x = -2 to x = 2.
Answer: B
Var: 1

7) The potential as a function of position x is shown in the graph in the figure. Which statement about the electric field is true?



A) The electric field is zero at $x = 0$, its magnitude is at a maximum at $x = 5$ cm, and the field is directed to the right there.
B) The electric field is zero at $x = 5$ cm, its magnitude is at a maximum at $x = 0$, and the field is directed to the right there.
C) The electric field is zero at $x = 0$, its magnitude is at a maximum at $x = 15$ cm, and the field is directed to the left there.
D) The electric field is zero at $x = 10$ cm, its magnitude is at a maximum at $x = 5$ cm, and the field is directed to the left there.
Answer: A
Var: 1

8) The charge on the square plates of a parallel-plate capacitor is Q. The potential across the plates is maintained with constant voltage by a battery as they are pulled apart to twice their original separation, which is small compared to the dimensions of the plates. The amount of charge on the plates is now equal to
A) $4Q$.
B) $2Q$.
C) Q.
D) $Q/2$.
E) $Q/4$.
Answer: D
Var: 1

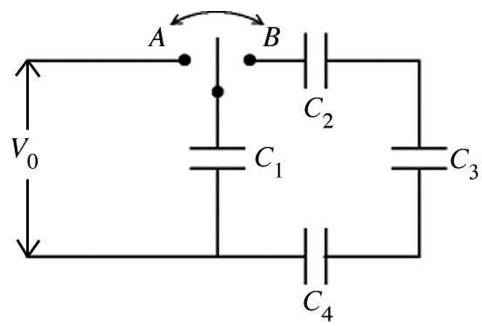
9) The electric field between square the plates of a parallel-plate capacitor has magnitude E. The potential across the plates is maintained with constant voltage by a battery as they are pulled apart to twice their original separation, which is small compared to the dimensions of the plates. The magnitude of the electric field between the plates is now equal to
A) $4E$.
B) $2E$.
C) E.
D) $E/2$.
E) $E/4$.
Answer: D
Var: 1

10) Equal but opposite charges Q are placed on the square plates of an air-filled parallel-plate capacitor. The plates are then pulled apart to twice their original separation, which is small compared to the dimensions of the plates. Which of the following statements about this capacitor are true? (There may be more than one correct choice.)
A) The energy stored in the capacitor has doubled.
B) The energy density in the capacitor has increased.
C) The electric field between the plates has increased.
D) The potential difference across the plates has doubled.
E) The capacitance has doubled.
Answer: A, D
Var: 1

11) When two or more capacitors are connected in series across a potential difference,
A) the potential difference across the combination is the algebraic sum of the potential differences across the individual capacitors.
B) each capacitor carries the same amount of charge.
C) the equivalent capacitance of the combination is less than the capacitance of any of the capacitors.
D) All of the above choices are correct.
E) None of the above choices are correct.
Answer: D
Var: 1

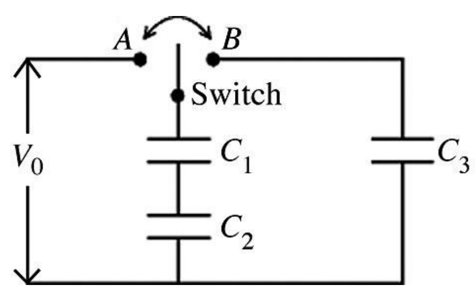
12) When two or more capacitors are connected in parallel across a potential difference,
A) the potential difference across each capacitor is the same.
B) each capacitor carries the same amount of charge.
C) the equivalent capacitance of the combination is less than the capacitance of any of the capacitors.
D) All of the above choices are correct.
E) None of the above choices are correct.
Answer: A
Var: 1

13) The four identical capacitors in the circuit shown in the figure are initially uncharged. Let the charges on the capacitors be Q_1, Q_2, Q_3, and Q_4 and the potential differences across them be V_1, V_2, V_3, and V_4. The switch is thrown first to position *A* and kept there for a long time. It is then thrown to position *B*. Which of the following conditions is true with the switch in position *B*?



A) $V_1 = V_2 = V_3 = V_4$
B) $V_1 = V_0$
C) $V_1 + V_2 + V_3 + V_4 = V_0$
D) $Q_1 = 3\ Q_2$
E) $Q_1 = Q_2$
Answer: D
Var: 1

14) In the circuit shown in the figure, the capacitors are initially uncharged. The switch is first thrown to position *A* and kept there for a long time. It is then thrown to position *B*. Let the charges on the capacitors be Q_1, Q_2, and Q_3 and the potential differences across them be V_1, V_2, and V_3. Which of the following conditions must be true with the switch in position *B*?



A) $V_1 = V_2 = V_3$
B) $V_1 + V_2 = V_3$
C) $V_3 = V_0$
D) $Q_1 = Q_2 = Q_3$
E) $Q_1 + Q_2 = Q_3$
Answer: B
Var: 1

15) An ideal parallel-plate capacitor consists of a set of two parallel plates of area *A* separated by a very small distance *d*. When this capacitor is connected to a battery that maintains a constant potential difference between the plates, the energy stored in the capacitor is U_0. If the separation between the plates is doubled, how much energy is stored in the capacitor?
A) $4U_0$
B) $2U_0$
C) U_0
D) $U_0/2$
E) $U_0/4$
Answer: D
Var: 1

16) An ideal parallel-plate capacitor consists of a set of two parallel plates of area *A* separated by a very small distance *d*. When the capacitor plates carry charges +*Q* and -*Q*, the capacitor stores energy U_0. If the separation between the plates is doubled, how much electrical energy is stored in the capacitor?
A) $4U_0$
B) $2U_0$
C) U_0
D) $U_0/2$
E) $U_0/4$
Answer: B
Var: 1

17) An ideal air-filled parallel-plate capacitor has round plates and carries a fixed amount of equal but opposite charge on its plates. All the geometric parameters of the capacitor (plate diameter and plate separation) are now DOUBLED. If the original capacitance was C_0, what is the new capacitance?
A) $4C_0$
B) $2C_0$
C) C_0
D) $C_0/2$
E) $C_0/4$
Answer: B
Var: 1

18) An ideal air-filled parallel-plate capacitor has round plates and carries a fixed amount of equal but opposite charge on its plates. All the geometric parameters of the capacitor (plate diameter and plate separation) are now DOUBLED. If the original energy stored in the capacitor was U_0, how much energy does it now store?

A) $4U_0$

B) $2U_0$

C) U_0

D) $U_0/2$

E) $U_0/4$

Answer: D
Var: 1

19) An ideal air-filled parallel-plate capacitor has round plates and carries a fixed amount of equal but opposite charge on its plates. All the geometric parameters of the capacitor (plate diameter and plate separation) are now DOUBLED. If the original energy density between the plates was u_0, what is the new energy density?

A) $16u_0$

B) $4u_0$

C) u_0

D) $u_0/4$

E) $u_0/16$

Answer: E
Var: 1

20) A charged capacitor stores energy U. Without connecting this capacitor to anything, dielectric having dielectric constant K is now inserted between the plates of the capacitor, completely filling the space between them. How much energy does the capacitor now store?

A) $2KU$

B) KU

C) U

D) $\frac{U}{K}$

E) $\frac{U}{2K}$

Answer: D
Var: 1

21) Two capacitors, C_1 and C_2, are connected in series across a source of potential difference. With the potential source still connected, a dielectric is now inserted between the plates of capacitor C_1. What happens to the charge on capacitor C_2?
A) The charge on C_2 increases.
B) The charge on C_2 decreases.
C) The charge on C_2 remains the same.
Answer: A
Var: 1

22) An air-filled parallel-plate capacitor is connected to a battery and allowed to charge up. Now a slab of dielectric material is placed between the plates of the capacitor while the capacitor is still connected to the battery. After this is done, we find that
A) the energy stored in the capacitor had decreased.
B) the voltage across the capacitor had increased.
C) the charge on the capacitor had increased.
D) the charge on the capacitor had not changed.
E) None of these choices is true.
Answer: C
Var: 1

26.2 Problems

1) If the electric potential in a region is given by $V(x) = 6/x^2$, the x component of the electric field in that region is
A) $-12x^{-3}$.
B) $-6x$.
C) $12x^{-3}$.
D) $12x$.
E) $6x$.
Answer: C
Var: 1

2) If the potential in a region is given by $V(x,y,z) = xy - 3z^{-2}$, then the y component of the electric field in that region is
A) $x + y - 6z^{-3}$.
B) $-y$.
C) $-x$.
D) $x + y$.
Answer: C
Var: 1

3) In a certain region, the electric potential due to a charge distribution is given by the equation $V(x,y,z) = 3x^2y^2 + yz^3 - 2z^3x$, where x, y, and z are measured in meters and V is in volts. Calculate the magnitude of the electric field vector at the position $(x,y,z) = (1.0, 1.0, 1.0)$.
A) 4.3 V/m
B) 2.0 V/m
C) -8.1 V/m
D) 8.6 V/m
E) 74 V/m
Answer: D
Var: 1

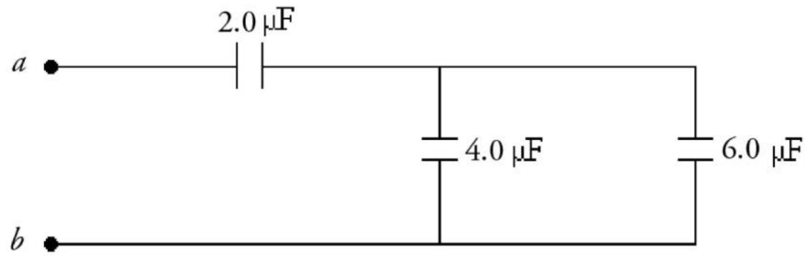
4) In a certain region, the electric potential due to a charge distribution is given by the equation $V(x,y) = 2xy - x^2 - y$, where x and y are measured in meters and V is in volts. At which point is the electric field equal to zero?
A) $x = 0.5$ m, $y = 1$ m
B) $x = 1$ m, $y = 1$ m
C) $x = 1$ m, $y = 0.5$ m
D) $x = 0.5$ m, $y = 0.5$ m
E) $x = 0$ m, $y = 0$ m
Answer: D
Var: 1

5) A parallel-plate capacitor has plates of area 0.40 m^2 and plate separation of 0.20 mm. The capacitor is connected across a 9.0-V potential source. ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)
(a) What is the magnitude of the electric field between the plates?
(b) What is the capacitance of the capacitor?
(c) What is the magnitude of the charge on each plate of the capacitor?
Answer: (a) 4.5×10^4 N/C (b) 18 nF (c) 160 nC
Var: 1

6) Each plate of a parallel-plate air-filled capacitor has an area of 0.0020 m^2, and the separation of the plates is 0.020 mm. An electric field of 3.9×10^6 V/m is present between the plates. What is the surface charge density on the plates? ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)
A) 35 $\mu C/m^2$
B) 73 $\mu C/m^2$
C) 17 $\mu C/m^2$
D) 52 $\mu C/m^2$
E) 87 $\mu C/m^2$
Answer: A
Var: 50+

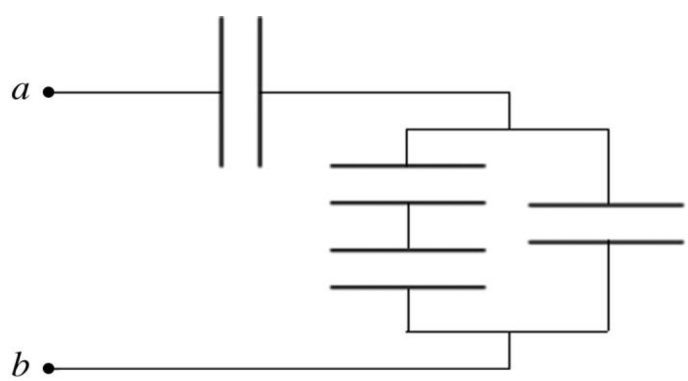
7) Two thin-walled concentric conducting spheres of radii 5.0 cm and 10 cm have a potential difference of 100 V between them. ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9$ N · m^2/C^2)
(a) What is the capacitance of this combination?
(b) What is the charge carried by each sphere?
Answer: (a) 11 pF (b) 1.1 nC
Var: 1

8) Three capacitors are connected as shown in the figure. What is the equivalent capacitance between points *a* and *b*?



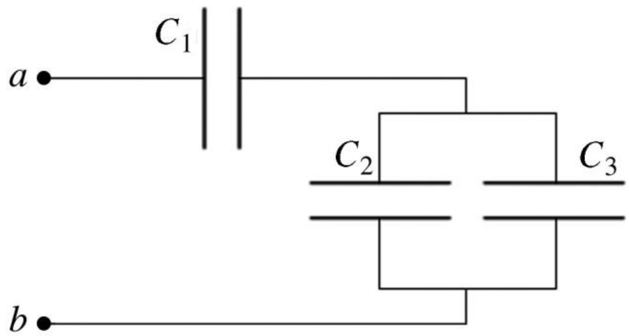
A) 1.7 μF
B) 4.0 μF
C) 7.1 μF
D) 12 μF
E) 8.0 μF
Answer: A
Var: 1

9) The capacitors in the network shown in the figure all have a capacitance of 5.0 μF. What is the equivalent capacitance, C_{ab}, of this capacitor network?



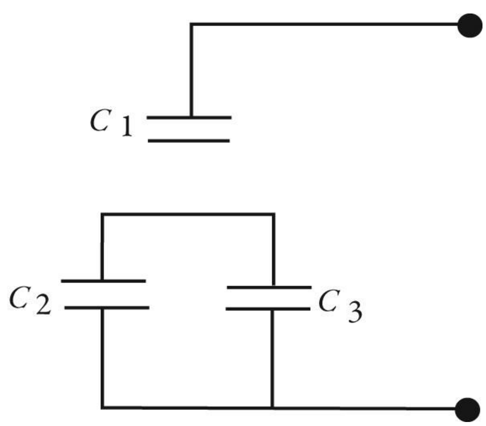
A) 20 μF
B) 3.0 μF
C) 10 μF
D) 5.0 μF
E) 1.0 μF
Answer: B
Var: 1

10) Three capacitors, with capacitances C_1 = 4.0 μF, C_2 = 3.0 μF, and C_3 = 2.0 μF, are connected to a 12 -V voltage source, as shown in the figure. What is the charge on capacitor C_2?



A) 16 μC
B) 32 μC
C) 2.0 μC
D) 8.0 μC
E) 4.0 μC
Answer: A
Var: 5

11) Three capacitors are arranged as shown in the figure. C_1 has a capacitance of 5.0 pF, C_2 has a capacitance of 10.0 pF, and C_3 has a capacitance of 15.0 pF. Find the voltage drop across the entire arrangement if the voltage drop across C_2 is 311 V.

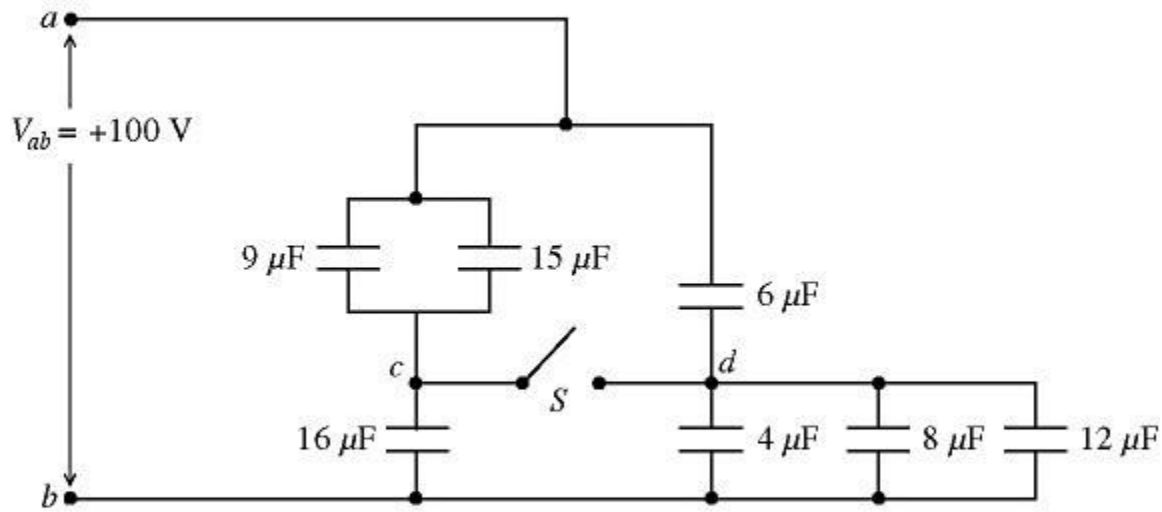


A) 1900 V
B) 1200 V
C) 570 V
D) 520 V
Answer: A
Var: 1

12) The capacitive network shown in the figure is assembled with initially uncharged capacitors. A potential difference, V_{ab} = +100V, is applied across the network. The switch S in the network is initially open but is then closed. Assume that all the capacitances shown are accurate to two significant figures. What is the equivalent capacitance between ab

(a) with the switch S open?

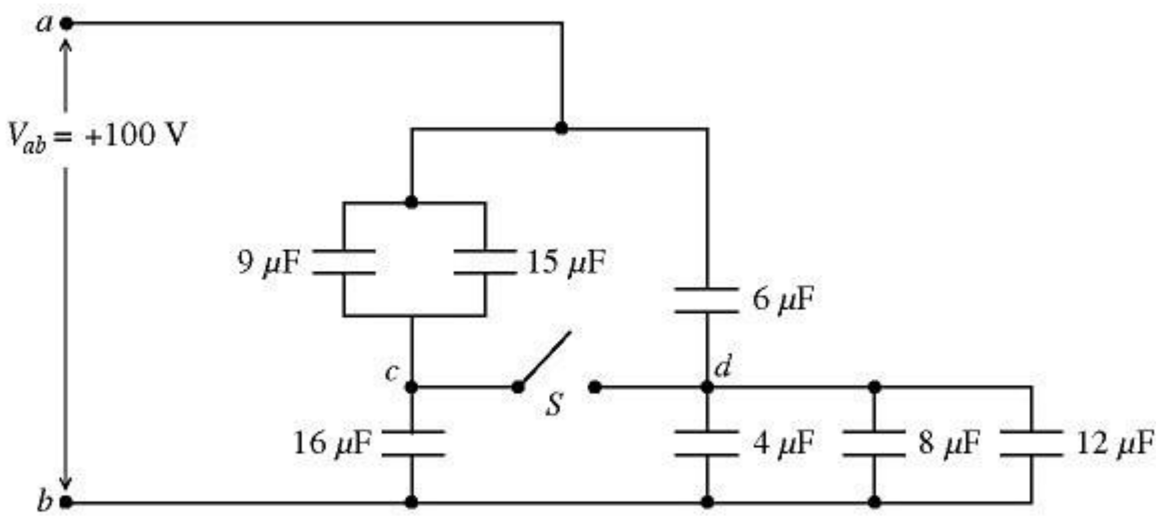
(b) with the switch S closed?



Answer: (a) 14 μF (b) 17 μF

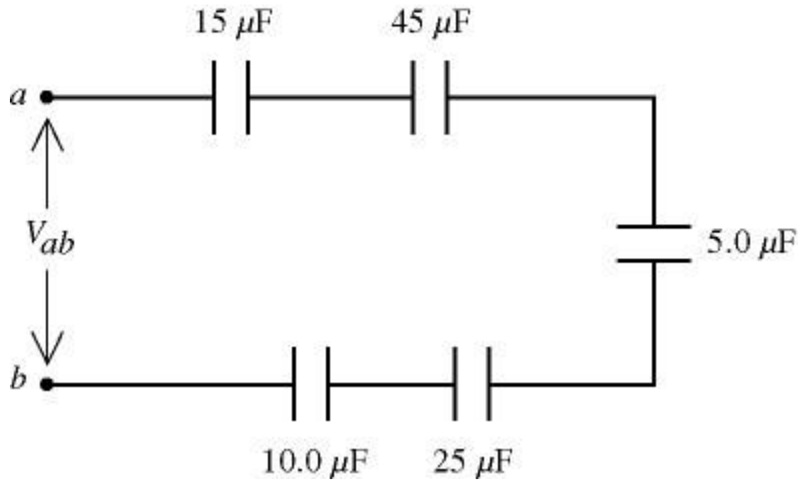
Var: 1

13) The capacitive network shown in the figure is assembled with initially uncharged capacitors. A potential difference, V_{ab} = +100V, is applied across the network. The switch S in the network is kept open. Assume that all the capacitances shown are accurate to two significant figures. What is potential difference V_{cd} across the open switch S?



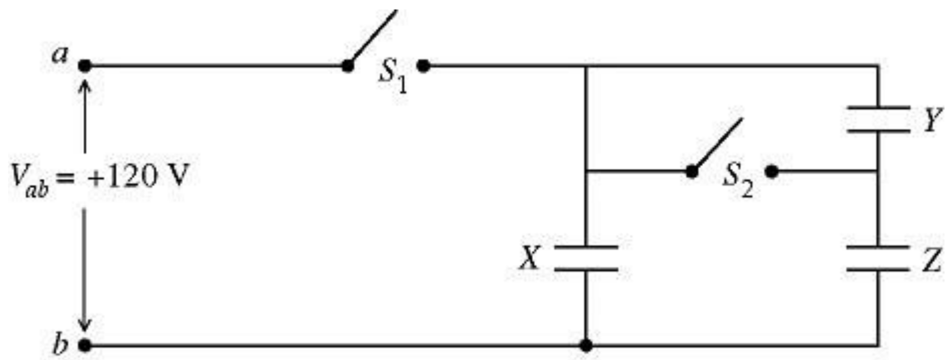
A) 0 V
B) 40 V
C) 50 V
D) 60 V
E) 70 V
Answer: B
Var: 1

14) Five capacitors are connected across a potential difference V_{ab} as shown in the figure. Because of the dielectrics used, each capacitor will break down if the potential across it exceeds 30.0 V. The largest that V_{ab} can be without damaging any of the capacitors is closest to



A) 6.0 V.
B) 30 V.
C) 64 V.
D) 150 V.
E) 580 V.
Answer: C
Var: 1

15) The network shown in the figure is assembled with uncharged capacitors X, Y, and Z, with $C_X = 7.0\ \mu\text{F}$, $C_Y = 7.0\ \mu\text{F}$, and $C_Z = 6.0\ \mu\text{F}$, and open switches, S_1 and S_2. A potential difference V_{ab} = +120 V is applied between points a and b. After the network is assembled, switch S_1 is closed for a long time, but switch S_2 is kept open. Then switch S_1 is opened and switch S_2 is closed. What is the final voltage across capacitor X?

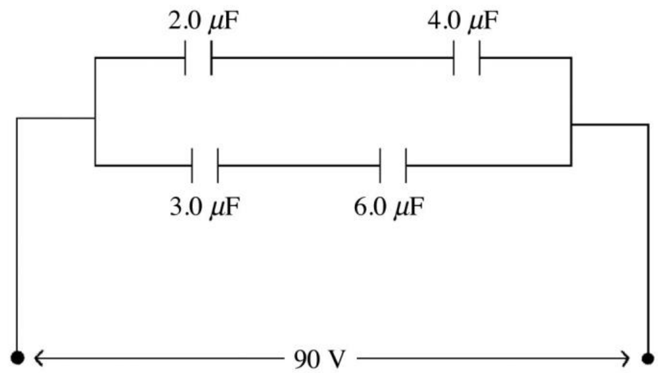


A) 94 V
B) 87 V
C) 79 V
D) 71 V
E) 63 V
Answer: A
Var: 50+

16) A 1.0-μF and a 2.0-μF capacitor are connected in series across a 3.0-V voltage source.
(a) What is the charge on the 1.0-μF capacitor?
(b) What is the voltage across the 2.0-μF capacitor?
Answer: (a) 2.0 μC (b) 1.0 V
Var: 1

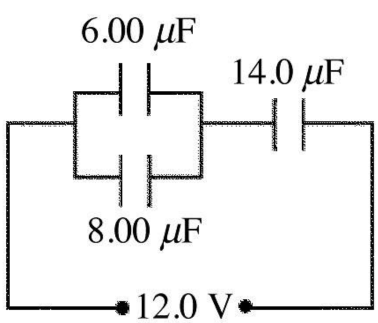
17) Three capacitors, of capacitance 5.00 μF, 10.0 μF, and 50.0 μF, are connected in series across a 12.0-V voltage source.
(a) How much charge is stored in the 5.00-μF capacitor?
(b) What is the potential difference across the 10.0-μF capacitor?
Answer: (a) 37.5 μC (b) 3.75 V
Var: 1

18) Four capacitors are connected across a 90-V voltage source as shown in the figure.



(a) What is the charge on the 4.0-μF capacitor?
(b) What is the charge on a 2.0-μF capacitor?
(c) What is the charge on the 3.0-μF capacitor?
(d) What is the potential difference across the 6.0-μF capacitor?
Answer: (a) 120 μC (b) 120 μC (c) 180 μC (d) 30 V
Var: 1

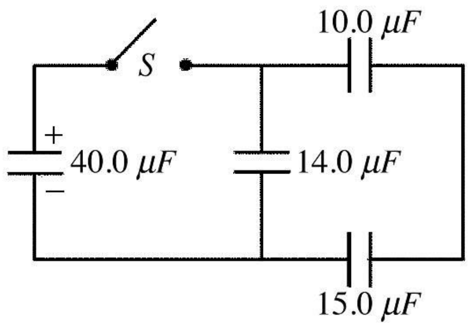
19) Two capacitors of capacitance 6.00 μF and 8.00 μF are connected in parallel. The combination is then connected in series with a 12.0-V voltage source and a 14.0-μF capacitor, as shown in the figure.



(a) What is the equivalent capacitance of this combination?
(b) What is the charge on the 6.00-μF capacitor?
(c) What is the potential difference across the 6.00-μF capacitor?
Answer: (a) 7.00 μF (b) 36.0 μC (c) 6.00 V
Var: 1

20) An isolated air-filled parallel-plate capacitor that is no longer connected to anything has been charged up to Q = 2.9 nC. The separation between the plates initially is 1.20 mm, and for this separation the capacitance is 31 pF. Calculate the work that must be done to pull the plates apart until their separation becomes 5.30 mm, if the charge on the plates remains constant. ($\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$)
Answer: 0.46 μJ
Var: 1

21) In the circuit shown in the figure, all the capacitors are air-filled. With the switch *S* open, the 40.0-μF capacitor has an initial charge of 5.00 μC while the other three capacitors are uncharged. The switch is then closed and left closed for a long time. Calculate the initial and final values of the total electrical energy stored in these four capacitors.



Answer: U_i = 0.313 μJ, U_f = 0.208 μJ
Var: 1

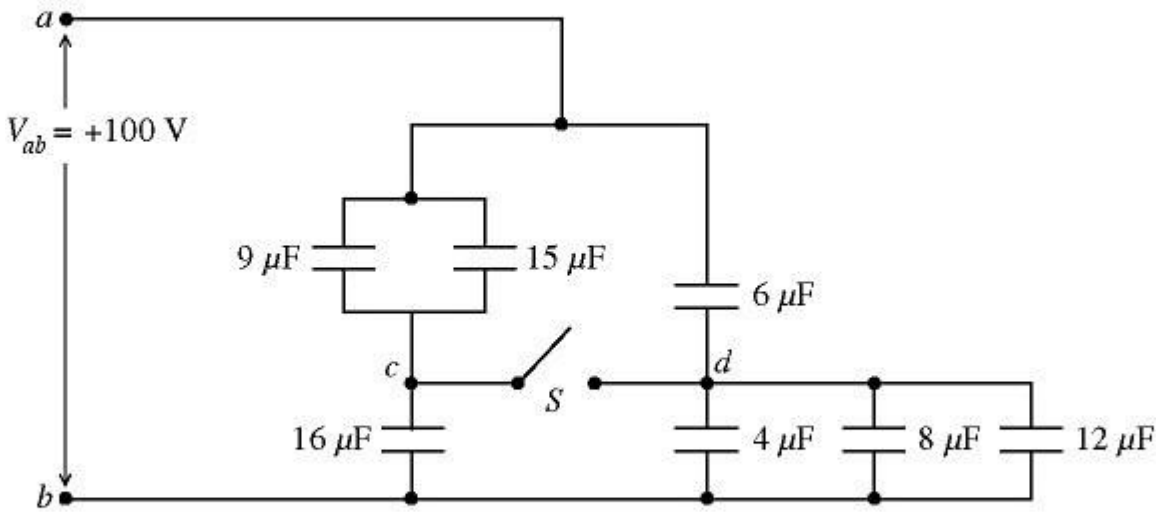
22) A 6.00-μF parallel-plate capacitor has charges of ±40.0 μC on its plates. How much potential energy is stored in this capacitor?
A) 103 μJ
B) 113 μJ
C) 123 μJ
D) 133 μJ
E) 143 μJ
Answer: D
Var: 5

23) A charge of 2.00 μC flows onto the plates of a capacitor when it is connected to a 12.0-V potential source. What is the minimum amount of work that must be done in charging this capacitor?
A) 6.00 μJ
B) 24.0 μJ
C) 12.0 μJ
D) 144 μJ
E) 576 μJ
Answer: C
Var: 1

4) A 1.0 μF capacitor has a potential difference of 6.0 V applied across its plates. If the potential difference across its plates is increased to 8.0 V, how much ADDITIONAL energy does the capacitor store?
A) 14 μJ
B) 28 μJ
C) 2.0 μJ
D) 4.0 μJ
Answer: A
Var: 28

25) Two square air-filled parallel plates that are initially uncharged are separated by 1.2 mm, and each of them has an area of 190 mm^2. How much charge must be transferred from one plate to the other if 1.1 nJ of energy are to be stored in the plates? (ε_{00} = 8.85 × 10^{-12} $C^2/N \cdot m^2$)
A) 56 pC
B) 39 pC
C) 78 pC
D) 3.5 μC
Answer: A
Var: 1

26) The capacitive network shown in the figure is assembled with initially uncharged capacitors. A potential difference, V_{ab} = +100V, is applied across the network. The switch S in the network is kept open. Assume that all the capacitances shown are accurate to two significant figures. What is the total energy stored in the seven capacitors?



A) 48 mJ
B) 72 mJ
C) 96 mJ
D) 120 mJ
E) 144 mJ
Answer: B
Var: 1

27) Each plate of an air-filled parallel-plate air capacitor has an area of 0.0040 m^2, and the separation of the plates is 0.080 mm. An electric field of 5.3×10^6 V/m is present between the plates. What is the energy density between the plates? ($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$)

A) 124 J/m^3
B) 84 J/m^3
C) 170 J/m^3
D) 210 J/m^3
E) 250 J/m^3
Answer: A
Var: 1

28) A 15-μF air-filled capacitor is connected to a 50-V voltage source and becomes fully charged. The voltage source is then removed and a slab of dielectric that completely fills the space between the plates is inserted. The dielectric has a dielectric constant of 5.0.
(a) What is the capacitance of the capacitor after the slab has been inserted?
(b) What is the potential difference across the plates of the capacitor after the slab has been inserted?
Answer: (a) 75 μF (b) 10 V
Var: 1

29) A parallel-plate capacitor with plate separation of 1.0 cm has square plates, each with an area of 6.0×10^{-2} m^2. What is the capacitance of this capacitor if a dielectric material with a dielectric constant of 2.4 is placed between the plates, completely filling them?
($\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N · m^2)
A) 15×10^{-12} F
B) 15×10^{-14} F
C) 64×10^{-14} F
D) 1.3×10^{-12} F
E) 1.3×10^{-10} F
Answer: E
Var: 1

30) A parallel-plate capacitor has a capacitance of 10 mF and is charged with a 20-V power supply. The power supply is then removed and a dielectric material of dielectric constant 4.0 is used to fill the space between the plates. What is the voltage now across the capacitor?
A) 80 V
B) 20 V
C) 10 V
D) 5.0 V
E) 2.5 V
Answer: D
Var: 1

31) A 6.0-μF air-filled capacitor is connected across a 100-V voltage source. After the source fully charges the capacitor, the capacitor is immersed in transformer oil (of dielectric constant 4.5). How much ADDITIONAL charge flows from the voltage source, which remained connected during the process?
A) 1.2 mC
B) 1.5 mC
C) 1.7 mC
D) 2.1 mC
E) 2.5 mC
Answer: D
Var: 1

32) A parallel-plate capacitor has a capacitance of 10 mF and charged with a 20-V power supply. The power supply is then removed and a dielectric material of dielectric constant 4.0 is used to fill the space between the plates. How much energy is now stored by the capacitor?
A) 250 mJ
B) 125 mJ
C) 500 mJ
D) 62.5 mJ
E) 1200 mJ
Answer: C
Var: 1

33) A parallel-plate capacitor consists of two parallel, square plates that have dimensions 1.0 cm by 1.0 cm. If the plates are separated by 1.0 mm, and the space between them is filled with teflon, what is the capacitance of this capacitor? (The dielectric constant for teflon is 2.1, and $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$.)
A) 1.9 pF
B) 0.44 pF
C) 2.1 pF
D) 0.89 pF
Answer: A
Var: 5

34) An air-filled capacitor stores a potential energy of 6.00 mJ due to its charge. It is accidentally filled with water in such a way as not to discharge its plates. How much energy does it continue to store after it is filled? (The dielectric constant for water is 78 and for air it is 1.0006.)
A) 0.077 mJ
B) 468 mJ
C) 0.040 mJ
D) 6.00 mJ
Answer: A
Var: 18

35) A parallel-plate capacitor, with air between the plates, is connected across a voltage source. This source establishes a potential difference between the plates by placing charge of magnitude 4.15×10^{-6} C on each plate. The space between the plates is then filled with a dielectric material, with a dielectric constant of 7.74. What must the magnitude of the charge on each capacitor plate now be, to produce the same potential difference between the plates as before?
Answer: 3.21×10^{-5} C
Var: 50+