

4 Figure 25-20 shows three circuits, each consisting of a switch and two capacitors, initially charged as indicated (top plate positive). After the switches have been closed, in which circuit (if any) will the charge on the left-hand capacitor (a) increase, (b) decrease, and (c) remain the same?

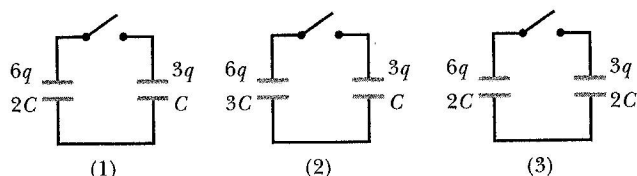


Fig. 25-20 Question 4.

5 Initially, a single capacitance  $C_1$  is wired to a battery. Then capacitance  $C_2$  is added in parallel. Are (a) the potential difference across  $C_1$  and (b) the charge  $q_1$  on  $C_1$  now more than, less than, or the same as previously? (c) Is the equivalent capacitance  $C_{12}$  of  $C_1$  and  $C_2$  more than, less than, or equal to  $C_1$ ? (d) Is the charge stored on  $C_1$  and  $C_2$  together more than, less than, or equal to the charge stored previously on  $C_1$ ?

6 Repeat Question 5 for  $C_2$  added in series rather than in parallel.

7 For each circuit in Fig. 25-21, are the capacitors connected in series, in parallel, or in neither mode?

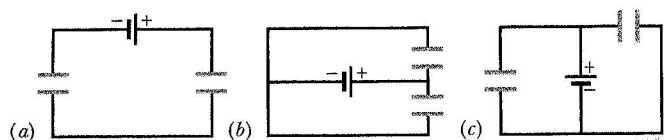


Fig. 25-21 Question 7.

8 Figure 25-22 shows an open switch, a battery of potential difference  $V$ , a current-measuring meter  $A$ , and three identical uncharged capacitors of capacitance  $C$ . When the switch is closed and the circuit reaches equilibrium, what are (a) the potential difference across each capacitor and (b) the charge on the left plate of each capacitor? (c) During charging, what net charge passes through the meter?

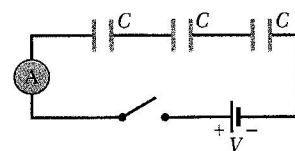


Fig. 25-22 Question 8.

9 A parallel-plate capacitor is connected to a battery of electric potential difference  $V$ . If the plate separation is decreased, do the following quantities increase, decrease, or remain the same: (a) the capacitor's capacitance, (b) the potential difference across the capacitor, (c) the charge on the capacitor, (d) the energy stored by the capacitor, (e) the magnitude of the electric field between the plates, and (f) the energy density of that electric field?

10 When a dielectric slab is inserted between the plates of one of the two identical capacitors in Fig. 25-23, do the following properties of that capacitor increase, decrease, or remain the same: (a) capacitance, (b) charge, (c) potential difference, and (d) potential energy? (e) How about the same properties of the other capacitor?

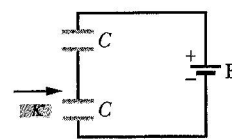


Fig. 25-23 Question 10.

11 You are to connect capacitances  $C_1$  and  $C_2$ , with  $C_1 > C_2$ , to a battery, first individually, then in series, and then in parallel. Rank those arrangements according to the amount of charge stored, greatest first.

## PROBLEMS

WILEY  
PLUS

GO Tutoring problem available (at instructor's discretion) in WileyPLUS and WebAssign

SSM Worked-out solution available in Student Solutions Manual

Number of dots indicates level of problem difficulty

Additional information available in *The Flying Circus of Physics* and at [flyingcircusofphysics.com](http://flyingcircusofphysics.com)

WWW Worked-out solution is at

ILW Interactive solution is at

<http://www.wiley.com/college/halliday>

### sec. 25-2 Capacitance

•1 The two metal objects in Fig. 25-24 have net charges of  $+70$  pC and  $-70$  pC, which result in a  $20$  V potential difference between them. (a) What is the capacitance of the system? (b) If the charges are changed to  $+200$  pC and  $-200$  pC, what does the capacitance become? (c) What does the potential difference become?



Fig. 25-24 Problem 1.

•2 The capacitor in Fig. 25-25 has a capacitance of  $25$   $\mu$ F and is initially uncharged. The battery provides a potential difference of  $120$  V. After switch  $S$  is closed, how much charge will pass through it?

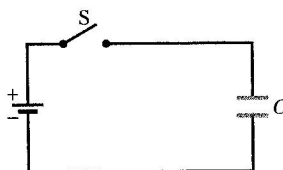


Fig. 25-25 Problem 2.

### sec. 25-3 Calculating the Capacitance

•3 SSM A parallel-plate capacitor has circular plates of  $8.20$  cm radius and  $1.30$  mm separation. (a) Calculate the capacitance. (b) Find the charge for a potential difference of  $120$  V.

•4 The plates of a spherical capacitor have radii  $38.0$  mm and  $40.0$  mm. (a) Calculate the capacitance. (b) What must be the plate area of a parallel-plate capacitor with the same plate separation and capacitance?

•5 What is the capacitance of a drop that results when two mercury spheres, each of radius  $R = 2.00$  mm, merge?

•6 You have two flat metal plates, each of area  $1.00$  m<sup>2</sup>, with which to construct a parallel-plate capacitor. (a) If the capacitance of the device is to be  $1.00$  F, what must be the separation between the plates? (b) Could this capacitor actually be constructed?

•7 If an uncharged parallel-plate capacitor (capacitance  $C$ ) is connected to a battery, one plate becomes negatively charged as electrons move to the plate face (area  $A$ ). In Fig. 25-26, the depth  $d$  from which the electrons come in the plate in a particular capacitor is plotted against a range of values for the

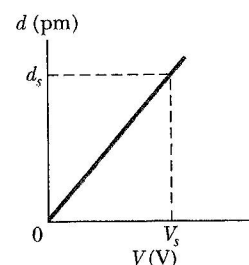


Fig. 25-26 Problem 7.

potential difference  $V$  of the battery. The density of conduction electrons in the copper plates is  $8.49 \times 10^{28}$  electrons/m<sup>3</sup>. The vertical scale is set by  $d_s = 1.00$  pm, and the horizontal scale is set by  $V_s = 20.0$  V. What is the ratio  $C/A$ ?

### sec. 25-4 Capacitors in Parallel and in Series

•8 How many  $1.00 \mu\text{F}$  capacitors must be connected in parallel to store a charge of  $1.00 \text{ C}$  with a potential of  $110 \text{ V}$  across the capacitors?

•9 Each of the uncharged capacitors in Fig. 25-27 has a capacitance of  $25.0 \mu\text{F}$ . A potential difference of  $V = 4200 \text{ V}$  is established when the switch is closed. How many coulombs of charge then pass through meter A?

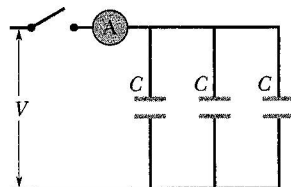


Fig. 25-27 Problem 9.

•10 In Fig. 25-28, find the equivalent capacitance of the combination. Assume that  $C_1$  is  $10.0 \mu\text{F}$ ,  $C_2$  is  $5.00 \mu\text{F}$ , and  $C_3$  is  $4.00 \mu\text{F}$ .

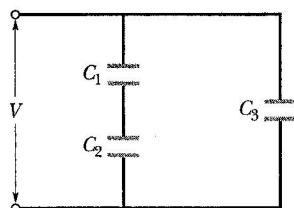


Fig. 25-28 Problems 10 and 34.

•11 ILW In Fig. 25-29, find the equivalent capacitance of the combination. Assume that  $C_1 = 10.0 \mu\text{F}$ ,  $C_2 = 5.00 \mu\text{F}$ , and  $C_3 = 4.00 \mu\text{F}$ .

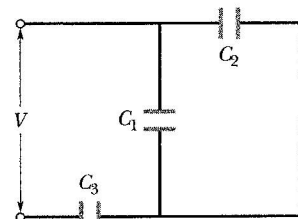


Fig. 25-29 Problems 11, 17, and 38.

•12 Two parallel-plate capacitors,  $6.0 \mu\text{F}$  each, are connected in parallel to a  $10 \text{ V}$  battery. One of the capacitors is then squeezed so that its plate separation is  $50.0\%$  of its initial value. Because of the squeezing, (a) how much additional charge is transferred to the capacitors by the battery and (b) what is the increase in the total charge stored on the capacitors?

•13 SSM ILW A  $100 \text{ pF}$  capacitor is charged to a potential difference of  $50 \text{ V}$ , and the charging battery is disconnected. The capacitor is then connected in parallel with a second (initially uncharged) capacitor. If the potential difference across the first capacitor drops to  $35 \text{ V}$ , what is the capacitance of this second capacitor?

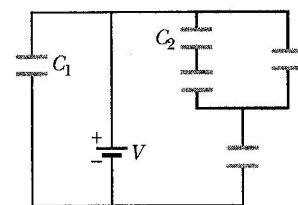


Fig. 25-30 Problem 14.

•14 In Fig. 25-30, the battery has a potential difference of  $V = 10.0 \text{ V}$  and the five capacitors each have a capacitance of  $10.0 \mu\text{F}$ . What is the charge on (a) capacitor 1 and (b) capacitor 2?

•15 GO In Fig. 25-31, a  $20.0 \text{ V}$  battery is connected across capacitors of capacitances  $C_1 = C_6 = 3.00 \mu\text{F}$  and  $C_3 = C_5 = 2.00 C_2 = 2.00 C_4 = 4.00 \mu\text{F}$ . What are (a) the equivalent capacitance  $C_{\text{eq}}$  of the capacitors and (b) the charge stored by  $C_{\text{eq}}$ ? What

are (c)  $V_1$  and (d)  $q_1$  of capacitor 1, (e)  $V_2$  and (f)  $q_2$  of capacitor 2, and (g)  $V_3$  and (h)  $q_3$  of capacitor 3?

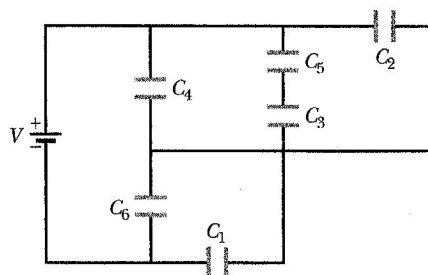
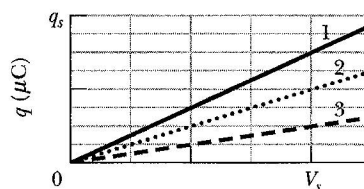
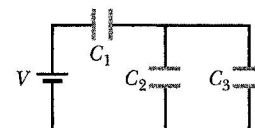


Fig. 25-31 Problem 15.

•16 Plot 1 in Fig. 25-32a gives the charge  $q$  that can be stored on capacitor 1 versus the electric potential  $V$  set up across it. The vertical scale is set by  $q_s = 16.0 \mu\text{C}$ , and the horizontal scale is set by  $V_s = 2.0 \text{ V}$ . Plots 2 and 3 are similar plots for capacitors 2 and 3, respectively. Figure 25-32b shows a circuit with those three capacitors and a  $6.0 \text{ V}$  battery. What is the charge stored on capacitor 2 in that circuit?



(a)



(b)

Fig. 25-32 Problem 16.

•17 GO In Fig. 25-29, a potential difference of  $V = 100.0 \text{ V}$  is applied across a capacitor arrangement with capacitances  $C_1 = 10.0 \mu\text{F}$ ,  $C_2 = 5.00 \mu\text{F}$ , and  $C_3 = 4.00 \mu\text{F}$ . If capacitor 3 undergoes electrical breakdown so that it becomes equivalent to conducting wire, what is the increase in (a) the charge on capacitor 1 and (b) the potential difference across capacitor 1?

•18 Figure 25-33 shows a circuit section of four air-filled capacitors that is connected to a larger circuit. The graph below the section shows the electric potential  $V(x)$  as a function of position  $x$

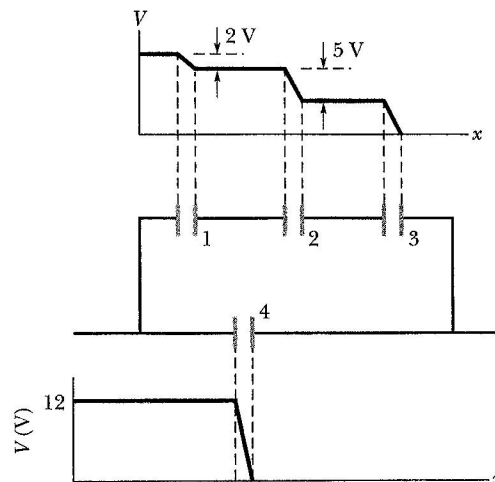


Fig. 25-33 Problem 18.

along the lower part of the section, through capacitor 4. Similarly, the graph above the section shows the electric potential  $V(x)$  as a function of position  $x$  along the upper part of the section, through capacitors 1, 2, and 3. Capacitor 3 has a capacitance of  $0.80 \mu\text{F}$ . What are the capacitances of (a) capacitor 1 and (b) capacitor 2?

**••19 GO** In Fig. 25-34, the battery has potential difference  $V = 9.0 \text{ V}$ ,  $C_2 = 3.0 \mu\text{F}$ ,  $C_4 = 4.0 \mu\text{F}$ , and all the capacitors are initially uncharged. When switch  $S$  is closed, a total charge of  $12 \mu\text{C}$  passes through point  $a$  and a total charge of  $8.0 \mu\text{C}$  passes through point  $b$ . What are (a)  $C_1$  and (b)  $C_3$ ?

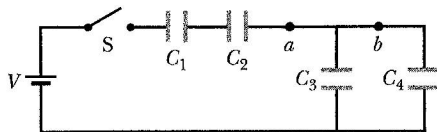


Fig. 25-34 Problem 19.

**••20** Figure 25-35 shows a variable “air gap” capacitor for manual tuning. Alternate plates are connected together; one group of plates is fixed in position, and the other group is capable of rotation. Consider a capacitor of  $n = 8$  plates of alternating polarity, each plate having area  $A = 1.25 \text{ cm}^2$  and separated from adjacent plates by distance  $d = 3.40 \text{ mm}$ . What is the maximum capacitance of the device?

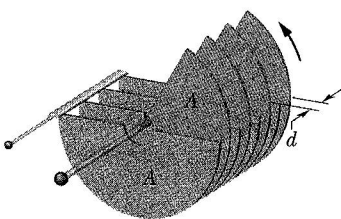


Fig. 25-35 Problem 20.

**••21 SSM WWW** In Fig. 25-36, the capacitances are  $C_1 = 1.0 \mu\text{F}$  and  $C_2 = 3.0 \mu\text{F}$ , and both capacitors are charged to a potential difference of  $V = 100 \text{ V}$  but with opposite polarity as shown. Switches  $S_1$  and  $S_2$  are now closed. (a) What is now the potential difference between points  $a$  and  $b$ ? What now is the charge on capacitor (b) 1 and (c) 2?

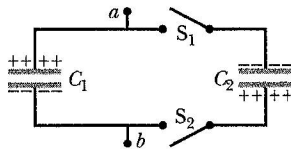


Fig. 25-36 Problem 21.

**••22** In Fig. 25-37,  $V = 10 \text{ V}$ ,  $C_1 = 10 \mu\text{F}$ , and  $C_2 = C_3 = 20 \mu\text{F}$ . Switch  $S$  is first thrown to the left side until capacitor 1 reaches equilibrium. Then the switch is thrown to the right. When equilibrium is again reached, how much charge is on capacitor 1?

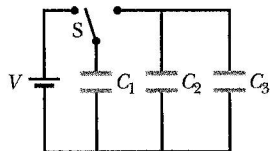


Fig. 25-37 Problem 22.

**••23** The capacitors in Fig. 25-38 are initially uncharged. The capacitances are  $C_1 = 4.0 \mu\text{F}$ ,  $C_2 = 8.0 \mu\text{F}$ , and  $C_3 = 12 \mu\text{F}$ , and the battery's potential difference is  $V = 12 \text{ V}$ . When switch  $S$  is closed, how many electrons travel through (a) point  $a$ , (b) point  $b$ , (c) point  $c$ , and (d) point  $d$ ? In the figure, do the electrons travel up or down through (e) point  $b$  and (f) point  $c$ ?

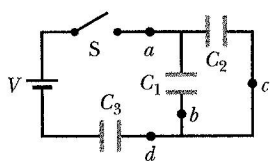


Fig. 25-38 Problem 23.

**••24** Figure 25-39 represents two air-filled cylindrical capacitors connected in series across a battery with potential  $V = 10 \text{ V}$ . Capacitor 1 has an inner plate radius of  $5.0 \text{ mm}$ , an outer plate radius of  $1.5 \text{ cm}$ , and a length of  $5.0 \text{ cm}$ . Capacitor 2 has an inner plate radius

of  $2.5 \text{ mm}$ , an outer plate radius of  $1.0 \text{ cm}$ , and a length of  $9.0 \text{ cm}$ . The outer plate of capacitor 2 is a conducting organic membrane that can be stretched, and the capacitor can be inflated to increase the plate separation. If the outer plate radius is increased to  $2.5 \text{ cm}$  by inflation, (a) how many electrons move through point  $P$  and (b) do they move toward or away from the battery?

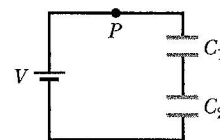


Fig. 25-39 Problem 24.

**••25** In Fig. 25-40, two parallel-plate capacitors (with air between the plates) are connected to a battery. Capacitor 1 has a plate area of  $1.5 \text{ cm}^2$  and an electric field (between its plates) of magnitude  $2000 \text{ V/m}$ . Capacitor 2 has a plate area of  $0.70 \text{ cm}^2$  and an electric field of magnitude  $1500 \text{ V/m}$ . What is the total charge on the two capacitors?

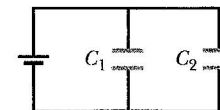


Fig. 25-40 Problem 25.

**••26** Capacitor 3 in Fig. 25-41a is a *variable capacitor* (its capacitance  $C_3$  can be varied). Figure 25-41b gives the electric potential  $V_1$  across capacitor 1 versus  $C_3$ . The horizontal scale is set by  $C_{3s} = 12.0 \mu\text{F}$ . Electric potential  $V_1$  approaches an asymptote of  $10 \text{ V}$  as  $C_3 \rightarrow \infty$ . What are (a) the electric potential  $V$  across the battery, (b)  $C_1$ , and (c)  $C_2$ ?

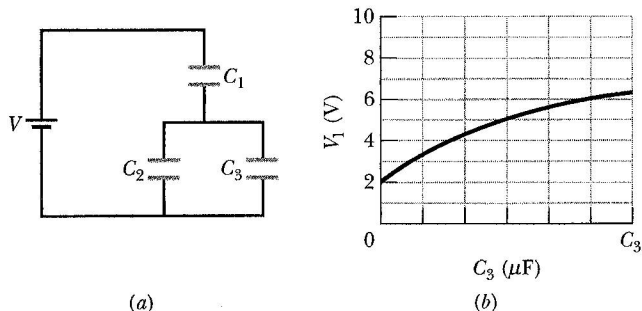


Fig. 25-41 Problem 26.

**••27 GO** Figure 25-42 shows a  $12.0 \text{ V}$  battery and four uncharged capacitors of capacitances  $C_1 = 1.00 \mu\text{F}$ ,  $C_2 = 2.00 \mu\text{F}$ ,  $C_3 = 3.00 \mu\text{F}$ , and  $C_4 = 4.00 \mu\text{F}$ . If only switch  $S_1$  is closed, what is the charge on (a) capacitor 1, (b) capacitor 2, (c) capacitor 3, and (d) capacitor 4? If both switches are closed, what is the charge on (e) capacitor 1, (f) capacitor 2, (g) capacitor 3, and (h) capacitor 4?

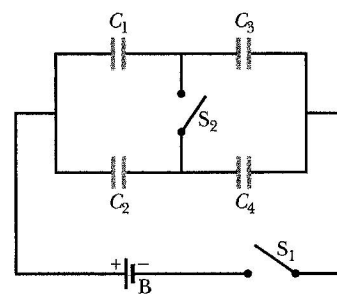


Fig. 25-42 Problem 27.

**••28 GO** Figure 25-43 displays a  $12.0 \text{ V}$  battery and 3 uncharged capacitors of capacitances  $C_1 = 4.00 \mu\text{F}$ ,  $C_2 = 6.00 \mu\text{F}$ , and  $C_3 = 3.00 \mu\text{F}$ . The switch is thrown to the left side until capacitor 1 is fully charged. Then the switch is thrown to the right. What is the final charge on (a) capacitor 1, (b) capacitor 2, and (c) capacitor 3?

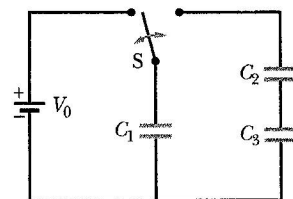


Fig. 25-43 Problem 28.

### sec. 25-5 Energy Stored in an Electric Field

•29 What capacitance is required to store an energy of  $10 \text{ kW} \cdot \text{h}$  at a potential difference of  $1000 \text{ V}$ ?

•30 How much energy is stored in  $1.00 \text{ m}^3$  of air due to the “fair weather” electric field of magnitude  $150 \text{ V/m}$ ?

•31 **SSM** A  $2.0 \mu\text{F}$  capacitor and a  $4.0 \mu\text{F}$  capacitor are connected in parallel across a  $300 \text{ V}$  potential difference. Calculate the total energy stored in the capacitors.

•32 A parallel-plate air-filled capacitor having area  $40 \text{ cm}^2$  and plate spacing  $1.0 \text{ mm}$  is charged to a potential difference of  $600 \text{ V}$ . Find (a) the capacitance, (b) the magnitude of the charge on each plate, (c) the stored energy, (d) the electric field between the plates, and (e) the energy density between the plates.

•33 A charged isolated metal sphere of diameter  $10 \text{ cm}$  has a potential of  $8000 \text{ V}$  relative to  $V = 0$  at infinity. Calculate the energy density in the electric field near the surface of the sphere.

•34 In Fig. 25-28, a potential difference  $V = 100 \text{ V}$  is applied across a capacitor arrangement with capacitances  $C_1 = 10.0 \mu\text{F}$ ,  $C_2 = 5.00 \mu\text{F}$ , and  $C_3 = 4.00 \mu\text{F}$ . What are (a) charge  $q_3$ , (b) potential difference  $V_3$ , and (c) stored energy  $U_3$  for capacitor 3, (d)  $q_1$ , (e)  $V_1$ , and (f)  $U_1$  for capacitor 1, and (g)  $q_2$ , (h)  $V_2$ , and (i)  $U_2$  for capacitor 2?

•35 Assume that a stationary electron is a point of charge. What is the energy density  $u$  of its electric field at radial distances (a)  $r = 1.00 \text{ mm}$ , (b)  $r = 1.00 \mu\text{m}$ , (c)  $r = 1.00 \text{ nm}$ , and (d)  $r = 1.00 \text{ pm}$ ? (e) What is  $u$  in the limit as  $r \rightarrow 0$ ?

•36 **SSM** As a safety engineer, you must evaluate the practice of storing flammable conducting liquids in nonconducting containers. The company supplying a certain liquid has been using a squat, cylindrical plastic container of radius  $r = 0.20 \text{ m}$  and filling it to height  $h = 10 \text{ cm}$ , which is not the container's full interior height (Fig. 25-44).

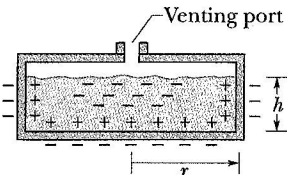


Fig. 25-44 Problem 36.

Your investigation reveals that during handling at the company, the exterior surface of the container commonly acquires a negative charge density of magnitude  $2.0 \mu\text{C/m}^2$  (approximately uniform). Because the liquid is a conducting material, the charge on the container induces charge separation within the liquid. (a) How much negative charge is induced in the center of the liquid's bulk? (b) Assume the capacitance of the central portion of the liquid relative to ground is  $35 \text{ pF}$ . What is the potential energy associated with the negative charge in that effective capacitor? (c) If a spark occurs between the ground and the central portion of the liquid (through the venting port), the potential energy can be fed into the spark. The minimum spark energy needed to ignite the liquid is  $10 \text{ mJ}$ . In this situation, can a spark ignite the liquid?

•37 **SSM ILW WWW** The parallel plates in a capacitor, with a plate area of  $8.50 \text{ cm}^2$  and an air-filled separation of  $3.00 \text{ mm}$ , are charged by a  $6.00 \text{ V}$  battery. They are then disconnected from the battery and pulled apart (without discharge) to a separation of  $8.00 \text{ mm}$ . Neglecting fringing, find (a) the potential difference between the plates, (b) the initial stored energy, (c) the final stored energy, and (d) the work required to separate the plates.

•38 In Fig. 25-29, a potential difference  $V = 100 \text{ V}$  is applied across a capacitor arrangement with capacitances  $C_1 = 10.0 \mu\text{F}$ ,

$C_2 = 5.00 \mu\text{F}$ , and  $C_3 = 15.0 \mu\text{F}$ . What are (a) charge  $q_3$ , (b) potential difference  $V_3$ , and (c) stored energy  $U_3$  for capacitor 3, (d)  $q_1$ , (e)  $V_1$ , and (f)  $U_1$  for capacitor 1, and (g)  $q_2$ , (h)  $V_2$ , and (i)  $U_2$  for capacitor 2?

•39 **GO** In Fig. 25-45,  $C_1 = 10.0 \mu\text{F}$ ,  $C_2 = 20.0 \mu\text{F}$ , and  $C_3 = 25.0 \mu\text{F}$ . If no capacitor can withstand a potential difference of more than  $100 \text{ V}$  without failure, what are (a) the magnitude

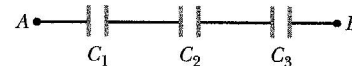


Fig. 25-45 Problem 39.

of the maximum potential difference that can exist between points A and B and (b) the maximum energy that can be stored in the three-capacitor arrangement?

### sec. 25-6 Capacitor with a Dielectric

•40 An air-filled parallel-plate capacitor has a capacitance of  $1.3 \text{ pF}$ . The separation of the plates is doubled, and wax is inserted between them. The new capacitance is  $2.6 \text{ pF}$ . Find the dielectric constant of the wax.

•41 **SSM** A coaxial cable used in a transmission line has an inner radius of  $0.10 \text{ mm}$  and an outer radius of  $0.60 \text{ mm}$ . Calculate the capacitance per meter for the cable. Assume that the space between the conductors is filled with polystyrene.

•42 A parallel-plate air-filled capacitor has a capacitance of  $50 \text{ pF}$ . (a) If each of its plates has an area of  $0.35 \text{ m}^2$ , what is the separation? (b) If the region between the plates is now filled with material having  $\kappa = 5.6$ , what is the capacitance?

•43 Given a  $7.4 \text{ pF}$  air-filled capacitor, you are asked to convert it to a capacitor that can store up to  $7.4 \mu\text{J}$  with a maximum potential difference of  $652 \text{ V}$ . Which dielectric in Table 25-1 should you use to fill the gap in the capacitor if you do not allow for a margin of error?

•44 You are asked to construct a capacitor having a capacitance near  $1 \text{ nF}$  and a breakdown potential in excess of  $10\,000 \text{ V}$ . You think of using the sides of a tall Pyrex drinking glass as a dielectric, lining the inside and outside curved surfaces with aluminum foil to act as the plates. The glass is  $15 \text{ cm}$  tall with an inner radius of  $3.6 \text{ cm}$  and an outer radius of  $3.8 \text{ cm}$ . What are the (a) capacitance and (b) breakdown potential of this capacitor?

•45 A certain parallel-plate capacitor is filled with a dielectric for which  $\kappa = 5.5$ . The area of each plate is  $0.034 \text{ m}^2$ , and the plates are separated by  $2.0 \text{ mm}$ . The capacitor will fail (short out and burn up) if the electric field between the plates exceeds  $200 \text{ kN/C}$ . What is the maximum energy that can be stored in the capacitor?

•46 In Fig. 25-46, how much charge is stored on the parallel-plate capacitors by the  $12.0 \text{ V}$  battery? One is filled with air, and the other is filled with a dielectric for which  $\kappa = 3.00$ ; both capacitors have a plate area of  $5.00 \times 10^{-3} \text{ m}^2$  and a plate separation of  $2.00 \text{ mm}$ .

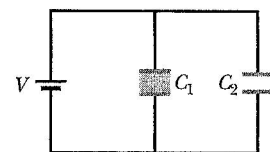


Fig. 25-46 Problem 46.

•47 **SSM ILW** A certain substance has a dielectric constant of  $2.8$  and a dielectric strength of  $18 \text{ MV/m}$ . If it is used as the dielectric material in a parallel-plate capacitor, what minimum area should the plates of the capacitor have to obtain a capacitance of  $7.0 \times 10^{-2} \mu\text{F}$  and to ensure that the capacitor will be able to withstand a potential difference of  $4.0 \text{ kV}$ ?

••48 Figure 25-47 shows a parallel-plate capacitor with a plate area  $A = 5.56 \text{ cm}^2$  and separation  $d = 5.56 \text{ mm}$ . The left half of the gap is filled with material of dielectric constant  $\kappa_1 = 7.00$ ; the right half is filled with material of dielectric constant  $\kappa_2 = 12.0$ . What is the capacitance?

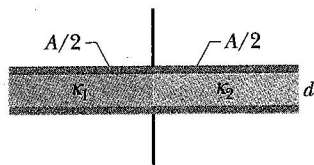


Fig. 25-47 Problem 48.

••49 Figure 25-48 shows a parallel-plate capacitor with a plate area  $A = 7.89 \text{ cm}^2$  and plate separation  $d = 4.62 \text{ mm}$ . The top half of the gap is filled with material of dielectric constant  $\kappa_1 = 11.0$ ; the bottom half is filled with material of dielectric constant  $\kappa_2 = 12.0$ . What is the capacitance?

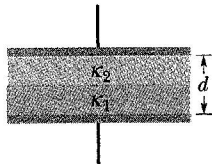


Fig. 25-48 Problem 49.

••50 GO Figure 25-49 shows a parallel-plate capacitor of plate area  $A = 10.5 \text{ cm}^2$  and plate separation  $2d = 7.12 \text{ mm}$ . The left half of the gap is filled with material of dielectric constant  $\kappa_1 = 21.0$ ; the top of the right half is filled with material of dielectric constant  $\kappa_2 = 42.0$ ; the bottom of the right half is filled with material of dielectric constant  $\kappa_3 = 58.0$ . What is the capacitance?

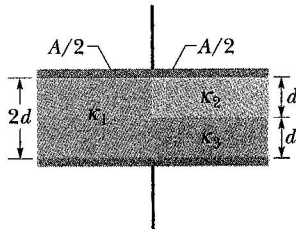


Fig. 25-49 Problem 50.

### sec. 25-8 Dielectrics and Gauss' Law

•51 SSM WWW A parallel-plate capacitor has a capacitance of  $100 \text{ pF}$ , a plate area of  $100 \text{ cm}^2$ , and a mica dielectric ( $\kappa = 5.4$ ) completely filling the space between the plates. At  $50 \text{ V}$  potential difference, calculate (a) the electric field magnitude  $E$  in the mica, (b) the magnitude of the free charge on the plates, and (c) the magnitude of the induced surface charge on the mica.

•52 For the arrangement of Fig. 25-17, suppose that the battery remains connected while the dielectric slab is being introduced. Calculate (a) the capacitance, (b) the charge on the capacitor plates, (c) the electric field in the gap, and (d) the electric field in the slab, after the slab is in place.

••53 A parallel-plate capacitor has plates of area  $0.12 \text{ m}^2$  and a separation of  $1.2 \text{ cm}$ . A battery charges the plates to a potential difference of  $120 \text{ V}$  and is then disconnected. A dielectric slab of thickness  $4.0 \text{ mm}$  and dielectric constant  $4.8$  is then placed symmetrically between the plates. (a) What is the capacitance before the slab is inserted? (b) What is the capacitance with the slab in place? What is the free charge  $q$  (c) before and (d) after the slab is inserted? What is the magnitude of the electric field (e) in the space between the plates and dielectric and (f) in the dielectric itself? (g) With the slab in place, what is the potential difference across the plates? (h) How much external work is involved in inserting the slab?

••54 Two parallel plates of area  $100 \text{ cm}^2$  are given charges of equal magnitudes  $8.9 \times 10^{-7} \text{ C}$  but opposite signs. The electric field within the dielectric material filling the space between the plates is  $1.4 \times 10^6 \text{ V/m}$ . (a) Calculate the dielectric constant of the material. (b) Determine the magnitude of the charge induced on each dielectric surface.

••55 The space between two concentric conducting spherical shells of radii  $b = 1.70 \text{ cm}$  and  $a = 1.20 \text{ cm}$  is filled with a sub-

stance of dielectric constant  $\kappa = 23.5$ . A potential difference  $V = 73.0 \text{ V}$  is applied across the inner and outer shells. Determine (a) the capacitance of the device, (b) the free charge  $q$  on the inner shell, and (c) the charge  $q'$  induced along the surface of the inner shell.

### Additional Problems

56 In Fig. 25-50, the battery potential difference  $V$  is  $10.0 \text{ V}$  and each of the seven capacitors has capacitance  $10.0 \mu\text{F}$ . What is the charge on (a) capacitor 1 and (b) capacitor 2?

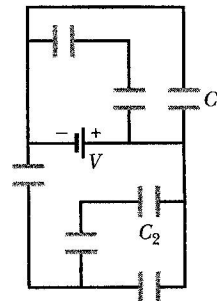


Fig. 25-50 Problem 56.

57 SSM In Fig. 25-51,  $V = 9.0 \text{ V}$ ,  $C_1 = C_2 = 30 \mu\text{F}$ , and  $C_3 = C_4 = 15 \mu\text{F}$ . What is the charge on capacitor 4?

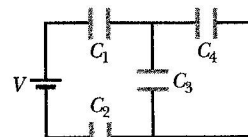


Fig. 25-51 Problem 57.

58 The capacitances of the four capacitors shown in Fig. 25-52 are given in terms of a certain quantity  $C$ . (a) If  $C = 50 \mu\text{F}$ , what is the equivalent capacitance between points  $A$  and  $B$ ? (Hint: First imagine that a battery is connected between those two points; then reduce the circuit to an equivalent capacitance.) (b) Repeat for points  $A$  and  $D$ .

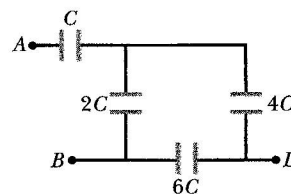


Fig. 25-52 Problem 58.

59 In Fig. 25-53,  $V = 12 \text{ V}$ ,  $C_1 = C_4 = 2.0 \mu\text{F}$ ,  $C_2 = 4.0 \mu\text{F}$ , and  $C_3 = 1.0 \mu\text{F}$ . What is the charge on capacitor 4?

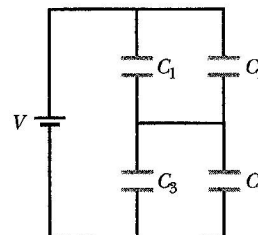


Fig. 25-53 Problem 59.

60 The chocolate crumb mystery. This story begins with Problem 60 in Chapter 23. As part of the investigation of the biscuit factory explosion, the electric potentials of the workers were measured as they emptied sacks of chocolate crumb powder into the loading bin, stirring up a cloud of the powder around themselves. Each worker had an electric potential of about  $7.0 \text{ kV}$  relative to the ground, which was taken as zero potential. (a) Assuming that each worker was effectively a capacitor with a typical capacitance of  $200 \text{ pF}$ , find the energy stored in that effective capacitor. If a single spark between the worker and any conducting object connected to the ground neutralized the worker, that energy would be transferred to the spark. According to measurements, a spark that could ignite a cloud of chocolate crumb powder, and thus set off an explosion, had to have an energy of at least  $150 \text{ mJ}$ . (b) Could a spark from a worker have set off an explosion in the cloud of powder in the loading bin? (The story continues with Problem 60 in Chapter 26.)

61 Figure 25-54 shows capacitor 1 ( $C_1 = 8.00 \mu\text{F}$ ), capacitor 2 ( $C_2 = 6.00 \mu\text{F}$ ), and capacitor 3 ( $C_3 = 8.00 \mu\text{F}$ ) connected to a  $12.0 \text{ V}$  battery. When switch  $S$  is closed so as to connect uncharged ca-

capacitor 4 ( $C_4 = 6.00 \mu\text{F}$ ), (a) how much charge passes through point  $P$  from the battery and (b) how much charge shows up on capacitor 4? (c) Explain the discrepancy in those two results.

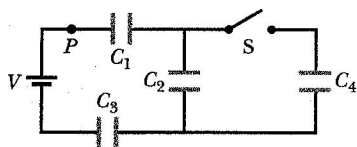


Fig. 25-54 Problem 61.

62 Two air-filled, parallel-plate capacitors are to be connected to a 10 V battery, first individually, then in series, and then in parallel. In those arrangements, the energy stored in the capacitors turns out to be, listed least to greatest:  $75 \mu\text{J}$ ,  $100 \mu\text{J}$ ,  $300 \mu\text{J}$ , and  $400 \mu\text{J}$ . Of the two capacitors, what is the (a) smaller and (b) greater capacitance?

63 Two parallel-plate capacitors,  $6.0 \mu\text{F}$  each, are connected in series to a 10 V battery. One of the capacitors is then squeezed so that its plate separation is halved. Because of the squeezing, (a) how much additional charge is transferred to the capacitors by the battery and (b) what is the increase in the total charge stored on the capacitors (the charge on the positive plate of one capacitor plus the charge on the positive plate of the other capacitor)?

64 In Fig. 25-55,  $V = 12 \text{ V}$ ,  $C_1 = C_5 = C_6 = 6.0 \mu\text{F}$ , and  $C_2 = C_3 = C_4 = 4.0 \mu\text{F}$ . What are (a) the net charge stored on the capacitors and (b) the charge on capacitor 4?

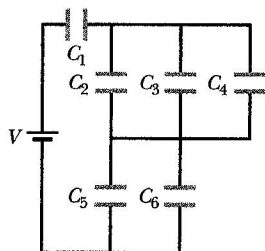


Fig. 25-55 Problem 64.

65 **SSM** In Fig. 25-56, the parallel-plate capacitor of plate area  $2.00 \times 10^{-2} \text{ m}^2$  is filled with two dielectric slabs, each with thickness 2.00 mm. One slab has dielectric constant 3.00, and the other, 4.00. How much charge does the 7.00 V battery store on the capacitor?

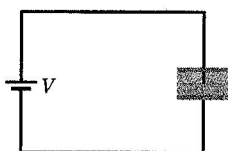


Fig. 25-56 Problem 65.

66 A cylindrical capacitor has radii  $a$  and  $b$  as in Fig. 25-6. Show that half the stored electric potential energy lies within a cylinder whose radius is  $r = \sqrt{ab}$ .

67 A capacitor of capacitance  $C_1 = 6.00 \mu\text{F}$  is connected in series with a capacitor of capacitance  $C_2 = 4.00 \mu\text{F}$ , and a potential difference of 200 V is applied across the pair. (a) Calculate the equivalent capacitance. What are (b) charge  $q_1$  and (c) potential difference  $V_1$  on capacitor 1 and (d)  $q_2$  and (e)  $V_2$  on capacitor 2?

68 Repeat Problem 67 for the same two capacitors but with them now connected in parallel.

69 A certain capacitor is charged to a potential difference  $V$ . If you wish to increase its stored energy by 10%, by what percentage should you increase  $V$ ?

70 A slab of copper of thickness  $b = 2.00 \text{ mm}$  is thrust into a parallel-plate capacitor of plate area  $A = 2.40 \text{ cm}^2$  and plate separation  $d = 5.00 \text{ mm}$ , as shown in Fig. 25-57; the

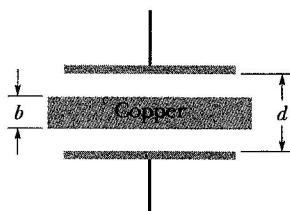


Fig. 25-57 Problems 70 and 71.

slab is exactly halfway between the plates. (a) What is the capacitance after the slab is introduced? (b) If a charge  $q = 3.40 \mu\text{C}$  is maintained on the plates, what is the ratio of the stored energy before to that after the slab is inserted? (c) How much work is done on the slab as it is inserted? (d) Is the slab sucked in or must it be pushed in?

71 Repeat Problem 70, assuming that a potential difference  $V = 85.0 \text{ V}$ , rather than the charge, is held constant.

72 A potential difference of 300 V is applied to a series connection of two capacitors of capacitances  $C_1 = 2.00 \mu\text{F}$  and  $C_2 = 8.00 \mu\text{F}$ . What are (a) charge  $q_1$  and (b) potential difference  $V_1$  on capacitor 1 and (c)  $q_2$  and (d)  $V_2$  on capacitor 2? The charged capacitors are then disconnected from each other and from the battery. Then the capacitors are reconnected with plates of the same signs wired together (the battery is not used). What now are (e)  $q_1$ , (f)  $V_1$ , (g)  $q_2$ , and (h)  $V_2$ ? Suppose, instead, the capacitors charged in part (a) are reconnected with plates of opposite signs wired together. What now are (i)  $q_1$ , (j)  $V_1$ , (k)  $q_2$ , and (l)  $V_2$ ?

73 Figure 25-58 shows a four-capacitor arrangement that is connected to a larger circuit at points A and B. The capacitances are  $C_1 = 10 \mu\text{F}$  and  $C_2 = C_3 = C_4 = 20 \mu\text{F}$ . The charge on capacitor 1 is  $30 \mu\text{C}$ . What is the magnitude of the potential difference  $V_A - V_B$ ?

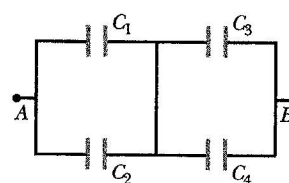


Fig. 25-58 Problem 73.

74 You have two plates of copper, a sheet of mica (thickness = 0.10 mm,  $\kappa = 5.4$ ), a sheet of glass (thickness = 2.0 mm,  $\kappa = 7.0$ ), and a slab of paraffin (thickness = 1.0 cm,  $\kappa = 2.0$ ). To make a parallel-plate capacitor with the largest  $C$ , which sheet should you place between the copper plates?

75 A capacitor of unknown capacitance  $C$  is charged to 100 V and connected across an initially uncharged  $60 \mu\text{F}$  capacitor. If the final potential difference across the  $60 \mu\text{F}$  capacitor is 40 V, what is  $C$ ?

76 A 10 V battery is connected to a series of  $n$  capacitors, each of capacitance  $2.0 \mu\text{F}$ . If the total stored energy is  $25 \mu\text{J}$ , what is  $n$ ?

77 **SSM** In Fig. 25-59, two parallel-plate capacitors A and B are connected in parallel across a 600 V battery. Each plate has area  $80.0 \text{ cm}^2$ ; the plate separations are 3.00 mm. Capacitor A is filled with air; capacitor B is filled with a dielectric of dielectric constant  $\kappa = 2.60$ . Find the magnitude of the electric field within (a) the dielectric of capacitor B and (b) the air of capacitor A. What are the free charge densities  $\sigma$  on the higher-potential plate of (c) capacitor A and (d) capacitor B? (e) What is the induced charge density  $\sigma'$  on the top surface of the dielectric?

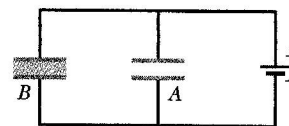


Fig. 25-59 Problem 77.

78 You have many  $2.0 \mu\text{F}$  capacitors, each capable of withstanding 200 V without undergoing electrical breakdown (in which they conduct charge instead of storing it). How would you assemble a combination having an equivalent capacitance of (a)  $0.40 \mu\text{F}$  and (b)  $1.2 \mu\text{F}$ , each combination capable of withstanding 1000 V?