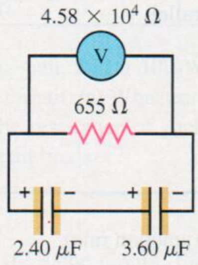
BRIDGING PROBLEM TWO CAPACITORS AND TWO RESISTORS

SOLUTION

A 2.40-μF capacitor and a 3.60-μF capacitor are connected in series. (a) A charge of 5.20 mC is placed on each capacitor. What is the energy stored in the capacitors? (b) A 655-Ω resistor is connected to the terminals of the capacitor combination, and a voltmeter with resistance $4.58 \times 10^4\ \Omega$ is connected across the resistor (**Fig. 26.27**). What is the rate of change of the energy stored in the capacitors just after the connection is made? (c) How long after the connection is made has the energy stored in the capacitors decreased to $1/e$ of its initial value? (d) At the instant calculated in part (c), what is the rate of change of the energy stored in the capacitors?

26.27 When the connection is made, the charged capacitors discharge.



SOLUTION GUIDE

IDENTIFY AND SET UP

1. The two capacitors act as a single equivalent capacitor (see Section 24.2), and the resistor and voltmeter act as a single equivalent resistor. Select equations that will allow you to calculate the values of these equivalent circuit elements.
2. In part (a) you will need to use Eq. (24.9), which gives the energy stored in a capacitor.
3. For parts (b), (c), and (d), you will need to use Eq. (24.9) as well as Eqs. (26.16) and (26.17), which give the capacitor charge and current as functions of time. (*Hint:* The rate at which energy is lost by the capacitors equals the rate at which energy is dissipated in the resistances.)

EXECUTE

4. Find the stored energy at $t = 0$.
5. Find the rate of change of the stored energy at $t = 0$.
6. Find the value of t at which the stored energy has $1/e$ of the value you found in step 4.
7. Find the rate of change of the stored energy at the time you found in step 6.

EVALUATE

8. Check your results from steps 5 and 7 by calculating the rate of change in a different way. (*Hint:* The rate of change of the stored energy U is dU/dt.)

Problems

For assigned homework and other learning materials, go to MasteringPhysics®. MP

•, ••, •••: Difficulty levels. **CP**: Cumulative problems incorporating material from earlier chapters. **CALC**: Problems requiring calculus. **DATA**: Problems involving real data, scientific evidence, experimental design, and/or statistical reasoning. **BIO**: Biosciences problems.

DISCUSSION QUESTIONS

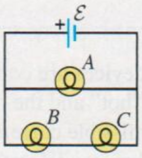
Q26.1 If you use an appliance with a power rating higher than that specified for your household power line, the fuse blows from your supply box. Does this mean the fuse is defective?

Q26.2 In a physics laboratory, you are constructing a direct current circuit and you need to get the maximum power from the components you have. If you have a number of resistors and power sources, what configuration of components would give the maximum power?

Q26.3 A galvanometer can be used as a sensitive ammeter. To increase the current sensitivity of an ammeter, a phosphorous bronze spring is used because its value of restoring force per unit twist is very small. Is a weak shunt resistance connected in series with the galvanometer when used as an ammeter?

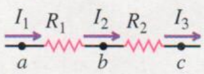
Q26.4 In the circuit shown in **Fig. Q26.4**, three identical light bulbs are connected to a flashlight battery. How do the brightnesses of the bulbs compare? Which light bulb has the greatest current passing through it? Which light bulb has the greatest potential difference between its terminals? What happens if bulb A is unscrewed? Bulb B? Bulb C? Explain your reasoning.

Figure **Q26.4**



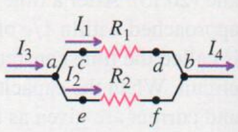
Q26.5 If two resistors R_1 and R_2 $(R_2 > R_1)$ are connected in series as shown in **Fig. Q26.5**, which of the following must be true? In each case justify your answer. (a) $I_1 = I_2 = I_3$. (b) The current is greater in R_1 than in R_2. (c) The electrical power consumption is the same for both resistors. (d) The electrical power consumption is greater in R_2 than in R_1. (e) The potential drop is the same across both resistors. (f) The potential at point a is the same as at point c. (g) The potential at point b is lower than at point c. (h) The potential at point c is lower than at point b.

Figure **Q26.5**



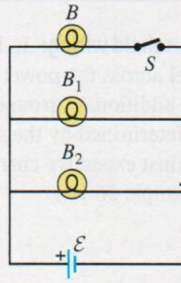
Q26.6 If two resistors R_1 and R_2 $(R_2 > R_1)$ are connected in parallel as shown in **Fig. Q26.6**, which of the following must be true? In each case justify your answer. (a) $I_1 = I_2$. (b) $I_3 = I_4$. (c) The current is greater in R_1 than in R_2. (d) The rate of electrical energy consumption is the same for both resistors. (e) The rate of electrical energy consumption is greater in R_2 than in R_1. (f) $V_{cd} = V_{ef} = V_{ab}$. (g) Point c is at higher potential than point d. (h) Point f is at higher potential than point e. (i) Point c is at higher potential than point e.

Figure **Q26.6**



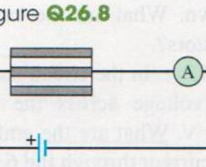
Q26.7 A battery with no internal resistance is connected across identical light bulbs as shown in **Fig. Q26.7**. When you close the switch S, will the brightness of bulbs B_1 and B_2 change? If so, how will it change? Explain.

Figure **Q26.7**



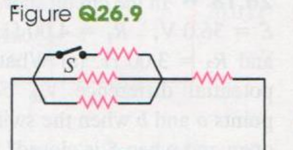
Q26.8 A resistor consists of three identical metal strips connected as shown in **Fig. Q26.8**. If one of the strips is cut out, does the ammeter reading increase, decrease, or stay the same? Why?

Figure **Q26.8**



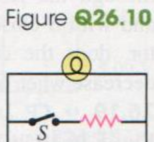
Q26.9 A light bulb is connected in the circuit shown in **Fig. Q26.9**. If we close the switch S, does the bulb's brightness increase, decrease, or remain the same? Explain why.

Figure **Q26.9**



Q26.10 A real battery, having nonnegligible internal resistance, is connected across a light bulb as shown in **Fig. Q26.10**. When the switch S is closed, what happens to the brightness of the bulb? Why?

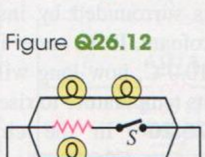
Figure **Q26.10**



Q26.11 If the battery in Discussion Question Q26.10 is ideal with no internal resistance, what will happen to the brightness of the bulb when S is closed? Why?

Q26.12 Consider the circuit shown in **Fig. Q26.12**. What happens to the brightnesses of the bulbs when the switch S is closed if the battery (a) has no internal resistance and (b) has nonnegligible internal resistance? Explain why.

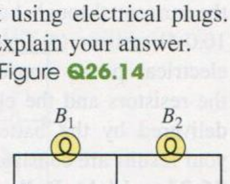
Figure **Q26.12**



Q26.13 In your household, many electrical outlets carry several units where you can attach your electrical equipment using electrical plugs. Are they connected in series or parallel? Explain your answer.

Q26.14 The battery in the circuit shown in **Fig. Q26.14** has no internal resistance. After you close the switch S, will the brightness of bulb B_1 increase, decrease, or stay the same?

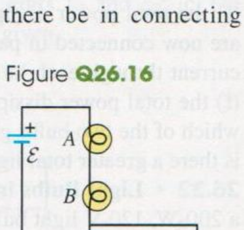
Figure **Q26.14**



Q26.15 In a two-cell flashlight, the batteries are usually connected in series. Why not connect them in parallel? What possible advantage could there be in connecting several identical batteries in parallel?

Q26.16 Identical light bulbs A, B, and C are connected as shown in **Fig. Q26.16**. When the switch S is closed, bulb C goes out. Explain why. What happens to the brightness of bulbs A and B? Explain.

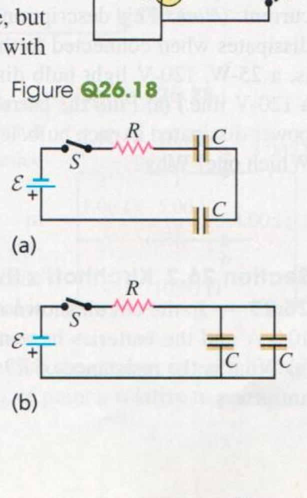
Figure **Q26.16**



Q26.17 The emf of a flashlight battery is roughly constant with time, but its internal resistance increases with age and use. What sort of meter should be used to test the freshness of a battery?

Q26.18 Will the capacitors in the circuits shown in **Fig. Q26.18** charge at the same rate when the switch S is closed? If not, in which circuit will the capacitors charge more rapidly? Explain.

Figure **Q26.18**



Q26.19 Verify that the time constant RC has units of time.

Q26.20 Your instructor asked you to change the time constant of the R-C circuit you made in the laboratory by changing only one component. To change the time constant of an R-C circuit, which element is easier to change and more effective?

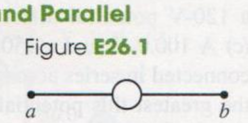
Q26.21 What are the main requirements of a reliable ammeter and voltmeter? What would happen if you used an ammeter in place of a voltmeter during a certain application? Explain your answer with an example.

EXERCISES

Section 26.1 Resistors in Series and Parallel

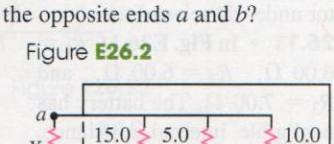
26.1 •• A uniform wire of resistance R is cut into three equal lengths. One of these is formed into a circle and connected between the other two (**Fig. E26.1**). What is the resistance between the opposite ends a and b?

Figure **E26.1**



26.2 •• A machine part has a resistor X protruding from an opening in the side. This resistor is connected to three other resistors, as shown in **Fig. E26.2**. An ohmmeter connected across a and b reads 2.00 Ω. What is the resistance of X?

Figure **E26.2**

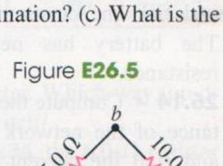


26.3 • A resistor with $R_1 = 30.0\ \Omega$ is connected to a battery that has negligible internal resistance and electrical energy is dissipated by R_1 at a rate of 34.0 W. If a second resistor with $R_2 = 18.0\ \Omega$ is connected in series with R_1, what is the total rate at which electrical energy is dissipated by the two resistors?

26.4 • A 34-Ω resistor and a 16-Ω resistor are connected in parallel, and the combination is connected across a 240-V dc line. (a) What is the resistance of the parallel combination? (b) What is the total current through the parallel combination? (c) What is the current through each resistor?

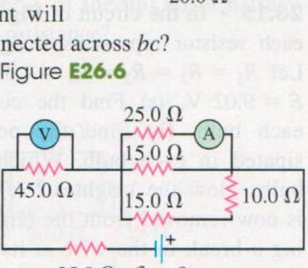
26.5 • A triangular array of resistors is shown in **Fig. E26.5**. What current will this array draw from a 30.0-V battery having negligible internal resistance if we connect it across (a) ab; (b) bc; (c) ac? (d) If the battery has an internal resistance of 5.00 Ω, what current will the array draw if the battery is connected across bc?

Figure **E26.5**



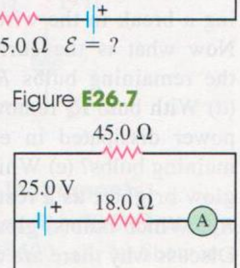
26.6 •• For the circuit shown in **Fig. E26.6** both meters are idealized, the battery has no appreciable internal resistance, and the ammeter reads 1.15 A. (a) What does the voltmeter read? (b) What is the emf $\mathcal{E}$ of the battery?

Figure **E26.6**



26.7 •• For the circuit shown in **Fig. E26.7** find the reading of the idealized ammeter if the battery has an internal resistance of 3.86 Ω.

Figure **E26.7**



26.8 • Three resistors having resistances of 1.60 Ω, 2.40 Ω, and 4.80 Ω are connected in parallel to a 28.0-V battery that has negligible internal resistance. Find (a) the equivalent resistance of the combination; (b) the current in each resistor; (c) the total current through the battery; (d) the voltage across each resistor; (e) the power dissipated in each resistor.

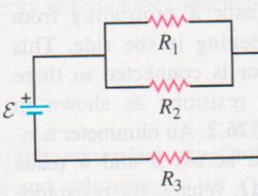
(f) Which resistor dissipates the most power: the one with the greatest resistance or the least resistance? Explain why this should be.

26.9 • Now the three resistors of Exercise 26.8 are connected in series to the same battery. Answer the same questions for this situation.

26.10 •• **Power Rating of a Resistor.** The *power rating* of a resistor is the maximum power the resistor can safely dissipate without too great a rise in temperature and hence damage to the resistor. (a) If the power rating of a 15-kΩ resistor is 5.0 W, what is the maximum allowable potential difference across the terminals of the resistor? (b) A 9.0-kΩ resistor is to be connected across a 120-V potential difference. What power rating is required? (c) A 100.0-Ω and a 150.0-Ω resistor, both rated at 2.00 W, are connected in series across a variable potential difference. What is the greatest this potential difference can be without overheating either resistor, and what is the rate of heat generated in each resistor under these conditions?

26.11 • In **Fig. E26.11**, $R_1 = 6.00\ \Omega$, $R_2 = 6.00\ \Omega$, and $R_3 = 7.00\ \Omega$. The battery has negligible internal resistance. The current I_2 through R_2 is 4.00 A. (a) What are the currents I_1 and I_3? (b) What is the emf of the battery?

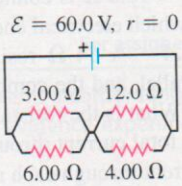
Figure **E26.11**



26.12 •• In Fig. E26.11 the battery has emf 25.0 V and negligible internal resistance. $R_1 = 2.00\ \Omega$. The current through R_1 is 2.00 A, and the current through $R_3 = 4.90$ A. What are the resistances R_2 and R_3?

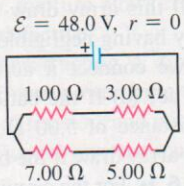
26.13 • Compute the equivalent resistance of the network in **Fig. E26.13**, and find the current in each resistor. The battery has negligible internal resistance.

Figure **E26.13**



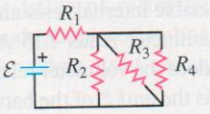
26.14 • Compute the equivalent resistance of the network in **Fig. E26.14**, and find the current in each resistor. The battery has negligible internal resistance.

Figure **E26.14**



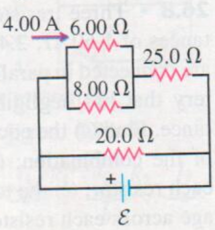
26.15 • In the circuit of **Fig. E26.15**, each resistor represents a light bulb. Let $R_1 = R_2 = R_3 = R_4 = 4.37\ \Omega$ and $\mathcal{E} = 9.02$ V. (a) Find the current in each bulb. (b) Find the power dissipated in each bulb. Which bulb or bulbs glow the brightest? (c) Bulb R_4 is now removed from the circuit, leaving a break in the wire at its position. Now what is the current in each of the remaining bulbs R_1, R_2, and R_3? (d) With bulb R_4 removed, what is the power dissipated in each of the remaining bulbs? (e) Which light bulb(s) glow brighter as a result of removing R_4? Which bulb(s) glow less brightly? Discuss why there are different effects on different bulbs.

Figure **E26.15**



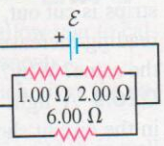
26.16 • Consider the circuit shown in **Fig. E26.16**. The current through the 6.00-Ω resistor is 4.00 A, in the direction shown. What are the currents through the 25.0-Ω and 20.0-Ω resistors?

Figure **E26.16**



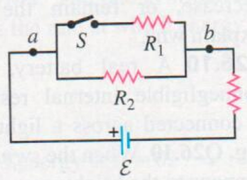
26.17 • In the circuit shown in **Fig. E26.17**, the voltage across the 2.00-Ω resistor is 12.0 V. What are the emf of the battery and the current through the 6.00-Ω resistor?

Figure **E26.17**



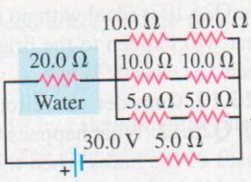
26.18 •• In the circuit shown in **Fig. E26.18**, $\mathcal{E} = 36.0$ V, $R_1 = 4.00\ \Omega$, $R_2 = 6.00\ \Omega$, and $R_3 = 3.00\ \Omega$. (a) What is the potential difference V_{ab} between points a and b when the switch S is open and when S is closed? (b) For each resistor, calculate the current through the resistor with S open and with S closed. For each resistor, does the current increase or decrease when S is closed?

Figure **E26.18**



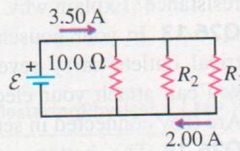
26.19 •• **CP** In the circuit in **Fig. E26.19**, a 20.0-Ω resistor is inside 100 g of pure water that is surrounded by insulating styrofoam. If the water is initially at 10.0°C, how long will it take for its temperature to rise to 57.0°C?

Figure **E26.19**



26.20 • In the circuit shown in **Fig. E26.20**, the rate at which R_1 is dissipating electrical energy is 15.0 W. (a) Find R_1 and R_2. (b) What is the emf of the battery? (c) Find the current through both R_2 and the 10.0-Ω resistor. (d) Calculate the total electrical power consumption in all the resistors and the electrical power delivered by the battery. Show that your results are consistent with conservation of energy.

Figure **E26.20**



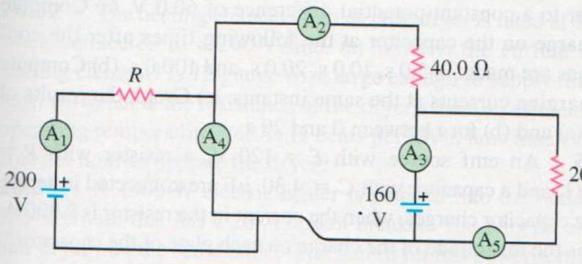
26.21 • **Light Bulbs in Series and in Parallel.** Two light bulbs have constant resistances of 400 Ω and 800 Ω. If the two light bulbs are connected in series across a 120-V line, find (a) the current through each bulb; (b) the power dissipated in each bulb; (c) the total power dissipated in both bulbs. The two light bulbs are now connected in parallel across the 120-V line. Find (d) the current through each bulb; (e) the power dissipated in each bulb; (f) the total power dissipated in both bulbs. (g) In each situation, which of the two bulbs glows the brightest? (h) In which situation is there a greater total light output from both bulbs combined?

26.22 • **Light Bulbs in Series.** A 60-W, 120-V light bulb and a 200-W, 120-V light bulb are connected in series across a 240-V line. Assume that the resistance of each bulb does not vary with current. (*Note:* This description of a light bulb gives the power it dissipates when connected to the stated potential difference; that is, a 25-W, 120-V light bulb dissipates 25 W when connected to a 120-V line.) (a) Find the current through the bulbs. (b) Find the power dissipated in each bulb. (c) One bulb burns out very quickly. Which one? Why?

Section 26.2 Kirchhoff's Rules

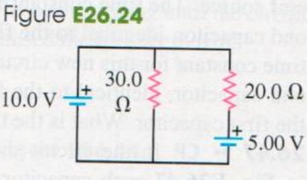
26.23 •• In the circuit shown in **Fig. E26.23**, ammeter A_1 reads 10.0 A and the batteries have no appreciable internal resistance. (a) What is the resistance of R? (b) Find the readings in the other ammeters.

Figure E26.23



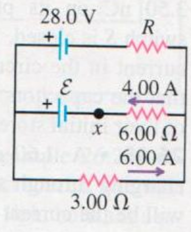
26.24 •• The batteries shown in the circuit in **Fig. E26.24** have negligibly small internal resistances. Find the current through (a) the 30.0-Ω resistor; (b) the 20.0-Ω resistor; (c) the 10.0-V battery.

Figure E26.24



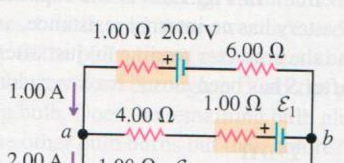
26.25 • In the circuit shown in **Fig. E26.25** find (a) the current in resistor R; (b) the resistance R; (c) the unknown emf $\mathcal{E}$. (d) If the circuit is broken at point x, what is the current in resistor R?

Figure E26.25



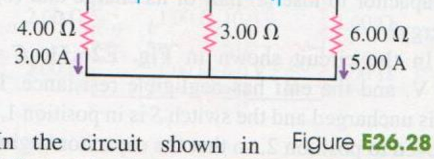
26.26 • Find the emfs $\mathcal{E}_1$ and $\mathcal{E}_2$ in the circuit of **Fig. E26.26**, and find the potential difference of point b relative to point a.

Figure E26.26



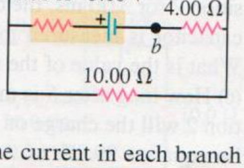
26.27 • In the circuit shown in **Fig. E26.27**, find (a) the current in the 3.00-Ω resistor; (b) the unknown emfs $\mathcal{E}_1$ and $\mathcal{E}_2$; (c) the resistance R. Note that three currents are given.

Figure E26.27



26.28 •• In the circuit shown in **Fig. E26.28**, find (a) the current in each branch and (b) the potential difference V_{ab} of point a relative to point b.

Figure E26.28

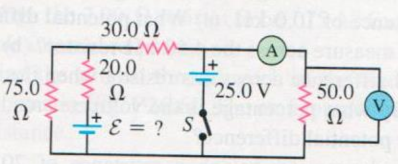


26.29 • The 10.00-V battery in Fig. E26.28 is removed from the circuit and reinserted with the opposite polarity, so that its positive terminal is now next to point a. The rest of the circuit is as shown in the figure. Find (a) the current in each branch and (b) the potential difference V_{ab} of point a relative to point b.

26.30 • The 5.00-V battery in Fig. E26.28 is removed from the circuit and replaced by a 15.00-V battery, with its negative terminal next to point b. The rest of the circuit is as shown in the figure. Find (a) the current in each branch and (b) the potential difference V_{ab} of point a relative to point b.

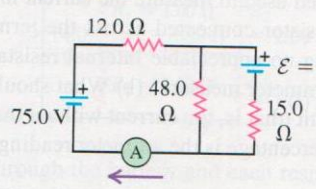
26.31 •• In the circuit shown in **Fig. E26.31** the batteries have negligible internal resistance and the meters are both idealized. With the switch S open, the voltmeter reads 17.0 V. (a) Find the emf $\mathcal{E}$ of the battery. (b) What will the ammeter read when the switch is closed?

Figure E26.31



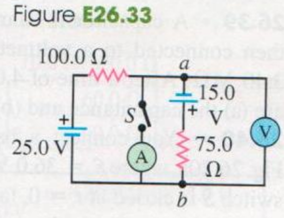
26.32 •• In the circuit shown in **Fig. E26.32** both batteries have insignificant internal resistance and the idealized ammeter reads 1.80 A in the direction shown. Find the emf $\mathcal{E}$ of the battery. Is the polarity shown correct?

Figure E26.32



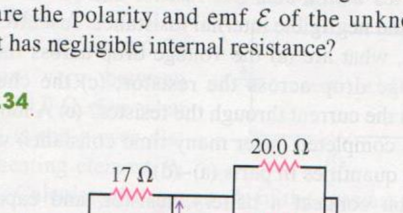
26.33 • In the circuit shown in **Fig. E26.33** all meters are idealized and the batteries have no appreciable internal resistance. (a) Find the reading of the voltmeter with the switch S open. Which point is at a higher potential: a or b? (b) With S closed, find the reading of the voltmeter and the ammeter. Which way (up or down) does the current flow through the switch?

Figure E26.33



26.34 •• In the circuit shown in **Fig. E26.34**, the 6.0-Ω resistor is consuming energy at a rate of 23 J/s when the current through it flows as shown. (a) Find the current through the ammeter A. (b) What are the polarity and emf $\mathcal{E}$ of the unknown battery, assuming it has negligible internal resistance?

Figure E26.34

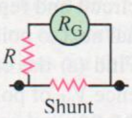


Section 26.3 Electrical Measuring Instruments

26.35 • The resistance of a galvanometer coil is 30.0 Ω, and the current required for full-scale deflection is 500 μA. (a) Show in a diagram how to convert the galvanometer to an ammeter reading 25.0 mA full scale, and compute the shunt resistance. (b) Show how to convert the galvanometer to a voltmeter reading 500 mV full scale, and compute the series resistance.

26.36 • The resistance of the coil of a pivoted-coil galvanometer is 9.99 Ω, and a current of 0.0250 A causes it to deflect full scale. We want to convert this galvanometer to an ammeter reading 20.0 A full scale. The only shunt available has a resistance of 0.0300 Ω. What resistance R must be connected in series with the coil (**Fig. E26.36**)?

Figure **E26.36**



26.37 • A circuit consists of a series combination of 5.50-kΩ and 4.50-kΩ resistors connected across a 50.0-V battery having negligible internal resistance. You want to measure the true potential difference (that is, the potential difference without the meter present) across the 4.50-kΩ resistor using a voltmeter having an internal resistance of 10.0 kΩ. (a) What potential difference does the voltmeter measure across the 4.50-kΩ resistor? (b) What is the *true* potential difference across this resistor when the meter is not present? (c) By what percentage is the voltmeter reading in error from the true potential difference?

26.38 • A galvanometer having a resistance of 20.0 Ω has a 1.00-Ω shunt resistance installed to convert it to an ammeter. It is then used to measure the current in a circuit consisting of a 10.0-Ω resistor connected across the terminals of a 25.0-V battery having no appreciable internal resistance. (a) What current does the ammeter measure? (b) What should be the *true* current in the circuit (that is, the current without the ammeter present)? (c) By what percentage is the ammeter reading in error from the *true* current?

Section 26.4 *R-C* Circuits

26.39 • A capacitor is charged to a potential of 12.0 V and is then connected to a voltmeter having an internal resistance of 3.40 MΩ. After a time of 4.00 s the voltmeter reads 3.0 V. What are (a) the capacitance and (b) the time constant of the circuit?

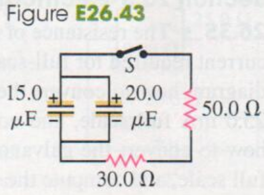
26.40 •• You connect a battery, resistor, and capacitor as in Fig. 26.20a, where $\mathcal{E} = 36.0$ V, $C = 5.00$ μF, and $R = 120$ Ω. The switch S is closed at $t = 0$. (a) When the voltage across the capacitor is 8.00 V, what is the magnitude of the current in the circuit? (b) At what time t after the switch is closed is the voltage across the capacitor 8.00 V? (c) When the voltage across the capacitor is 8.00 V, at what rate is energy being stored in the capacitor?

26.41 • A 5.20-μF capacitor that is initially uncharged is connected in series with a 5.20-kΩ resistor and an emf source with $\mathcal{E} = 225$ V and negligible internal resistance. Just after the circuit is completed, what are (a) the voltage drop across the capacitor; (b) the voltage drop across the resistor; (c) the charge on the capacitor; (d) the current through the resistor? (e) A long time after the circuit is completed (after many time constants) what are the values of the quantities in parts (a)–(d)?

26.42 •• You connect a battery, resistor, and capacitor as in Fig. 26.20a, where $R = 12.0$ Ω and $C = 5.00 \times 10^{-6}$ F. The switch S is closed at $t = 0$. When the current in the circuit has magnitude 3.00 A, the charge on the capacitor is 40.0×10^{-6} C. (a) What is the emf of the battery? (b) At what time t after the switch is closed is the charge on the capacitor equal to 40.0×10^{-6} C? (c) When the current has magnitude 3.00 A, at what rate is energy being (i) stored in the capacitor, (ii) supplied by the battery?

26.43 •• **CP** In the circuit shown in **Fig. E26.43** both capacitors are initially charged to 50.0 V. (a) How long after closing the switch S will the potential across each capacitor be reduced to 15.0 V, and (b) what will be the current at that time?

Figure **E26.43**



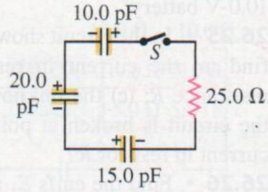
26.44 • A 12.6-μF capacitor is connected through a 0.895-MΩ resistor to a constant potential difference of 60.0 V. (a) Compute the charge on the capacitor at the following times after the connections are made: 0, 5.0 s, 10.0 s, 20.0 s, and 100.0 s. (b) Compute the charging currents at the same instants. (c) Graph the results of parts (a) and (b) for t between 0 and 20 s.

26.45 • An emf source with $\mathcal{E} = 120$ V, a resistor with $R = 72.0$ Ω, and a capacitor with $C = 4.30$ μF are connected in series. As the capacitor charges, when the current in the resistor is 0.900 A, what is the magnitude of the charge on each plate of the capacitor?

26.46 • A resistor and a capacitor are connected in series to an emf source. The time constant for the circuit is 0.780 s. (a) A second capacitor, identical to the first, is added in series. What is the time constant for this new circuit? (b) In the original circuit a second capacitor, identical to the first, is connected in parallel with the first capacitor. What is the time constant for this new circuit?

26.47 •• **CP** In the circuit shown in **Fig. E26.47** each capacitor initially has a charge of magnitude 3.50 nC on its plates. After the switch S is closed, what will be the current in the circuit at the instant that the capacitors have lost 80.0% of their initial stored energy?

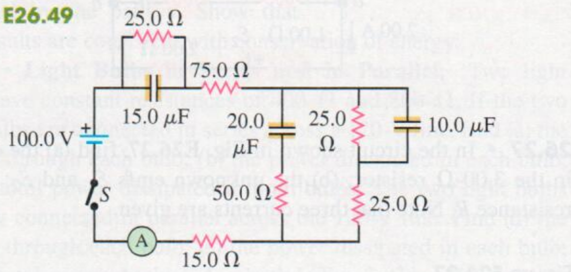
Figure **E26.47**



26.48 • A 1.60-μF capacitor is charging through a 14.0-Ω resistor using a 10.0-V battery. What will be the current when the capacitor has acquired $\frac{1}{4}$ of its maximum charge? Will it be $\frac{1}{4}$ of the maximum current?

26.49 • In the circuit in **Fig. E26.49** the capacitors are initially uncharged, the battery has no internal resistance, and the ammeter is idealized. Find the ammeter reading (a) just after the switch S is closed and (b) after S has been closed for a very long time.

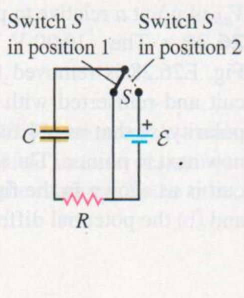
Figure **E26.49**



26.50 • A 12.0-μF capacitor is charged to a potential of 50.0 V and then discharged through a 225-Ω resistor. How long does it take the capacitor to lose (a) half of its charge and (b) half of its stored energy?

26.51 • In the circuit shown in **Fig. E26.51**, $C = 5.90$ μF, $\mathcal{E} = 28.0$ V, and the emf has negligible resistance. Initially the capacitor is uncharged and the switch S is in position 1. The switch is then moved to position 2, so that the capacitor begins to charge. (a) What will be the charge on the capacitor a long time after S is moved to position 2? (b) After S has been in position 2 for 3.00 ms, the charge on the capacitor is measured to be 110 μC. What is the value of the resistance R? (c) How long after S is moved to position 2 will the charge on the capacitor be equal to 99.0% of the final value found in part (a)?

Figure **E26.51**



Section 26.5 Power Distribution Systems

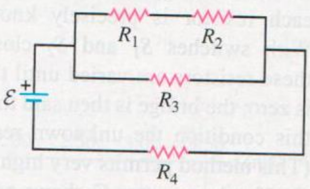
26.52 • The heating element of an electric dryer is rated at 4.1 kW when connected to a 240-V line. (a) What is the current in the heating element? Is 12-gauge wire large enough to supply this current? (b) What is the resistance of the dryer's heating element at its operating temperature? (c) At 11 cents per kWh, how much does it cost per hour to operate the dryer?

26.53 • A 1500-W electric heater is plugged into the outlet of a 120-V circuit that has a 20-A circuit breaker. You plug an electric hair dryer into the same outlet. The hair dryer has power settings of 600 W, 900 W, 1200 W, and 1500 W. You start with the hair dryer on the 600-W setting and increase the power setting until the circuit breaker trips. What power setting caused the breaker to trip?

PROBLEMS

26.54 •• In Fig. P26.54, the battery has negligible internal resistance and $\mathcal{E} = 48.0$ V. $R_1 = R_2 = 3.70\ \Omega$ and $R_4 = 4.00\ \Omega$. What must the resistance R_3 be for the resistor network to dissipate electrical energy at a rate of 270 W?

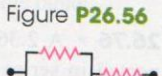
Figure P26.54



26.55 • The two identical light bulbs in Example 26.2 (Section 26.1) are connected in parallel to a different source, one with $\mathcal{E} = 8.0$ V and internal resistance 0.7 Ω. Each light bulb has a resistance $R = 2.0\ \Omega$ (assumed independent of the current through the bulb). (a) Find the current through each bulb, the potential difference across each bulb, and the power delivered to each bulb. (b) Suppose one of the bulbs burns out, so that its filament breaks and current no longer flows through it. Find the power delivered to the remaining bulb. Does the remaining bulb glow more or less brightly after the other bulb burns out than before?

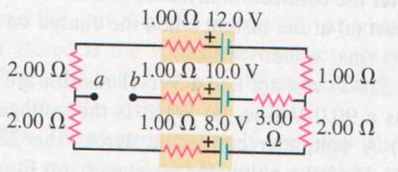
26.56 •• Each of the three resistors in Fig. P26.56 has a resistance of 3.5 Ω and can dissipate a maximum of 34 W without becoming excessively heated. What is the maximum power the circuit can dissipate?

Figure P26.56



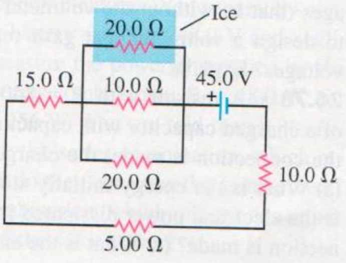
26.57 •• (a) Find the potential of point a with respect to point b in Fig. P26.57. (b) If points a and b are connected by a wire with negligible resistance, find the current in the 8.0-V battery.

Figure P26.57



26.58 •• **CP** For the circuit shown in Fig. P26.58 a 20.0-Ω resistor is embedded in a large block of ice at 0.00°C, and the battery has negligible internal resistance. At what rate (in g/s) is this circuit melting the ice? (The latent heat of fusion for ice is 3.34×10^5 J/kg.)

Figure P26.58



26.59 • Calculate the three currents I_1, I_2, and I_3 indicated in the circuit diagram shown in Fig. P26.59.

Figure P26.59

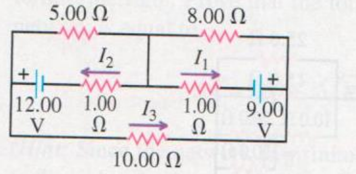
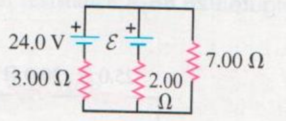


Figure P26.60



26.60 ••• What must the emf $\mathcal{E}$ in Fig. P26.60 be in order for the current through the 7.00-Ω resistor to be 1.75 A? Each emf source has negligible internal resistance.

26.61 • Find the current through each of the three resistors of the circuit shown in Fig. P26.61. The emf sources have negligible internal resistance.

Figure P26.61

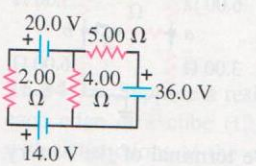
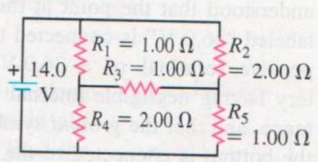


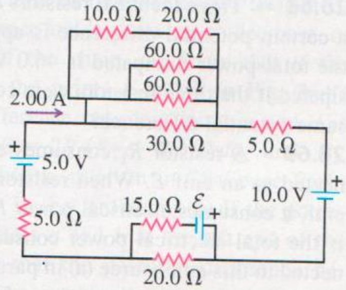
Figure P26.62



26.62 • (a) Find the current through the battery and each resistor in the circuit shown in Fig. P26.62. (b) What is the equivalent resistance of the resistor network?

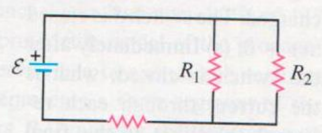
26.63 •• Consider the circuit shown in Fig. P26.63. (a) What must the emf $\mathcal{E}$ of the battery be in order for a current of 2.00 A to flow through the 5.00-V battery as shown? Is the polarity of the battery correct as shown? (b) How long does it take for 60.0 J of thermal energy to be produced in the 10.0-Ω resistor?

Figure P26.63



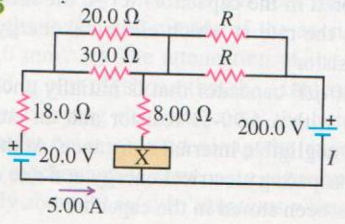
26.64 •• In the circuit shown in Fig. P26.64, $\mathcal{E} = 24.0$ V, $R_1 = 6.00\ \Omega$, $R_3 = 12.0\ \Omega$, and R_2 can vary between 3.00 Ω and 24.0 Ω. For what value of R_2 is the power dissipated by heating element R_1 the greatest? Calculate the magnitude of the greatest power.

Figure P26.64



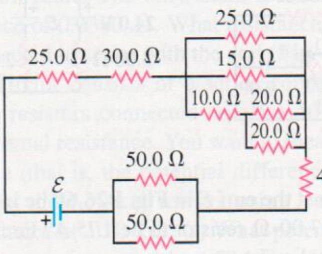
26.65 • In the circuit shown in Fig. P26.65, the current in the 20.0-V battery is 5.00 A in the direction shown and the voltage across the 8.00-Ω resistor is 17.0 V, with the lower end of the resistor at higher potential. Find (a) the emf (including its polarity) of the battery X; (b) the current I through the 200.0-V battery (including its direction); (c) the resistance R.

Figure P26.65



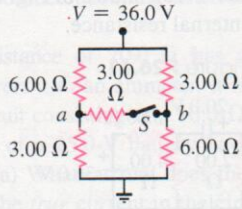
26.66 ••• In the circuit shown in **Fig. P26.66** all the resistors are rated at a maximum power of 2.00 W. What is the maximum emf $\mathcal{E}$ that the battery can have without burning up any of the resistors?

Figure **P26.66**



26.67 • **Figure P26.67** employs a convention often used in circuit diagrams. The battery (or other power supply) is not shown explicitly. It is understood that the point at the top, labeled "36.0 V," is connected to the positive terminal of a 36.0-V battery having negligible internal resistance, and that the *ground* symbol at the bottom is connected to the negative terminal of the battery. The circuit is completed through the battery, even though it is not shown. (a) What is the potential difference V_{ab}, the potential of point *a* relative to point *b*, when the switch *S* is open? (b) What is the current through *S* when it is closed? (c) What is the equivalent resistance when *S* is closed?

Figure **P26.67**

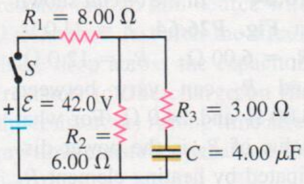


26.68 •• Three identical resistors are connected in series. When a certain potential difference is applied across the combination, the total power dissipated is 46.0 W. What power would be dissipated if the three resistors were connected in parallel across the same potential difference?

26.69 • A resistor R_1 consumes electrical power P_1 when connected to an emf $\mathcal{E}$. When resistor R_2 is connected to the same emf, it consumes electrical power P_2. In terms of P_1 and P_2, what is the total electrical power consumed when they are both connected to this emf source (a) in parallel and (b) in series?

26.70 • The capacitor in **Fig. P26.70** is initially uncharged. The switch *S* is closed at $t = 0$. (a) Immediately after the switch is closed, what is the current through each resistor? (b) What is the final charge on the capacitor?

Figure **P26.70**

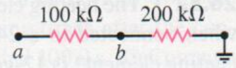


26.71 •• A 1.21-μF capacitor that is initially uncharged is connected in series with a 5.41-kΩ resistor and an emf source with $\mathcal{E} = 57.8$ V and negligible internal resistance. The circuit is completed at $t = 0$. (a) Just after the circuit is completed, what is the rate at which electrical energy is being dissipated in the resistor? (b) At what value of *t* is the rate at which electrical energy is being dissipated in the resistor equal to the rate at which electrical energy is being stored in the capacitor? (c) At the time calculated in part (b), what is the rate at which electrical energy is being dissipated in the resistor?

26.72 •• A 5.80-μF capacitor that is initially uncharged is connected in series with a 4.90-Ω resistor and an emf source with $\mathcal{E} = 53.0$ V and negligible internal resistance. At the instant when the resistor is dissipating electrical energy at a rate of 287 W, how much energy has been stored in the capacitor?

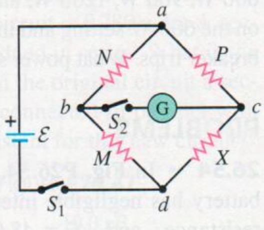
26.73 • Point *a* in **Fig. P26.73** is maintained at a constant potential of 400 V above ground. (See Problem 26.67.) (a) What is the reading of a voltmeter with the proper range and with resistance 5.00×10^4 Ω when connected between point *b* and ground? (b) What is the reading of a voltmeter with resistance 5.00×10^6 Ω? (c) What is the reading of a voltmeter with infinite resistance?

Figure **P26.73**



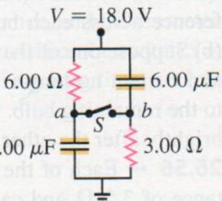
26.74 •• **The Wheatstone Bridge.** The circuit shown in **Fig. P26.74**, called a *Wheatstone bridge*, is used to determine the value of an unknown resistor *X* by comparison with three resistors *M*, *N*, and *P* whose resistances can be varied. For each setting, the resistance of each resistor is precisely known. With switches S_1 and S_2 closed, these resistors are varied until the current in the galvanometer G is zero; the bridge is then said to be *balanced*. (a) Show that under this condition the unknown resistance is given by $X = MP/N$. (This method permits very high precision in comparing resistors.) (b) If galvanometer G shows zero deflection when $M = 860$ Ω, $N = 14.00$ Ω, and $P = 33.38$ Ω, what is the unknown resistance *X*?

Figure **P26.74**



26.75 • (See Problem 26.67.) (a) What is the potential of point *a* with respect to point *b* in **Fig. P26.75** when the switch *S* is open? (b) Which point, *a* or *b*, is at the higher potential? (c) What is the final potential of point *b* with respect to ground when *S* is closed? (d) How much does the charge on each capacitor change when *S* is closed?

Figure **P26.75**



26.76 • A 2.36-μF capacitor that is initially uncharged is connected in series with a 5.86-Ω resistor and an emf source with $\mathcal{E} = 120$ V and negligible internal resistance. (a) Just after the connection is made, what are (i) the rate at which electrical energy is being dissipated in the resistor; (ii) the rate at which the electrical energy stored in the capacitor is increasing; (iii) the electrical power output of the source? How do the answers to parts (i), (ii), and (iii) compare? (b) Answer the same questions as in part (a) at a long time after the connection is made. (c) Answer the same questions as in part (a) at the instant when the charge on the capacitor is one-half its final value.

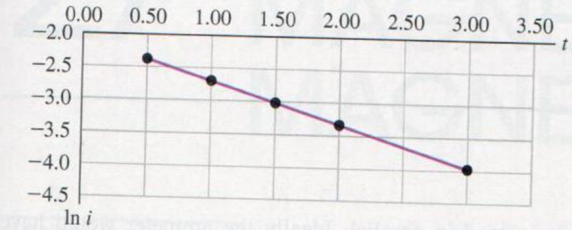
26.77 • A 228-Ω resistor and a 591-Ω resistor are connected in series across a 90.0-V line. (a) What is the voltage across each resistor? (b) A voltmeter connected across the 228-Ω resistor reads 23.6 V. Find the voltmeter resistance. (c) Find the reading of the same voltmeter if it is connected across the 591-Ω resistor. (d) The readings on this voltmeter are lower than the "true" voltages (that is, without the voltmeter present). Would it be possible to design a voltmeter that gave readings *higher* than the "true" voltages? Explain.

26.78 • A resistor with $R = 840$ Ω is connected to the plates of a charged capacitor with capacitance $C = 4.58$ μF. Just before the connection is made, the charge on the capacitor is 8.10 mC. (a) What is the energy initially stored in the capacitor? (b) What is the electrical power dissipated in the resistor just after the connection is made? (c) What is the electrical power dissipated in the resistor at the instant when the energy stored in the capacitor has decreased to half the value calculated in part (a)?

26.79 • A capacitor that is initially uncharged is connected in series with a resistor and an emf source with $\mathcal{E} = 100$ V and negligible internal resistance. Just after the circuit is completed, the current through the resistor is 6.3×10^{-5} A. The time constant for the circuit is 6.5 s. What are the resistance of the resistor and the capacitance of the capacitor?

26.80 •• **DATA** You set up the circuit shown in Fig. 26.22a, where $R = 196\ \Omega$. You close the switch at time $t = 0$ and measure the magnitude i of the current in the resistor R as a function of time t since the switch was closed. Your results are shown in **Fig. P26.80**, where you have chosen to plot $\ln i$ as a function of t. (a) Explain why your data points lie close to a straight line. (b) Use the graph in Fig. P26.80 to calculate the capacitance C and the initial charge Q_0 on the capacitor. (c) When $i = 0.0500$ A, what is the charge on the capacitor? (d) When $q = 0.500 \times 10^{-4}$ C, what is the current in the resistor?

Figure **P26.80**



26.81 •• **DATA** You set up the circuit shown in Fig. 26.20, where $C = 5.00 \times 10^{-6}$ F. At time $t = 0$, you close the switch and then measure the charge q on the capacitor as a function of the current i in the resistor. Your results are given in the table:

i (mA)	56.0	48.0	40.0	32.0	24.0
q (μC)	10.1	19.8	30.2	40.0	49.9

(a) Graph q as a function of i. Explain why the data points, when plotted this way, fall close to a straight line. Find the slope and y-intercept of the straight line that gives the best fit to the data. (b) Use your results from part (a) to calculate the resistance R of the resistor and the emf $\mathcal{E}$ of the battery. (c) At what time t after the switch is closed is the voltage across the capacitor equal to 10.0 V? (d) When the voltage across the capacitor is 4.00 V, what is the voltage across the resistor?

26.82 •• **DATA** The electronics supply company where you work has two different resistors, R_1 and R_2, in its inventory, and you must measure the values of their resistances. Unfortunately, stock is low, and all you have are R_1 and R_2 in parallel and in series—and you can't separate these two resistor combinations. You separately connect each resistor network to a battery with emf 48.0 V and negligible internal resistance and measure the power P supplied by the battery in both cases. For the series combination, $P = 48.0$ W; for the parallel combination, $P = 256$ W. You are told that $R_1 > R_2$. (a) Calculate R_1 and R_2. (b) For the series combination, which resistor consumes more power, or do they consume the same power? Explain. (c) For the parallel combination, which resistor consumes more power, or do they consume the same power?

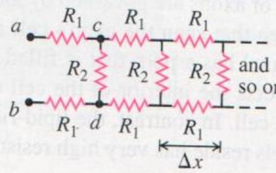
CHALLENGE PROBLEMS

26.83 ••• **An Infinite Network.** As shown in **Fig. P26.83**, a network of resistors of resistances R_1 and R_2 extends to infinity toward the right. Prove that the total resistance R_T of the infinite network is equal to

$$R_T = R_1 + \sqrt{R_1^2 + 2R_1R_2}$$

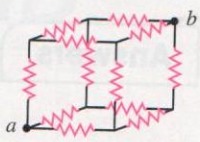
(*Hint:* Since the network is infinite, the resistance of the network to the right of points c and d is also equal to R_T.)

Figure **P26.83**



26.84 ••• Suppose a resistor R lies along each edge of a cube (12 resistors in all) with connections at the corners. Find the equivalent resistance between two diagonally opposite corners of the cube (points a and b in **Fig. P26.84**).

Figure **P26.84**



26.85 ••• **BIO** **Attenuator Chains and Axons.** The infinite network of resistors shown in Fig. P26.83 is known as an *attenuator chain*, since this chain of resistors causes the potential difference between the upper and lower wires to decrease, or attenuate, along the length of the chain. (a) Show that if the potential difference between the points a and b in Fig. 26.83 is V_{ab}, then the potential difference between points c and d is $V_{cd} = V_{ab}/(1 + \beta)$, where $\beta = 2R_1(R_T + R_2)/R_TR_2$ and R_T, the total resistance of the network, is given in Challenge Problem 26.83. (See the hint given in that problem.) (b) If the potential difference between terminals a and b at the left end of the infinite network is V_0, show that the potential difference between the upper and lower wires n segments from the left end is $V_n = V_0/(1 + \beta)^n$. If $R_1 = R_2$, how many segments are needed to decrease the potential difference V_n to less than 1.0% of V_0? (c) An infinite attenuator chain provides a model of the propagation of a voltage pulse along a nerve fiber, or axon. Each segment of the network in Fig. P26.83 represents a short segment of the axon of length Δx. The resistors R_1 represent the resistance of the fluid inside and outside the membrane wall of the axon. The resistance of the membrane to current flowing through the wall is represented by R_2. For an axon segment of length $\Delta x = 1.0\ \mu$m, $R_1 = 6.4 \times 10^3\ \Omega$ and $R_2 = 8.0 \times 10^8\ \Omega$ (the membrane wall is a good insulator). Calculate the total resistance R_T and β for an infinitely long axon. (This is a good approximation, since the length of an axon is much greater than its width; the largest axons in the human nervous system are longer than 1 m but only about 10^{-7} m in radius.) (d) By what fraction does the potential difference between the inside and outside of the axon decrease over a distance of 2.0 mm? (e) The attenuation of the potential difference calculated in part (d) shows that the axon cannot simply be a passive, current-carrying electrical cable; the potential difference must periodically be reinforced along the axon's length. This reinforcement mechanism is slow, so a signal propagates along the axon at only about 30 m/s. In situations where faster response is required, axons are covered with a segmented sheath of fatty myelin. The segments are about 2 mm long, separated by gaps called the *nodes of Ranvier.* The myelin increases the resistance of a 1.0-μm-long segment of the membrane to $R_2 = 3.3 \times 10^{12}\ \Omega$. For such a myelinated axon, by what fraction does the potential difference between the inside and outside of the axon decrease over the distance from one node of Ranvier to the next? This smaller attenuation means the propagation speed is increased.

PASSAGE PROBLEMS

BIO NERVE CELLS AND *R-C* CIRCUITS. The portion of a nerve cell that conducts signals is called an *axon.* Many of the electrical properties of axons are governed by ion channels, which are protein molecules that span the axon's cell membrane. When open, each ion channel has a pore that is filled with fluid of low resistivity and connects the interior of the cell electrically to the medium outside the cell. In contrast, the lipid-rich cell membrane in which ion channels reside has very high resistivity.

26.86 Assume that a typical open ion channel spanning an axon's membrane has a resistance of $1 \times 10^{11}\ \Omega$. We can model this ion channel, with its pore, as a 12-nm-long cylinder of radius 0.3 nm. What is the resistivity of the fluid in the pore? (a) 10 $\Omega \cdot$ m; (b) 6 $\Omega \cdot$ m; (c) 2 $\Omega \cdot$ m; (d) 1 $\Omega \cdot$ m.

26.87 In a simple model of an axon conducting a nerve signal, ions move across the cell membrane through open ion channels, which act as purely resistive elements. If a typical current density (current per unit cross-sectional area) in the cell membrane is 5 mA/cm^2 when the voltage across the membrane (the *action potential*) is 50 mV, what is the number density of open ion channels in the membrane? (a) 1/cm^2; (b) 10/cm^2; (c) 10/mm^2; (d) 100/μm^2.

26.88 Cell membranes across a wide variety of organisms have a capacitance per unit area of 1 μF/cm^2. For the electrical signal in a nerve to propagate down the axon, the charge on the membrane "capacitor" must change. What time constant is required when the ion channels are open? (a) 1 μs; (b) 10 μs; (c) 100 μs; (d) 1 ms.

Answers

Chapter Opening Question ?

(ii) The potential difference V is the same across resistors connected in parallel. However, there is a different current I through each resistor if the resistances R are different: $I = V/R$.

Test Your Understanding Questions

26.1 (a), (c), (d), (b) Here's why: The three resistors in Fig. 26.1a are in series, so $R_{eq} = R + R + R = 3R$. In Fig. 26.1b the three resistors are in parallel, so $1/R_{eq} = 1/R + 1/R + 1/R = 3/R$ and $R_{eq} = R/3$. In Fig. 26.1c the second and third resistors are in parallel, so their equivalent resistance R_{23} is given by $1/R_{23} = 1/R + 1/R = 2/R$; hence $R_{23} = R/2$. This combination is in series with the first resistor, so the three resistors together have equivalent resistance $R_{eq} = R + R/2 = 3R/2$. In Fig. 26.1d the second and third resistors are in series, so their equivalent resistance is $R_{23} = R + R = 2R$. This combination is in parallel with the first resistor, so the equivalent resistance of the three-resistor combination is given by $1/R_{eq} = 1/R + 1/2R = 3/2R$. Hence $R_{eq} = 2R/3$.

26.2 loop *cbdac*, no Equation (2) minus Eq. (1) gives $-I_2(1\ \Omega) - (I_2 + I_3)(2\ \Omega) + (I_1 - I_3)(1\ \Omega) + I_1(1\ \Omega) = 0$. We can obtain this equation by applying the loop rule around the path from c to b to d to a to c in Fig. 26.12. This isn't an independent equation, so it would not have helped with the solution of Example 26.6.

26.3 (a) (ii), (b) (iii) An ammeter must always be placed in series with the circuit element of interest, and a voltmeter must always be placed in parallel. Ideally the ammeter would have zero resistance and the voltmeter would have infinite resistance so that their presence would have no effect on either the resistor current or the voltage. Neither of these idealizations is possible, but the ammeter resistance should be much less than 2 Ω and the voltmeter resistance should be much greater than 2 Ω.

26.4 (ii) After one time constant, $t = RC$ and the initial charge Q_0 has decreased to $Q_0e^{-t/RC} = Q_0e^{-RC/RC} = Q_0e^{-1} = Q_0/e$. Hence the stored energy has decreased from $Q_0^2/2C$ to $(Q_0/e)^2/2C = Q_0^2/2Ce^2$, a fraction $1/e^2 = 0.135$ of its initial value. This result doesn't depend on the initial value of the energy.

26.5 no This is a very dangerous thing to do. The circuit breaker will allow currents up to 40 A, double the rated value of the wiring. The amount of power $P = I^2R$ dissipated in a section of wire can therefore be up to four times the rated value, so the wires could get very warm and start a fire. (This assumes the resistance R remains unchanged. In fact, R increases with temperature, so the dissipated power can be even greater, and more dangerous, than we have estimated.)

Bridging Problem

(a) 9.39 J (b) 2.02×10^4 W (c) 4.65×10^{-4} s
(d) 7.43×10^3 W

The University of Jordan / Physics Department

General Physics (102) / Chapter 26 / Sears and Zemansky

Sample Solutions / Prof. Mahmoud Jaghoub

أ. د. محمود الجاغوب

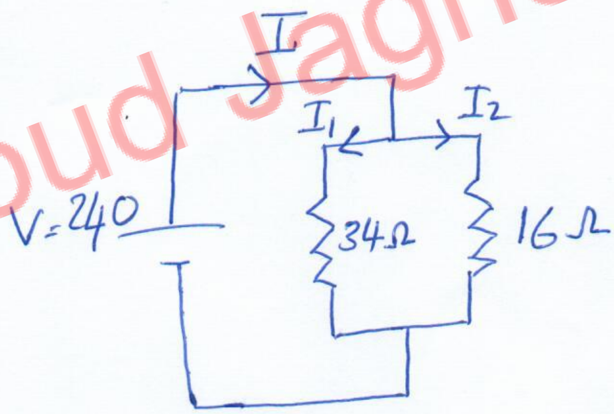
Q4] (a) $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow R_{eq} = \frac{(16)(34)}{16+34} \approx 10.88\ \Omega$

(b) $V = I R_{eq} \Rightarrow I = \frac{V}{R_{eq}} = \frac{240}{10.88} \approx 22\ A$.

$I = I_1 + I_2 = 22$ — (1)

$I_1(34) = I_2(16)$

$\Rightarrow I_2 = \frac{34}{16} I_1 = \frac{17}{8} I_1$

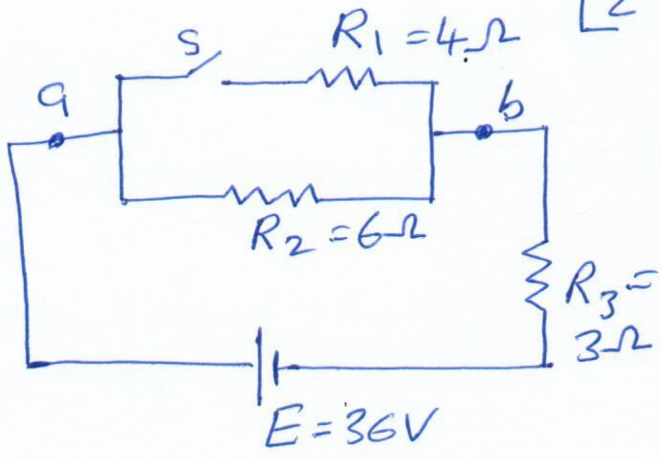


$\therefore$ using (1) $I_1 + \frac{17}{8} I_1 = 22$

$I_1 \left(\frac{8+17}{8}\right) = 22 \Rightarrow I_1 = 7.04\ A$.

$\Rightarrow I_2 = 14.96\ A$.

Q18] L2



(a) when switch S is open no current passes through R_1.

In this case

$R_{eq} = R_2 + R_3 = 9\Omega$

$\Rightarrow 36 = I(9) \Rightarrow I = 4\,A.$

$V_{ab} = I R_2 = (4)(6) = 24\,V$

---

when switch S is closed $\Rightarrow$ R_1 and R_2 are in parallel

$\frac{1}{R'_{eq}} = \frac{1}{4} + \frac{1}{6} = \frac{6+4}{24} \Rightarrow R'_{eq} = 2.4\Omega$

R'_{eq} is in series with $R_3 \Rightarrow R_{eq} = R'_{eq} + R_3 = 5.4\Omega$

$I = \frac{36}{5.4} \simeq 6.67\,A \Rightarrow V_{ab} = I R'_{eq} = 16V$

(b) when switch S is open the same current $I = 4A$ passes through R_2 and R_3.

---

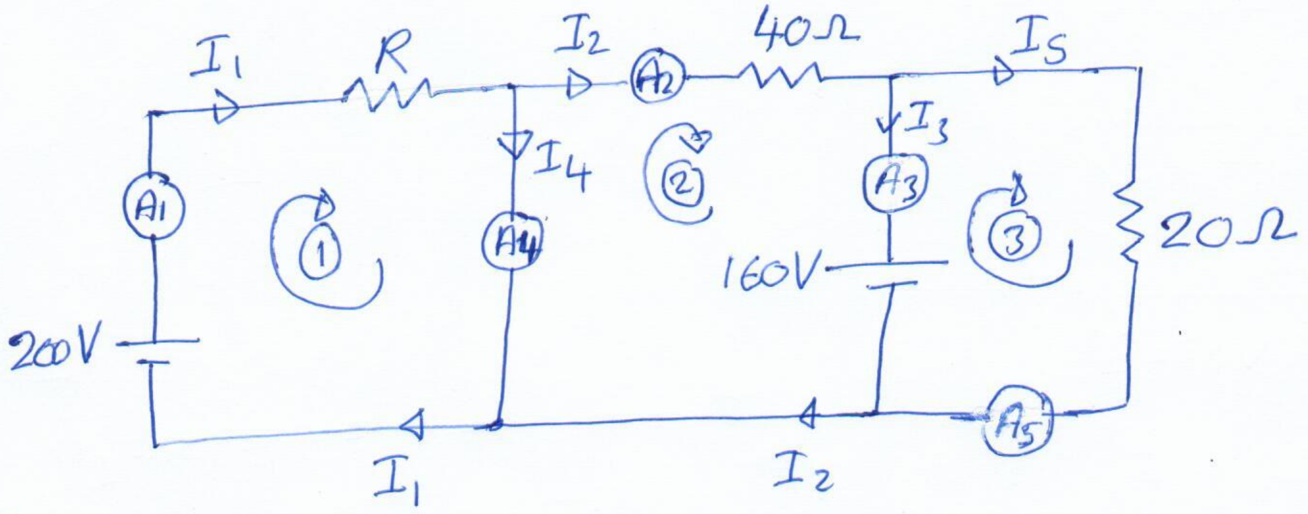
when switch S is closed the current that passes through R_3 is $I = 6.67\,A$

$V_{ab} = 16 = I_1 R_1 = I_2 R_2$

$\therefore I_1 = \frac{16}{R_1} = \frac{16}{4} = 4A$, $I_2 = \frac{16}{6} = 2.67$

NOTE: $I_1 + I_2 = I = 6.67A$.

Q23] The figure can be drawn as



(a)
loop ① $200 - I_1 R = 0 \Rightarrow R = \frac{200}{10} = 20\,\Omega$.

(b) loop ② $-40 I_2 - 160 = 0$

$\therefore I_2 = -4A$ (this means it flows from right to left opposite to the direction shown)

$I_1 = I_2 + I_4$

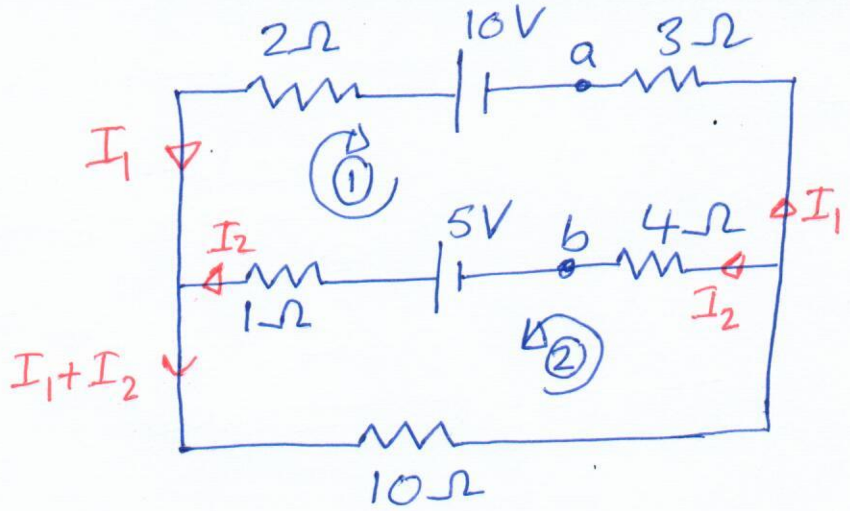
$10 = -4 + I_4 \Rightarrow I_4 = 14A$ (direction correct as value is positive).

loop ③ $160 - 20 I_5 = 0 \Rightarrow I_5 = 8A$

$I_2 = I_3 + I_5 \Rightarrow I_3 = I_2 - I_5 = -4 - 8 = -12A$.

current flows upwards.

Q28 4



loop ①

$-4I_2 + 5 - I_2 + 2I_1 - 10 + 3I_1 = 0$

$-5I_2 - 5 + 5I_1 = 0$

$\therefore \; I_1 - I_2 - 1 = 0 \quad — ①$

loop ② $\; -4I_2 + 5 - I_2 - (I_1 + I_2)(10) = 0$

$-15I_2 - 10I_1 + 5 = 0$

$-3I_2 - 2I_1 + 1 = 0 \quad — ②$

$① + ② \Rightarrow \; -I_1 - 4I_2 = 0$

$\Rightarrow \boxed{I_2 = -\frac{1}{4} I_1}$

in $① \Rightarrow \; I_1 - \left(-\frac{1}{4}I_1\right) - 1 = 0 \Rightarrow \frac{5}{4} I_1 = 1$

$\therefore I_1 = \frac{4}{5} = 0.8 \text{ A}$

$\Rightarrow I_2 = -\frac{1}{4}(0.8) = -0.2 \text{ A}$

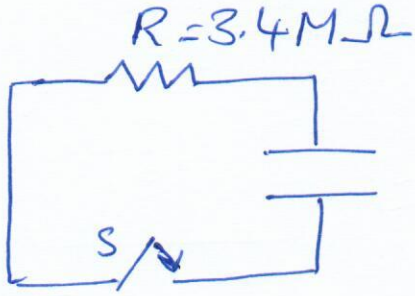
$\Rightarrow I_1 + I_2 = 0.8 - 0.2 = 0.6 \text{ A}.$

$V_a + 3I_1 - 4I_2 = V_b \Rightarrow V_b - V_a = 4I_2 - 3I_1$

$V_b - V_a = 4(-0.2) - 3(0.8) = -3.2 \text{ V}$

V_a is 3.2 V higher than V_b.

Q39] The circuit is equivalent to a discharge circuit



Initial voltage of capacitor (at $t=0$) is $12\ V = V_0$

after 3 s $V = 3$ Volt.

$$q = Q_0 e^{-t/RC}$$

$$/C \Rightarrow \frac{q}{C} = \frac{Q_0}{C} e^{-t/RC} \Rightarrow V = V_0 e^{-t/RC}$$

$$\Rightarrow 3 = 12 e^{-4/RC} \Rightarrow \frac{1}{4} = e^{-4/RC}$$

$$\ln\frac{1}{4} = \frac{-4}{RC} \Rightarrow RC = \tau = \frac{-4}{\ln\frac{1}{4}} = \frac{4}{\ln 4}$$

$$\tau = RC = \frac{4}{\ln 4} = 2.89\ s.$$

$$RC = 2.89 \Rightarrow C = \frac{2.89}{R} = \frac{2.89}{3.4\times10^{6}}$$

$$\therefore C = 0.85\times10^{-6}\ F = 0.85\ \mu F.$$

Q49]

a) just after closing switch S. Each capacitor is uncharged and behaves as a short circuit. So any resistor in parallel with it can be eliminated as no current passes through it. Note the potential difference across any uncharged capacitor is zero, and at this instant can be though of as a ~~wire~~ short circuit. In this case the circuit simplifies to:

25 Ω and 50 Ω are in parallel

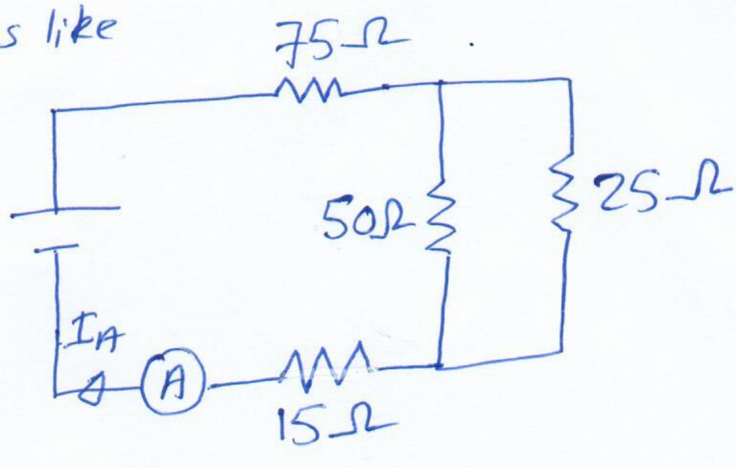
$$\frac{1}{R'_{eq}} = \frac{1}{25} + \frac{1}{50} = \frac{2+1}{50} \Rightarrow R'_{eq} = 50/3\ \Omega$$

R'_{eq} is in series with the 15 Ω, 75 Ω ⇒

$$R_{eq} = 75 + 15 + \frac{50}{3} = 106.7\ \Omega$$

$$V = I_A R_{eq} \Rightarrow I_A = \frac{V}{R_{eq}} = \frac{100}{106.7} \simeq 0.938\ A.$$

At t=0, circuit looks like



Q49] After a very long time each capacitor is fully charged ⇒ no current passes through it ⇒ any resistor in ~~parallel~~ series with it can be eleminated

Circuit can be simplified to

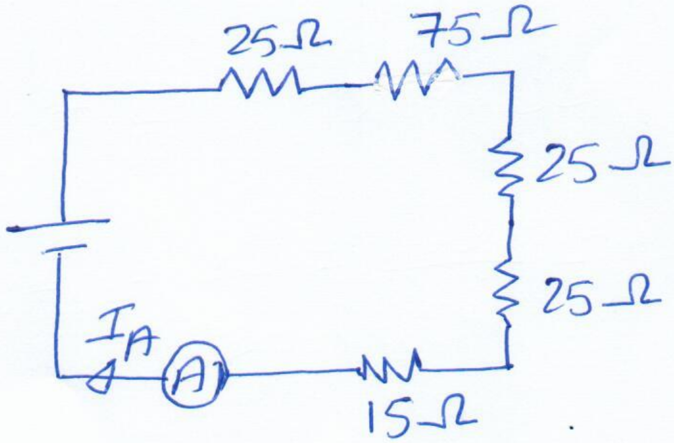
25 Ω and 25 Ω are in series ⇒ $R'_{eq} = 50\,\Omega$

R'_{eq} is in series with the 75 Ω, 25 Ω and 15 Ω

$\Rightarrow R_{eq} = R'_{eq} + 75 + 25 + 15 = 165\,\Omega$

$\Rightarrow I_A = \frac{100}{165} \simeq 0.61$ A

The circuit look like (as $t \to \infty$)



Q68]

Connection in series $\Rightarrow R_{eq} = 3R$

$$V = I R_{eq} = I(3R) \Rightarrow I = \frac{V}{3R}$$

$$P = IV = \frac{V}{3R} \cdot V = \frac{V^2}{3R} = 46\ W.$$

Connection in parallel

$$\frac{1}{R'_{eq}} = \frac{3}{R} \Rightarrow R'_{eq} = \frac{R}{3} \Rightarrow V = I' R'_{eq}$$

$$I' = \frac{V}{R'_{eq}} = 3\frac{V}{R}$$

$$P' = I'V = 3\frac{V}{R}V = \frac{3V^2}{R} = 9\frac{V^2}{3R}$$

$$= 9P$$

$$= 9(46) = 414\ W.$$