11. For what use are batteries connected in series? For what use are they connected in parallel? Does it matter if the batteries are nearly identical or not in either case?

11. When batteries are connected in series, their emfs add together, producing a larger potential. The batteries do not need to be identical in this case. When batteries are connected in parallel, the currents they can generate add together, producing a larger current over a longer time period. Batteries in this case need to be nearly identical, or the battery with the larger emf will end up charging the battery with the smaller emf.

14. In an *RC* circuit, current flows from the battery until the capacitor is completely charged. Is the total energy supplied by the battery equal to the total energy stored by the capacitor? If not, where does the extra energy go?

14. No. As current passes through the resistor in the *RC* circuit, energy is dissipated in the resistor. Therefore, the total energy supplied by the battery during the charging is the combination of the energy dissipated in the resistor and the energy stored in the capacitor.

16. Figure 26–35 is a diagram of a capacitor (or condenser) **microphone**. The changing air pressure in a sound wave causes one plate of the capacitor *C* to move back and forth. Explain how a current of the same frequency as the sound wave is produced.

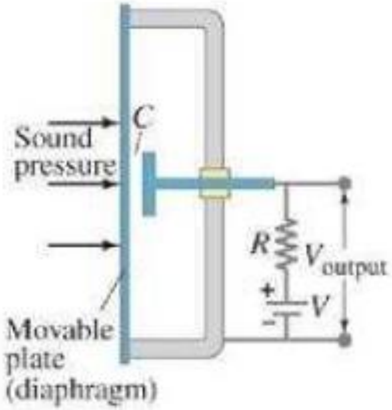


FIGURE 26–35 Diagram of a capacitor microphone. Question 16.

16. The capacitance of a parallel plate capacitor is inversely proportional to the distance between the plates: $(C = \varepsilon_0 A/d)$. As the diaphragm moves in and out, the distance between the plates changes and therefore the capacitance changes with the same frequency. This changes the amount of charge that can be stored on the capacitor, creating a current as the capacitor charges or discharges. The current oscillates with the same frequency as the diaphragm, which is the same frequency as the incident sound wave, and produces an oscillating V_{output}.

4. (II) What is the internal resistance of a 12.0-V car battery whose terminal voltage drops to 8.4 V when the starter draws 95 A? What is the resistance of the starter?

4. See Figure 26-2 for a circuit diagram for this problem. Use Eq. 26-1.

$$V_{ab} = \mathcal{E} - Ir \rightarrow r = \frac{\mathcal{E} - V_{ab}}{I} = \frac{12.0\,\text{V} - 8.4\,\text{V}}{95\,\text{A}} = \boxed{0.038\,\Omega}$$

$$V_{ab} = IR \rightarrow R = \frac{V_{ab}}{I} = \frac{8.4\,\text{V}}{95\,\text{A}} = \boxed{0.088\,\Omega}$$

16. (II) Determine (*a*) the equivalent resistance of the circuit shown in Fig. 26–39, and (*b*) the voltage across each resistor.

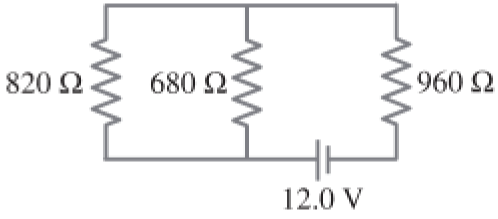


FIGURE 26–39 Problem 16.

16. (*a*) The equivalent resistance is found by combining the 820 Ω and 680 Ω resistors in parallel, and then adding the 960 Ω resistor in series with that parallel combination.

$$R_{eq} = \left(\frac{1}{820\,\Omega} + \frac{1}{680\,\Omega}\right)^{-1} + 960\,\Omega = 372\,\Omega + 960\,\Omega = 1332\,\Omega \approx \boxed{1330\,\Omega}$$

(*b*) The current delivered by the battery is $I = \frac{V}{R_{eq}} = \frac{12.0\,\text{V}}{1332\,\Omega} = 9.009 \times 10^{-3}\,\text{A}$. This is the current in the 960 Ω resistor. The voltage across that resistor can be found by Ohm's law.

$$V_{470} = IR = \left(9.009 \times 10^{-3}\,\text{A}\right)\left(960\,\Omega\right) = 8.649\,\text{V} \approx \boxed{8.6\,\text{V}}$$

Thus the voltage across the parallel combination must be $12.0\,\text{V} - 8.6\,\text{V} = \boxed{3.4\,\text{V}}$. This is the voltage across both the 820 Ω and 680 Ω resistors, since parallel resistors have the same voltage across them. Note that this voltage value could also be found as follows.

$$V_{parallel} = IR_{parallel} = \left(9.009 \times 10^{-3}\,\text{A}\right)\left(372\,\Omega\right) = 3.351\,\text{V} \approx 3.4\,\text{V}$$

19. (II) What is the net resistance of the circuit connected to the battery in Fig. 26–41?

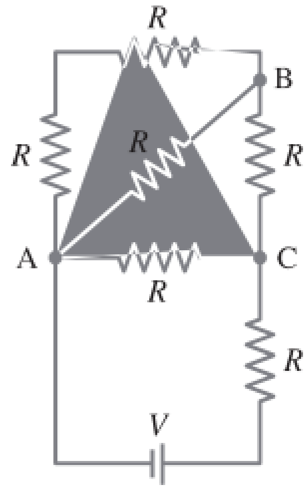
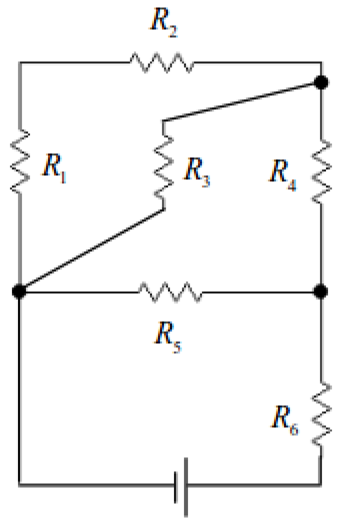


FIGURE 26–41 Problems 19 and 20.

19. The resistors have been numbered in the accompanying diagram to help in the analysis. R_1 and R_2 are in series with an equivalent resistance of $R_{12} = R + R = 2R$. This combination is in parallel with R_3, with an equivalent resistance of $R_{123} = \left(\frac{1}{R} + \frac{1}{2R}\right)^{-1} = \frac{2}{3}R$. This combination is in series with R_4, with an equivalent resistance of $R_{1234} = \frac{2}{3}R + R = \frac{5}{3}R$. This combination is in parallel with R_5, with an equivalent resistance of $R_{12345} = \left(\frac{1}{R} + \frac{3}{5R}\right)^{-1} = \frac{5}{8}R$. Finally, this combination is in series with R_6, and we calculate the final equivalent resistance.

$$R_{eq} = \frac{5}{8}R + R = \boxed{\frac{13}{8}R}$$



31. (II) (*a*) What is the potential difference between points a and d in Fig. 26–49 (similar to Fig. 26–13, Example 26–9), and (*b*) what is the terminal voltage of each battery?

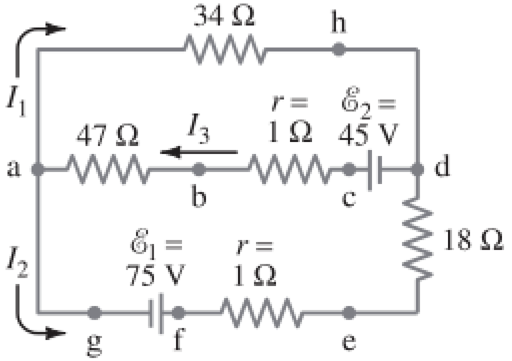


FIGURE 26–49 Problem 31.

31. This circuit is identical to Example 26-9 and Figure 26-13 except for the numeric values. So we may copy the same equations as developed in that Example, but using the current values.

Eq. (*a*): $I_3 = I_1 + I_2$; Eq. (*b*): $-34I_1 + 45 - 48I_3 = 0$

Eq. (*c*): $-34I_1 + 19I_2 - 75 = 0$ Eq. (*d*): $I_2 = \frac{75 + 34I_1}{19} = 3.95 + 1.79I_1$

Eq. (*e*): $I_3 = \frac{45 - 34I_1}{48} = 0.938 - 0.708I_1$

$I_3 = I_1 + I_2 \rightarrow 0.938 - 0.708I_1 = I_1 + 3.95 + 1.79I_1 \rightarrow I_1 = -0.861\,\text{A}$

$I_2 = 3.95 + 1.79I_1 = 2.41\,\text{A}$; $I_3 = 0.938 - 0.708I_1 = 1.55\,\text{A}$

31. (II) (*a*) What is the potential difference between points a and d in Fig. 26–49 (similar to Fig. 26–13, Example 26–9), and (*b*) what is the terminal voltage of each battery?

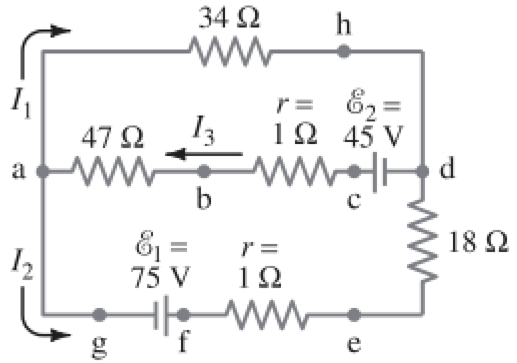


FIGURE 26–49 Problem 31.

(*a*) To find the potential difference between points a and d, start at point a and add each individual potential difference until reaching point d. The simplest way to do this is along the top branch.

$$V_{ad} = V_d - V_a = -I_1(34\Omega) = -(-0.861\,\text{A})(34\Omega) = 29.27\,\text{V} \approx \boxed{29\,\text{V}}$$

Slight differences will be obtained in the final answer depending on the branch used, due to rounding. For example, using the bottom branch, we get the following.

$$V_{ad} = V_d - V_a = \mathcal{E}_1 - I_2(19\Omega) = 75\,\text{V} - (2.41\,\text{A})(19\Omega) = 29.21\,\text{V} \approx 29\,\text{V}$$

(*b*) For the 75-V battery, the terminal voltage is the potential difference from point g to point e. For the 45-V battery, the terminal voltage is the potential difference from point d to point b.

$$75\,\text{V battery: } V_{\text{terminal}} = \mathcal{E}_1 - I_2 r = 75\,\text{V} - (2.41\,\text{A})(1.0\Omega) = \boxed{73\,\text{V}}$$

$$45\,\text{V battery: } V_{\text{terminal}} = \mathcal{E}_2 - I_3 r = 45\,\text{V} - (1.55\,\text{A})(1.0\Omega) = \boxed{43\,\text{V}}$$

44. (II) In Fig. 26–58 (same as Fig. 26–17a), the total resistance is 15.0 kΩ, and the battery's emf is 24.0 V. If the time constant is measured to be 24.0 μs, calculate (*a*) the total capacitance of the circuit and (*b*) the time it takes for the voltage across the resistor to reach 16.0 V after the switch is closed.

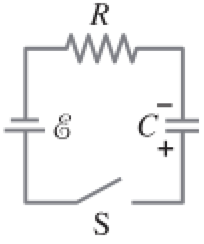


FIGURE 26–58 Problems 44 and 46.

44. (*a*) From Eq. 26-7 the product RC is equal to the time constant.

$$\tau = RC \rightarrow C = \frac{\tau}{R} = \frac{24.0\times10^{-6}\,\text{s}}{15.0\times10^{3}\,\Omega} = \boxed{1.60\times10^{-9}\,\text{F}}$$

(*b*) Since the battery has an EMF of 24.0 V, if the voltage across the resistor is 16.0 V, the voltage across the capacitor will be 8.0 V as it charges. Use the expression for the voltage across a charging capacitor.

$$V_C = \mathcal{E}\left(1 - e^{-t/\tau}\right) \rightarrow e^{-t/\tau} = \left(1 - \frac{V_C}{\mathcal{E}}\right) \rightarrow -\frac{t}{\tau} = \ln\left(1 - \frac{V_C}{\mathcal{E}}\right) \rightarrow$$

$$t = -\tau \ln\left(1 - \frac{V_C}{\mathcal{E}}\right) = -(24.0\times10^{-6}\,\text{s})\ln\left(1 - \frac{8.0\,\text{V}}{24.0\,\text{V}}\right) = \boxed{9.73\times10^{-6}\,\text{s}}$$

79. In the circuit shown in Fig. 26–68, the 33-Ω resistor dissipates 0.80 W. What is the battery voltage?

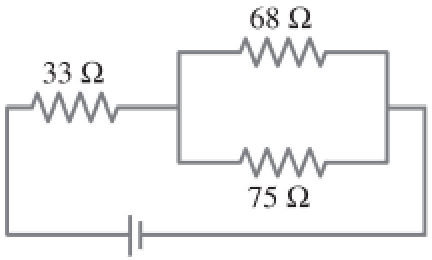


FIGURE 26–68
Problem 79.

79. The current in the circuit can be found from the resistance and the power dissipated. Then the product of that current and the equivalent resistance is equal to the battery voltage.

$$P = I^2R \rightarrow I = \sqrt{\frac{P_{33}}{R_{33}}} = \sqrt{\frac{0.80\,\text{W}}{33\Omega}} = 0.1557\,\text{A}$$

$$R_{eq} = 33\Omega + \left(\frac{1}{68\Omega} + \frac{1}{75\Omega}\right)^{-1} = 68.66\Omega \qquad V = IR_{eq} = (0.1557\,\text{A})(68.66\Omega) = 10.69\,\text{V} \approx \boxed{11\,\text{V}}$$

83. A flashlight bulb rated at 2.0 W and 3.0 V is operated by a 9.0-V battery. To light the bulb at its rated voltage and power, a resistor R is connected in series as shown in Fig. 26–72. What value should the resistor have?

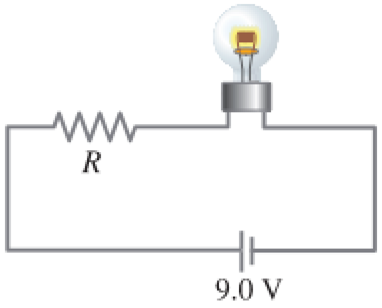


FIGURE 26–72
Problem 83.

83. Write Kirchhoff's loop rule for the circuit, and substitute for the current and the bulb resistance based on the bulb ratings.

$$P_{bulb} = \frac{V_{bulb}^2}{R_{bulb}} \rightarrow R_{bulb} = \frac{V_{bulb}^2}{P_{bulb}} \qquad P_{bulb} = I_{bulb}V_{bulb} \rightarrow I_{bulb} = \frac{P_{bulb}}{V_{bulb}}$$

$$\mathcal{E} - I_{bulb}R - I_{bulb}R_{bulb} = 0 \rightarrow$$

$$R = \frac{\mathcal{E}}{I_{bulb}} - R_{bulb} = \frac{\mathcal{E}}{P_{bulb}/V_{bulb}} - \frac{V_{bulb}^2}{P_{bulb}} = \frac{V_{bulb}}{P_{bulb}}(\mathcal{E} - V_{bulb}) = \frac{3.0\,\text{V}}{2.0\,\text{W}}(9.0\,\text{V} - 3.0\,\text{V}) = \boxed{9.0\Omega}$$

*91. Measurements made on circuits that contain large resistances can be confusing. Consider a circuit powered by a battery $\mathcal{E} = 15.000\ \text{V}$ with a 10.00-MΩ resistor in series with an unknown resistor R. As shown in Fig. 26–80, a particular voltmeter reads $V_1 = 366\ \text{mV}$ when connected across the 10.00-MΩ resistor, and this meter reads $V_2 = 7.317\ \text{V}$ when connected across R. Determine the value of R. [*Hint*: Define R_V as the voltmeter's internal resistance.]

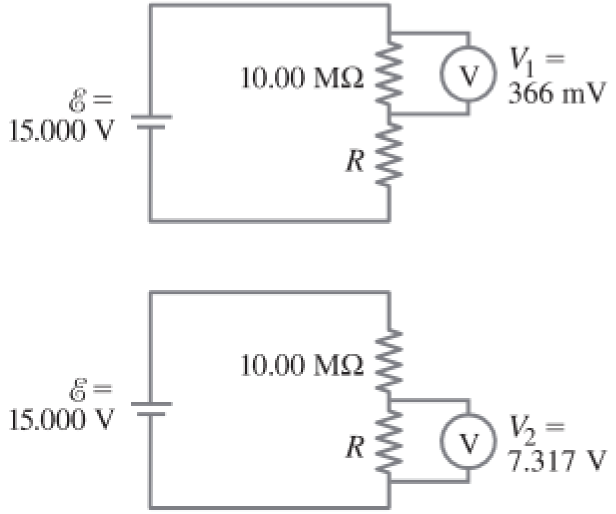


FIGURE 26–80 Problem 91.

91. We represent the 10.00-MΩ resistor by R_{10}, and the resistance of the voltmeter as R_V. In the first configuration, we find the equivalent resistance R_{eqA}, the current in the circuit I_A, and the voltage drop across R.

$$R_{eqA} = R + \frac{R_{10}R_V}{R_{10}+R_V} \ ; \ I_A = \frac{\mathcal{E}}{R_{eqA}} \ ; \ V_R = I_A R = \mathcal{E} - V_A \ \rightarrow \ \mathcal{E}\frac{R}{R_{eqA}} = \mathcal{E} - V_A$$

In the second configuration, we find the equivalent resistance R_{eqB}, the current in the circuit I_B, and the voltage drop across R_{10}.

$$R_{eqB} = R_{10} + \frac{RR_V}{R+R_V} \ ; \ I_B = \frac{\mathcal{E}}{R_{eqB}} \ ; \ V_{R_{10}} = I_B R_{10} = \mathcal{E} - V_B \ \rightarrow \ \mathcal{E}\frac{R_{10}}{R_{eqB}} = \mathcal{E} - V_B$$

We now have two equations in the two unknowns of R and R_V. We solve the second equation for R_V and substitute that into the first equation. We are leaving out much of the algebra in this solution.

$$\mathcal{E}\frac{R}{R_{eqA}} = \mathcal{E}\frac{R}{R + \dfrac{R_{10}R_V}{R_{10}+R_V}} = \mathcal{E} - V_A \ ;$$

$$\mathcal{E}\frac{R_{10}}{R_{eqB}} = \mathcal{E}\frac{R_{10}}{R_{10} + \dfrac{RR_V}{R+R_V}} = \mathcal{E} - V_B \ \rightarrow \ R_V = \frac{V_B R_{10} R}{\left(\mathcal{E}R - V_B R_{10} - V_B R\right)}$$

$$\mathcal{E} - V_A = \mathcal{E}\frac{R}{R + \dfrac{R_{10}R_V}{R_{10}+R_V}} = \mathcal{E}\frac{R}{R + \dfrac{R_{10}\left[\dfrac{V_B R_{10} R}{\left(\mathcal{E}R - V_B R_{10} - V_B R\right)}\right]}{R_{10} + \left[\dfrac{V_B R_{10} R}{\left(\mathcal{E}R - V_B R_{10} - V_B R\right)}\right]}} \ \rightarrow$$

$$R = \frac{V_B}{V_A}R_{10} = \frac{7.317\ \text{V}}{0.366\ \text{V}}(10.00\ \text{M}\Omega) = 199.92\ \text{M}\Omega \approx \boxed{200\ \text{M}\Omega}\ \ (3\ \text{sig. fig.})$$