Problem 2–9. A 100-kΩ resistor has a power rating of 0.125 W. Find the maximum voltage that can be applied to the resistor.

The power dissipated by a resistor can be expressed as $p = v^2/R$. Solving for the voltage, we have $v = \sqrt{pR} = \sqrt{(0.125)(10^5)} = 111.803$ V.

Problem 2–14. In Figure P2–14 $v_1 = 3$ V and $v_3 = 5$ V. Find v_2, v_4 and v_5.

We can use a KVL equation on the left loop and the two given voltages to solve for v_2. The KVL equation is $-v_1 + v_2 + v_3 = 0$. Solving for $v_2 = v_1 - v_3 = 3 - 5 = -2$ V. In examining the circuit, there is a ground on each side of v_5, so the voltage difference across this element is zero, $v_5 = 0$ V. We can now use KVL around the right loop to solve for v_4. The KVL equation is $-v_3 + v_4 + v_5 = 0$. Solve for $v_4 = v_3 - v_5 = 5 - 0 = 5$ V.

Problem 2–15. For the circuit in Figure P2–15:

(a). Identify the nodes and at least two loops.

The circuit has three nodes and three loops. The nodes are labeled A, B, and C. The first loop contains elements 1 and 2, the second loop contains elements 2, 3, and 4, and the third loop contains elements 1, 3 and 4.

(b). Identify any elements connected in series or in parallel.

Elements 3 and 4 are connected in series. Elements 1 and 2 are connected in parallel.

(c). Write KCL and KVL connection equations for the circuit.

The KCL equations are

$$\begin{array}{rc} \text{Node A} & -i_1 - i_2 - i_3 = 0 \\ \text{Node B} & i_3 - i_4 = 0 \\ \text{Node C} & i_1 + i_2 + i_4 = 0 \end{array}$$

The KVL equations are

$$\begin{array}{rc} \text{Loop 1 2} & -v_1 + v_2 = 0 \\ \text{Loop 2 3 4} & -v_2 + v_3 + v_4 = 0 \\ \text{Loop 1 3 4} & -v_1 + v_3 + v_4 = 0 \end{array}$$

Problem 2–17. For the circuit in Figure P2–17:

(a). Identify the nodes and at least three loops in the circuit.

The are four nodes and at least five loops. There are only three independent KVL equations. The nodes are labeled A, B, C, and D. Valid loops include the following sequences of elements: (1, 3, 2), (2, 4, 5), (3, 6, 4), (1, 6, 5), and (2, 3, 6, 5).

(b). Identify any elements connected in series or in parallel.

In this circuit, none of the elements are connected in series and none of them are connected in parallel.

(c). Write KCL and KVL connection equations for the circuit.

The KCL equations are

$$\begin{array}{ll} \text{Node A} & -i_2 - i_3 - i_4 = 0 \\[2ex] \text{Node B} & -i_1 + i_3 - i_6 = 0 \\[2ex] \text{Node C} & i_1 + i_2 + i_5 = 0 \\[2ex] \text{Node D} & i_4 - i_5 + i_6 = 0 \end{array}$$

Three independent KVL equations are

$$\begin{array}{ll} \text{Loop 1 3 2} & -v_1 - v_3 + v_2 = 0 \\[2ex] \text{Loop 2 4 5} & -v_2 + v_4 + v_5 = 0 \\[2ex] \text{Loop 3 6 4} & v_3 + v_6 - v_4 = 0 \end{array}$$

Problem 2–18. In Figure P2–17 $v_2 = 10$ V, $v_3 = -10$ V, and $v_4 = 3$ V. Find v_1, v_5, and v_6.

The KVL equations are

$$\begin{array}{ll} \text{Loop 1 3 2} & -v_1 - v_3 + v_2 = 0 \\[2ex] \text{Loop 2 4 5} & -v_2 + v_4 + v_5 = 0 \\[2ex] \text{Loop 3 6 4} & v_3 + v_6 - v_4 = 0 \end{array}$$

Using the first equation, we can solve for $v_1 = v_2 - v_3 = 10 + 10 = 20$ V. Using the second equation, we can solve for $v_5 = v_2 - v_4 = 10 - 3 = 7$ V. Using the third equation, we can solve $v_6 = v_4 - v_3 = 3 + 10 = 13$ V.

Problem 2–19. In many circuits the ground is often the metal case that houses the circuit. Occasionally a failure occurs whereby a wire connected to a particular node touches the case causing that node to become connected to ground. Suppose that in Figure P2–17 Node B accidently touches ground. How would that affect the voltages found in Problem 2–18?

If Node B is connected to ground, then element 6 is connected to ground on both sides, so its voltage is $v_6 = 0$ V. If we define $v_6 = 0$ V, all of the original KVL equations found in Problem 2–17 are still valid. Even though the equations are valid, Problem 2–18 is no longer valid because there is a conflict with the given voltages. Using the KVL equation $v_3 + v_6 - v_4 = 0$ and substituting in $v_6 = 0$, we get $v_3 = v_4$. In Problem 2–18, the given values are $v_3 = -10$ V and $v_4 = 3$ V, which is not possible if Node B is connected to ground.

Problem 2–21. In Figure P2–21 $v_2 = 10$ V, $v_4 = 5$ V, and $v_5 = 15$ V. Find v_1, v_3, and v_6.

The KVL equations for the circuit are

$$\text{Loop } 1\,2\,3 \quad -v_1 + v_2 + v_3 = 0$$

$$\text{Loop } 3\,4\,5 \quad -v_3 + v_4 + v_5 = 0$$

$$\text{Loop } 2\,6\,4 \quad -v_2 + v_6 - v_4 = 0$$

Using the second loop equation, we can solve for $v_3 = v_4 + v_5 = 5 + 15 = 20$ V. Using the first loop equation, we can solve for $v_1 = v_2 + v_3 = 10 + 20 = 30$ V. Finally, using the third loop equation, we can solve for $v_6 = v_2 + v_4 = 10 + 5 = 15$ V.

Problem 2–26. Find v_{x} and i_{x} in Figure P2–26.

The circuit has a single current, i_{x}, which flows clockwise. Label the 22-kΩ resistor as R_1 with voltage drop v_1 following the passive sign convention (positive on left and negative on right). The KVL equation for

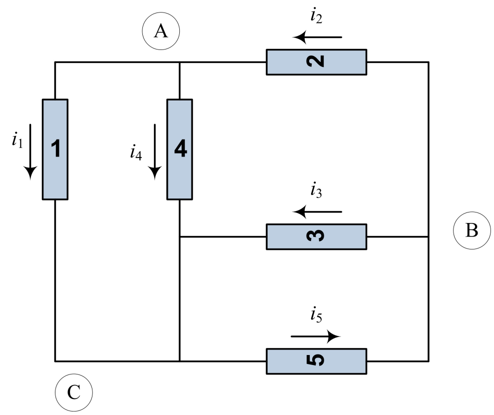

Figure P2–24

the circuit combined with Ohm's law provides the solution.

$$\begin{aligned}
-18 + v_1 + v_x &= 0 \\
v_1 + v_x &= 18 \\
R_1 i_x + R_x i_x &= 18 \\
(22 \times 10^3) i_x + (68 \times 10^3) i_x &= 18 \\
(90 \times 10^3) i_x &= 18 \\
i_x &= 200\,\mu\text{A} \\
v_x &= (68 \times 10^3) i_x \quad = \quad 13.6\,\text{V}
\end{aligned}$$

Problem 2–27. Find v_x and i_x in Figure P2–27. Compare the results of your answers with those in Problem 2–26. What effect did adding the 33-kΩ resistor have on the overall circuit? Why isn't i_y zero?

Label the 22-kΩ resistor as R_1 with voltage drop v_1 following the passive sign convention (positive on left and negative on right). Label the 33-kΩ resistor with voltage v_y following the passive sign convention (positive on top and negative on bottom). Label the source current as i_S following the passive sign convention (flowing into the positive terminal of the voltage source). The KVL equations for the circuit are:

$$\begin{aligned}
-18 + v_y &= 0 \\
-v_y + v_1 + v_x &= 0
\end{aligned}$$

The KCL equation for the circuit is

$$-i_S - i_x - i_y = 0$$

Solving the first KVL equation, we have $v_y = 18$ V. Substituting this result into the second KVL equation, we get $v_1 + v_x = 18$. Current i_x flows through both R_1 and R_x, so we can solve as follows:

$$\begin{aligned} v_1 + v_x &= 18 \\ R_1 i_x + R_x i_x &= 18 \\ (22 \times 10^3) i_x + (68 \times 10^3) i_x &= 18 \\ (90 \times 10^3) i_x &= 18 \\ i_x &= 200\,\mu\text{A} \\ v_x &= (68 \times 10^3) i_x = 13.6\,\text{V} \end{aligned}$$

These results for v_x and i_x match those in Problem 2–26. We can also find i_y using Ohm's law, $i_y = v_y/R_y = (18)/(33 \times 10^3) = 545.5\ \mu$A. Applying the KCL equation, we get $i_S = -i_x - i_y = -200 - 545.5 = -745.5$ μA. Adding the 33-kΩ resistor increased the amount of current flowing from the source. The current i_y is not zero because there is a voltage across the 33-kΩ resistor.

Problem 2–28. A modeler wants to light his model building using miniature grain-of-wheat light bulbs connected in parallel as shown in Figure P2–28. He uses two 1.5-V "C-cells" to power his lights. He wants to use as many lights as possible, but wants to limit his current drain to 500 μA to preserve the batteries. If each light has a resistance of 36 kΩ, how many lights can he install and still be under his current limit?

The two 1.5-V batteries are connected in series to provide a total of 3 V to the circuit. Since the light bulbs are connected in parallel, the entire 3 V appears across each one. Using Ohm's law, the current through each bulb is $i = v/R = 3/(36 \times 10^3) = 83.3\ \mu$A. The design requires the batteries to provide no more the 500 μA, so we can connect up to $500/83.3 = 6$ bulbs in parallel across the batteries.

Problem 2–29. Find v_x and i_x in Figure P2–29.

In the circuit, 0.5 A flows through the 10-Ω resistor in the center. The voltage drop across this resistor is $v = Ri = (10)(0.5) = 5$ V. The 10-Ω resistor is connected in parallel to the 5-Ω resistor, so they have the same voltage drop. The associated KVL equation verifies this fact. With 5 V across the 5-Ω resistor, the current is $i_x = v/R = 5/5 = 1$ A. KCL at the top node requires that the current entering the node equal the current leaving the node. Since we have $0.5 + 1.0 = 1.5$ A leaving the node, 1.5 A must enter the node through the 4 Ω resistor. The voltage drop across the 4 Ω resistor is $v = Ri = (4)(1.5) = 6$ V. We can now write a KVL equation around the first loop to get $-v_x + 6 + 5 = 0$, which implies $v_x = 11$ V.

Problem 2–39. Find R_{EQ} in Figure P2–39 when the switch is open. Repeat when the switch is closed.

When the switch is open, the two 100-Ω resistors are in parallel and that result is in series with the two 50-Ω resistors. We can calculate $R_{\text{EQ}} = 50 + (100 \parallel 100) + 50 = 50 + 50 + 50 = 150\ \Omega$. With the switch closed, the wire shorts out the two 100-Ω resistors, so they do not contribute to the equivalent resistance. The results is that the two 50-Ω resistors are in series, so $R_{\text{EQ}} = 50 + 50 = 100\ \Omega$.