**Problem 1.24**  The plot in Fig. P1.24 displays the cumulative charge $q(t)$ that has entered a certain device up to time $t$. Sketch a plot of the corresponding current $i(t)$.

![Figure P1.24: $q(t)$ for Problem 1.24.](image)

**Solution:** Based on the slope of $q(t)$:

$$i(t) = \frac{dq}{dt} = \begin{cases} 
20 \text{ A} & \text{for } 0 \leq t \leq 1 \text{ s} \\
-20 \text{ A} & \text{for } 1 \leq t \leq 3 \text{ s} \\
0 & \text{for } 3 \leq t \leq 4 \text{ s} \\
20 \text{ A} & \text{for } 4 \leq t \leq 5 \text{ s} \\
0 & \text{for } t \geq 5 \text{ s}
\end{cases}$$

![Fig. P1.24](image)
**Problem 2.3** A thin-film resistor made of germanium is 2 mm in length and its rectangular cross section is 0.2 mm × 1 mm, as shown in Fig. P2.3. Determine the resistance that an ohmmeter would measure if connected across its:

(a) Top and bottom surfaces  
(b) Front and back surfaces  
(c) Right and left surfaces  

[Resistivity ρ of germanium: 0.47 Ωm; or conductivity σ of germanium: 2.13 (Ωm).]

![Figure P2.3: Film resistor of Problem 2.3.](image)

**Solution:**

(a)  
\[ R = \frac{\ell}{\sigma A} \]  
\[ \ell = 0.2 \text{ mm}, \quad A = 1 \text{ mm} \times 2 \text{ mm} = 2 \times 10^{-6} \text{ m}^2 \]  
\[ = \frac{2 \times 10^{-4}}{2.13 \times 2 \times 10^{-6}} \approx 47 \Omega. \]

(b)  
\[ R = \frac{\ell}{\sigma A} \]  
\[ \ell = 1 \text{ mm}, \quad A = 2 \text{ mm} \times 0.2 \text{ mm} = 4 \times 10^{-7} \text{ m}^2 \]  
\[ = \frac{10^{-3}}{2.13 \times 4 \times 10^{-7}} \approx 1,174 \Omega. \]

(c)  
\[ R = \frac{\ell}{\sigma A} \]  
\[ \ell = 2 \text{ mm}, \quad A = 1 \text{ mm} \times 0.2 \text{ mm} = 2 \times 10^{-7} \text{ m}^2 \]  
\[ = \frac{2 \times 10^{-3}}{2.13 \times 2 \times 10^{-7}} \approx 4,695 \Omega. \]
Problem 2.17  Determine currents $I_1$ to $I_4$ in the circuit of Fig. P2.17.

![Figure P2.17: Circuit for Problem 2.17.](image)

Solution: The same voltage exists across all four resistors. Hence,

$$2I_1 = 4I_2 = 2I_3 = 4I_4.$$ 

Also, KCL mandates that 

$$I_1 + I_2 + I_3 + I_4 = 6$$

It follows that $I_1 = 2$ A, $I_2 = 1$ A, $I_3 = 2$ A, and $I_4 = 1$ A.
**Problem 2.18** Determine the amount of power dissipated in the 3-kΩ resistor in the circuit of Fig. P2.18.

![Circuit for Problem 2.18](image)

**Solution:** In the left loop,

\[ V_0 = 10 \times 10^{-3} \times 2 \times 10^3 = 20 \text{ V}. \]

The dependent current source is \( I_0 = 10^{-3}V_0 = 20 \text{ mA}. \)

The power dissipated in the 3-kΩ resistor is

\[ p = I_0^2R = (20 \times 10^{-3})^2 \times 3 \times 10^3 = 1.2 \text{ W}. \]
Problem 2.19  Determine $I_x$ and $I_y$ in the circuit of Fig. P2.19.

Solution: Application of KVL to the two loops gives

$$-10 + 2I_x + 4I = 0$$
$$-4I + 6I_y - 4I_x = 0.$$ 

Additionally,

$$I = I_x - I_y.$$ 

Solution of the three equations yields

$$I_x = 3.57 \text{ A}, \quad I_y = 2.86 \text{ A}.$$
Problem 2.25  After assigning node $V_4$ in the circuit of Fig. P2.25 as the ground node, determine node voltages $V_1$, $V_2$, and $V_3$.

![Figure P2.25: Circuit of Problem 2.25.](image)

Solution:

![Fig. P2.25 (a) ](image)

From KCL at node $V_1$, the sum of currents leaving the node is

$$3 + I_1 - 1 = 0,$$

or

$$I_1 = -3 + 1 = -2 \text{ A}.$$  

Node voltages (relative to $V_4$):

$$V_1 = -6 \times 1 = -6 \text{ V},$$

$$V_2 = V_1 - 3I_1 = -6 - 3(-2) = 0,$$

$$V_3 = 6 \times 1 = 6 \text{ V}.$$
Problem 2.36  Use resistance reduction and source transformation to find $V_x$ in the circuit of Fig. P2.36. All resistance values are in ohms.

Solution:

Figure P2.36: Circuit for Problem 2.36.

\[ V_x = \frac{30 \times 4}{3 + 4 + 8} = 8 \text{ V}. \]
**Problem 2.49**  Determine current $I$ in the circuit of Fig. P2.49.

**Solution:** Resistance combining leads to

\[ I = \frac{50}{5 + 20.43} = 1.97 \text{ A.} \]
Problem 2.50  Determine the equivalent resistance $R_{eq}$ at terminals $(a,b)$ in the circuit of Fig. P2.50.

Solution:

$$R = 4 + 4 + (5 \parallel 5 \parallel 10) = 10 \Omega.$$
**Problem 2.52**  Determine voltage $V_a$ in the circuit of Fig. P2.52.

**Solution:**

By current division,

$$I = \frac{4 \times 8}{4 + 8} = 2.67 \, \text{A}$$
and

\[ V = 4I = 10.67 \text{ V}. \]
Problem 3.9  Apply nodal analysis to find node voltages $V_1$ to $V_3$ in the circuit of Fig. P3.9 and then determine $I_x$.

Solution: At nodes $V_1$, $V_2$, and $V_3$:

Node 1: \[ \frac{V_1}{2} + \frac{V_1 - V_2}{3} - 4 = 0 \]  
Node 2: \[ \frac{V_2 - V_1}{3} + \frac{V_2 - 48}{2} + \frac{V_2 - V_3}{6} = 0 \]  
Node 3: \[ \frac{V_3 - V_2}{6} + \frac{V_3}{4} + 4 = 0 \]

Simplification of the three equations leads to:

\[ 5V_1 - 2V_2 = 24 \]  
\[ -2V_1 + 6V_2 - V_3 = 144 \]  
\[ -2V_2 + 5V_3 = -48 \]

Simultaneous solution of Eqs. (4)–(6) leads to:

\[ V_1 = \frac{84}{5} \text{ V}, \quad V_2 = 30 \text{ V}, \quad V_3 = \frac{12}{5} \text{ V}. \]

Hence,

\[ I_x = \frac{V_2 - V_3}{6} = \frac{30 - 12/5}{6} = 4.6 \text{ A}. \]
Problem 3.29  Apply mesh analysis to find $I$ in the circuit of Fig. P3.29.

![Circuit for Problem 3.29.](image)

**Figure P3.29:** Circuit for Problem 3.29.

**Solution:**

Mesh 1: $\ -16 + I_1 + (I_1 - I_2) = 0$
Mesh 2: $(I_2 - I_1) + I_2 + (I_2 - I_3) = 0$
Mesh 3: $(I_3 - I_2) + I_3 = 0$

Solution is:

$I_1 = 10 \text{ A}, \quad I_2 = 4 \text{ A}, \quad I_3 = 2 \text{ A}.$

$I = (I_1 - I_2) = 10 - 4 = 6 \text{ A}.$