3.1 Find both I_o and V_o in the network in Fig. P3.1 using nodal analysis.

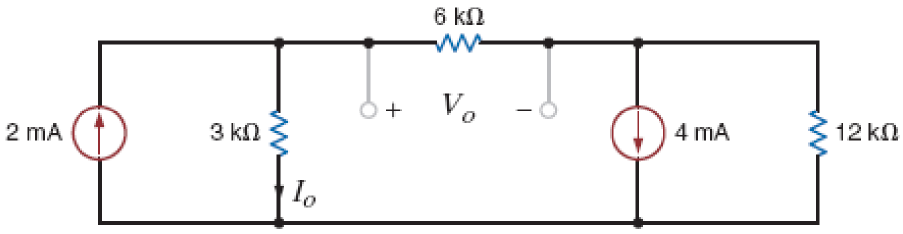
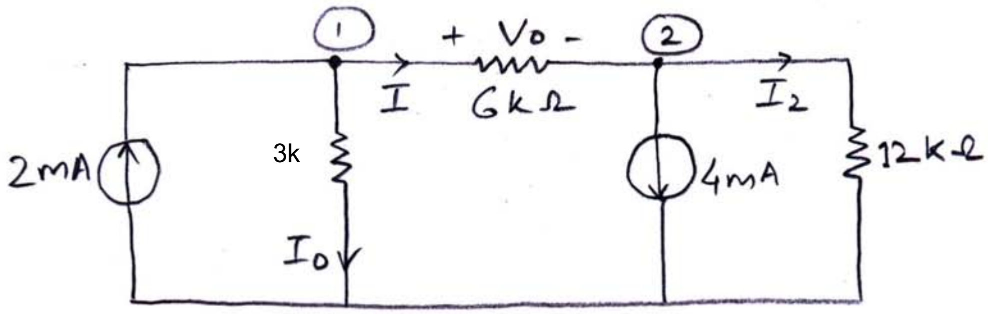


Figure P3.1

SOLUTION:



KCL at 1:

$$2m = I_o + I$$

$$\frac{V_1}{3k} + \frac{V_1 - V_2}{6k} = 2m$$

$$2V_1 + V_1 - V_2 = 12$$

$$\boxed{3V_1 - V_2 = 12}$$

KCL at 2:

$$I = 4m + I_2$$

$$\frac{V_1 - V_2}{6k} = 4m + \frac{V_2}{12k}$$

$$2V_1 - 2V_2 = 48 + V_2$$

$$\boxed{2V_1 - 3V_2 = 48}$$

$$3V_1 - V_2 = 12$$

$$2V_1 - 3V_2 = 48$$

$$V_1 = -1.71 \text{ V}$$

$$V_2 = -17.14 \text{ V}$$

$$V_o = V_1 - V_2$$

$$V_o = -1.71 - (-17.14)$$
$$V_o = 15.43 \text{ V}$$

$$I_o = \frac{V_1}{3k}$$
$$= \frac{-1.71}{3K} = -0.57$$
$$I_o = -0.57 \text{ mA}$$

3.2 Use nodal analysis to find V_1 in the circuit in Fig. P3.2.

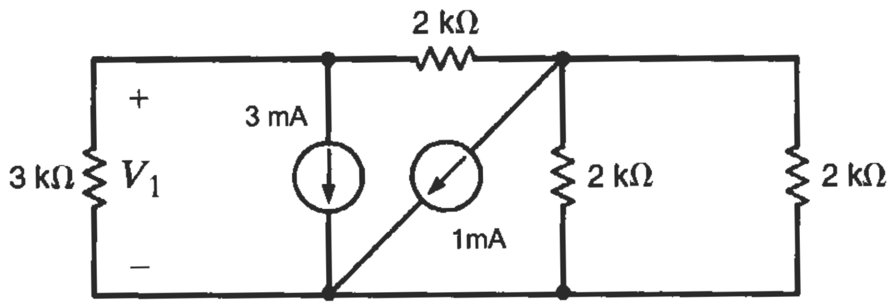
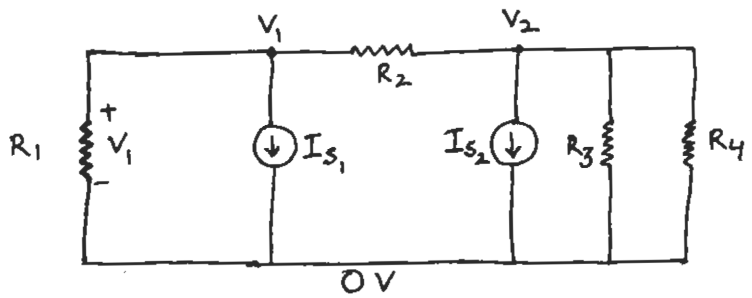


Figure P3.2

SOLUTION: 3.2



$R_1 = 3\,k\Omega,\ R_2 = R_3 = R_4 = 2\,k\Omega,\ I_{s_1} = 3\,mA,\ I_{s_2} = 1\,mA$

KCL @ V_1 : $\dfrac{V_1}{R_1} + I_{s_1} + \dfrac{V_1 - V_2}{R_2} = 0$

$$\frac{V_1}{3\times10^3} + 3\times10^{-3} + \frac{V_1 - V_2}{2\times10^3} = 0$$

$$5V_1 - 3V_2 = -18 \quad \text{—— ①}$$

KCL @ V_2 : $\dfrac{V_2 - V_1}{R_2} + I_{s_2} + \dfrac{V_2}{R_3} + \dfrac{V_2}{R_4} = 0$

$$\frac{V_2 - V_1}{2\times10^3} + 1\times10^{-3} + \frac{V_2}{2\times10^3} + \frac{V_2}{2\times10^3} = 0$$

$$3V_2 - V_1 = -2 \quad \text{—— ②}$$

Substituting equation ② in ①, we get

$$V_2 = -\frac{28}{12}$$

$$V_1 = \frac{3V_2 - 18}{5} \Rightarrow \boxed{V_1 = -5\,V}$$

3.3 Find V_1 and V_2 in the circuit in Fig. P3.3 using nodal analysis. Then solve the problem using MATLAB and compare your answers.

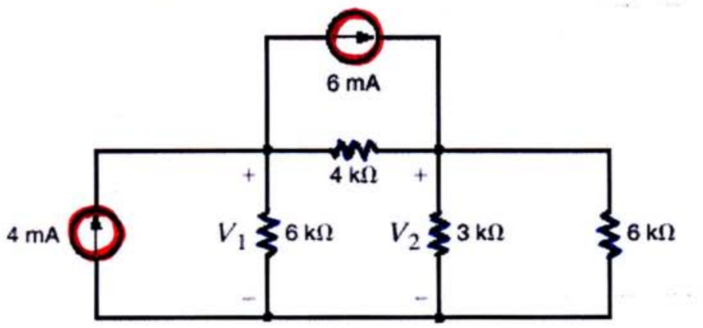
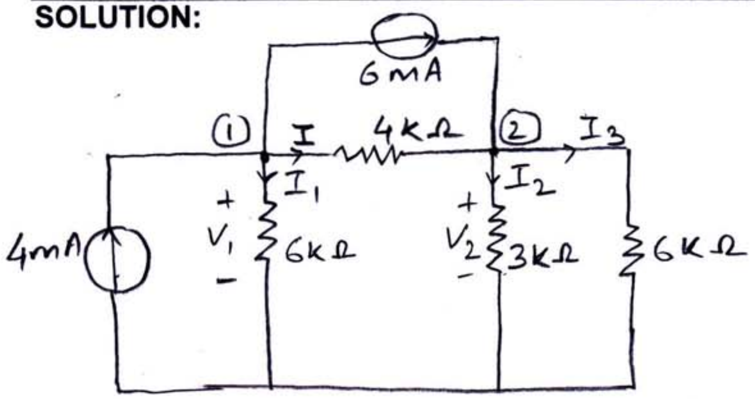


Figure P3.3

SOLUTION:



KCL at ①: $4m = 6m + I + I_1$

$$\frac{V_1 - V_2}{4k} + \frac{V_1}{6k} = -2m$$

$$3V_1 - 3V_2 + 2V_1 = -24$$

$$\boxed{5V_1 - 3V_2 = -24}$$

KCL at ②: $6m + I = I_2 + I_3$

$$\frac{V_2}{3k} + \frac{V_2}{6k} = 6m + \frac{V_1 - V_2}{4k}$$

$$4V_2 + 2V_2 = 72 + 3V_1 - 3V_2$$

$$\boxed{-3V_1 + 9V_2 = 72}$$

$$5V_1 - 3V_2 = -24$$
$$-3V_1 + 9V_2 = 72$$

$$V_1 = 0 \text{ V}$$
$$V_2 = 8 \text{ V}$$

```
% MATLAB Code and Solution for Problem 3.4

G = [5, -3; -3, 9];
Imatrix = [-24; 72];
V = inv(G)*Imatrix

>>
  V =
      0.00
      8.00
```

3.4 Use nodal analysis to find both V_1 and V_o in the circuit in Fig. P3.4.

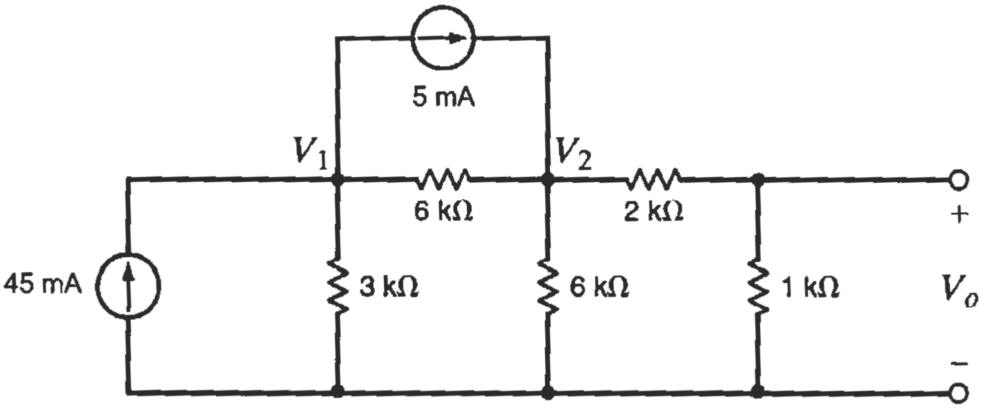
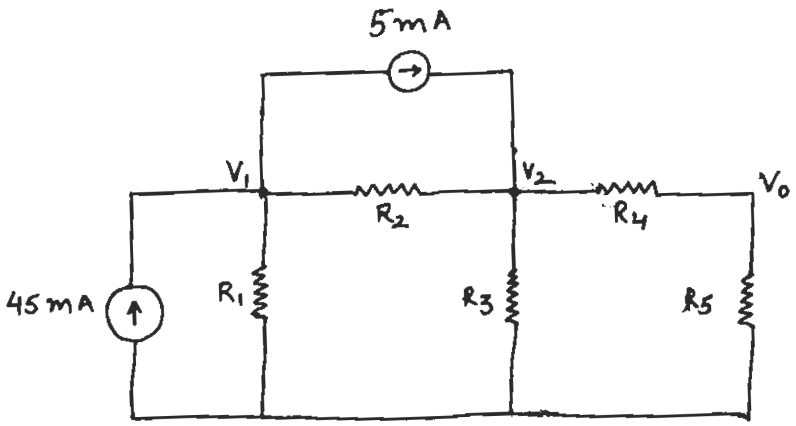


Figure P3.4

SOLUTION: 3.4



$R_1 = 3k\Omega$, $R_2 = 6k\Omega$, $R_3 = 6k\Omega$, $R_4 = 2k\Omega$, $R_5 = 1k\Omega$

KCL @ V_1 : $\dfrac{V_1 - V_2}{R_2} + \dfrac{V_1}{R_1} + I_{s_2} - I_{s_1} = 0$

$$\frac{V_1 - V_2}{6 \times 10^3} + \frac{V_1}{3 \times 10^3} + 5 \times 10^{-3} - 45 \times 10^{-3} = 0$$

$$3V_1 - V_2 = 240 \quad \text{———} \quad (1)$$

KCL @ V_2 : $\dfrac{V_2 - V_1}{R_2} + \dfrac{V_2 - V_o}{R_4} + \dfrac{V_2}{R_3} - I_{s_2} = 0$

$$\frac{V_2 - V_1}{6 \times 10^3} + \frac{V_2 - V_0}{2 \times 10^3} + \frac{V_2}{6 \times 10^3} - 5 \times 10^{-3} = 0$$

$$5V_2 - V_1 - 3V_0 = 30 \quad \text{——} \quad (2)$$

KCL at V_0: $\dfrac{V_2 - V_0}{R_4} - \dfrac{V_0}{R_5} = 0$

$$\frac{V_2 - V_0}{2 \times 10^3} - \frac{V_0}{10^3} = 0$$

$$V_2 = 3V_0 \quad \text{——} \quad (3)$$

Substituting equation (3) in (2), we get

$$5(3V_0) - V_1 - 3V_0 = 30$$

$$12V_0 - 30 = V_1 \quad \text{——} \quad (4)$$

Substituting equations (3) and (4) in (1), we get

$$3(12V_0 - 30) - 3V_0 = 240$$

$$\boxed{V_0 = 10\,V}$$

Substituting the value of V_0 in equation (4), we get

$$12(10) - 30 = V_1$$

$$\Rightarrow \boxed{V_1 = 90\,V}$$

3.5 Find V_o in the network in Fig. P3.5.

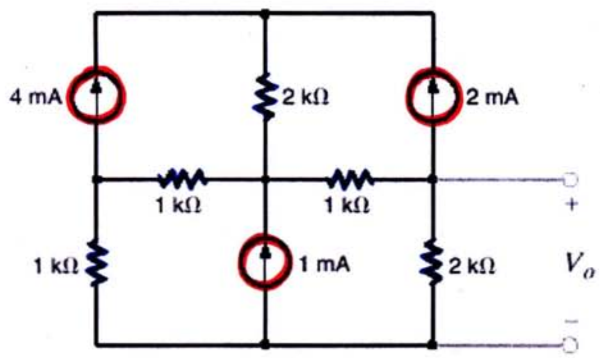
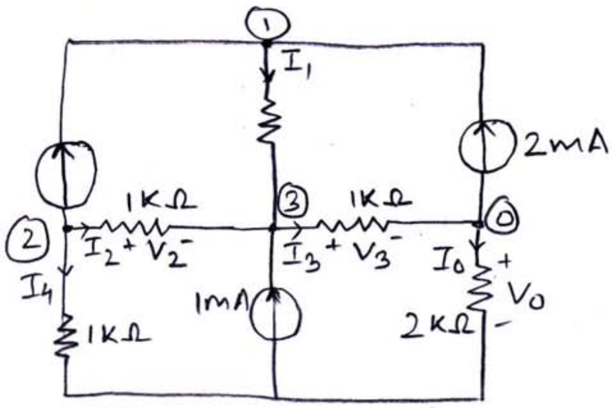


Figure P3.5

SOLUTION:



KCL at 2 : $4m + I_2 + I_4 = 0$

$$\frac{V_2 - V_3}{1K} + \frac{V_2}{1K} = -4m$$

$$V_2 - V_3 + V_2 = -4$$

$$\boxed{2V_2 - V_3 = -4}$$

KCL at 3 : $I_1 + 1m + I_2 = I_3$

$$\frac{V_1 - V_3}{2K} + 1m + \frac{V_2 - V_3}{1K} = \frac{V_3 - V_o}{1K}$$

$$V_1 - V_3 + 2 + 2V_2 - 2V_3 = 2V_3 - 2V_o$$

$$-2V_o + 5V_3 - 2V_2 - V_1 = 2$$

$$\boxed{-2V_o - V_1 - 2V_2 + 5V_3 = 2}$$

KCL at 0 : $I_3 = 2m + I_0$

$$\frac{V_3 - V_0}{1K} = 2m + \frac{V_0}{2K}$$

$$2V_3 - 2V_0 = 4 + V_0$$

$$\boxed{-3V_0 + 2V_3 = 4}$$

KCL at 1 : $4m + 2m = I_1$

$$\frac{V_1 - V_3}{2K} = 6m$$

$$\boxed{V_1 - V_3 = 12}$$

$$0V_0 + 0V_1 + 2V_2 - V_3 = -4$$
$$-2V_0 - V_1 - 2V_2 + 5V_3 = 2$$
$$-3V_0 + 0V_1 + 0V_2 + 2V_3 = 4$$
$$0V_0 + V_1 + 0V_2 - V_3 = 12$$

$V_0 = 1.6\ V$

$V_1 = 16.4\ V$

$V_2 = 0.2\ V$

$V_3 = 4.4\ V$

3.6 Use nodal analysis to find V_o in the circuit in Fig. P3.6.

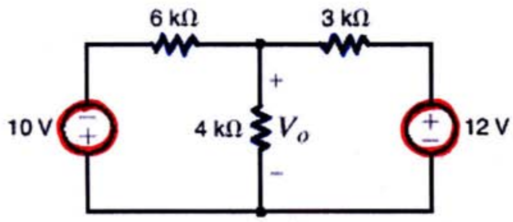
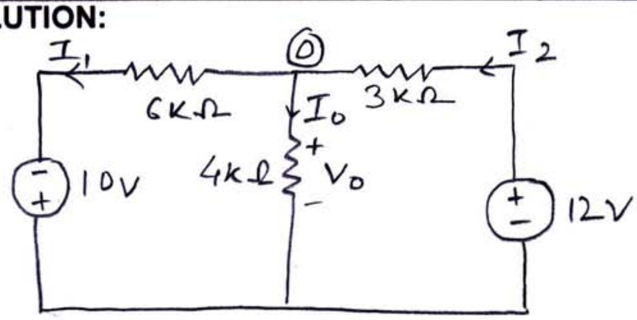


Figure P3.6

SOLUTION:



KCL at 0: $I_2 = I_o + I_1$

$$\frac{12 - V_o}{3K} = \frac{V_o}{4K} + \frac{V_o - (-10)}{6K}$$

$$48 - 4V_o = 3V_o + 2V_o + 20$$

$$9V_o = 28$$

$$V_o = 3.11 \text{ V}$$

3.7 Find V_o in the network in Fig. P3.7 using nodal analysis.

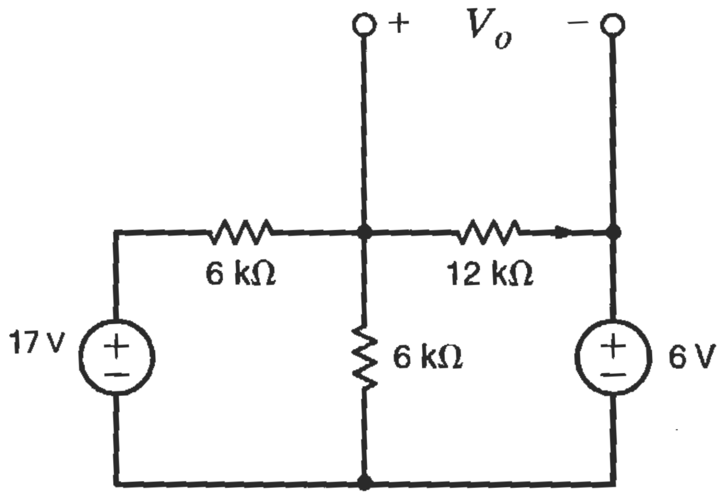
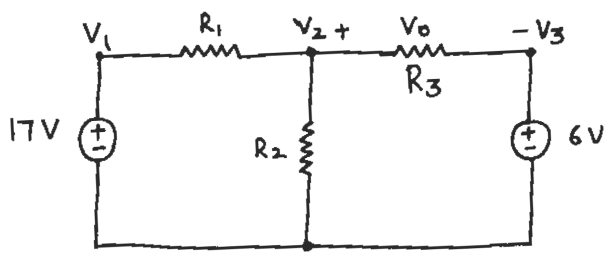


Figure P3.7

SOLUTION: 3.7



$R_1 = R_2 = 6\ k\Omega$, $R_3 = 12\ k\Omega$

@ V_1 : $V_1 = 17\ V$

KCL @ V_2 : $\frac{V_2 - V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_2 - V_3}{R_3} = 0$ —— ①

@ V_3 : $V_3 = 6\ V$

Substituting values of V_1 and V_3 in equation ①, we get

$$\frac{V_2}{R_1} - \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_2}{R_3} - \frac{V_3}{R_3} = 0$$

$$V_2 \left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right] - \frac{V_1}{R_1} - \frac{V_3}{R_3} = 0$$

$$V_2\left[\frac{1}{6}+\frac{1}{6}+\frac{1}{12}\right]-\frac{17}{6}-\frac{6}{12}=0$$

$$V_2 = 8\text{ V}$$

$$V_0 = V_2 - V_3$$

$$\boxed{V_0 = 2\text{V}}$$

3.8 Use nodal analysis to find V_o in the circuit in Fig. P3.8.

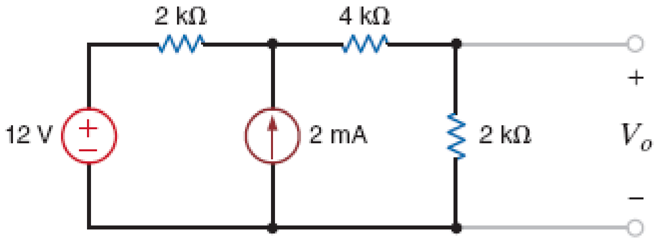
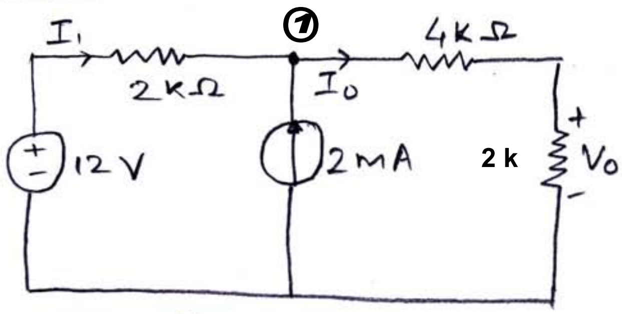


Figure P3.8

SOLUTION:



KCL at (1) : $I_1 + 2m = I_o$

$$\frac{12 - V_1}{2K} + 2m = \frac{V_1}{4K + 2K}$$

$$36 - 3V_1 + 12 = V_1$$

$$4V_1 = 48$$

$$V_1 = 12 \text{ V}$$

$$I_o = \frac{V_1}{4K+2K}$$

$$= \frac{12}{6K}$$

$$I_o = 2 \text{ mA}$$

$$V_o = I_o (2K)$$

$$= 2m (2K)$$

$$V_o = 4 \text{ V}$$

3.9 Use nodal analysis to find V_o in the circuit in Fig. P3.9.

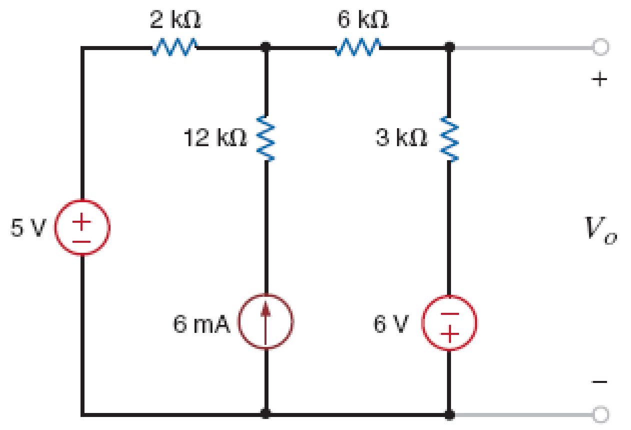
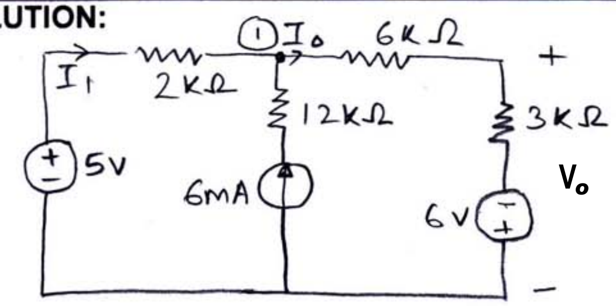


Figure P3.9

SOLUTION:



KCL at 1 : $I_1 + 6m = I_o$

$$\frac{5 - V_1}{2K} + 6m = \frac{V_1 - (-6)}{6K + 3K}$$

$$45 - 9V_1 + 108 = 2V_1 + 12$$

$$11V_1 = 141$$

$$V_1 = 12.82 \text{ V}$$

$$I_o = \frac{V_1 - (-6)}{6K + 3K}$$

$$= \frac{12.82 + 6}{9K}$$

$$I_o = 2.09 \text{ mA}$$

$$6 + V_o = 3K\, I_o$$

$$V_o = 3K(2.09m) - 6$$

$$V_o = 0.27 \text{ V}$$

3.10 Use nodal analysis to find V_o in the network in Fig. P3.10.

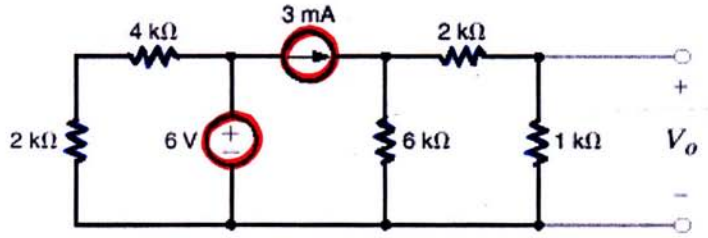
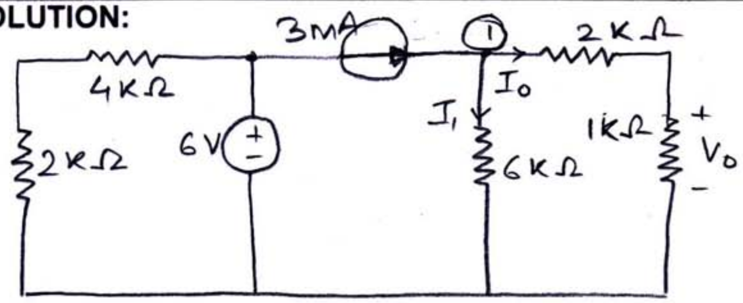


Figure P3.10

SOLUTION:



KCL at 1: $3m = I_1 + I_o$

$$\frac{V_1}{6K} + \frac{V_1}{2K+1K} = 3m$$

$$V_1 + 2V_1 = 18$$

$$3V_1 = 18$$

$$V_1 = 6 \text{ V}$$

$$I_o = \frac{V_1}{2K+1K} = \frac{6}{3K}$$

$$I_o = 2 \text{ mA}$$

$$V_o = I_o(1K)$$

$$= 2m(1K)$$

$$V_o = 2 \text{ V}$$

3.11 Use nodal analysis to find V_o in the circuit in Fig. P3.11.

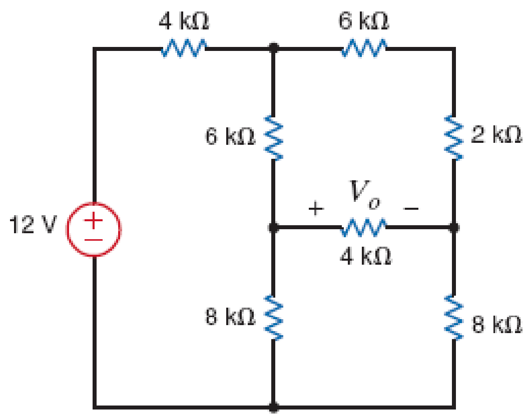
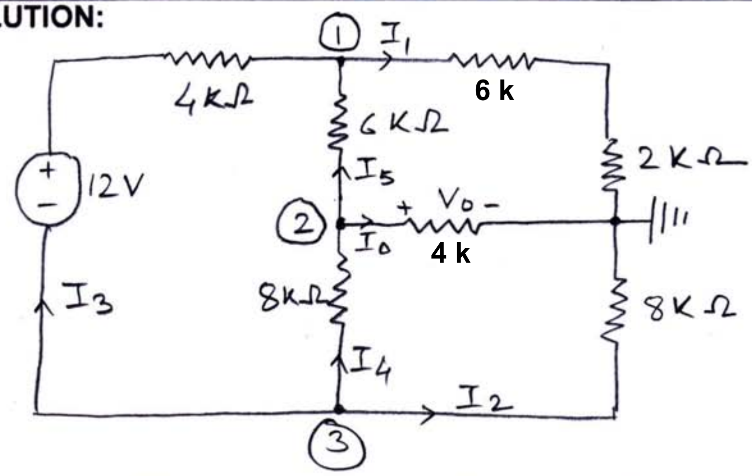


Figure P3.11

SOLUTION:



KCL at 1 :

$$I_3 + I_5 = I_1$$

$$\frac{12 - V_1}{4K} + \frac{V_2 - V_1}{6K} = \frac{V_1}{6K + 2K}$$

$$72 - 6V_1 + 4V_2 - 4V_1 = 3V_1$$

$$\boxed{13V_1 - 4V_2 = 72}$$

KCL at 2 :

$$I_4 = I_o + I_5$$

$$\frac{V_3 - V_2}{8K} = \frac{V_2}{4K} + \frac{V_2 - V_1}{6K}$$

$$3V_3 - 3V_2 = 6V_2 + 4V_2 - 4V_1$$

$$\boxed{4V_1 - 13V_2 + 3V_3 = 0}$$

KCL at 3: $I_2 + I_3 + I_4 = 0$

$$\frac{-12+V_1}{4K} + \frac{V_3}{8K} + \frac{V_3 - V_2}{8K} = 0$$

$$-24 + 2V_1 + V_3 + V_3 - V_2 = 0$$

$$\boxed{2V_1 - V_2 + 2V_3 = 24}$$

$$13V_1 - 4V_2 + 0V_3 = 72$$
$$4V_1 - 13V_2 + 3V_3 = 0$$
$$2V_1 - V_2 + 2V_3 = 24$$

$$V_1 = 6.68 \text{ V}$$
$$V_2 = 3.71 \text{ V}$$
$$V_3 = 7.18 \text{ V}$$

$$V_o = V_2 = 3.71 \text{ V}$$

3.12 Find I_o in the network in Fig. P3.12 using nodal analysis.

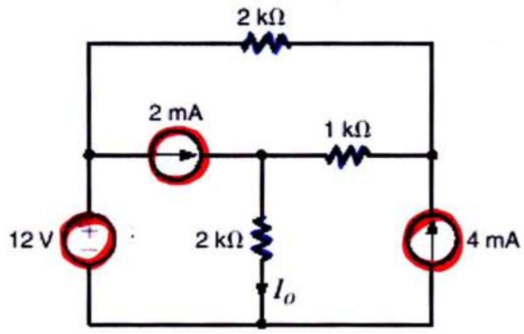
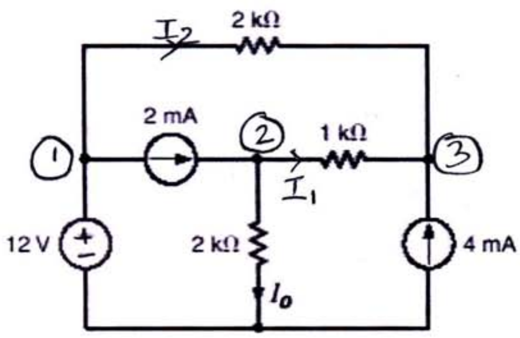


Figure P3.12

SOLUTION:



KCL at 2 :

$$2m = \frac{V_2}{2K} + \frac{V_2 - V_3}{1K}$$

$$4 = V_2 + 2V_2 - 2V_3$$

$$\boxed{3V_2 - 2V_3 = 4}$$

KCL at 3 :

$$I_1 + I_2 + 4m = 0$$

$$\frac{V_2 - V_3}{1K} + \frac{V_1 - V_3}{2K} + 4m = 0$$

$$2V_2 - 2V_3 + V_1 - V_3 + 8 = 0$$

$$V_1 = 12V$$

$$\boxed{2V_2 - 3V_3 = -20}$$

$$3V_2 - 2V_3 = 4$$
$$2V_2 - 3V_3 = -20$$

$$V_2 = 10.4 \ V$$
$$V_3 = 13.6 \ V$$

$$I_o = \frac{V_2}{2K}$$
$$= \frac{10.4}{2K}$$
$$I_o = 5.2 \ mA$$

3.13 Use nodal analysis to solve for the node voltages in the circuit in Fig. P3.13. Also calculate the power supplied by the 1-A current source.

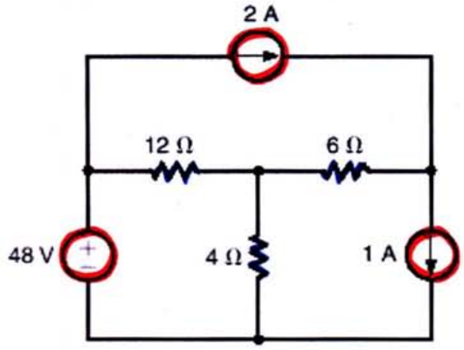
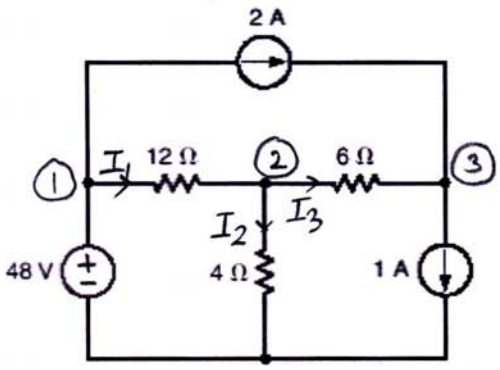


Figure P3.13

SOLUTION:



KCL at 2: $I_1 = I_2 + I_3$

$$\frac{V_1 - V_2}{12} = \frac{V_2}{4} + \frac{V_2 - V_3}{6}$$

$$V_1 - V_2 = 3V_2 + 2V_2 - 2V_3$$

$$V_1 = 48 \text{ V}$$

$$\boxed{6V_2 - 2V_3 = 48}$$

KCL at 3: $2 + I_3 - 1 = 0$

$$\frac{V_2 - V_3}{6} = -1$$

$$\boxed{V_2 - V_3 = -6}$$

$$6V_2 - 2V_3 = 48$$
$$V_2 - V_3 = -6$$

$$V_2 = 15 \text{ V}$$
$$V_3 = 21 \text{ V}$$

$$P_{1A} = V_3(1)$$
$$= 21(1)$$

$$P_{1A} = 21 \text{ W}$$

3.14 Find V_o in the network in Fig. P3.14 using nodal equations.

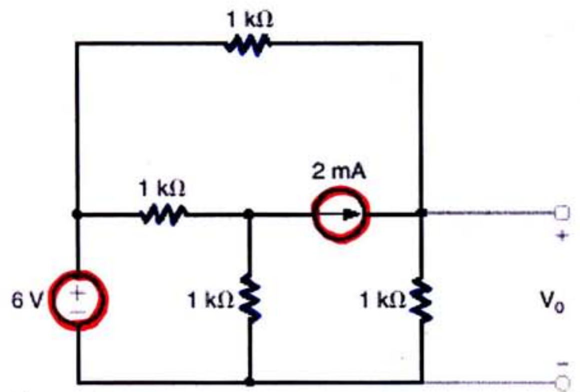
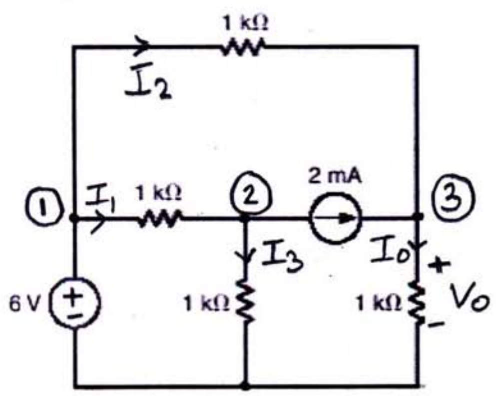


Figure P3.14

SOLUTION:



KCL at 2 : $I_1 = I_3 + 2m$

$$\frac{V_1 - V_2}{1K} = \frac{V_2}{1K} + 2m$$

$$V_1 - V_2 = V_2 + 2$$

$$\boxed{V_1 - 2V_2 = 2}$$

$$V_1 = 6\text{ V}$$
$$-2V_2 = -4$$
$$V_2 = 2\text{ V}$$

KCL at 3 : $I_2 + 2m = I_o$

$$\frac{V_1 - V_3}{1K} + 2m = \frac{V_3}{1K}$$

$$V_1 - V_3 + 2 = V_3$$

$$2V_3 = 8$$
$$V_3 = 4\ V$$

$$V_0 = V_3$$

$$V_0 = 4\ V$$

3.15 Find I_o in the network in Fig. P3.15 using nodal analysis.

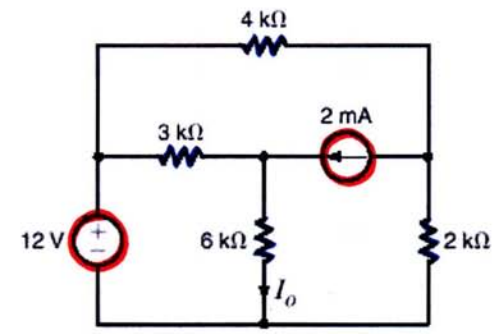
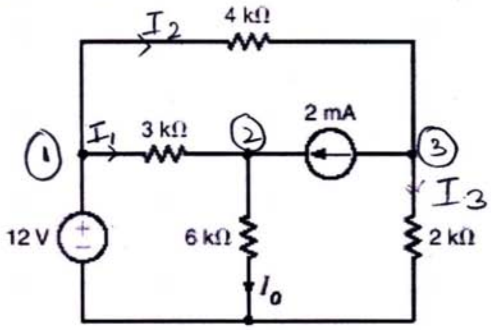


Figure P3.15

SOLUTION:



KCL at (2) : $I_1 + 2m = I_o$

$$\frac{V_1 - V_2}{3K} + 2m = \frac{V_2}{6K}$$

$$2V_1 - 2V_2 + 12 = V_2$$

$$\boxed{2V_1 - 3V_2 = -12}$$

KCL at (3) : $I_2 = 2m + I_3$

$$\frac{V_1 - V_3}{4K} = 2m + \frac{V_3}{2K}$$

$$V_1 - V_3 = 8 + 2V_3$$

$$\boxed{V_1 - 3V_3 = 8}$$

$V_1 = 12\ V$

$$2(12) - 3V_2 = -12$$

$$-3V_2 = -36$$

$$V_2 = 12\ V$$

$$I_o = \frac{V_2}{6K}$$

$$= \frac{12}{6K}$$

$$I_o = 2mA$$

3.16 Use nodal analysis to find I_o in the circuit in Fig. P3.16.

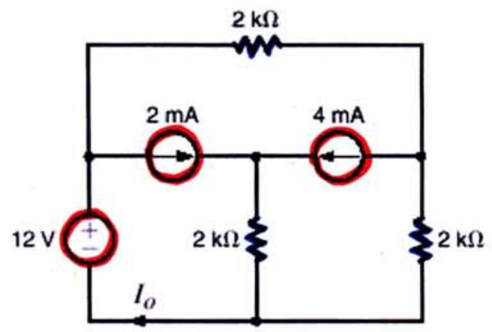
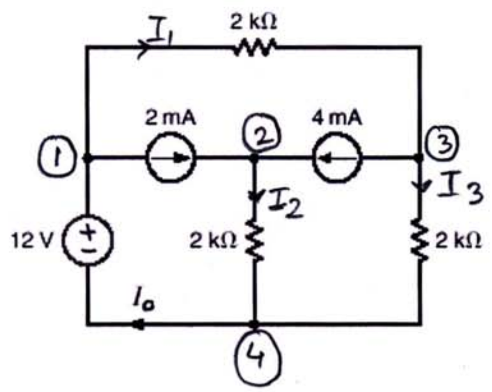


Figure P3.16

SOLUTION:



KCL at (2): $2m + 4m = I_2$

$$\frac{V_2}{2K} = 6m$$

$$V_2 = 12V$$

KCL at (3): $I_1 = 4m + I_3$

$$\frac{V_1 - V_3}{2K} = 4m + \frac{V_3}{2K}$$

$$V_1 - V_3 = 8 + V_3$$

$$2V_3 = V_1 - 8$$

$$V_1 = 12 \text{ V}$$

$$2V_3 = 12 - 8$$

$$V_3 = 2 \text{ V}$$

$$I_2 = \frac{V_2}{2K}$$

$$I_2 = \frac{12}{2K} = 6mA$$

$$I_3 = \frac{V_3}{2K} = \frac{2}{2K} = 1mA$$

KCL at 4 : $I_2 + I_3 = I_0$

$$I_0 = 6m + 1m$$

$$I_0 = 7mA$$

3.17 Find V_o in the circuit in Fig. P3.17 using nodal analysis.

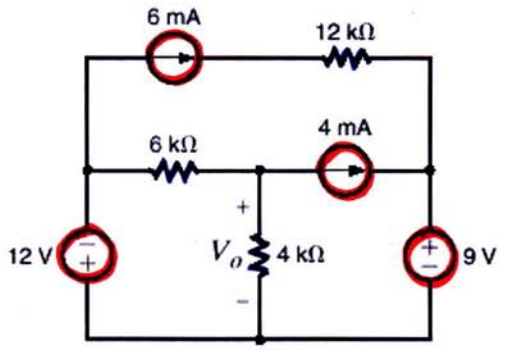
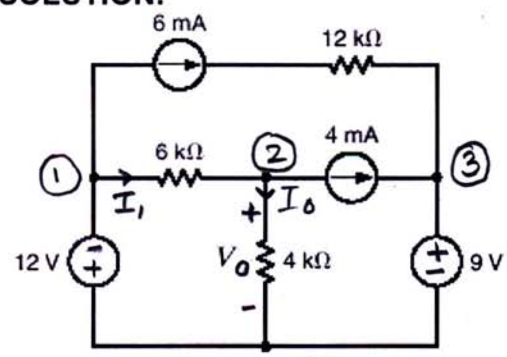


Figure P3.17

SOLUTION:



KCL at 2 : $I_1 = I_o + 4m$

$$\frac{V_1 - V_2}{6K} = \frac{V_2}{4K} + 4m$$

$$2V_1 - 2V_2 = 3V_2 + 48$$

$$\boxed{2V_1 - 5V_2 = 48}$$

$$V_1 = -12\text{ V}$$

$$2(-12) - 5V_2 = 48$$

$$V_2 = -14.4\text{ V}$$

$$V_o = V_2 = -14.4\text{ V}$$

$$V_o = -14.4\text{ V}$$

3.18 Use nodal analysis to find V_o in the network in Fig. P3.18.

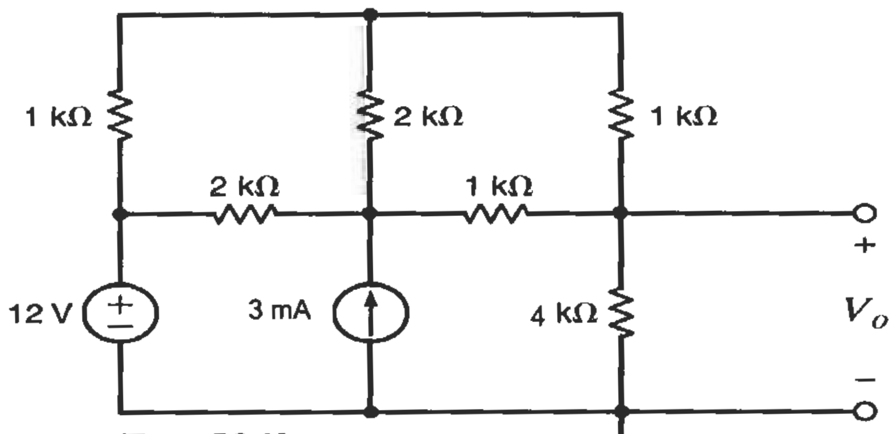
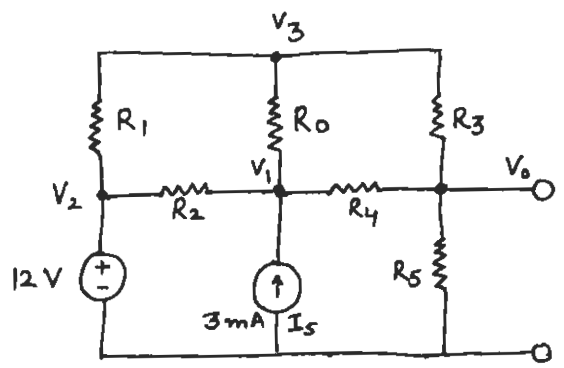


Figure P3.18

SOLUTION: 3.18



$V_2 = 12\,V$

$R_5 = 4k\Omega,\ R_1 = 1\,k\Omega,\ R_2 = 2\,k\Omega,\ R_3 = 1\,k\Omega,\ R_4 = 1\,k\Omega,\ R_0 = 2\,k\Omega$

KCL @ V_1 : $\dfrac{V_1 - V_0}{R_4} + \dfrac{V_1 - V_3}{R_0} + \dfrac{V_1 - V_2}{R_2} = I_s$

$$\frac{V_1 - V_0}{1\times 10^3} + \frac{V_1 - V_3}{2\times 10^3} + \frac{V_1 - 12}{2\times 10^3} = 3\times 10^{-3}$$

$$2V_1 - 2V_0 + V_1 - V_3 + V_1 - 12 = 6$$

$$4V_1 - V_3 - 2V_0 = 18 \qquad \text{——} \qquad (1)$$

KCL @ V_3: $\frac{V_3 - V_2}{R_1} + \frac{V_3 - V_1}{R_0} + \frac{V_3 - V_0}{R_3} = 0$

$$\frac{V_3 - 12}{1\times10^3} + \frac{V_3 - V_1}{2\times10^3} + \frac{V_3 - V_0}{1\times10^3} = 0$$

$$-V_1 + 5V_3 - 2V_0 = 24 \quad \text{—— (2)}$$

KCL @ V_0: $\frac{V_0 - V_3}{R_3} + \frac{V_0 - V_1}{R_4} + \frac{V_0}{R_5} = 0$

$$\frac{V_0 - V_3}{1\times10^3} + \frac{V_0 - V_1}{1\times10^3} + \frac{V_0}{4\times10^3} = 0$$

$$-4V_1 - 4V_3 + 9V_0 = 0 \quad \text{—— (3)}$$

From equation (1)

$$V_1 = \frac{18 + V_3 + 2V_0}{4} \quad \text{—— (4)}$$

Substituting equation (4) in (2), we get

$$19V_3 - 10V_0 = 114 \quad \text{—— (5)}$$

Substituting equation (4) in (3), we get

$$-4V_1 - 4V_3 + 9V_0 = 0$$

$$-\cancel{4}\left[\frac{18 + V_3 + 2V_0}{\cancel{4}}\right] - 4V_3 + 9V_0 = 0$$

$$-5V_3 + 7V_0 = 18 \quad \text{—— (6)}$$

From equations (5) and (6), we get

$$83V_0 = 912$$

$$V_0 = \frac{912}{83} = 10.99$$

$$\boxed{V_0 = 11.0V}$$

3.19 Find I_o in the circuit in Fig. P3.19 using nodal analysis.

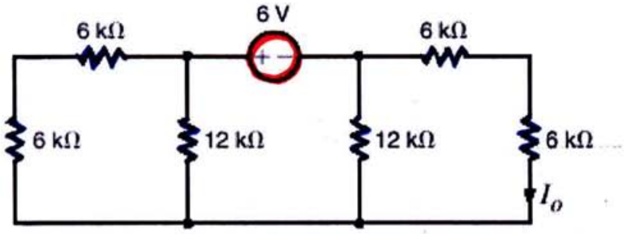
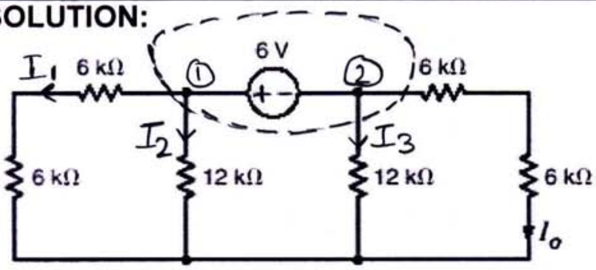


Figure P3.19

SOLUTION:



KCL at supernode : $I_1 + I_2 + I_3 + I_0 = 0$

$$\frac{V_1}{6K+6K} + \frac{V_1}{12K} + \frac{V_2}{12K} + \frac{V_2}{6K+6K} = 0$$

$$V_1 + V_1 + V_2 + V_2 = 0$$

$$\boxed{2V_1 + 2V_2 = 0}$$

$$\boxed{V_1 - V_2 = 6}$$

$$2V_1 + 2V_2 = 0$$
$$V_1 - V_2 = 6$$

$$V_1 = 3\ V$$
$$V_2 = -3\ V$$

$$I_0 = \frac{V_2}{12k}$$
$$= \frac{-3}{12k}$$
$$I_0 = -0.25\ mA$$

3.20 Use nodal analysis to find I_o in the circuit in Fig. P3.20.

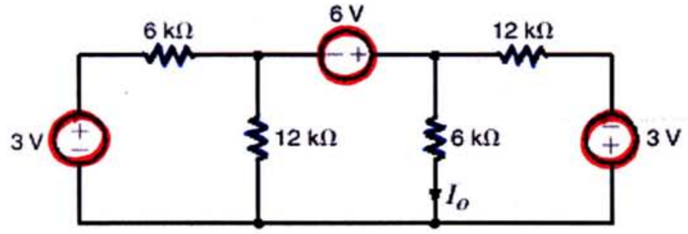
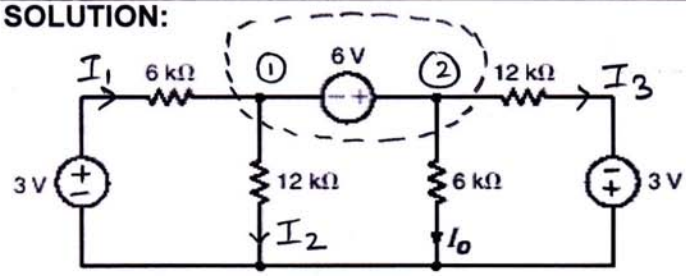


Figure P3.20

SOLUTION:



KCL at supernode : $I = I_2 + I_o + I_3$

$$\frac{3 - V_1}{6K} = \frac{V_1}{12K} + \frac{V_2}{6K} + \frac{V_2 - (-3)}{12K}$$

$$6 - 2V_1 = V_1 + 2V_2 + V_2 + 3$$

$$\boxed{3V_1 + 3V_2 = 3}$$

$$V_2 - V_1 = 6$$

$$\boxed{-V_1 + V_2 = 6}$$

$$3V_1 + 3V_2 = 3$$
$$-V_1 + V_2 = 6$$

$$V_1 = -2.5 \text{ V}$$
$$V_2 = 3.5 \text{ V}$$

$$I_o = \frac{V_2}{6K}$$
$$= \frac{3.5}{6K}$$
$$I_o = 0.583 \text{ mA}$$

3.21 Using nodal analysis, find V_o in the network in Fig. P3.21.

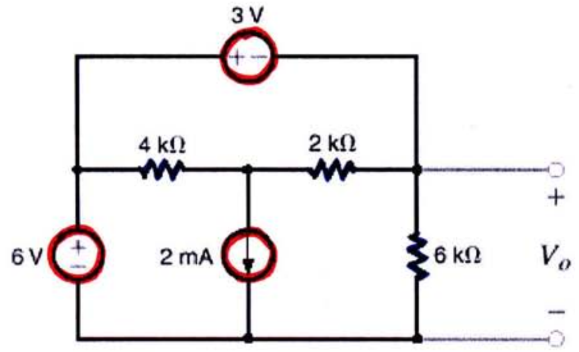
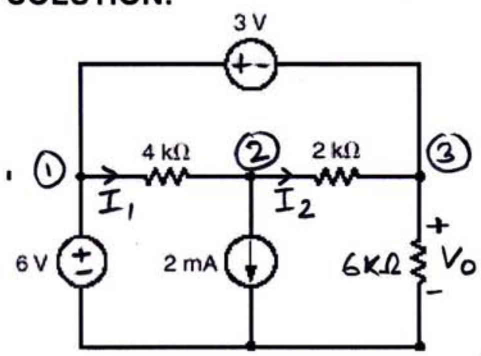


Figure P3.21

SOLUTION:



KCL at 2 : $I_1 = 2m + I_2$

$$\frac{V_1 - V_2}{4K} = 2m + \frac{V_2 - V_3}{2K}$$

$$V_1 - V_2 = 8 + 2V_2 - 2V_3$$

$$\boxed{3V_2 - 2V_3 = -2}$$

$$V_1 - V_3 = 3$$
$$-V_3 = 3 - 6$$
$$V_3 = 3V$$

$$V_o = V_3 = 3\ V$$
$$V_o = 3\ V$$

3.22 Find V_o in the network in Fig. P3.22 using nodal analysis.

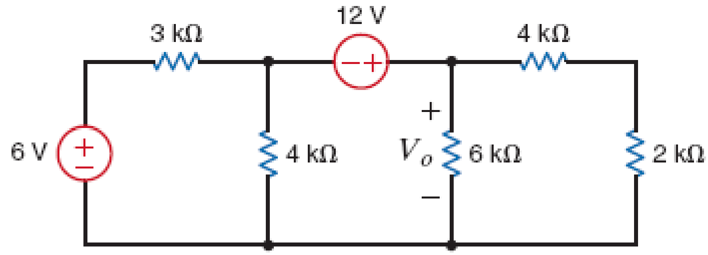
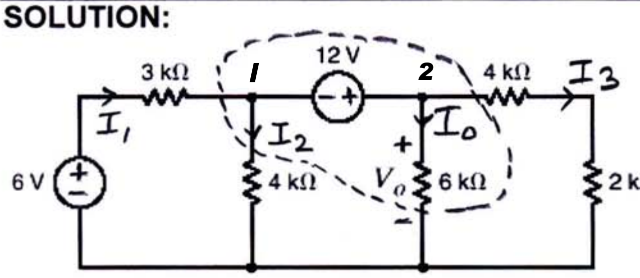


Figure P3.22

SOLUTION:



KCL at supernode : $I_1 = I_2 + I_o + I_3$

$$\frac{6 - V_1}{3K} = \frac{V_1}{4K} + \frac{V_2}{6K} + \frac{V_2}{4K + 2K}$$

$$24 - 4V_1 = 3V_1 + 2V_2 + 2V_2$$

$$\boxed{7V_1 + 4V_2 = 24}$$

$$V_2 - V_1 = 12$$

$$\boxed{-V_1 + V_2 = 12}$$

$$7V_1 + 4V_2 = 24$$
$$-V_1 + V_2 = 12$$

$$V_1 = -2.18 \text{ V}$$
$$V_2 = 9.82 \text{ V}$$
$$V_o = V_2 = 9.82 \text{ V}$$

$$V_o = 9.82 \text{ V}$$

3.23 Find V_o in the circuit in Fig. P3.23 using nodal analysis.

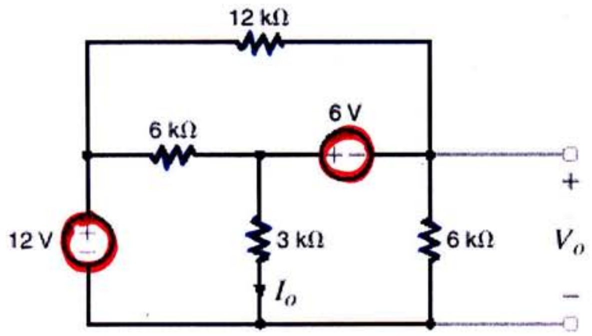
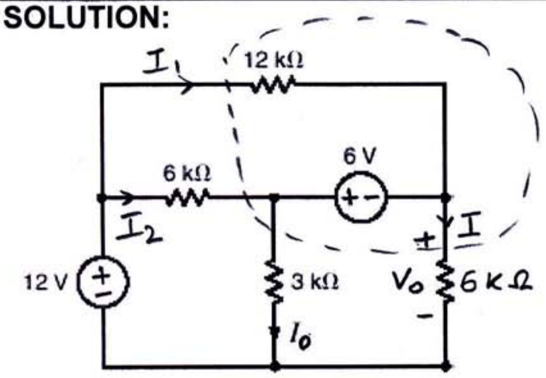


Figure P3.23

SOLUTION:



KCL at supernode: $I_1 + I_2 = I_0 + I$

$$\frac{V_1 - V_3}{12K} + \frac{V_1 - V_2}{6K} = \frac{V_2}{3K} + \frac{V_3}{6K}$$

$$V_1 - V_3 + 2V_1 - 2V_2 = 4V_2 + 2V_3$$

$V_1 = 12\,V$

$$\boxed{6V_2 + 3V_3 = 36}$$

$$\boxed{V_2 - V_3 = 6}$$

$$6V_2 + 3V_3 = 36$$
$$V_2 - V_3 = 6$$

$V_2 = 6\,V$

$V_3 = 0\,V$

$V_0 = V_3 = 0\,V$

$V_0 = 0\,V$

3.24 Use nodal analysis to find V_o in the circuit in Fig. P3.24.

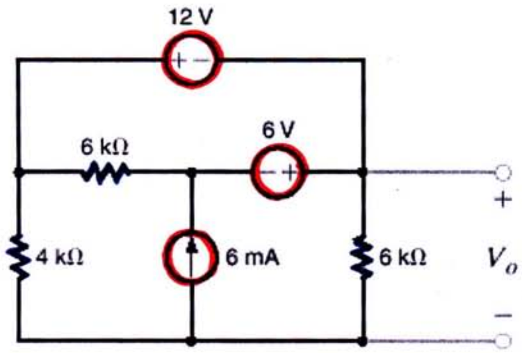
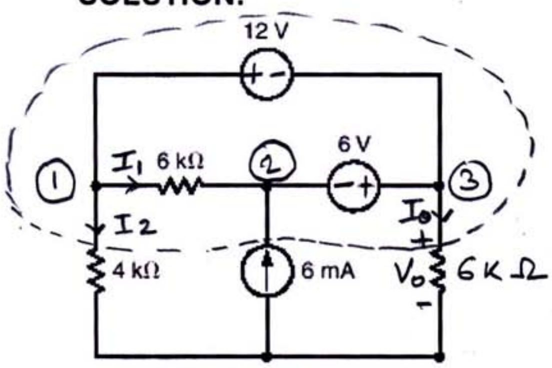


Figure P3.24

SOLUTION:



KCL at supernode: $6m = I_2 + I_o$

$$\frac{V_1}{4K} + \frac{V_3}{6K} = 6m$$

$$\boxed{3V_1 + 2V_3 = 72}$$

$$\boxed{V_1 - V_3 = 12}$$

$$3V_1 + 2V_3 = 72$$
$$V_1 - V_3 = 12$$

$$V_1 = 19.2 \text{ V}$$
$$V_3 = 7.2 \text{ V}$$

$$V_o = V_3 = 7.2 \text{ V}$$

$$V_o = 7.2 \text{ V}$$

3.25 Find V_o in the circuit in Fig. P3.25.

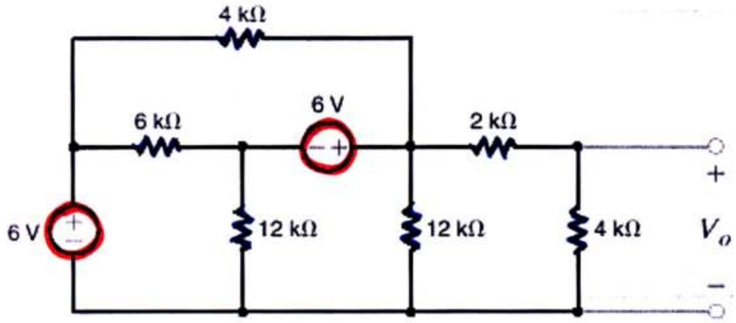
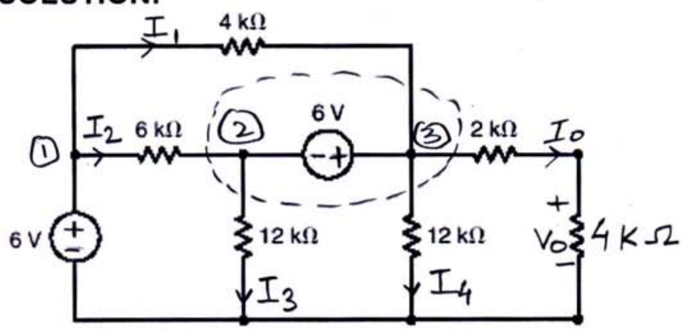


Figure P3.25

SOLUTION:



KCL at supernode : $I_1 + I_2 = I_3 + I_4 + I_o$

$$\frac{V_1 - V_3}{4K} + \frac{V_1 - V_2}{6K} = \frac{V_2}{12K} + \frac{V_3}{12K} + \frac{V_3}{2K + 4K}$$

$$3V_1 - 3V_3 + 2V_1 - 2V_2 = V_2 + V_3 + 2V_3$$

$$V_1 = 6V$$

$$\boxed{3V_2 + 6V_3 = 30}$$

$$V_3 - V_2 = 6$$

$$\boxed{-V_2 + V_3 = 6}$$

$$3V_2 + 6V_3 = 30$$
$$-V_2 + V_3 = 6$$

$$V_2 = -0.667\ V$$
$$V_3 = 5.33\ V$$

$$I_o = \frac{V_3}{2K + 4K} = \frac{5.33}{6K} = 0.888\ mA$$

$$V_o = I_o(4K) = 0.888(4) = 3.55\ V$$

3.26 Find V_o in the circuit in Fig. P3.26 using nodal analysis.

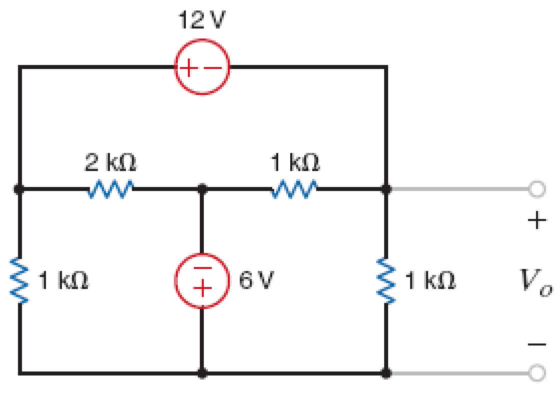
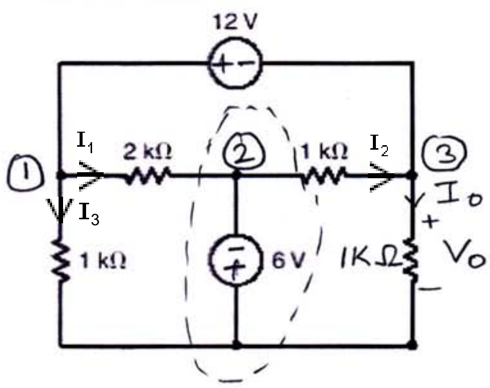


Figure P3.26

SOLUTION:



KCL at supernode: $I_1 + I_3 + I_o = I_2$

$$\frac{V_1 - V_2}{2K} + \frac{V_1}{1K} + \frac{V_3}{1K} = \frac{V_2 - V_3}{1K}$$

$$V_1 - V_2 + 2V_1 + 2V_3 = 2V_2 - 2V_3$$

$$V_2 = -6V$$

$$\boxed{3V_1 + 4V_3 = -18}$$

$$\boxed{V_1 - V_3 = 12}$$

$$V_1 = 4.29 \ V$$

$$V_3 = -7.71 \ V$$

$$V_o = V_3 = -7.71 \ V$$

$$V_o = -7.71 \ V$$

3.27 Use nodal analysis to find V_o in the circuit in Fig. P3.27.

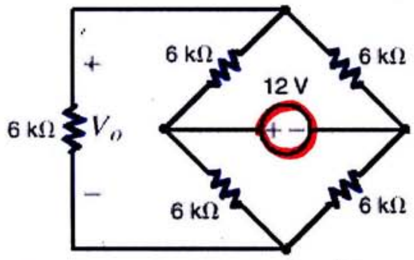
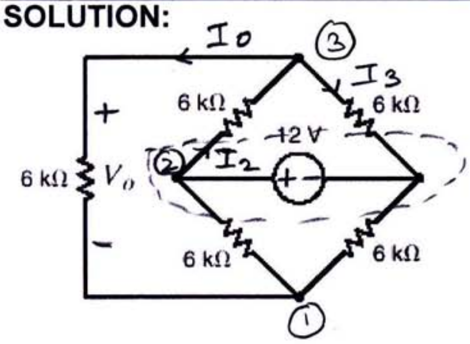


Figure P3.27

SOLUTION:



KCL at supernode: $I_1 + I_4 + I_3 = I_2$

$$\frac{V_1}{6K} + \frac{V_1 - V_2}{6K} + \frac{V_3}{6K} = \frac{V_2 - V_3}{6K}$$

$$V_1 + V_1 - V_2 + V_3 = V_2 - V_3$$

$$\boxed{2V_1 - 2V_2 + 2V_3 = 0}$$

KCL at 1 : $I_o = I_1 + I_4$

$$\frac{V_3 - V_1}{6K} = \frac{V_1}{6K} + \frac{V_1 - V_2}{6K}$$

$$V_3 - V_1 = V_1 + V_1 - V_2$$

$$\boxed{3V_1 - V_2 - V_3 = 0} \qquad \boxed{V_2 = 12V}$$

$$\boxed{2V_1 + 2V_3 = 24} \qquad \boxed{3V_1 - V_3 = 12}$$

$$2V_1 + 2V_3 = 24$$
$$3V_1 - V_3 = 12$$

$$2V_1 + 2V_3 = 24$$
$$3V_1 - V_3 = 12$$

$$V_1 = 6\text{ V}$$
$$V_3 = 6\text{ V}$$

$$V_o = V_3 - V_1 = 6 - 6$$
$$V_o = 0\text{ V}$$

It should be noted that this circuit is a balanced Wheatstone bridge. Therefore, the output voltage is zero.

3.28 Use nodal analysis to find V_o in the circuit in Fig. P3.28.

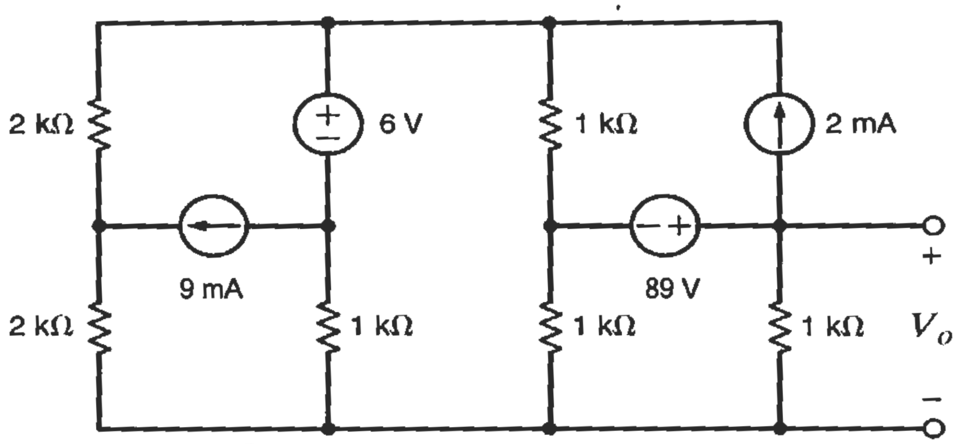
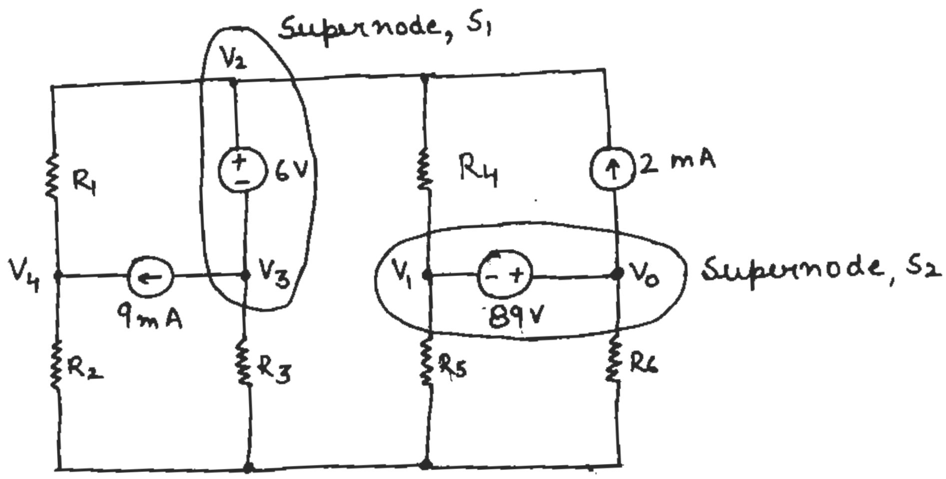


Figure P3.28

SOLUTION: 3.28



$R_1 = R_2 = 2\ k\Omega$, $R_3 = R_4 = R_5 = R_6 = 1\ k\Omega$

$$V_2 - V_3 = 6\ V \quad \text{—— (1)}$$

$$V_o - V_1 = 89\ V \quad \text{—— (2)}$$

KCL @ S_1: $\frac{V_2 - V_4}{R_1} + \frac{V_2 - V_1}{R_4} - 2\times10^{-3} + 9\times10^{-3} + \frac{V_3}{R_3} = 0$

$$-2V_1 + 3V_2 + 2V_3 - V_4 = -14 \quad \text{—— (3)}$$

KCL @ S_2: $2\times10^{-3} + \frac{V_o}{R_6} + \frac{V_1 - V_2}{R_4} + \frac{V_1}{R_5} = 0$

$$V_o + 2V_1 - V_2 = -2 \quad \text{—— (4)}$$

KCL at V_4 : $\frac{V_4 - V_2}{R_1} - 9 \times 10^{-3} + \frac{V_4}{R_2} = 0$

$$V_4 = 9 + \frac{V_2}{2} \quad \text{——} \quad (5)$$

Substituting equations (1), (2) and (5) in (3), we get

$$-2(V_0 - 89) + 3V_2 + 2(V_2 - 6) - \left(9 + \frac{V_2}{2}\right) = -14$$

$$-4V_0 + 9V_2 = -342 \quad \text{——} \quad (6)$$

Substituting equation (1) in (4), we get

$$V_2 = 3V_0 - 176$$

Substituting the value of V_2 in equation (6), we get

$$-4V_0 + 9(3V_0 - 176) = -342$$

$$V_0 = 53.7 \text{ V}$$

$$\boxed{V_0 = 54.0 \text{ V}}$$

3.29 Find V_o in the network in Fig. P3.29.

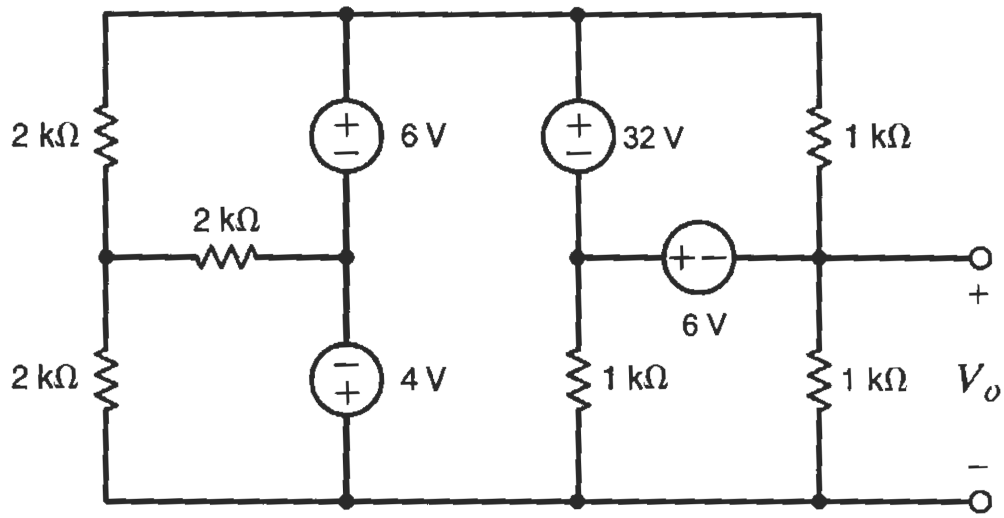
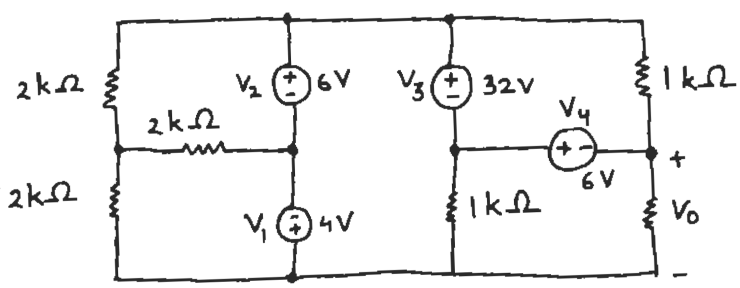


Figure P3.29

SOLUTION: 3.29



$$\text{KVL}: \quad V_1 - V_2 + V_3 + V_4 + V_o = 0$$

$$4 - 6 + 32 + 6 + V_o = 0$$

$$36 + V_o = 0$$

$$\boxed{V_o = -36.0 \text{ V}}$$

3.30 Find I_o in the circuit in Fig. P3.30 using nodal analysis.

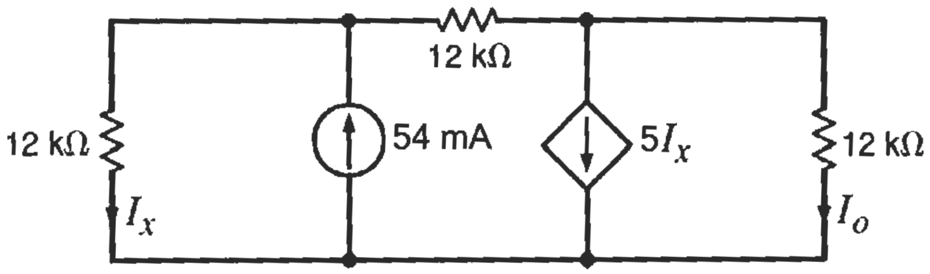
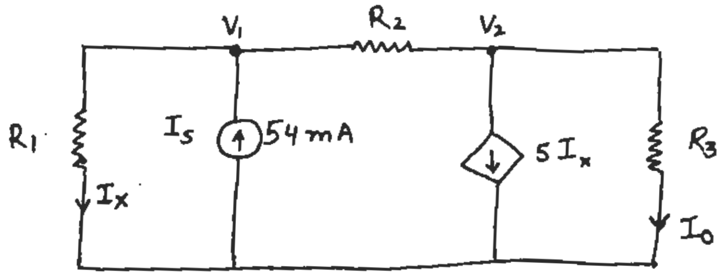


Figure P3.30

SOLUTION: 3.30



$R_1 = R_2 = R_3 = 12\ k\Omega$

KCL @ V_1 : $\dfrac{V_1}{R_1} - I_s + \dfrac{V_1 - V_2}{R_2} = 0$

$$\frac{V_1}{12 \times 10^3} - 54 \times 10^{-3} + \frac{V_1 - V_2}{12 \times 10^3} = 0$$

$$2V_1 - V_2 = 648 \quad \text{— } ①$$

$$I_x = \frac{V_1}{R_1}$$

$$I_o = \frac{V_2}{R_3} \quad \text{— } ②$$

KCL @ V_2 : $\dfrac{V_2 - V_1}{R_2} + 5I_x + \dfrac{V_2}{R_3} = 0$

$$\frac{V_2 - V_1}{12 \times 10^3} + 5 \cdot \frac{V_1}{12 \times 10^3} + \frac{V_2}{12 \times 10^3} = 0$$

$$2V_1 + V_2 = 0 \quad \text{---} \quad (3)$$

From equations (1) and (3), we get

$$V_2 = -324\ V$$

Substituting the value of V_2 in equation (2), we get

$$I_0 = \frac{V_2}{R_3}$$

$$\boxed{I_0 = -27.0\ mA}$$

3.31 Find V_o in the circuit in Fig. P3.31 using nodal analysis.

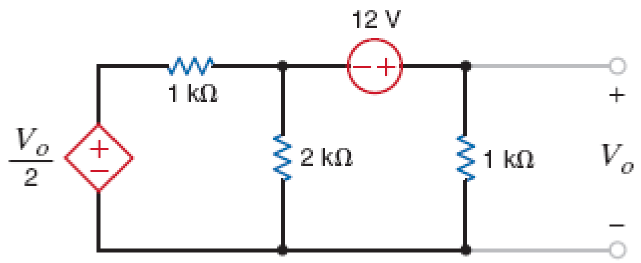
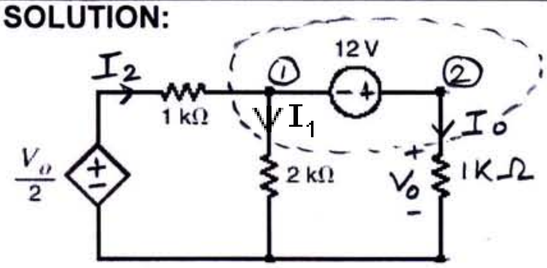


Figure P3.31

SOLUTION:



KCL at supernode: $I_2 = I_1 + I_o$

$$\frac{\frac{V_o}{2} - V_1}{1K} = \frac{V_1}{2K} + \frac{V_2}{1K}$$

$$V_o = V_2$$

$$\frac{\frac{V_2}{2} - V_1}{1K} = \frac{V_1}{2K} + \frac{V_2}{1K}$$

$$V_2 - 2V_1 = V_1 + 2V_2$$

$$\boxed{3V_1 + V_2 = 0}$$

$$V_2 - V_1 = 12$$

$$\boxed{-V_1 + V_2 = 12}$$

$$3V_1 + V_2 = 0$$
$$-V_1 + V_2 = 12$$

$$V_1 = -3V$$

$$V_2 = 9 \text{ V}$$

$$V_o = V_2 = 9 \text{ V}$$

$$V_o = 9 \text{ V}$$

3.32 Find V_o in the circuit in Fig. P3.32.

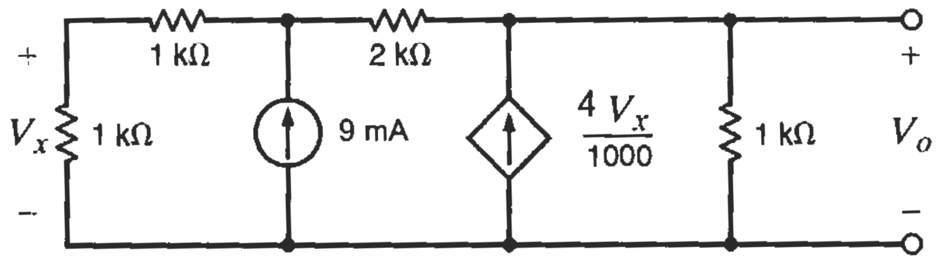
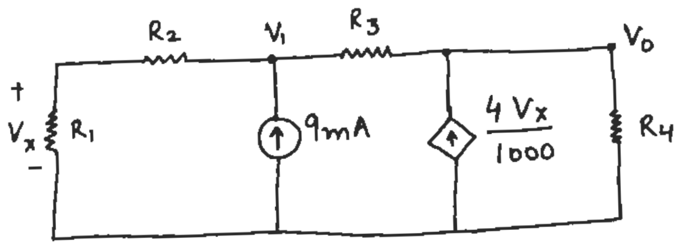


Figure P3.32

SOLUTION: 3.32



$R_1 = R_2 = 1\,k\Omega \;,\; R_3 = 2\,k\Omega$

KCL @ V_1 : $\dfrac{V_1}{R_1+R_2} - 9\times10^{-3} + \dfrac{V_1-V_0}{R_3} = 0$

$$\frac{V_1}{2\times10^3} + \frac{V_1-V_0}{2\times10^3} = 9\times10^{-3}$$

$$2V_1 - V_0 = 18 \quad \text{—} \quad (1)$$

Voltage Division : $V_x = V_1 \dfrac{R_1}{R_1+R_2}$

$$V_x = \frac{V_1}{2} \quad \text{—} \quad (2)$$

KCL @ V_0 : $\dfrac{-4V_x}{1000} + \dfrac{V_0-V_1}{R_3} + \dfrac{V_0}{R_4} = 0$

$$\frac{V_0-V_1}{2\times10^3} + \frac{V_0}{1\times10^3} = \frac{4V_x}{1000} \quad - (3)$$

Substituting equation (2) in (3), we get

$$5V_1 - 3V_0 = 0 \quad \text{—} \quad (4)$$

From equation (1) and (3), we get

$$\boxed{V_0 = 90.0\,V}$$

3.33 Use nodal analysis to find V_o in the circuit in Fig. P3.33.

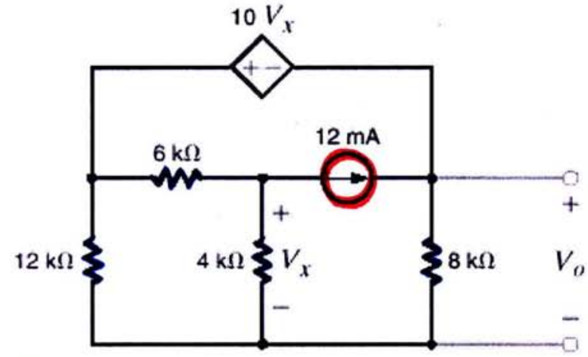
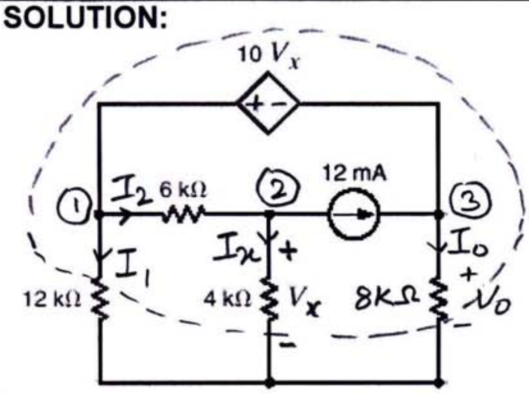


Figure P3.33

SOLUTION:



KCL at supernode : $I_1 + I_x + I_o = 0$

$$\frac{V_1}{12K} + \frac{V_2}{4K} + \frac{V_3}{8K} = 0$$

$$\boxed{2V_1 + 6V_2 + 3V_3 = 0}$$

KCL at 2 : $I_2 = I_x + 12m$

$$\frac{V_1 - V_2}{6K} = \frac{V_2}{4K} + 12m$$

$$2V_1 - 2V_2 = 3V_2 + 144$$

$$\boxed{2V_1 - 5V_2 = 144}$$

$$V_1 - V_3 = 10V_x$$

$$V_x = V_2$$

$$V_1 - V_3 = 10V_2$$

$$\boxed{V_1 - 10V_2 - V_3 = 0}$$

$$2V_1 + 6V_2 + 3V_3 = 0$$
$$2V_1 - 5V_2 + 0V_3 = 144$$
$$V_1 - 10V_2 - V_3 = 0$$

$$V_1 = 150.26 \text{ V}$$
$$V_2 = 31.3 \text{ V}$$
$$V_3 = -162.78 \text{ V}$$

$$V_o = V_3 = -162.78 \text{ V}$$

$$V_o = -162.78 \text{ V}$$

3.34 Use nodal analysis to find V_o in the circuit in Fig. P3.34.

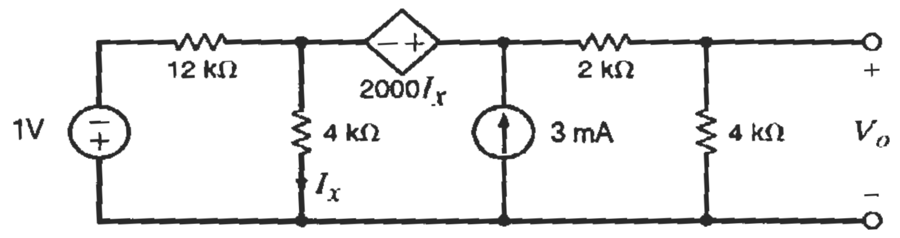
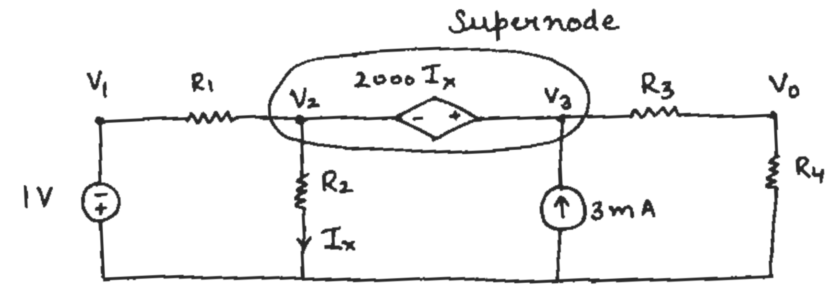


Figure P3.34

SOLUTION: 3.34



$R_1 = 12\ k\Omega,\ R_2 = R_4 = 4\ k\Omega,\ R_3 = 2\,k\Omega$

$$V_1 = -1\text{ V} \quad \text{— (1)}$$

$$V_3 - V_2 = 2000 I_x \quad \text{— (2)}$$

$$I_x = \frac{V_2}{R_2} = \frac{V_2}{4\times 10^3} \quad \text{— (3)}$$

Substituting equation (3) in (2), we get

$$V_3 - \frac{3}{2}V_2 = 0$$

$$V_2 = \frac{2}{3}V_3 \quad \text{— (4)}$$

KCL @ supernode:

$$\frac{V_2 - V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3 - V_0}{R_3} - 3\times 10^{-3} = 0$$

$$\frac{V_2 - V_1}{12\times 10^3} + \frac{V_2}{4\times 10^3} + \frac{V_3 - V_0}{2\times 10^3} - 3\times 10^{-3} = 0$$

$$6V_3 + 4V_2 - V_1 - 6V_0 = 36 \quad \text{— (5)}$$

KCL @ V_0 :

$$\frac{V_0}{R_4} + \frac{V_0 - V_3}{R_3} = 0$$

$$\frac{V_0}{4\times 10^3} + \frac{V_0 - V_3}{2\times 10^3} = 0$$

$$3V_o - 2V_3 = 0$$

$$V_3 = \frac{3}{2}V_o \quad \text{—} \quad (6)$$

Substituting equations (1) and (4) in (5), we get

$$26V_3 - 18V_o = 105 \quad \text{—} \quad (7)$$

Substituting equation (6) in (7), we get

$$21 V_o = 105$$

$$\boxed{V_o = 5.00\ V}$$

3.35 Determine V_o in the network in Fig. P3.35 using nodal analysis.

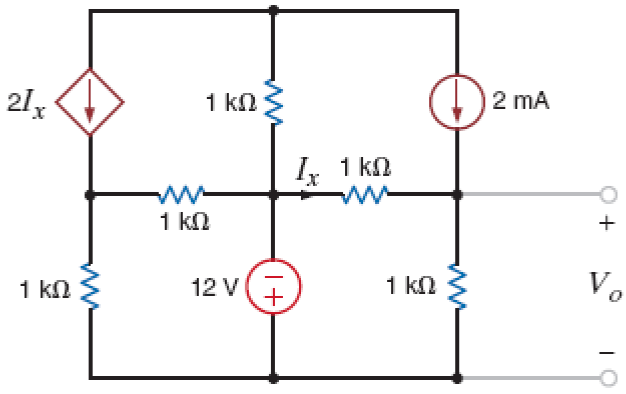
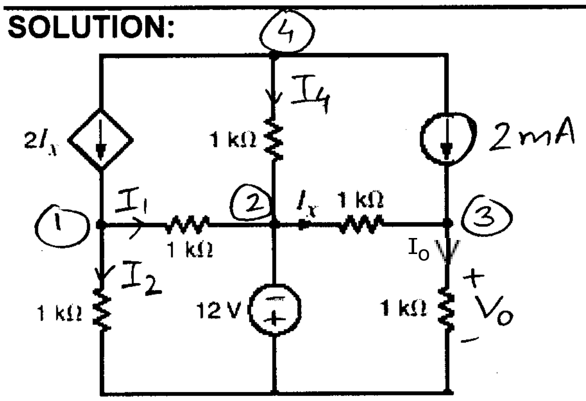


Figure P3.35

SOLUTION:



KCL at 4 : $2I_x + I_4 + 2m = 0$

$$I_x = \frac{V_2 - V_3}{1K}$$

$$2\left[\frac{V_2 - V_3}{1K}\right] + \frac{V_4}{1K} + 2m = 0$$

$$2V_2 - 2V_3 + V_4 + 2 = 0$$

$$\boxed{2V_2 - 2V_3 + V_4 = -2}$$

KCL at 3: $I_x + 2m = I_0$

$$\frac{V_2 - V_3}{1k} + 2m = \frac{V_3}{1k}$$

$$V_2 - V_3 + 2 = V_3$$

$$\boxed{V_2 - 2V_3 = -2}$$

KCL at 1: $2I_x = I_1 + I_2$

$$2\left[\frac{V_2 - V_3}{1K}\right] = \frac{V_1 - V_2}{1K} + \frac{V_1}{1K}$$

$$2V_2 - 2V_3 = V_1 - V_2 + V_1$$

$$\boxed{2V_1 - 3V_2 + 2V_3 = 0}$$

$$V_2 = -12\text{ V}$$

$$-12 - 2V_3 = -2$$

$$-2V_3 = 10$$

$$V_3 = -5\text{ V}$$

$$V_0 = V_3 = -5\text{ V}$$

$$V_0 = -5\text{ V}$$

3.36 Determine V_o in the network in Fig. P3.36.

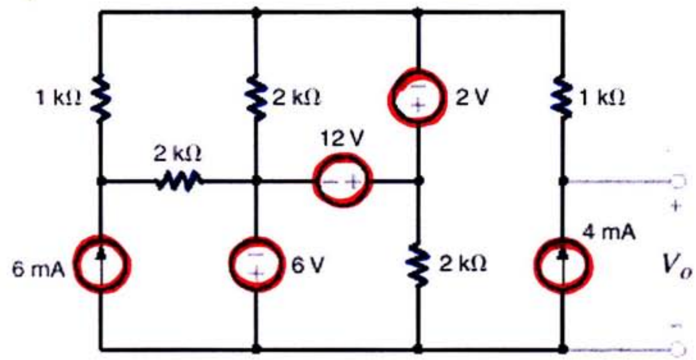
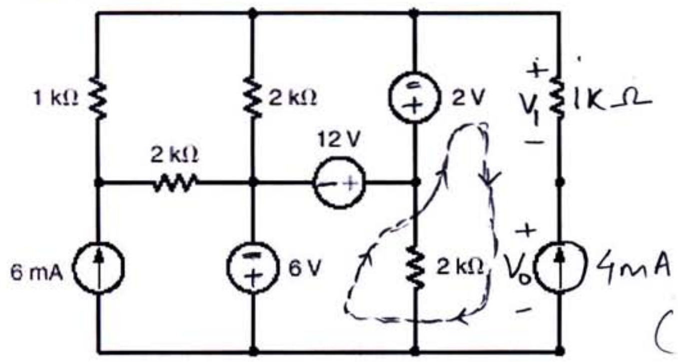


Figure P3.36

SOLUTION:



(Loop indicated by arrows)

$V_1 = 1K(-4m) = -4V$

KVL in loop: $12 = 6 + 2 + V_1 + V_o$

$V_o = 12 - 8 + 4$

$V_o = 8\ V$

3.37 Find I_o in the circuit in Fig. P3.37.

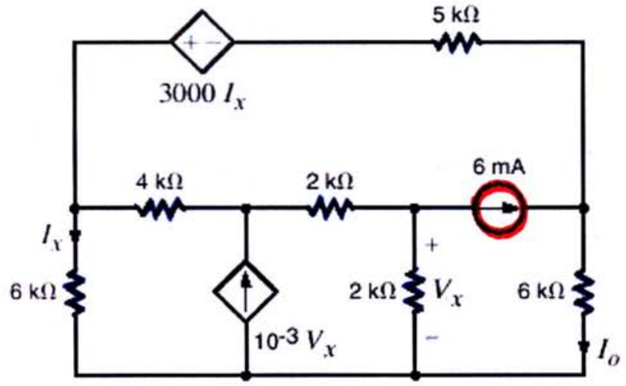
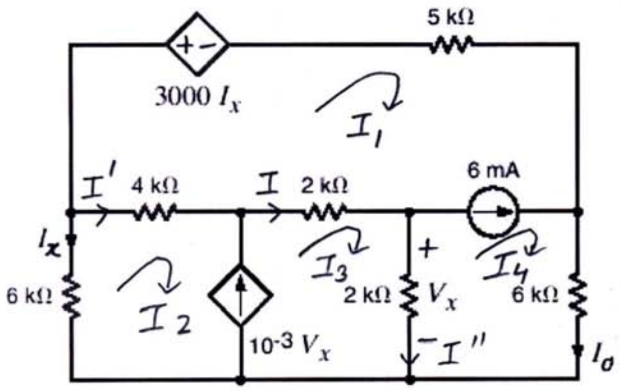


Figure P3.37

SOLUTION:



$$I_2 = -I_x \quad ; \quad I_4 = I_o$$

KCL : $I_2 = I' + I'$

$$I' = I_2 - I_1$$

KCL : $I'' + I_4 = I_3$

$$I'' = I_3 - I_4$$

KCL : $I = I'' + 6m$

$$I = I_3 - I_4 + 6m$$

KCL : $I_3 = 10^{-3} V_x + I_2$

$$-I_2 + I_3 = 10^{-3} V_x$$

$$V_x = 2k\, I''$$

$$V_x = 2k\,(I_3 - I_4)$$

$$-I_2 + I_3 = 10^{-3}(2K)(I_3 - I_4)$$

$$\boxed{I_2 + I_3 - 2I_4 = 0}$$

KCL: $I_1 + 6m = I_4$

$$\boxed{I_1 - I_4 = -6m}$$

KVL: $3000I_x + 5KI_1 + 6KI_4 + 6KI_2 = 0$

$$3000(-I_2) + 5KI_1 + 6KI_4 + 6KI_2 = 0$$

$$\boxed{5KI_1 + 3KI_2 + 6KI_4 = 0}$$

KVL: $4KI' + 2KI + 2KI'' + 6KI_2 = 0$

$$0 = 4K(I_2 - I_1) + 2K(I_3 - I_4 + 6m) + 2K(I_3 - I_4) + 6KI_2$$

$$\boxed{-4KI_1 + 10KI_2 + 4KI_3 - 4KI_4 = -12}$$

$$I_2 + I_3 - 2I_4 = 0$$
$$I_1 - I_4 = -6m$$
$$5KI_1 + 3KI_2 + 6KI_4 = 0$$

$$-4KI_1 + 10KI_2 + 4KI_3 - 4KI_4 = -12$$

$I_1 = -1.64$ mA
$I_2 = -6$ mA
$I_3 = 14.7$ mA
$I_4 = 4.36$ mA

$I_o = I_4$
$I_o = 4.36$ mA

3.38 Use nodal analysis to solve for I_A in the network in Fig. P3.38.

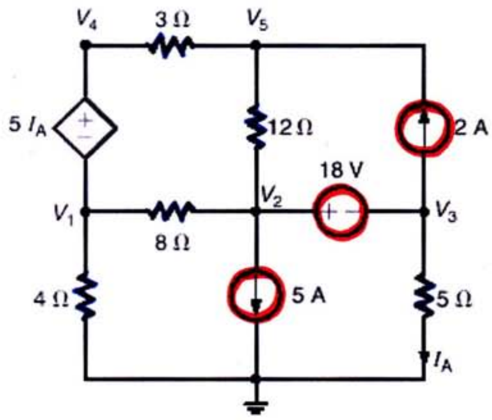
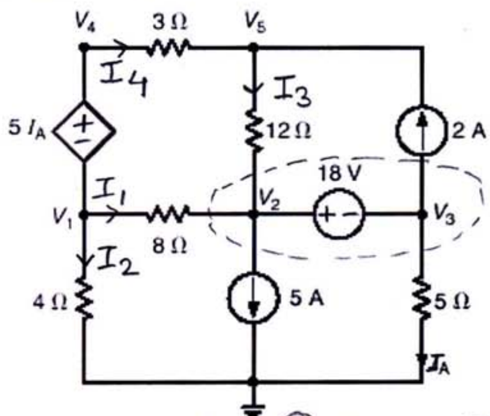


Figure P3.38

SOLUTION:



KCL at 5 : $I_4 + 2 = I_3$

$$\frac{V_4 - V_5}{3} + 2 = \frac{V_5 - V_2}{12}$$

$$4V_4 - 4V_5 + 24 = V_5 - V_2$$

$$\boxed{V_2 + 4V_4 - 5V_5 = -24}$$

KCL at supernode: $I_3 + I_1 = 5 + I_A + 2$

$$\frac{V_5 - V_2}{12} + \frac{V_1 - V_2}{8} = 5 + \frac{V_3}{5} + 2$$

$$5V_5 - 5V_2 + 7.5V_1 - 7.5V_2 = 300 + 12V_3 + 120$$

$$\boxed{7.5V_1 - 12.5V_2 - 12V_3 + 5V_5 = 420}$$

$$V_4 - V_1 = 5I_A$$
$$I_A = \frac{V_3}{5}$$

$$V_4 - V_1 = 5(V_3/5)$$
$$V_4 - V_1 = V_3 \quad ; \quad \boxed{-V_1 - V_3 + V_4 = 0}$$
$$\boxed{V_2 - V_3 = 18}$$

KCL at reference: $I_2 + 5 + I_A = 0$

$$\frac{V_1}{4} + 5 + \frac{V_3}{5} = 0$$
$$5V_1 + 100 + 4V_3 = 0$$
$$\boxed{5V_1 + 4V_3 = -100}$$

$$0V_1 + V_2 + 0V_3 + 4V_4 - 5V_5 = -24$$
$$7.5V_1 - 12.5V_2 - 12V_3 + 0V_4 + 5V_5 = 420$$
$$-V_1 + 0V_2 - V_3 + V_4 + 0V_5 = 0$$
$$0V_1 + V_2 - V_3 + 0V_4 + 0V_5 = 18$$
$$5V_1 + 0V_2 + 4V_3 + 0V_4 + 0V_5 = -100$$

$$V_1 = 3.22\text{ V}$$
$$V_2 = -11.02\text{ V}$$
$$V_3 = -29.02\text{ V}$$
$$V_4 = -25.81\text{ V}$$
$$V_5 = -18.05\text{ V}$$

$$I_A = \frac{V_3}{5} = \frac{-29.02}{5}$$
$$I_A = -5.8\text{ A}$$

3.39 Use nodal analysis to find V_1, V_2, V_3, and V_4 in the circuit in Fig. P3.39.

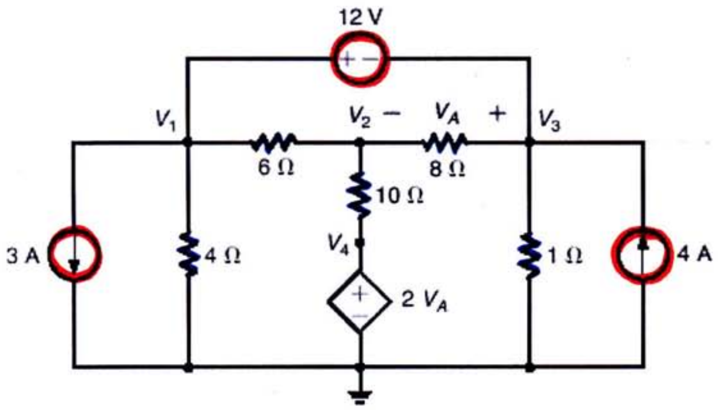
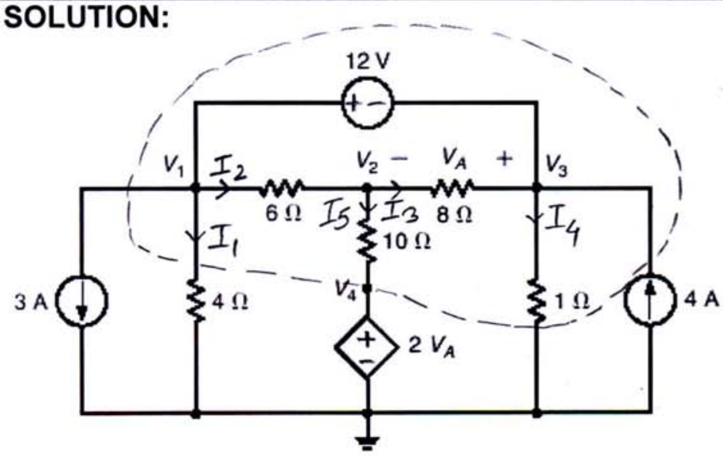


Figure P3.39

SOLUTION:



KCL at 2: $I_2 = I_5 + I_3$

$$\frac{V_1 - V_2}{6} = \frac{V_2 - V_4}{10} + \frac{V_2 - V_3}{8}$$

$$5V_1 - 5V_2 = 3V_2 - 3V_4 + 3.75\,V_2 - 3.75\,V_3$$

$$\boxed{5V_1 - 11.75\,V_2 + 3.75\,V_3 + 3V_4 = 0}$$

KCL at supernode: $3 + I_1 + I_5 + I_4 = 4$

$$\frac{V_1}{4} + \frac{V_2 - V_4}{10} + \frac{V_3}{1} = 1$$

$$5V_1 + 2V_2 - 2V_4 + 20V_3 = 20$$

$$\boxed{5V_1 + 2V_2 + 20V_3 - 2V_4 = 20}$$

$$V_1 - V_3 = 12$$
$$V_4 = 2V_A$$

$$V_A = V_3 - V_2$$
$$V_4 = 2(V_3 - V_2) \qquad \boxed{-2V_2 + 2V_3 - V_4 = 0}$$

$$5V_1 - 11.75V_2 + 3.75V_3 + 3V_4 = 0$$
$$5V_1 + 2V_2 + 20V_3 - 2V_4 = 20$$
$$V_1 + 0V_2 - V_3 + 0V_4 = 12$$
$$0V_1 - 2V_2 + 2V_3 - V_4 = 0$$

$$V_1 = 9.68\ V$$
$$V_2 = 1.45\ V$$
$$V_3 = -2.32\ V$$
$$V_4 = -7.54\ V$$

3.40 Use nodal analysis to find V_1, V_2, V_3, and V_4 in the network in Fig. P3.40

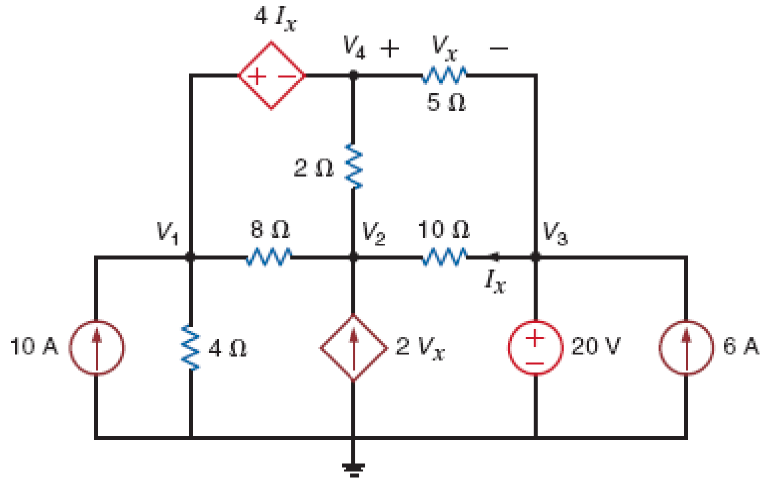
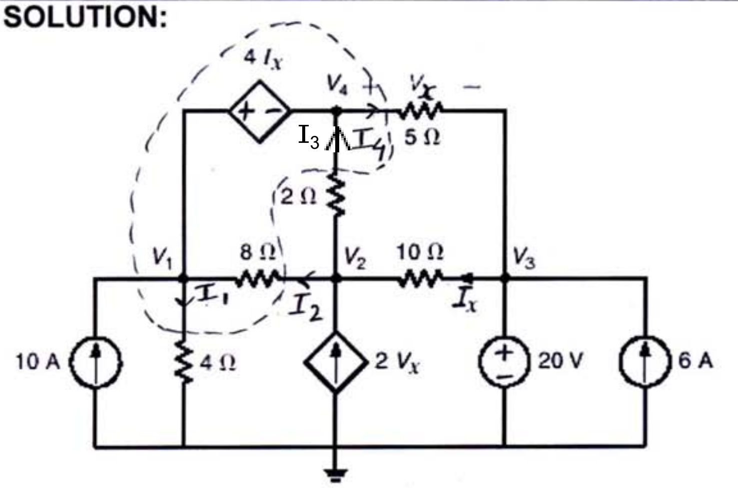


Figure P3.40

SOLUTION:



KCL at (2): $2V_x + I_x = I_2 + I_3$

$V_x = V_4 - V_3$

$$2(V_4 - V_3) + \frac{V_3 - V_2}{10} = \frac{V_2 - V_1}{8} + \frac{V_2 - V_4}{2}$$

$$80V_4 - 80V_3 + 4V_3 - 4V_2 = 5V_2 - 5V_1 + 20V_2 - 20V_4$$

$$\boxed{5V_1 - 29V_2 - 76V_3 + 100V_4 = 0}$$

$V_3 = 20V$

$$\boxed{5V_1 - 29V_2 + 100V_4 = 1520}$$

KCL at supernode: $10 + I_2 + I_3 = I_1 + I_4$

$$10 + \frac{V_2 - V_1}{8} + \frac{V_2 - V_4}{2} = \frac{V_1}{4} + \frac{V_4 - V_3}{5}$$

$$400 + 5V_2 - 5V_1 + 20V_2 - 20V_4 = 10V_1 + 8V_4 - 8V_3$$

$$\boxed{-15V_1 + 25V_2 + 8V_3 - 28V_4 = -400}$$

$$\boxed{-15V_1 + 25V_2 - 28V_4 = -560}$$

$$V_1 - V_4 = 4I_x$$

$$I_x = \frac{V_3 - V_2}{10}$$

$$V_1 - V_4 = 4\left(\frac{V_3 - V_2}{10}\right)$$

$$10V_1 - 10V_4 = 4V_3 - 4V_2$$

$$\boxed{10V_1 + 4V_2 - 4V_3 - 10V_4 = 0}$$

$$\boxed{10V_1 + 4V_2 - 10V_4 = 80}$$

$$5V_1 - 29V_2 + 100V_4 = 1520$$

$$-15V_1 + 25V_2 - 28V_4 = -560$$

$$10V_1 + 4V_2 - 10V_4 = 80$$

$$V_1 = 21.14 \text{ V}$$

$$V_2 = 9.07 \text{ V}$$

$$V_4 = 16.77 \text{ V}$$

$$V_3 = 20 \text{ V}$$

3.41 Find I_o in the network in Fig. P3.41 using nodal analysis.

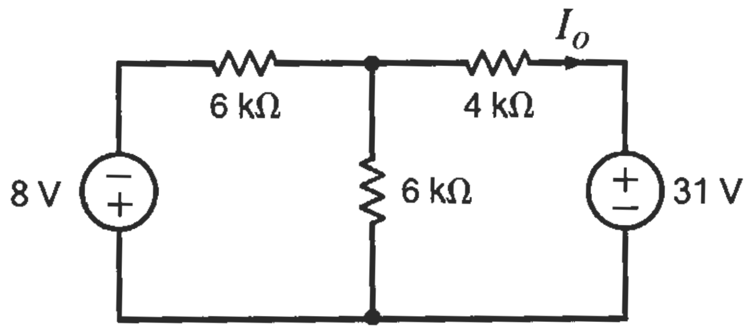
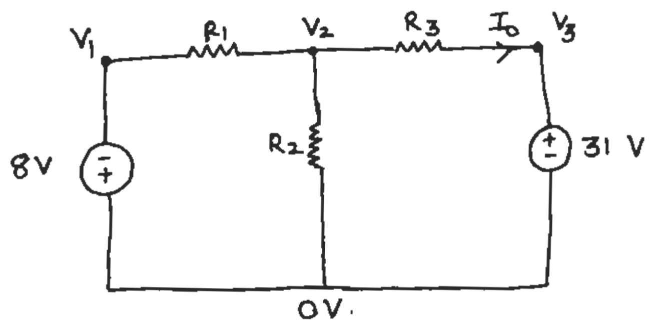


Figure P3.41

SOLUTION: 3.41



$$R_1 = R_2 = 6\,k\Omega, \quad R_3 = 4\,k\Omega, \quad I_o = \frac{V_2 - V_3}{R_3} \quad \text{— (1)}$$

@ V_1 : $V_1 = -8\,V$ — (2)

KCL @ V_2 :

$$\frac{V_2 - V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_2 - V_3}{R_3} = 0$$

$$\frac{V_2 - V_1}{6 \times 10^3} + \frac{V_2}{6 \times 10^3} + \frac{V_2 - V_3}{4 \times 10^3} = 0$$

$$7V_2 - 3V_3 - 2V_1 = 0 \quad \text{— (3)}$$

@ V_3 : $V_3 = 31\,V$ — (4)

Substituting equations (4) and (2) in (3), we get

$$7V_2 - 3V_3 - 2V_1 = 0$$

$$7V_2 - 3(31) - 2(-8) = 0$$

$$V_2 = 11\,V \quad \text{— (5)}$$

Substituting equations (4) and (5) in (1), we get

$$I_o = \frac{V_2 - V_3}{R_3}$$

$$\boxed{I_o = -5.00 \text{ mA}}$$

3.42 Use nodal analysis to find V_o in the circuit in Fig. P3.42.

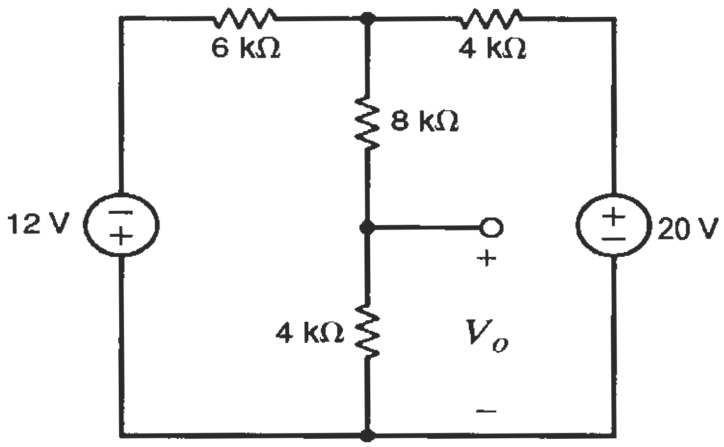
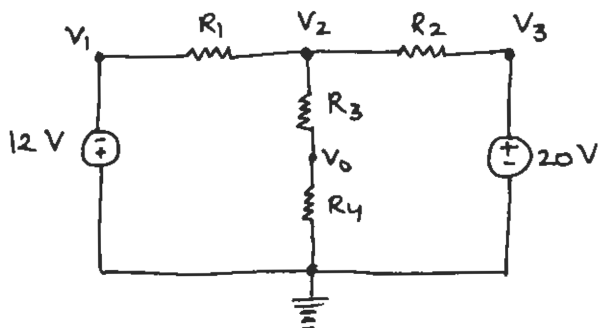


Figure P3.42

SOLUTION: 3.42



$R_1 = 6\ k\Omega$, $R_2 = R_4 = 4\ k\Omega$, $R_3 = 8\ k\Omega$

$V_1 = -12\ V$; $V_3 = 20\ V$

KCL @ V_2 : $$\frac{V_2 - V_1}{R_1} + \frac{V_2 - V_o}{R_3} + \frac{V_2 - V_3}{R_2} = 0$$

$$\frac{V_2 + 12}{6 \times 10^3} + \frac{V_2 - V_o}{8 \times 10^3} + \frac{V_2 - 20}{4 \times 10^3} = 0$$

$$\Rightarrow \quad 13 V_2 - 3 V_o = 72 \quad \text{—} \quad (1)$$

KCL @ V_o : $$\frac{V_o}{R_4} + \frac{V_o - V_2}{R_3} = 0$$

$$\frac{V_o}{4 \times 10^3} + \frac{V_o - V_2}{8 \times 10^3} = 0$$

$$\Rightarrow \quad 3 V_o - V_2 = 0 \quad \text{—} \quad (2)$$

From equations 1 and 2, we get

$$12\,V_2 = 72$$

$$V_2 = 6\text{ V}$$

Substituting the value of V_2 in equation 2, we get

$$3V_0 - V_2 = 0$$

$$\boxed{V_0 = 2.00\text{ V}}$$

3.43 Find I_o in the circuit in Fig. P3.43.

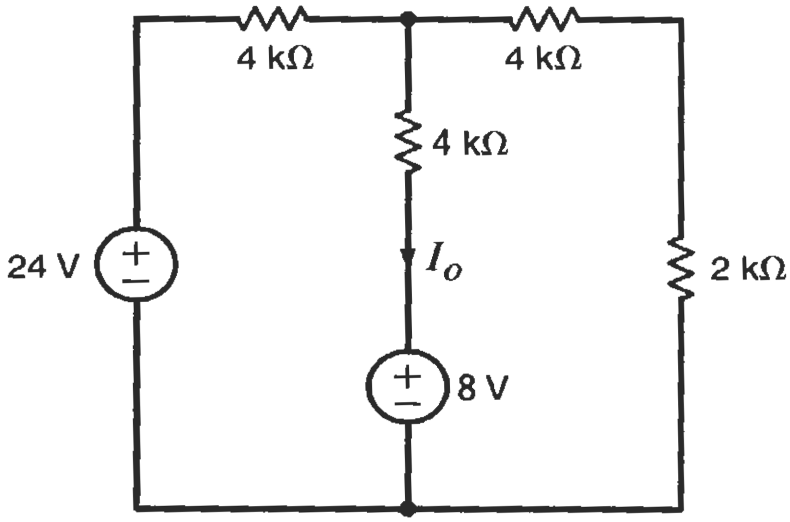
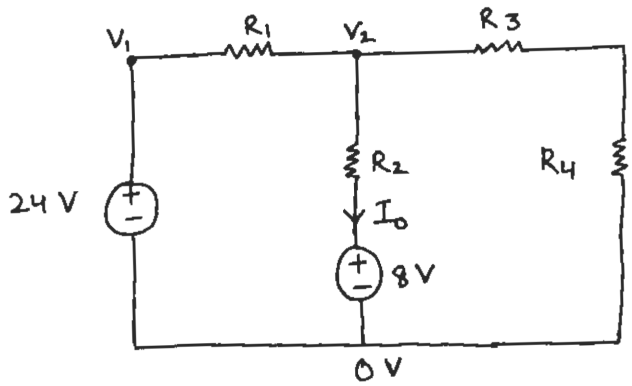


Figure P3.43

SOLUTION: 3.43



$R_1 = R_2 = R_3 = 4\,k\Omega\ ,\ R_4 = 2\,k\Omega$

@ V_1 : $V_1 = 24\,V$ — ①

KCL @ V_2 : $\dfrac{V_2 - V_1}{R_1} + \dfrac{V_2 - 8}{R_2} + \dfrac{V_2}{R_3 + R_4} = 0$

$$\frac{V_2 - V_1}{4\times10^3} + \frac{V_2 - 8}{4\times10^3} + \frac{V_2}{6\times10^3} = 0$$

$\Rightarrow\ 8V_2 - 3V_1 = 24$ — ②

Substituting equation ① in ②, we get

$8V_2 - 3V_1 = 24$

$$\Rightarrow V_2 = 12\ V$$

$$I_O = \frac{V_2 - 8}{R_2}$$

$$\boxed{I_O = 1.00\ mA}$$

3.44 Find V_o in the network in Fig. P3.44 using mesh equations.

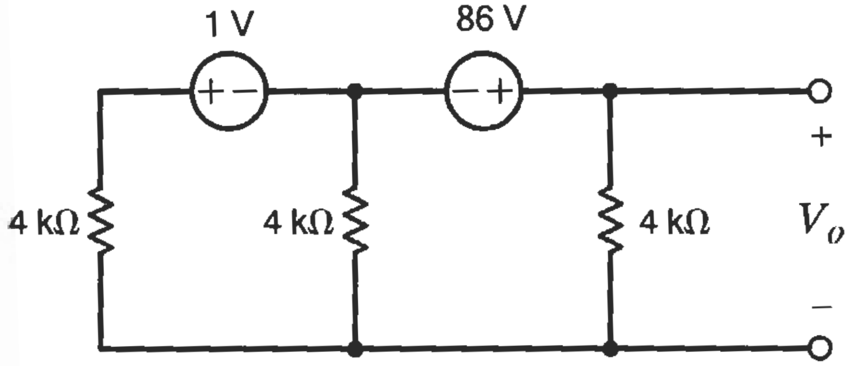
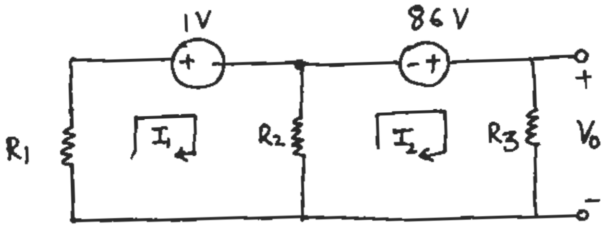


Figure P3.44

SOLUTION: 3.44



$R_1 = R_2 = R_3 = 4\ k\Omega$

KVL @ I_1 : $I_1R_1 + 1 + (I_1 - I_2)R_2 = 0$

$$I_1(4\times10^3) + (I_1 - I_2)(4\times10^3) = -1$$

$$8I_1 - 4I_2 = -1\times10^{-3} \qquad \text{①}$$

KVL @ I_2 : $(I_2 - I_1)R_2 - 86 + I_2R_3 = 0$

$$(I_2 - I_1)(4\times10^3) + I_2(4\times10^3) = 86$$

$$-8I_1 + 16I_2 = 172\times10^{-3} \qquad \text{②}$$

From equations ① and ②, we get

$$12I_2 = 171\times10^{-3}$$

$$I_2 = \frac{171}{12}\times10^{-3}\ A$$

$$V_o = I_2 R_3$$

$$= \frac{171}{12} \times 10^{-3} \times 4 \times 10^{3}$$

$$\boxed{V_o = 57.0V}$$

3.45 Find V_o in the network in Fig. P3.45 using mesh equations.

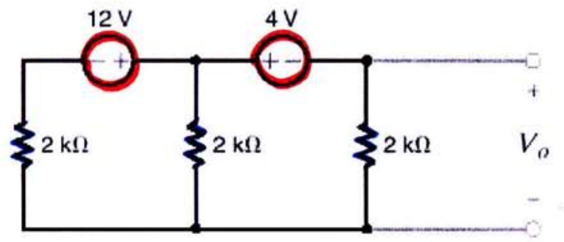
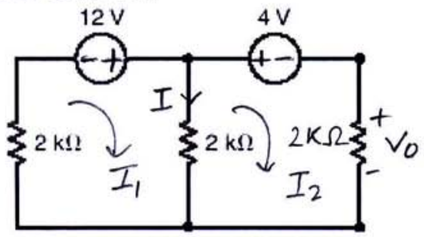


Figure P3.45

SOLUTION:



$$I_1 = I + I_2$$
$$I = I_1 - I_2$$

KVL left loop: $12 = 2KI_1 + 2KI$

$$2KI_1 + 2K(I_1 - I_2) = 12$$

$$\boxed{4KI_1 - 2KI_2 = 12}$$

KVL right loop: $4 + 2KI_2 + 2K(-I) = 0$

$$2KI_2 - 2K(I_1 - I_2) = -4$$

$$\boxed{-2KI_1 + 4KI_2 = -4}$$

$$4KI_1 - 2KI_2 = 12$$
$$-2KI_1 + 4KI_2 = -4$$

$I_1 = 3.333$ mA ; $I_2 = 0.667$ mA

$V_0 = I_2(2K) = 0.667m(2K)$

$V_0 = 1.33$ V

3.46 Find I_o in the circuit in Fig. P3.46.

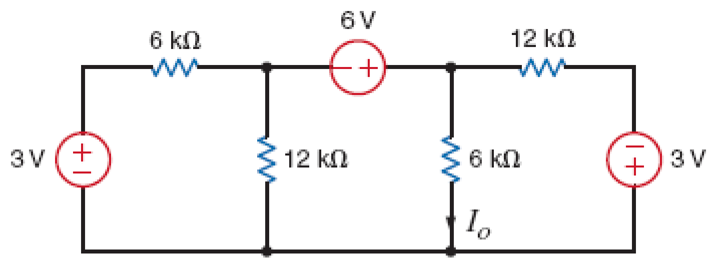
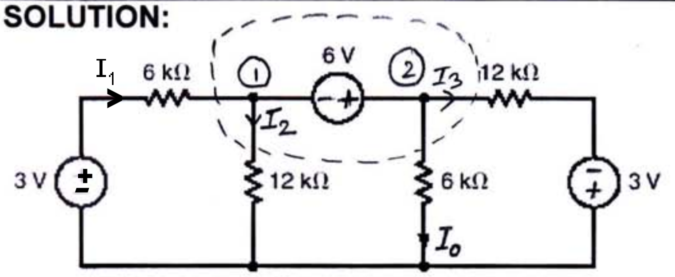


Figure P3.46

SOLUTION:



KCL at supernode : $I_1 = I_2 + I_O + I_3$

$$\frac{3-V_1}{6K} = \frac{V_1}{12K} + \frac{V_2}{6K} + \frac{V_2-(-3)}{12K}$$

$$6 - 2V_1 = V_1 + 2V_2 + V_2 + 3$$

$$\boxed{3V_1 + 3V_2 = 3}$$

$$V_2 - V_1 = 6 \qquad \boxed{-V_1 + V_2 = 6}$$

$$3V_1 + 3V_2 = 3$$
$$-V_1 + V_2 = 6$$

$$V_1 = -2.5 \text{ V}$$
$$V_2 = 3.5 \text{ V}$$

$$I_O = \frac{V_2}{6K} = \frac{3.5}{6K}$$

$$I_O = 0.5833 \text{ mA}$$

3.47 Find V_o in the circuit in Fig. P3.47 using nodal analysis.

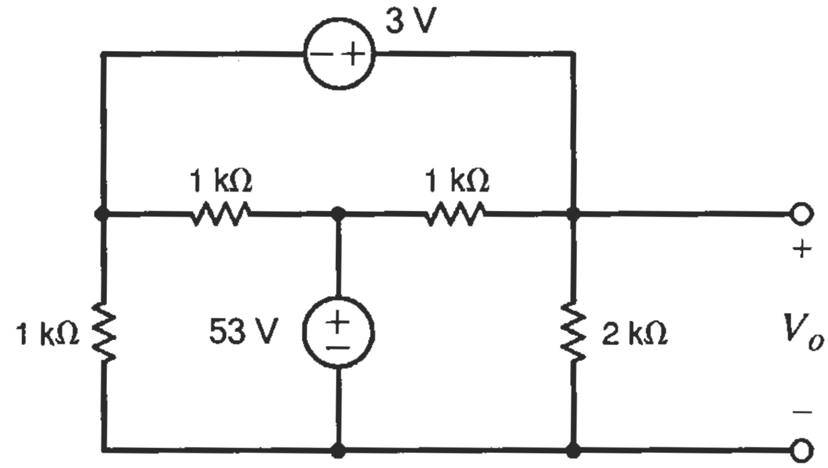
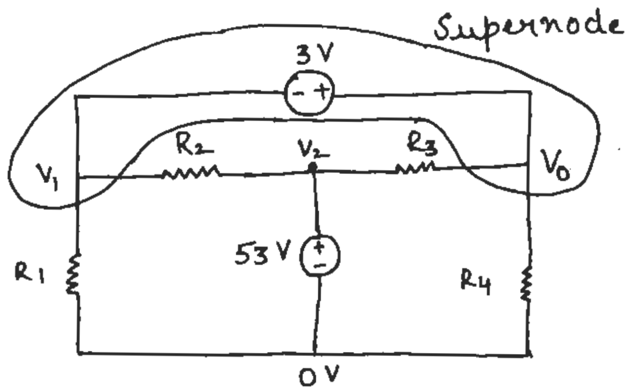


Figure P3.47

SOLUTION: 3.47



$R_1 = R_2 = R_3 = 1\,k\Omega$, $R_4 = 2\,k\Omega$

$V_o - V_1 = 3\,V$ — ① $V_2 = 53\,V$

KVL @ supernode,

$$\frac{V_1}{R_1} + \frac{V_1 - V_2}{R_2} + \frac{V_o}{R_4} + \frac{V_o - V_2}{R_3} = 0$$

$$4V_1 + 3V_o = 212 \quad \text{——} \quad ②$$

Substituting equation ① in ②, we get

$$4(V_o - 3) + 3V_o = 212$$

$$\boxed{V_o = 32.0\,V}$$

3.48 Solve Problem 3.23 using loop analysis.

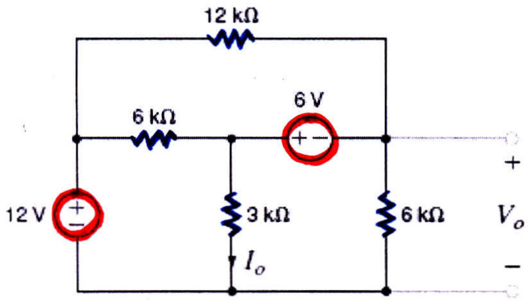
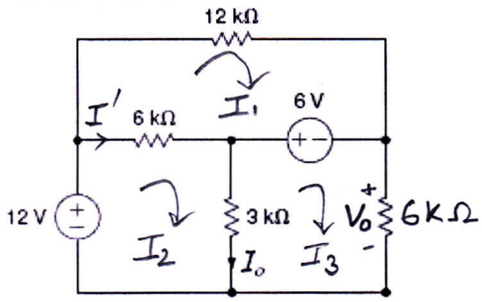


Figure P3.23

SOLUTION:



KCL: $I_2 = I' + I_1$

$I' = I_2 - I_1$

KVL: $\boxed{12KI_1 + 6KI_3 = 12}$

KCL: $I_0 + I_3 = I_2$

$I_0 = I_2 - I_3$

KVL: $6 + 6kI_3 + 3K(-I_0) = 0$

$6 + 6KI_3 - 3K(I_2 - I_3) = 0$

$\boxed{-3KI_2 + 9KI_3 = -6}$

KVL: $12 = 6KI + 6 + 6KI_3$

$6K(I_2 - I_1) + 6KI_3 = 6$

$\boxed{-6KI_1 + 6kI_2 + 6KI_3 = 6}$

$$12KI_1 + 0I_2 + 6KI_3 = 12$$
$$0I_1 - 3KI_2 + 9KI_3 = -6$$
$$-6KI_1 + 6KI_2 + 6KI_3 = 6$$

$$I_1 = 1\ mA$$

$$I_2 = 2\ mA$$

$$I_3 = 0\ A$$

$$V_0 = 6K I_3$$

$$V_0 = 6K(0)$$

$$V_0 = 0\ V$$

3.49 Solve Problem 3.27 using loop analysis.

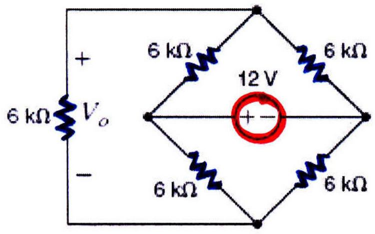
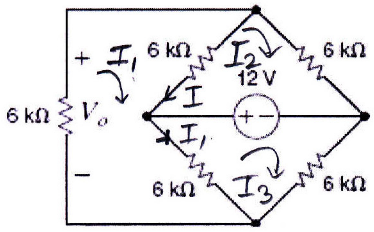


Figure P3.27

SOLUTION:



KCL : $I_1 = I + I_2$

$I = I_1 - I_2$

KCL : $I' + I_3 = I_1$

$I' = I_1 - I_3$

KVL : $\boxed{6KI_1 + 6KI_2 + 6KI_3 = 0}$

KVL : $12 = 6K(-I) + 6KI_2$

$-6K(I_1 - I_2) + 6KI_2 = 12$

$\boxed{-6KI_1 + 12KI_2 = 12}$

$6KI_1 + 6KI_2 + 6KI_3 = 0$

$18KI_1 - 6KI_2 - 6KI_3 = 0$

$-6KI_1 + 12KI_2 + 0I_3 = 12$

$I_1 = 0\ A$

$I_2 = 1\ mA$

$I_3 = -1\ mA$

$V_o = -I_1(6K)$

$V_o = 0\ V$

3.50 Use loop analysis to find V_o in the network in Fig. P3.50.

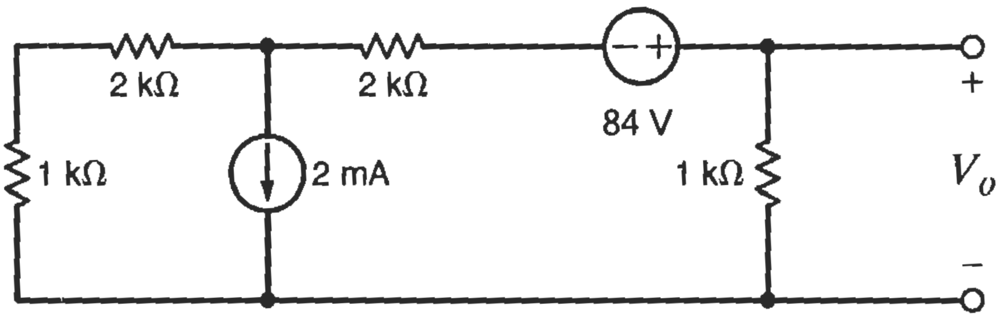
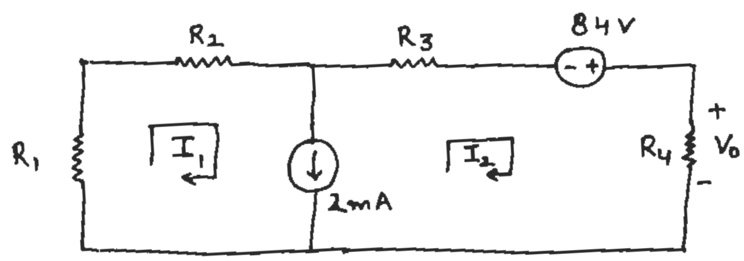


Figure P3.50

SOLUTION: 3.50



$R_1 = R_4 = 1\,k\Omega$, $R_2 = R_3 = 2\,k\Omega$

$V_o = I_2 R_4$

$I_1 - I_2 = 2 \times 10^{-3}\,A$ ——— (1)

$I_1 R_1 + I_1 R_2 + I_2 R_3 - 84 + I_2 R_4 = 0$

$I_1 (R_1 + R_2) + I_2 (R_3 + R_4) = 84$

$(3 \times 10^3) I_1 + (3 \times 10^3) I_2 = 84$

$I_1 + I_2 = 28 \times 10^{-3}$ ——— (2)

From equations (1) and (2), we get

$2 I_1 = 30 \times 10^{-3}$

$I_1 = 15\,mA$ and $I_2 = 13\,mA$

$V_o = I_2 R_4$

$= 13 \times 10^{-3} \times 1 \times 10^{3}$

$\boxed{V_o = 13.0\,V}$

3.51 Use mesh analysis to find V_o in the network in Fig. P3.51.

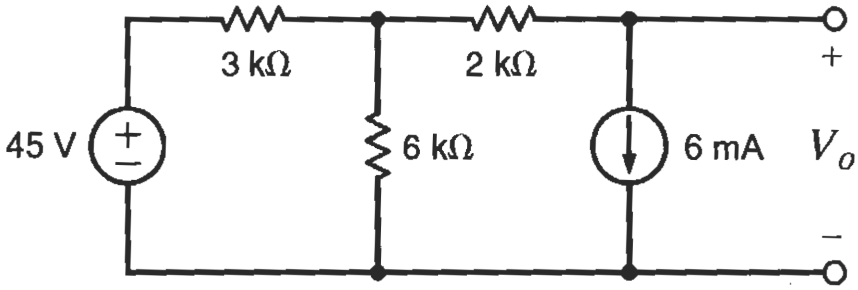
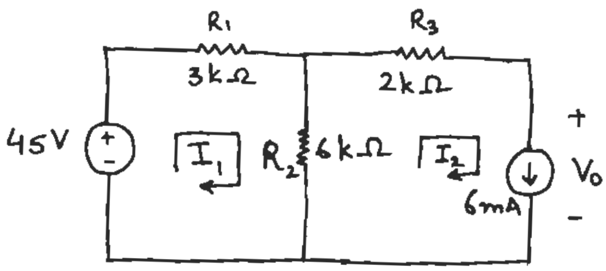


Figure P3.51

SOLUTION: 3.51



$I_2 = 6\,mA$

KVL @ I_1 : $-45 + I_1 R_1 + (I_1 - I_2) R_2 = 0$

$$I_1 (R_1 + R_2) - I_2 R_2 = 45$$

$$9 \times 10^3 (I_1) - 6 \times 10^3 (I_2) = 45$$

$$I_1 = 9 \times 10^{-3}$$

$$= 9\,mA$$

KVL @ I_2 : $-45 + I_1 R_1 + I_2 R_3 + V_o = 0$

$$-45 + [9 \times 10^{-3} \times 3 \times 10^3] + [(6 \times 10^{-3}) \times (2 \times 10^3)] + V_o = 0$$

$$\boxed{V_o = 6.00\ V}$$

3.52 Find I_o in the circuit in Fig. P3.52 using mesh analysis.

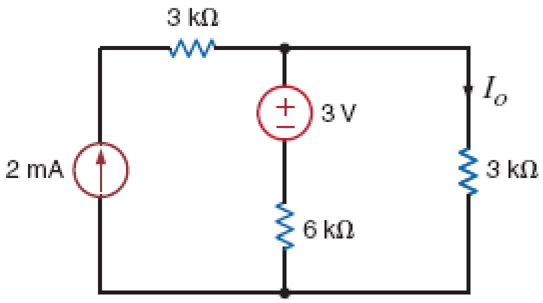
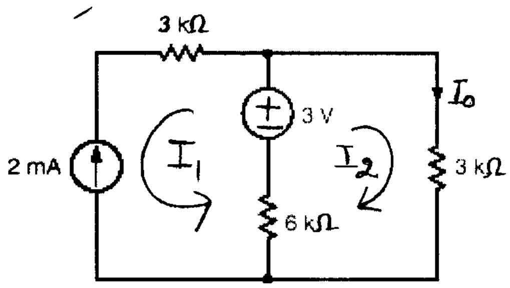


Figure P3.52

SOLUTION:



Let the loop currents be I_1 & I_2 mA

From loop 1:

$$I_1 = -2\,mA \quad — (1)$$

Applying KVL in second loop:

$$3 = 3I_2 + 6(I_1 + I_2)$$

$$\Rightarrow 3 = 9I_2 + 6I_1 \quad — (2)$$

From equation (1) & (2)

$$3 = 9(I_2) + 6I_1 = 9I_2 + 6(-2)$$

$$\Rightarrow \quad I_2 = \frac{15}{9}$$

$$\Rightarrow \quad I_2 = \frac{5}{3} = 1.667 \text{ mA}$$

$$I_0 = I_2 = 1.67 \text{ mA}$$

3.53 Find V_o in the circuit in Fig. P3.53 using mesh analysis.

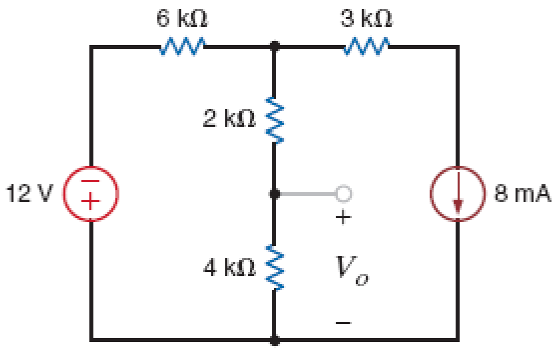
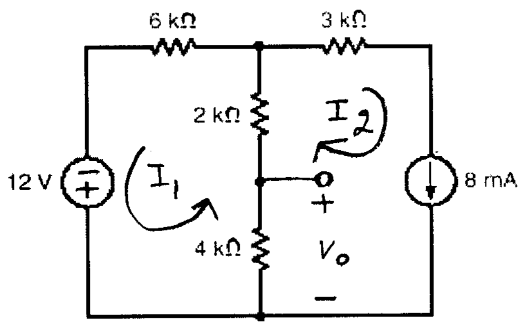


Figure P3.53

SOLUTION:



Let I_1 & I_2 be two loop currents in mA.

From loop 2:

$$I_2 = 8\,mA \quad -(1)$$

KVL in the loop 1:

$$12 = 4(I_1+I_2) + 2(I_1+I_2) + 6I_1$$

$$\Rightarrow 12 = 12I_1 + 6I_2 \quad -(2)$$

Substituting the value of I_2 from 1 in 2

$\Rightarrow \quad 12 = 12I_1 + 6(8)$

$\Rightarrow \quad I_1 = -3\,mA \quad — \; 3$

$V_0 = -4 \times (I_1 + I_2)$

$\Rightarrow \quad V_0 = -4\,(-3+8)$

$\Rightarrow \quad V_0 = -4\,(5)$

$V_0 = -20$ Volts

3.54 Use mesh analysis to find V_o in the circuit in Fig. P3.54.

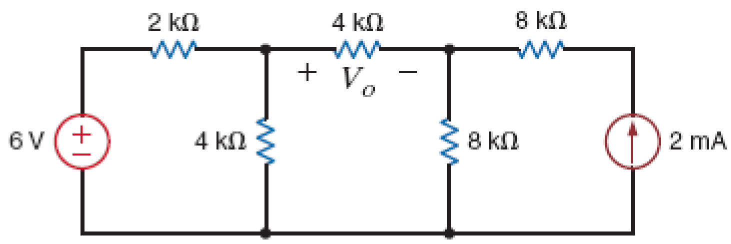
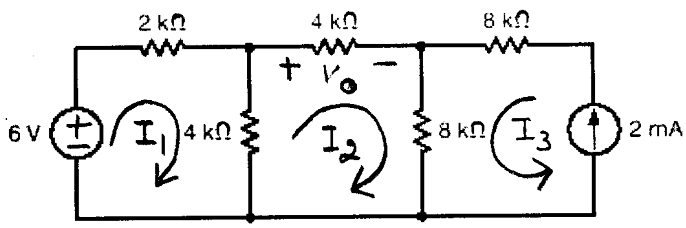


Figure P3.54

SOLUTION:



Let the loop currents be I_1, I_2 and I_3 mA as shown in the diagram.

KVL in the first loop gives:

$$6 = 2I_1 + 4(I_1 - I_2)$$

$$\Rightarrow 6 = 6I_1 - 4I_2 \quad — (1)$$

KVL in the second loop gives:

$$0 = 4(I_2 - I_1) + 4I_2 + 8(I_2 + I_3)$$

$$\Rightarrow 0 = 16I_2 - 4I_1 + 8I_3 \quad — (2)$$

From the third loop:

$$I_3 = 2\,mA \quad — (3)$$

From equation (2) & (3)

$$0 = 16 I_2 - 4 I_1 + 8(2)$$

$$\Rightarrow 16 = 4I_1 - 16 I_2 \quad — (4)$$

$$\Rightarrow 4 = I_1 - 4 I_2$$

$$6 = 6 I_1 - 4 I_2 \quad — (1)$$

Solving these two equations

$$2 = 5 I_1 \quad \therefore I_1 = \frac{2}{5} = 0.4\,mA$$

$$I_2 = -0.9\,mA$$

$$V_0 = I_2 \times 4K = 4 \times (-0.9) = -3.6 \text{ Volts}.$$

3.55 Use mesh analysis to find I_o in the network in Fig. P3.55.

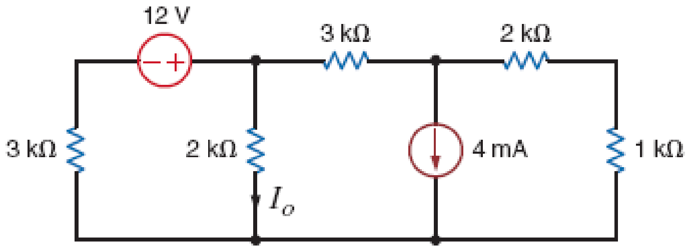
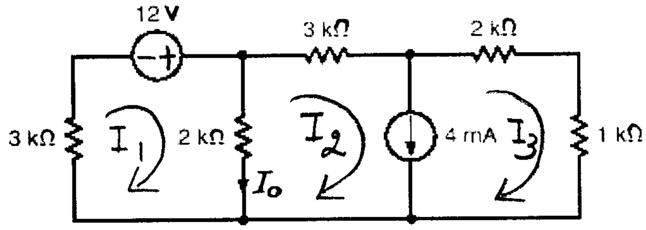


Figure P3.55

SOLUTION:



Let I_1, I_2 and I_3 be the loop currents (in mA) as shown in the diagram.

KVL in the first loop:

$$12 = 2(I_1 - I_2) + 3I_1$$

$$\Rightarrow 12 = 5I_1 - 2I_2 \quad \text{——} \quad (1)$$

From the second loop:

$$I_2 - I_3 = 4 \quad \text{——} \quad (2)$$

KVL in the loop outer to loop 2 & 3

$$0 = 3I_2 + 2I_3 + I_3 + 2(I_2 - I_1)$$

$$\Rightarrow 0 = 5I_2 + 3I_3 - 2I_1 \quad \text{——} \quad (3)$$

upon solving these three equations, we get

$$I_1 = \frac{10}{3}\,mA, \quad I_2 = \frac{7}{3}\,mA, \quad I_3 = -\frac{5}{3}\,mA$$

$$I_0 = I_1 - I_2$$

$$\Rightarrow I_0 = \frac{10}{3} - \frac{7}{3} = \frac{3}{3} = 1\,mA$$

$$\boxed{I_0 = 1\,mA}$$

3.56 Find I_o in the network in Fig. P3.56 using loop analysis.

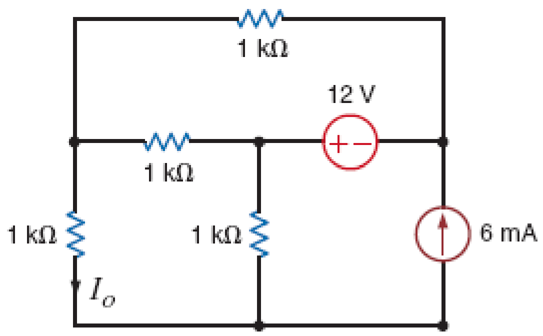
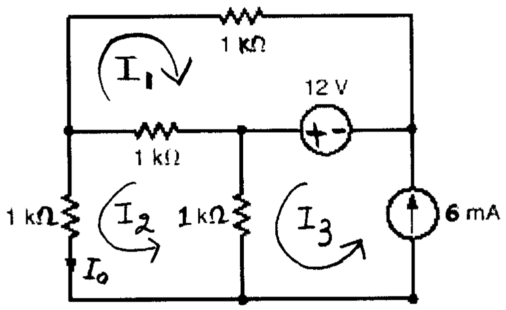


Figure P3.56

SOLUTION:



Let I_1, I_2 and I_3 be the loop currents (in mA).

KVL in the first loop:

$$12 = 1(I_1 + I_2) + 1 \times I_1$$

$$\Rightarrow 12 = 2I_1 + I_2 \quad \text{— (1)}$$

From the third loop:

$$I_3 = 6\text{ mA} \quad \text{— (2)}$$

KVL in the second loop:

$$1(I_1 + I_2) + 1(I_2) + 1(I_2 - I_3) = 0$$

$$\Rightarrow I_1 + 3I_2 - I_3 = 0 \quad \text{——} \quad (3)$$

From equation (2) & (3), we get :

$$I_1 + 3I_2 = I_3 = 6 \quad \text{——} \quad (4)$$

From equation (1) & (4) :

$$12 = 2I_1 + I_2 \quad \text{——} \quad (1)$$

$$6 = I_1 + 3I_2$$

$$\Rightarrow 12 = 2I_1 + 6I_2 \quad \text{——} \quad (5)$$

$$5I_2 = 0 \quad \{ eq.(5) - eq.(1) \}$$

$$\text{Or } \boxed{I_2 = 0\,mA}$$

3.57 Use loop analysis to find I_o and I_1 in the network in Fig. P3.57.

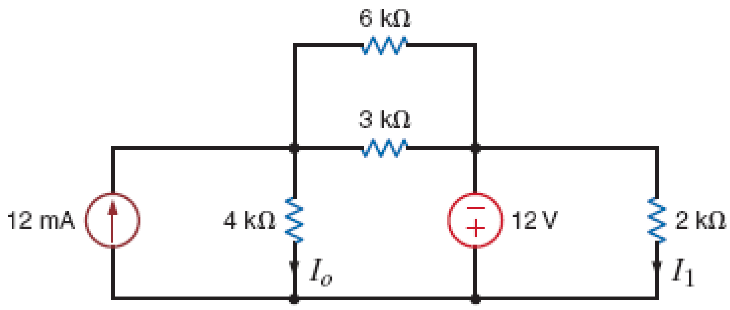
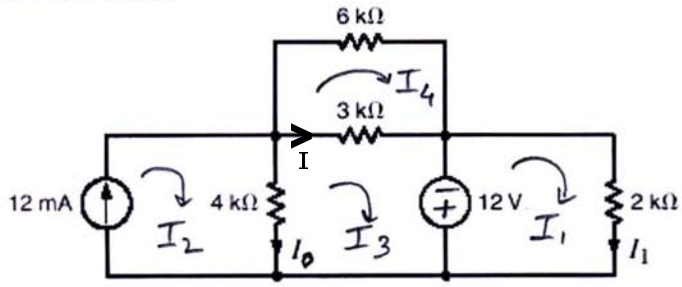


Figure P3.57

SOLUTION:



$$I_2 = 12\ mA$$

KCL : $I_0 + I_3 = I_2$

$I_0 = I_2 - I_3$

KCL : $I_2 = I + I_0 + I_4$

$I = I_2 - I_2 + I_3 - I_4$

$I = I_3 - I_4$

KVL: $12 = -2K I_1$

$I_1 = -6\ mA$

KVL: $12 = 4K(-I_0) + 6K I_4$

$-4K(-I_0) + 6K I_4$

$-4K(I_2 - I_3) + 6K I_4 = 12$

$-4K I_2 + 4K I_3 + 6K I_4 = 12$

$$\boxed{4K I_3 + 6K I_4 = 60}$$

KVL: $12 = 4K(-I_0) + 3KI$.

$-4K(I_2 - I_3) + 3K(I_3 - I_4) = 12$

$\boxed{7I_3 - 4I_2 - 3I_4 = 12}$

KVL:

$6k I_4 + 3k(I_4 - I_3) = 0$

$I_4 = I_3 | 3$

$I_3 = 10mA$

$I_4 = 3.33mA$

$I_0 = I_2 - I_3 = 12m - 10m = 2mA$

$I_0 = 2mA$

3.58 Find I_o in the network in Fig. P3.58 using loop analysis. Then solve the problem using MATLAB and compare your answers.

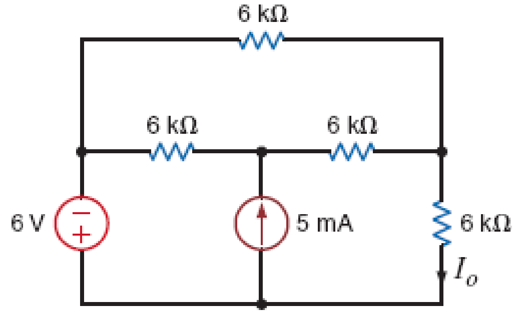
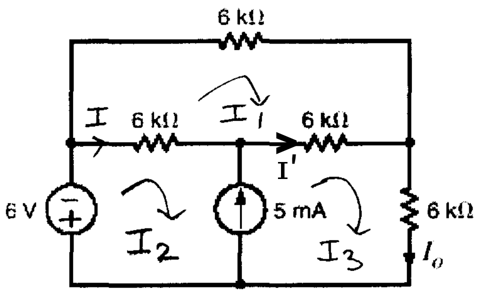


Figure P3.58

SOLUTION:



$$I_3 = I_o$$

KCL: $I_2 = I + I_1$

$$I = I_2 - I_1$$

KCL; $I_1 + I' = I_3$

$$I' = I_3 - I_1$$

KVL;

KVL in the top loop:

$$18I_1 - 6I_2 - 6I_3 = 0$$

$$\boxed{3I_1 - I_2 - I_3 = 0}$$

KVL: $6 + 6KI + 6KI' + 6kI_o = 0$

$$6k(I_2 - I_1) + 6k(I_3 - I_1) + 6kI_3 = -6$$

$$\boxed{-12kI_1 + 6kI_2 + 12kI_3 = -6} \Rightarrow \boxed{2I_1 - I_2 - 2I_3 = 1}$$

KCL: $I_3 = 5m + I_2$

$$\boxed{-I_2 + I_3 = 5m}$$

upon solving these equations we get, $i_3 = 2/5 = 0.4\,mA$

```
% MATLAB Code and Solution for Problem 3.65

R = [3,-1,-1; 2,-1,-2; 0,-2,1];

V = [0; 1; 5]

Imatrix = inv(R) * V

>>
Imatrix =

   -0.0016
   -0.0044
    0.0006
```

3.59 Use nodal analysis to find V_o in the circuit in Fig. P3.59.

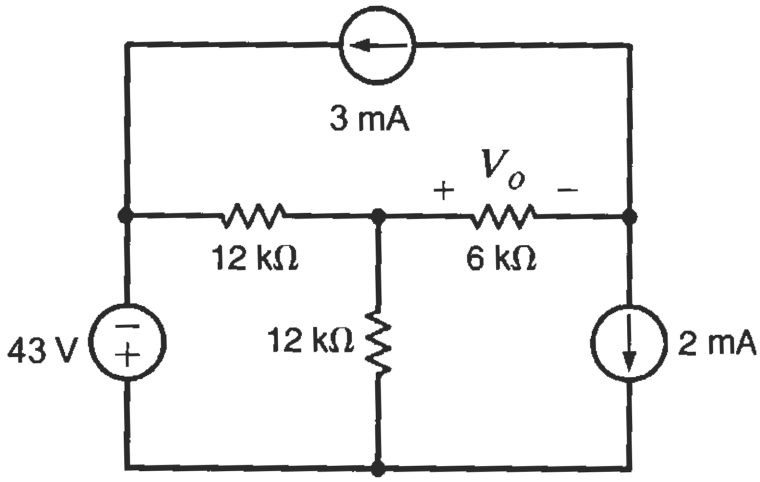
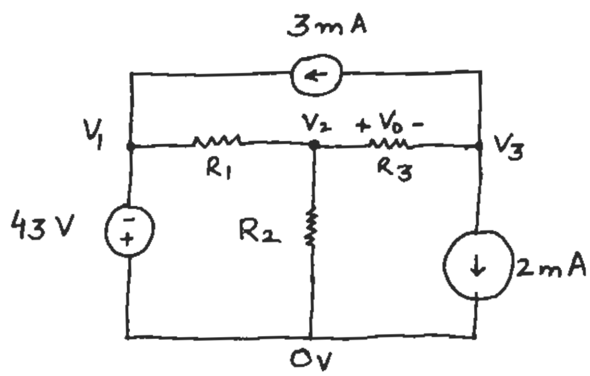


Figure P3.59

SOLUTION: 3.59



$R_1 = R_2 = 12\ k\Omega$, $R_3 = 6\ k\Omega$

$V_1 = -43\ V$

$V_2 - V_3 = V_o$ ——— ①

KCL @ V_2 : $\dfrac{V_2 - V_1}{R_1} + \dfrac{V_2 - V_3}{R_3} + \dfrac{V_2}{R_2} = 0$

KCL @ V_3 : $\dfrac{V_3 - V_2}{R_3} + 2\times10^{-3} + 3\times10^{-3} = 0$

$V_2 - V_3 = 30$ ——— ②

From equations ① and ②, we get

$\boxed{V_o = 30.0\ V}$

3.60 Determine V_0 in the circuit in Fig. P3.60 using loop analysis.

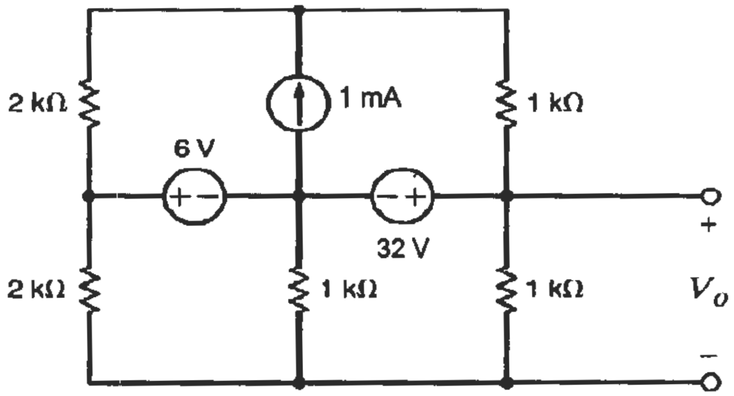
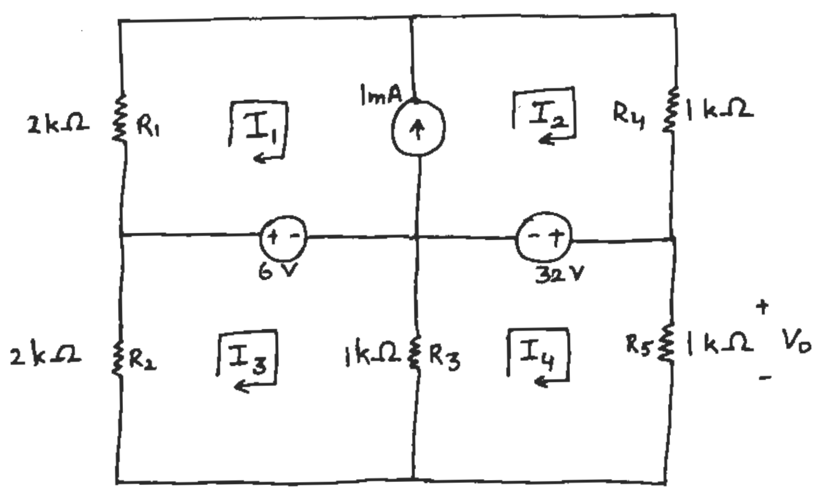


Figure P3.60

Solution: 3.60



$V_o = I_4 R_5$ $\qquad$ $I_2 - I_1 = 1\,mA$

KVL @ I_3 : $I_3 R_2 + 6 + (I_3 - I_4) R_3 = 0$

$$I_3 (R_2 + R_3) - I_4 R_3 = -6$$

$$I_3 (3 \times 10^3) - I_4 (10^3) = -6$$

$$3 I_3 - I_4 = -6 \times 10^{-3} \quad \text{———} \quad (1)$$

KVL @ I_4 : $(I_4 - I_3) R_3 - 32 + I_4 R_5 = 0$

$$2 I_4 - I_3 = 32 \times 10^{-3} \quad \text{———} \quad (2)$$

$$5 I_4 = 90 \times 10^{-3}$$

$$I_4 = 18 mA$$

$$V_0 = I_4 R_5$$

$$V_0 = 18 \times 10^{-3} \times 10^{3}$$

$$\boxed{V_0 = 18.0 V}$$

3.61 Find I_o in the circuit in Fig. P3.61.

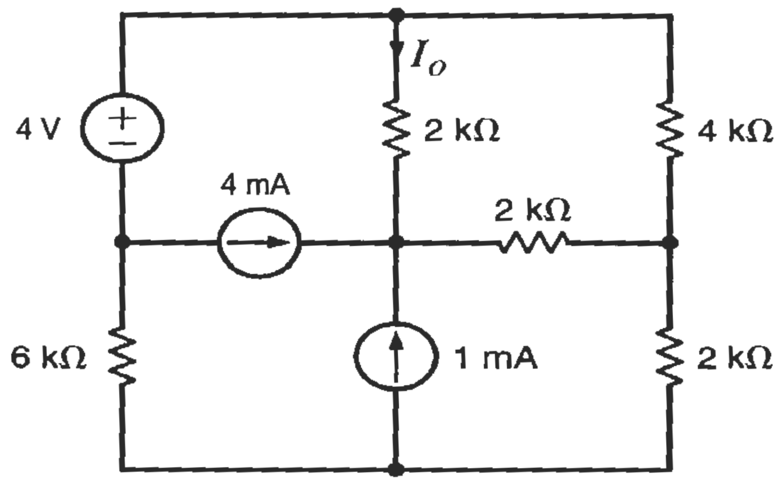
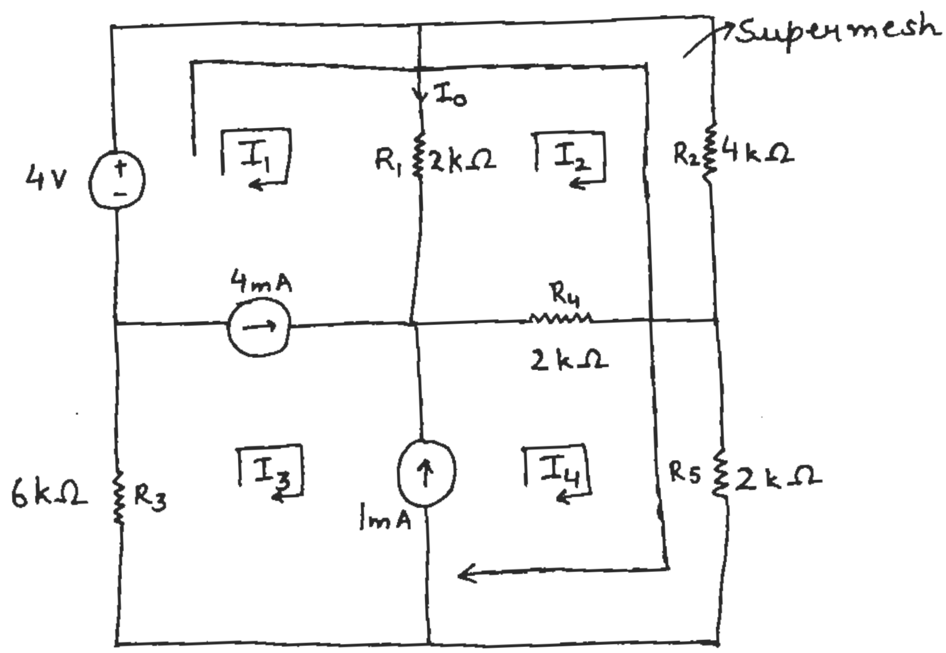


Figure P3.61

SOLUTION: 3.61



$I_3 - I_1 = 4\times10^{-3}\,A = 4\,mA$

$\Rightarrow I_3 = 4mA + I_1$ ——— ①

$I_4 - I_3 = 1\times10^{-3}\,A = 1\,mA$

$\Rightarrow I_4 = 1mA + I_3 = 5mA + I_1$ ——— ②

$I_1 - I_2 = I_0$

$\Rightarrow I_2 = I_1 - I_0$ ——— (3)

KVL for I_2 : $(I_2 - I_1)R_1 + I_2 R_2 + (I_2 - I_4)R_4 = 0$

$I_2(R_1 + R_2 + R_4) - I_1 R_1 - I_4 R_4 = 0$

$I_2(8\times10^3) - 2\times10^3 I_1 - (2\times10^3)I_4 = 0$

$\Rightarrow 4I_2 - I_1 - I_4 = 0$ ——— (4)

KVL for supermesh: $-4 + I_2 R_2 + I_4 R_5 + I_3 R_3 = 0$

$I_2(4\times10^3) + I_4(2\times10^3) + I_3(6\times10^3) = 4$

$\Rightarrow 2I_2 + I_4 + 3I_3 = 2\times10^{-3}$ ——— (5)

Substituting equations (2) and (3) in (4), we get

$4(I_1 - I_0) - I_1 - [(5\times10^{-3}) + I_1] = 0$

$2I_1 - 4I_0 = 5\times10^{-3}$ ——— (6)

Substituting equations (1), (2) and (3) in (5), we get

$2(I_1 - I_0) + 5\times10^{-3} + I_1 + 3(4\times10^{-3} + I_1) = 2\times10^{-3}$

$6I_1 - 2I_0 = -15\times10^{-3}$ ——— (7)

From equations (6) and (7), we get

$\boxed{I_0 = -3.00 \text{ mA}}$

3.62 Use loop analysis to find I_o in the network in Fig. P3.62.

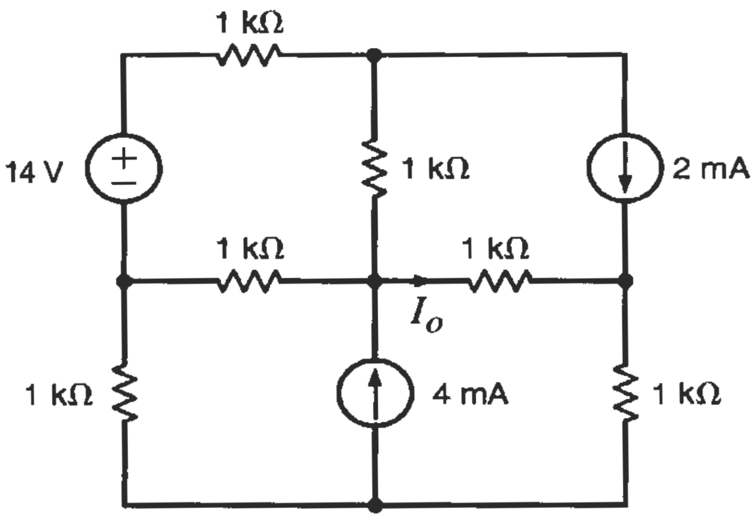
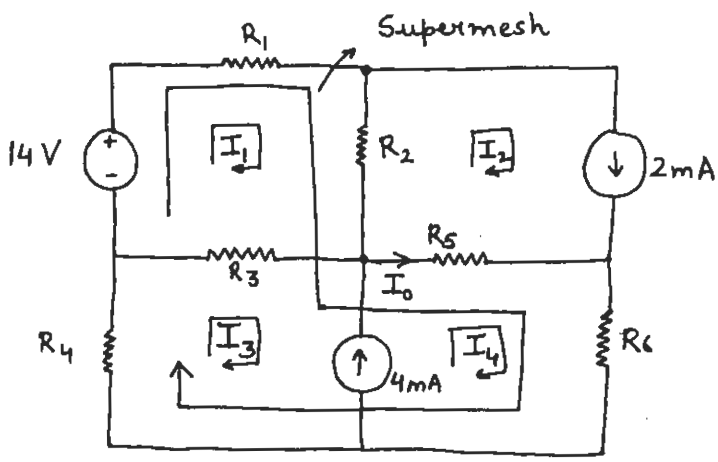


Figure P3.62

SOLUTION: 3.62



$R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = 1\,k\Omega$

$I_2 = 2mA$

$I_4 - I_2 = I_o \quad \Rightarrow \quad I_4 = I_o + 2mA$ ___ (1)

$I_4 - I_3 = 4mA$

$I_3 = I_4 - 4\times10^{-3}$

$$= I_0 + 2\times10^{-3} - 4\times10^{-3}$$

$$I_3 = I_0 - 2\times10^{-3} \qquad \text{—} \qquad (2)$$

KVL @ I_1: $-14 + I_1R_1 + (I_1 - I_2)R_2 + (I_1 - I_3)R_3 = 0$

$$I_1(R_1 + R_2 + R_3) - I_2R_2 - I_3R_3 = 14$$

Substituting $I_2 = 2\text{mA}$, $I_3 = I_0 - 2\text{mA}$ in above equation, we get

$$3I_1 - I_0 = 14\times10^{-3} \qquad \text{—} \qquad (3)$$

KVL @ Supermesh: $-14 + I_1R_1 + (I_1 - I_2)R_2 + (I_4 - I_2)R_5 + I_4R_6 + I_3R_4 = 0$

$$I_1(R_1 + R_2) - I_2(R_2 + R_5) + I_3R_4 + I_4(R_5 + R_6) = 14$$

$$2I_1 - 2I_2 + I_3 + 2I_4 = 14\times10^{-3}$$

$$2I_1 - 2(2\times10^{-3}) + I_0 - 2\times10^{-3} + 2(I_0 + 2\times10^{-3}) = 14\times10^{-3}$$

$$2I_1 + 3I_0 = 16\times10^{-3} \qquad \text{—} \qquad (4)$$

From equations (3) and (4), we get

$$\boxed{I_0 = 1.82\ \text{mA}}$$

3.63 Use loop analysis to find I_o in the network in Fig. P3.63.

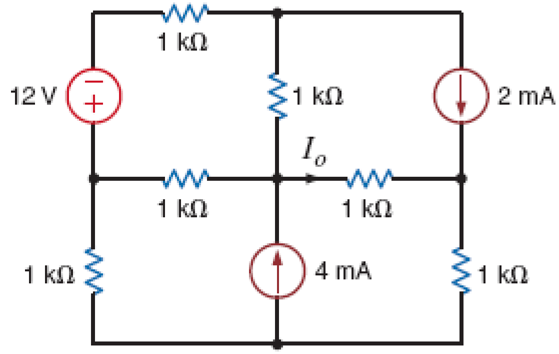
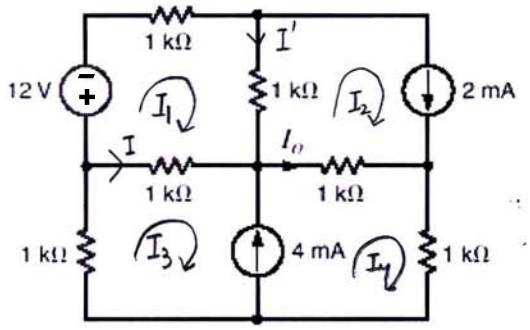


Figure P3.63

SOLUTION:



$$I_2 = 2mA$$

KCL: $I_3 = I + I_1$

$$I = I_3 - I_1$$

KCL: $I' + I_2 = I_1$

$$I' = I_1 - I_2$$

KCL: $I_o + 2m = I_4$

$$I_o = I_4 - 2m$$

KVL: $0 = 12 + 1kI_1 + 1kI' + 1k(-I)$

$$1kI_1 + 1k(I_1 - I_2) - 1k(I_3 - I_1) = -12$$

$$3kI_1 - 1kI_2 - 1kI_3 = -12$$

$$\boxed{3kI_1 - 1kI_3 = -10}$$

KVL: $1kI_3 + 1kI + 1kI_o + 1kI_4 = 0$

$$1kI_3 + 1k(I_3 - I_1) + 1k(I_4 - 2m) + 1kI_4 = 0$$

$$\boxed{-1k\,I_1 + 2k\,I_3 + 2k\,I_4 = 2}$$

KCL: $I_4 = 4m + I_3$

$$\boxed{-I_3 + I_4 = 4m}$$

KVL: $0 = 12 + 1k\,I_1 + 1k\,I' + 1k\,I_0 + 1k\,I_4 + 1k\,I_3$

$1k\,I_1 + 1k(I_1 - I_2) + 1k(I_4 - 2m) + 1k\,I_4 + 1k\,I_3 = -12$

$2k\,I_1 - 1k\,I_2 + 1k\,I_3 + 2k\,I_4 = -10$

$$\boxed{2k\,I_1 + 1k\,I_3 + 2k\,I_4 = -8}$$

$3k\,I_1 - 1k\,I_3 = -10$

$-1k\,I_1 + 2k\,I_3 + 2k\,I_4 = 2$

$-I_3 + I_4 = 4m$

$I_1 = -4.18mA$

$I_3 = -2.55mA$

$I_4 = 1.45mA$

$I_0 = I_4 - 2m$

$I_0 = 1.45m - 2m$

$I_0 = -0.55mA$

3.64 Use loop analysis to find V_0 in the network in the Fig. P3.64.

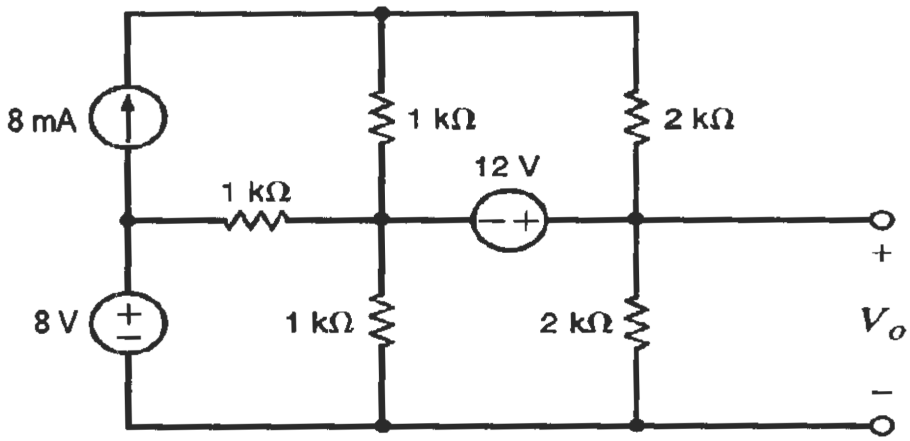
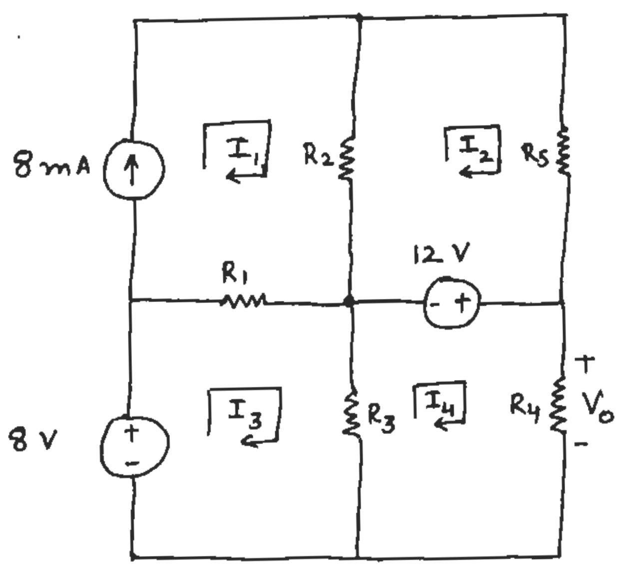


Figure P3.64

Solution: 3-64



$R_1 = R_2 = R_3 = 1\,k\Omega\,,\quad R_5 = R_4 = 2\,k\Omega$

$V_0 = I_4 R_4$ —— (1)

$I_1 = 8\,mA$

KVL @ I_2: $(I_2 - I_1) R_2 + I_2 R_5 + 12 = 0$

$I_2 = -2\,mA$

KVL @ I_3: $-8 + (I_3 - I_1)R_1 + (I_3 - I_4)R_3 = 0$

$$I_3(R_1 + R_3) - I_1 R_1 - I_4 R_3 = 8$$

$$I_3(2 \times 10^3) - (8 \times 10^{-3})(10^3) - I_4(10^3) = 8$$

$$2I_3 - I_4 = 16 \times 10^{-3} \quad \text{—} \quad (2)$$

KVL @ I_4: $(I_4 - I_3)R_3 - 12 + I_4 R_4 = 0$

$$I_4(R_3 + R_4) - I_3 R_3 = 12$$

$$(3 \times 10^3) I_4 - (10^3) I_3 = 12$$

$$3I_4 - I_3 = 12 \times 10^{-3} \quad \text{—} \quad (3)$$

From equations (2) and (3), we get

$$I_4 = 8\,mA$$

Substituting the value of I_4 in equation (1), we get

$$V_0 = (8 \times 10^{-3})(2 \times 10^3)$$

$$\boxed{V_0 = 16.0\,V}$$

3.65 Using loop analysis, find V_o in the network in Fig. P3.65.

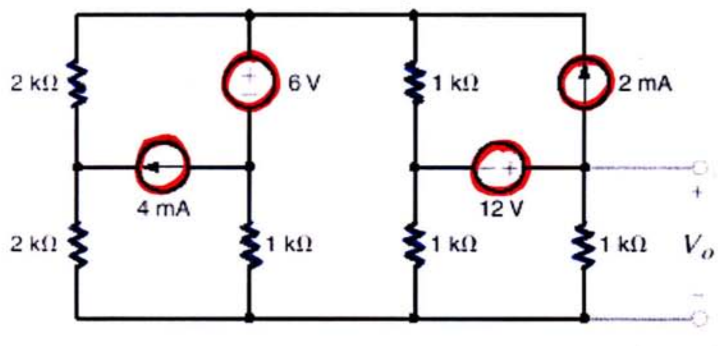
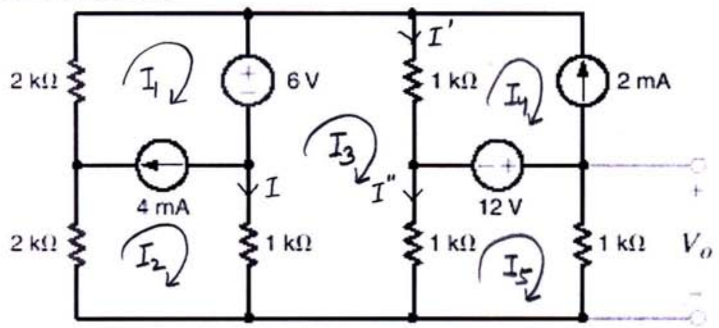


Figure P3.65

SOLUTION:



KCL: $I_3 + I = I_2$

$I = I_2 - I_3$

KCL: $I_3 = I' + I_4$

$I' = I_3 - I_4$

KCL: $I'' + I_5 = I_3$

$I'' = I_3 - I_5$

KVL: $12 = 1k\,I_5 + 1k(-I'')$

$-1k(I_3 - I_5) + 1k\,I_5 = 12$

$$\boxed{-1k\,I_3 + 2k\,I_5 = 12}$$

KVL: $6 = 1k\,I' + 1k\,I'' + 1k(-I)$

$1k(I_3 - I_4) + 1k(I_3 - I_5) - 1k(I_2 - I_3) = 6$

$$\boxed{-1kI_2 + 3kI_3 - 1kI_4 - 1kI_5 = 6}$$

KVL: $2kI_1 + 1kI' + 1kI_5 + 2kI_2 = 12$

$$2kI_1 + 1k(I_3 - I_4) + 1kI_5 + 2kI_2 = 12$$

$$\boxed{2kI_1 + 2kI_2 + 1kI_3 - 1kI_4 + 1kI_5 = 12}$$

KCL: $I_2 + 4m = I_1$

$$\boxed{-I_1 + I_2 = -4m}$$

$I_4 = -2mA$

$$-1kI_2 + 3kI_3 - 1k(-2m) - 1kI_5 = 6$$

$$\boxed{-1kI_2 + 3kI_3 - 1kI_5 = 4}$$

$$2kI_1 + 2kI_2 + 1kI_3 - 1k(-2m) + 1kI_5 = 12$$

$$\boxed{2kI_1 + 2kI_2 + 1kI_3 + 1kI_5 = 10}$$

$$0I_1 + 0I_2 - 1kI_3 - 1k(-2m) + 1kI_5 = 12$$

$$-I_1 + I_2 + 0I_3 + 0I_5 = -4m$$

$$0I_1 - 1kI_2 + 3kI_3 - 1kI_5 = 4$$

$$2kI_1 + 2kI_2 + 1kI_3 + 1kI_5 = 10$$

$I_1 = 1.83mA$

$I_2 = -2.17mA$

$I_3 = 3.13mA$

$I_5 = 7.57mA$

$V_o = 1k(I_5) = 1k(7.57m)$

$V_o = 7.57V$

3.66 Using loop analysis, find I_o in the circuit in Fig. P3.66.

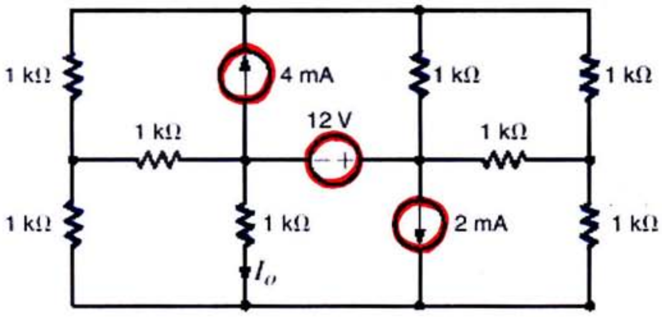
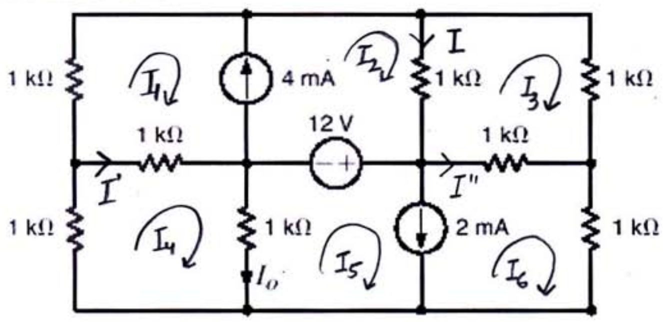


Figure P3.66

SOLUTION:



KCL: $I_2 = I + I_3$

$I = I_2 - I_3$

KCL: $I_3 + I'' = I_6$

$I'' = I_6 - I_3$

KCL: $I_4 = I_1 + I'$

$I' = I_4 - I_1$

KCL: $I_0 + I_5 = I_4$

$I_0 = I_4 - I_5$

KVL: $12 = 1kI'' + 1kI_6 + 1k(-I_0)$

$1k(I_6 - I_3) + 1kI_6 - 1k(I_4 - I_5) = 12$

$$\boxed{-1kI_3 - 1kI_4 + 1kI_5 + 2kI_6 = 12}$$

$$\text{KVL: } 1k\,I' + 1k\,I_0 + 1k\,I_4 = 0$$
$$1k(I_4 - I_1) + 1k(I_4 - I_5) + 1k\,I_4 = 0$$
$$\boxed{-1k\,I_1 + 3k\,I_4 - 1k\,I_5 = 0}$$

$$\text{KCL: } I_6 + 2m = I_5$$
$$\boxed{-I_5 + I_6 = -2m}$$

$$\text{KCL: } I_1 + 4m = I_2$$
$$\boxed{I_1 - I_2 = -4m}$$

$$\text{KVL: } 1k\,I_1 + 1k\,I_3 + 1k(-I'') + 12 + 1k(-I') = 0$$
$$1k\,I_1 + 1k\,I_3 - 1k(I_6 - I_3) - 1k(I_4 - I_1) = -12$$
$$\boxed{2k\,I_1 + 2k\,I_3 - 1k\,I_4 - 1k\,I_6 = -12}$$

$$\text{KVL: } 1k\,I_3 + 1k(-I'') + 1k(-I) = 0$$
$$1k\,I_3 - 1k(I_6 - I_3) - 1k(I_2 - I_3) = 0$$
$$\boxed{-1k\,I_2 + 3k\,I_3 - 1k\,I_6 = 0}$$

$$0I_1 + 0I_2 - 1k\,I_4 + 1k\,I_5 + 2k\,I_6 = 12$$
$$-1k\,I_1 + 0I_2 + 0I_3 + 3k\,I_4 - 1k\,I_5 + 0I_6 = 0$$
$$0I_1 + 0I_2 + 0I_3 + 0I_4 - I_5 + I_6 = -2m$$
$$I_1 - I_2 + 0I_3 + 0I_4 + 0I_5 + 0I_6 = -4m$$
$$2k\,I_1 + 0I_2 + 2k\,I_3 - 1k\,I_4 + 0I_5 - 1k\,I_6 = -12$$
$$0I_1 - 1k\,I_2 + 3k\,I_3 + 0I_4 + 0I_5 - 1k\,I_6 = 0$$

$I_1 = -4.93mA$

$I_2 = -0.933mA$

$I_3 = 0.933mA$

$I_4 = 0.267mA$

$I_5 = 5.73mA$

$I_6 = 3.73mA$

$I_0 = I_4 - I_5 = 0.267m - 5.73m$

$I_0 = -5.46mA$

3.67 Use MATLAB to find the mesh currents in the network in Fig. P3.6.

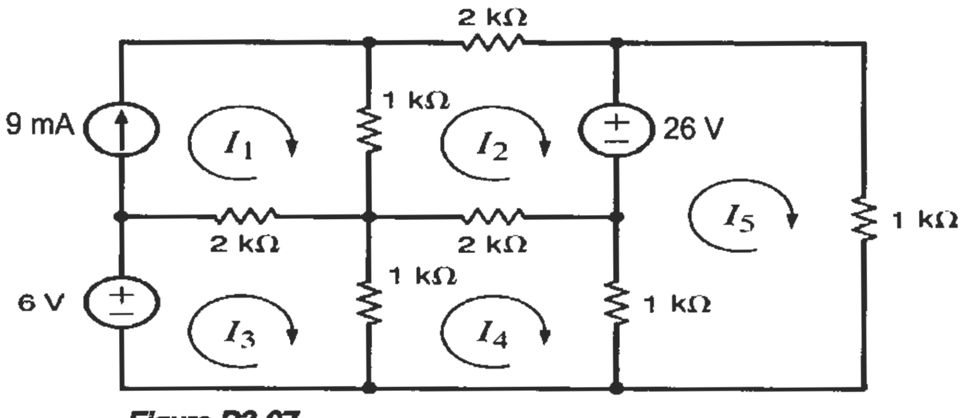
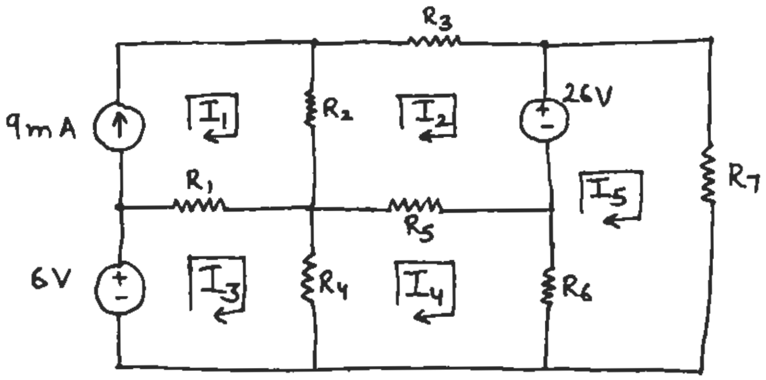


Figure P3.67

SOLUTION: 3.67



$R_1 = R_3 = R_5 = 2k\Omega$, $R_2 = R_4 = R_6 = R_7 = 1\ k\Omega$

$I_1 = 9\times10^{-3}$ A

KVL @ I_2: $(I_2 - I_1)R_2 + I_2R_3 + 26 + (I_2 - I_4)R_5 = 0$

$$-I_1(R_2) + I_2(R_2 + R_3 + R_5) - I_4R_5 = -26$$

$$-I_1(10^3) + I_2(5\times10^3) - I_4(2\times10^3) = -26$$

$$-I_1 + 5I_2 - 2I_4 = -26\times10^{-3}$$

KVL @ I_3: $-6 + (I_3 - I_1)R_1 + (I_3 - I_4)R_4 = 0$

$$-I_1R_1 + I_3(R_1 + R_4) - I_4(R_4) = 6$$

$$-I_1(2\times10^3) + I_3(3\times10^3) - I_4(10^3) = 6$$

$$-2I_1 + 3I_3 - I_4 = 6\times10^{-3}$$

KVL @ I_4: $(I_4 - I_3)R_4 + (I_4 - I_2)R_5 + (I_4 - I_5)R_6 = 0$

$$-I_2R_5 - I_3R_4 + I_4(R_4 + R_5 + R_6) - I_5R_6 = 0$$

$$-I_2(2\times10^3) - I_3(10^3) + I_4(4\times10^3) - I_5(10^3) = 0$$

$$-2I_2 - I_3 + 4I_4 - I_5 = 0$$

KVL @ I_5: $-26 + I_5R_7 + (I_5 - I_4)R_6 = 0$

$$-I_4R_6 + I_5(R_6 + R_7) = 26$$

$$-I_4(10^3) + I_5(2\times10^3) = 26$$

$$-I_4 + 2I_5 = 26\times10^{-3}$$

In matrix form

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ -1 & 5 & 0 & -2 & 0 \\ -2 & 0 & 3 & -1 & 0 \\ 0 & -2 & -1 & 4 & -1 \\ 0 & 0 & 0 & -1 & 2 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{bmatrix} = \begin{bmatrix} 0.009 \\ -0.026 \\ 0.006 \\ 0 \\ 0.026 \end{bmatrix}$$

3.68 Use loop analysis to find V_o in the network in Fig. P3.68.

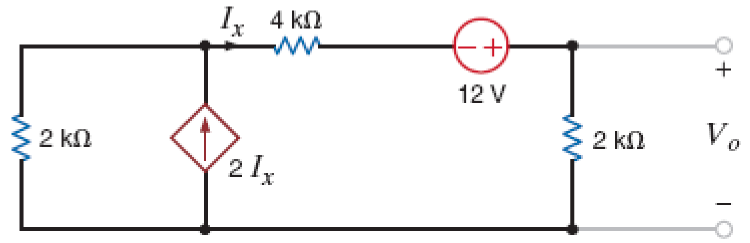
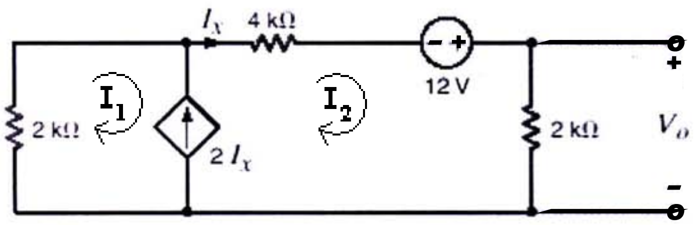


Figure P3.68

SOLUTION:



KCL: $I_1 + 2I_x = I_x$

$I_1 = -I_x$ and $I_2 = I_x$

KVL: $12 = 2kI_1 + 4kI_2 + 2kI_2$

$2kI_1 + 6kI_2 = 12$

$2k(-I_x) + 6k(I_x) = 12$

$4kI_x = 12$

$I_x = 3mA$

$V_0 = 2kI_x = 2k(3m)$

$V_0 = 6V$

3.69 Find V_o in the circuit in Fig. P3.69 using nodal analysis.

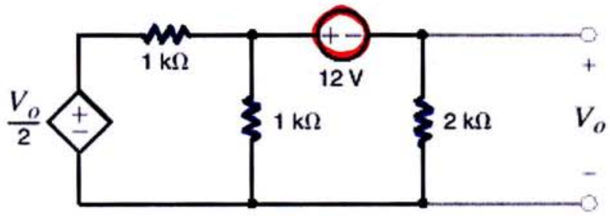
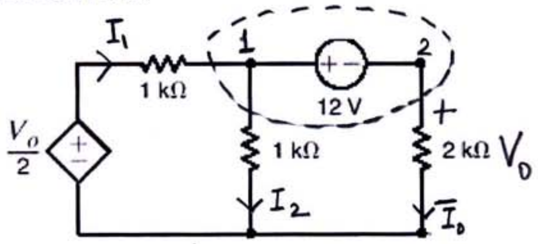


Figure P3.69

SOLUTION:



KCL at supernode:

$$I_1 = I_2 + I_0$$

$$\frac{\frac{V_0}{2} - V_1}{1k} = \frac{V_1}{1k} + \frac{V_2}{2k}$$

$$V_0 - 2V_1 = 2V_1 + V_2$$

$$V_2 = V_0$$

$$V_1 = 0V$$

$$V_1 - V_2 = 12$$

$$V_2 = -12V$$

$$V_0 = -12V$$

3.70 Use nodal analysis to find V_o in Fig. P3.70.

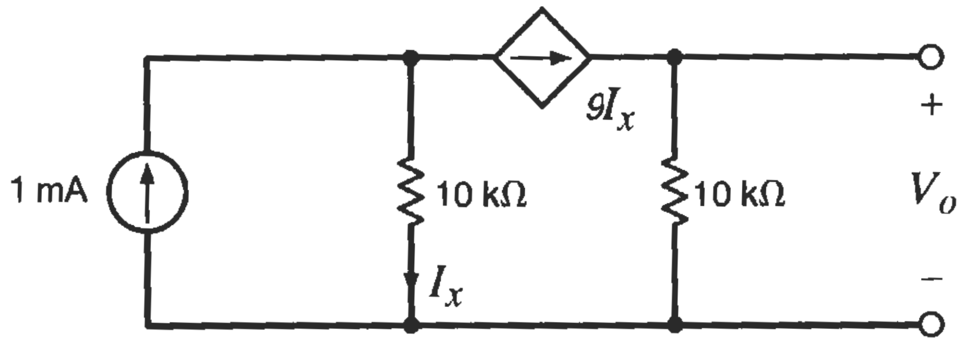
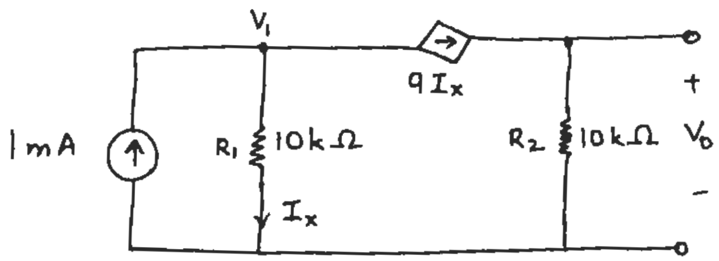


Figure P3.70

SOLUTION: 3.70



$R_1 = R_2 = 10\,k\Omega$

$$I_x = \frac{V_1}{R_1} \quad \Rightarrow \quad I_x = \frac{V_1}{10 \times 10^3} = \frac{V_1}{10} \times 10^{-3}$$

KCL @ V_1 : $\quad -1 \times 10^{-3} + \dfrac{V_1}{R_1} + 9\,I_x = 0$

$$V_1 = 1\,V$$

KCL @ V_o : $\quad -9\,I_x + \dfrac{V_o}{R_2} = 0$

$$V_o = 9\,V_1$$

$$\boxed{V_o = 9\,V}$$

3.71 Use nodal analysis to find V_o in the network in Fig. P3.71.

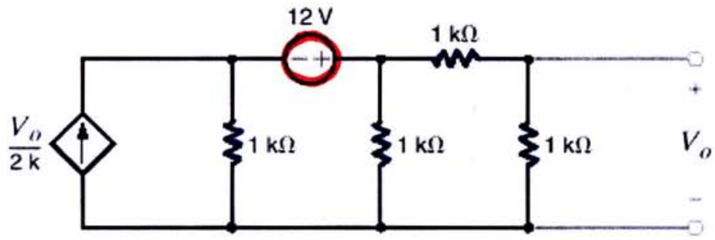
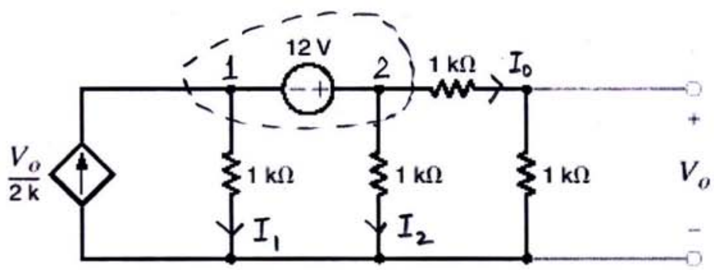


Figure P3.71

SOLUTION:



KCL at supernode:

$$\frac{V_0}{2k} = I_1 + I_2 + I_0$$

$$\frac{V_1}{1k} + \frac{V_2}{1k} + \frac{V_2}{1k+1k} = \frac{V_0}{2k}$$

$$2V_1 + 2V_2 + V_2 = V_0$$

$$\boxed{2V_1 + 3V_2 = V_0}$$

$$\boxed{-V_1 + V_2 = 12}$$

$$V_0 = I_0(1k)$$

$$I_0 = \frac{V_2}{1k+1k} = \frac{V_2}{2k}$$

$$\boxed{V_0 = \frac{V_2}{2}}$$

$$2V_1 + 3V_2 = \frac{V_2}{2}$$

$$4V_1 + 6V_2 = V_2$$

$$\boxed{4V_1 + 5V_2 = 0}$$

$$-V_1 + V_2 = 12$$
$$4V_1 + 5V_2 = 0$$

$$V_1 = -6.67V$$
$$V_2 = 5.33V$$

$$V_0 = \frac{V_2}{2} = \frac{5.33}{2}$$

$$V_0 = 2.67V$$

3.72 Find the power supplied by the 4-A current source in the network in Fig. P3.72 using nodal analysis.

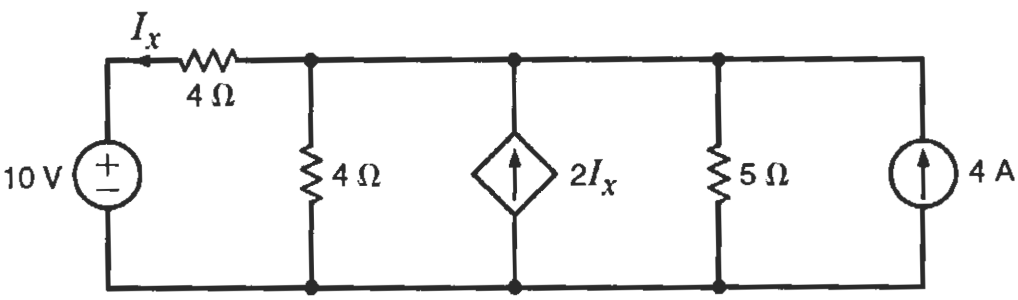
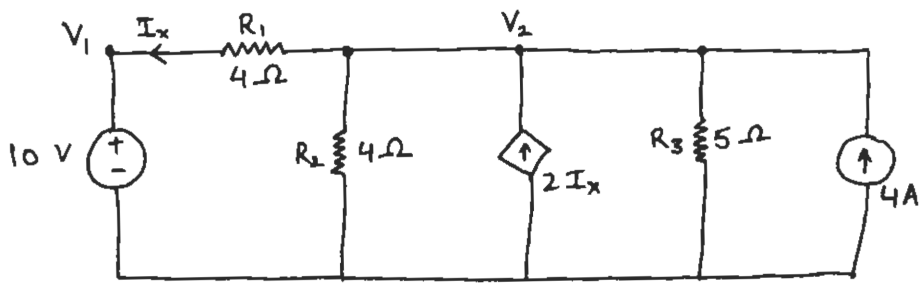


Figure P3.72

SOLUTION: 3.72



$R_1 = R_2 = 4\Omega, \quad R_3 = 5\Omega$

$V_1 = 10\text{ V}; \quad I_x = \dfrac{V_2 - V_1}{R_1} = \dfrac{V_2 - V_1}{4} = \dfrac{V_2 - 10}{4}\text{ A}$

KCL @ V_2: $\quad \dfrac{V_2 - V_1}{R_1} + \dfrac{V_2}{R_2} - 2I_x + \dfrac{V_2}{R_3} - 4 = 0$

$$\frac{V_2 - 10}{4} + \frac{V_2}{4} - 2\left(\frac{V_2 - 10}{4}\right) + \frac{V_2}{5} - 4 = 0$$

$$V_2 = 7.5\text{ V}$$

Power supplied by 4-A source,

$$P_{4A} = 4 \times 7.5$$

$$\boxed{P_{4A} = 30.0\text{ W}}$$

3.73 Find I_o in the network in Fig. P3.73.

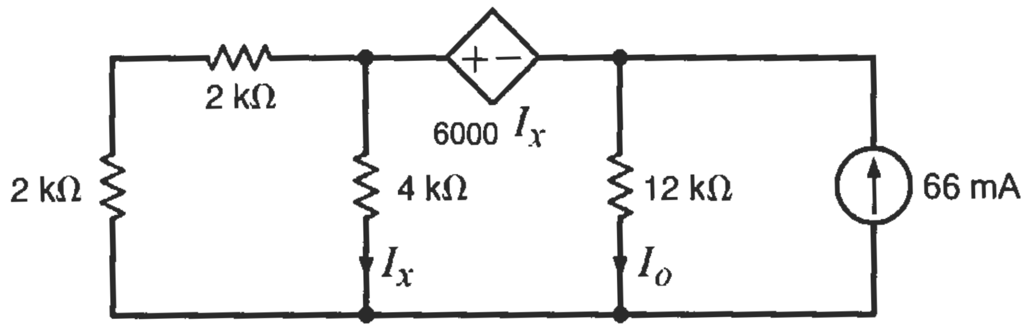
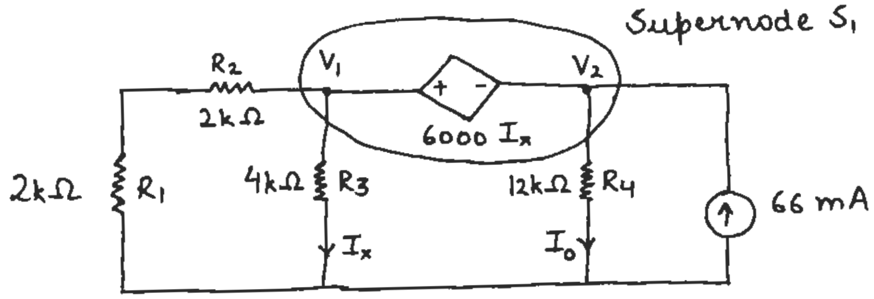


Figure P3.73

SOLUTION: 3.73



$R_1 = R_2 = 2\ k\Omega$, $R_3 = 4\ k\Omega$, $R_4 = 12\ k\Omega$

$V_1 - V_2 = 6000\ I_x$

Using $I_x = \dfrac{V_1}{R_3}$,

$V_1 - V_2 = \dfrac{3}{2} V_1 \quad \Rightarrow \quad V_1 = -2V_2$ —— (1)

KCL @ S_1 : $\dfrac{V_1}{R_1 + R_2} + \dfrac{V_1}{R_3} + \dfrac{V_2}{R_4} - 66 \times 10^{-3} = 0$

$6V_1 + V_2 = 792$ —— (2)

From equations (1) and (2) we get,

$-11 V_2 = 792$

$V_2 = -72.0V$

$$I_O = \frac{V_2}{R_4}$$

$$= \frac{-72}{12 \times 10^3}$$

$$\boxed{I_O = -6\,mA}$$

3.74 Find V_o in the circuit in Fig. P3.74 using nodal analysis.

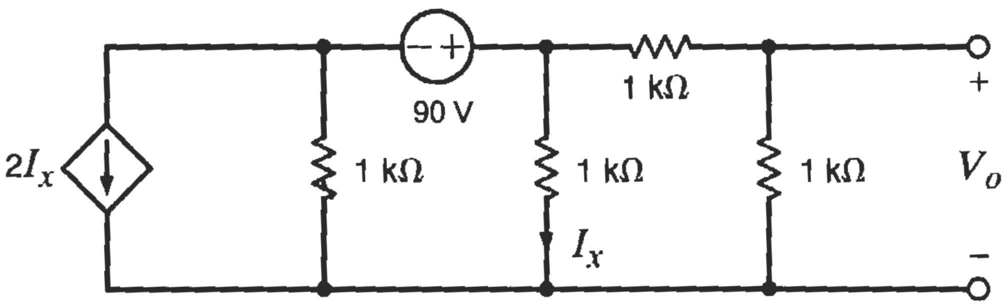
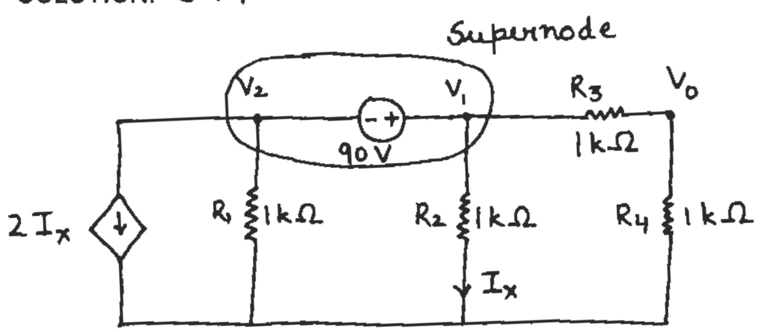


Figure P3.74

SOLUTION: 3.74



$R_1 = R_2 = R_3 = R_4 = 1\,k\Omega$

$V_1 - V_2 = 90\,V$ —— ①

$I_x = \dfrac{V_1}{R_2} = \dfrac{V_1}{10^3}$

KCL @ Supernode: $2I_x + \dfrac{V_2}{R_1} + \dfrac{V_1}{R_2} + \dfrac{V_1 - V_0}{R_3} = 0$

$4V_1 + V_2 - V_0 = 0$ —— ②

KCL @ V_0: $\dfrac{V_0}{R_4} + \dfrac{V_0 - V_1}{R_3} = 0$

$V_0 = \dfrac{V_1}{2}$ —— ③

Substituting equation ③ in ②, we get

$4V_1 + V_2 - \dfrac{V_1}{2} = 0$

$7V_1 + 2V_2 = 0$ — (4)

From equations (1) and (4), we get

$V_1 = 20\ V$

$V_0 = \frac{V_1}{2}$

$\boxed{V_0 = 10\ V}$

3.75 Find V_o in the network in Fig. P3.75 using nodal analysis.

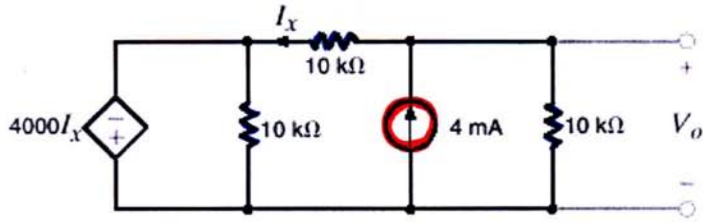
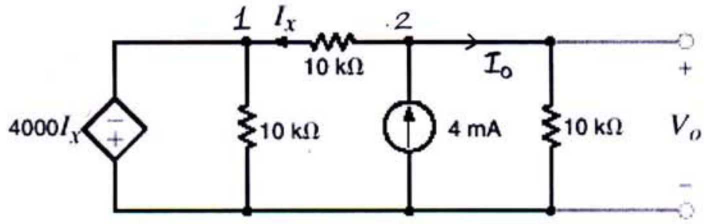


Figure P3.75

SOLUTION:



$$V_1 = -4000 I_x$$

$$I_x = \frac{V_2 - V_1}{10k}$$

KCL at 2: $4m = I_x + I_o$

$$\frac{V_2 - V_1}{10k} + \frac{V_2}{10k} = 4m$$

$$V_2 - V_1 + V_2 = 40$$

$$\boxed{-V_1 + 2V_2 = 40}$$

$$V_1 = -4000\left(\frac{V_2 - V_1}{10k}\right)$$

$$V_1 = -2/5\, V_2 + 2/5\, V_1$$

$$5V_1 = -2V_2 + 2V_1$$

$$\boxed{-3V_1 - 2V_2 = 0}$$

$$-V_1 + 2V_2 = 40$$

$$-3V_1 - 2V_2 = 0$$

$$V_1 = -10\,V$$
$$V_2 = 15\,V$$
$$V_0 = V_2 = 15\,V$$
$$V_0 = 15\,V$$

3.76 Use both nodal analysis and mesh analysis to find V_o in the circuit in Fig. P3.76.

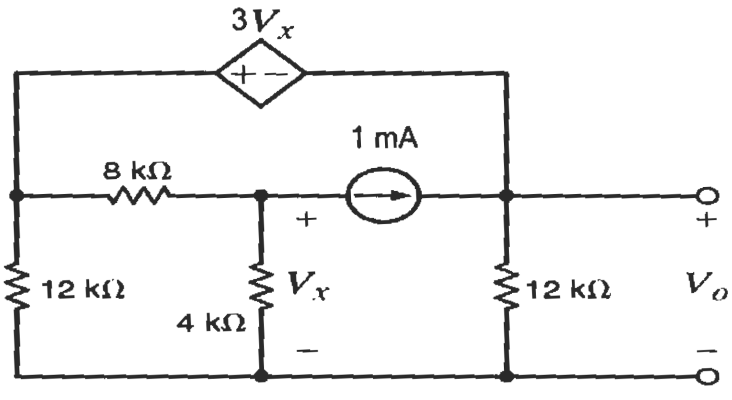
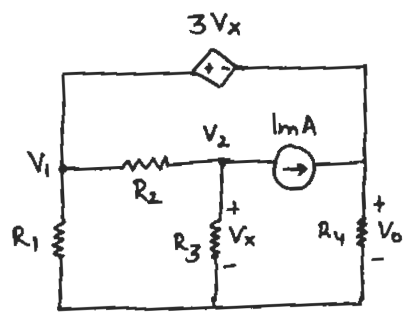


Figure P3.76

SOLUTION: 3.76 (a)



$R_1 = R_4 = 12\,k\Omega$, $R_2 = 8\,k\Omega$, $R_3 = 4\,k\Omega$, $V_x = V_2$

$$V_1 - V_o = 3V_x$$

$$\Rightarrow V_1 - V_o = 3V_2 \quad \text{——} \quad (1)$$

$$\text{KCL @ } V_2: \frac{V_2 - V_1}{R_2} + \frac{V_2}{R_3} + 1\times10^{-3} = 0$$

$$3V_2 - V_1 = -8$$

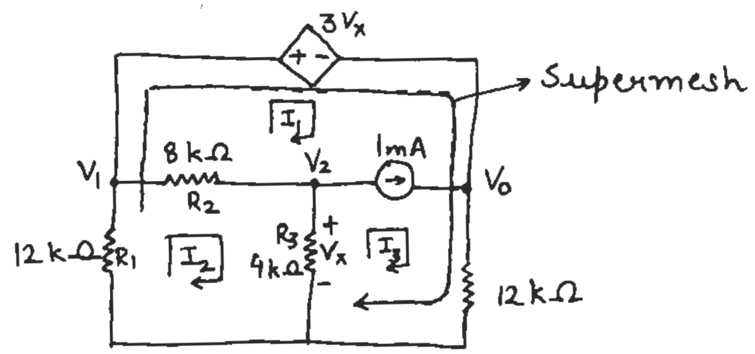
$$V_2 = \frac{-8 + V_1}{3} \quad \text{——} \quad (2)$$

Substituting equation (2) in (1), we get

$$V_1 - V_o = \frac{3(V_1 - 8)}{3}$$

$$\boxed{V_o = 8.00\ V}$$

3.76(b)



$R_1 = R_4 = 12\,k\Omega$, $R_2 = 8\,k\Omega$, $R_3 = 4\,k\Omega$

$I_3 - I_1 = 10^{-3} A$ —— ①

$V_x = (I_2 - I_3) R_3$

$V_o = I_3 R_4$

KVL @ Supermesh : $3V_x + I_3 R_4 + I_2 R_1 = 0$

$3 I_2 R_3 - 3 I_3 R_3 + I_3 R_4 + I_2 R_1 = 0$

$I_2 = 0 A$ — ②

KVL @ I_2 : $I_2 R_1 + (I_2 - I_1) R_2 + (I_2 - I_3) R_3 = 0$

$2 I_1 + I_3 = 0$

$I_1 = -\frac{I_3}{2}$ — ③

Substituting equation ③ in ②, we get

$I_3 = \frac{2}{3} \times 10^{-3} A$

$V_o = I_3 R_4$

$\boxed{V_o = 8.00\ V}$

3.77 Find V_x in the circuit in Fig. P3.77.

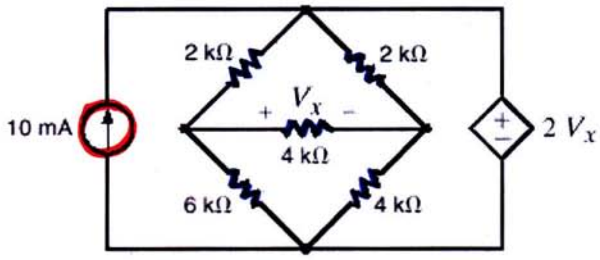
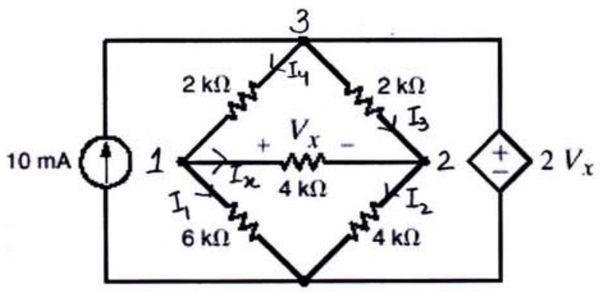


Figure P3.77

SOLUTION:



KCL at 1: $I_4 = I_x + I_1$

$$\frac{V_3 - V_1}{2k} = \frac{V_1 - V_2}{4k} + \frac{V_1}{6k}$$

$$6V_3 - 6V_1 = 3V_1 - 3V_2 + 2V_1$$

$$\boxed{11V_1 - 3V_2 - 6V_3 = 0}$$

KCL at 2: $I_x + I_3 = I_2$

$$\frac{V_1 - V_2}{4k} + \frac{V_3 - V_2}{2k} = \frac{V_2}{4k}$$

$$V_1 - V_2 + 2V_3 - 2V_2 = V_2$$

$$\boxed{V_1 - 4V_2 + 2V_3 = 0}$$

$$V_3 = 2V_x$$

$$V_x = V_1 - V_2$$

$$V_3 = 2(V_1 - V_2)$$

$$\boxed{2V_1 - 2V_2 - V_3 = 0}$$

$$11V_1 - 3V_2 - 6V_3 = 0$$
$$V_1 - 4V_2 + 2V_3 = 0$$
$$2V_1 - 2V_2 - V_3 = 0$$

$$V_1 = 0V$$
$$V_2 = 0V$$
$$V_3 = 0V$$
$$V_x = V_1 - V_2$$
$$V_x = 0V$$

3.78 Using mesh analysis, find V_o in the circuit in Fig. P3.78.

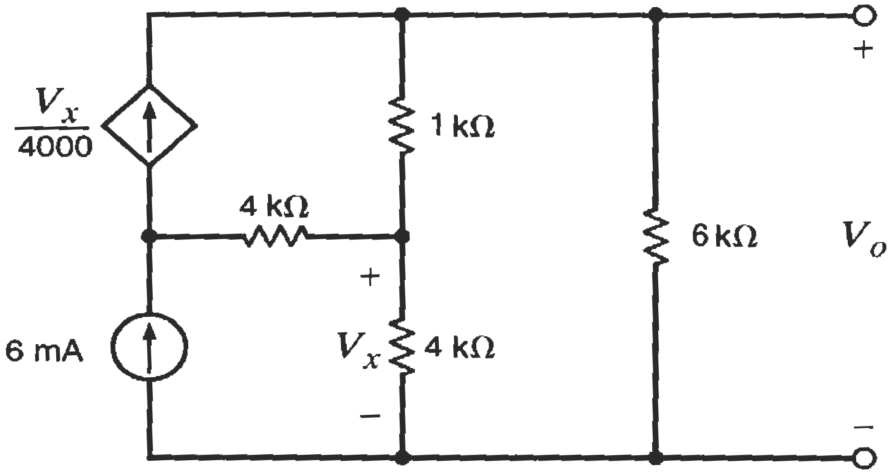
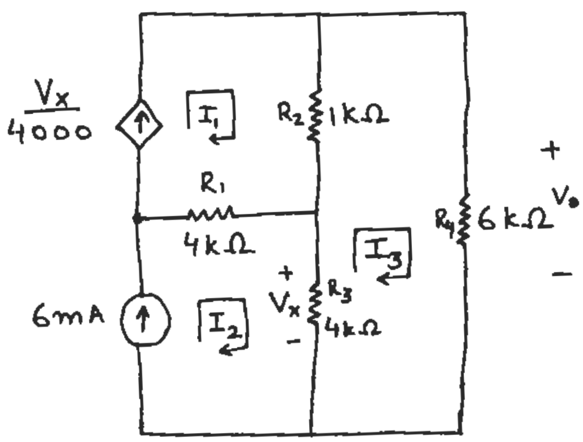


Figure P3.78

SOLUTION: 3.78



$R_1 = R_3 = 4\,k\Omega$, $R_2 = 1\,k\Omega$, $R_4 = 6\,k\Omega$

$I_2 = 6 \times 10^{-3}$ A —— ①

$V_x = (I_2 - I_3) R_3$ —— ②

$I_1 = \dfrac{V_x}{4000}$ —— ③

$V_0 = I_3 R_4$

KVL @ I_3: $(I_3 - I_1)R_2 + I_3R_4 + (I_3 - I_2)R_3 = 0$

$$11\,I_3 - I_1 = 24 \times 10^{-3} \quad \text{———} \quad (4)$$

Substituting equations (1) and (2) in (3), we get

$$I_1 = 6 \times 10^{-3} - I_3 \quad \text{———} \quad (5)$$

Substituting equation (5) in (4), we get

$$I_3 = \frac{30}{12} \times 10^{-3}\ A$$

$$V_0 = I_3 R_4$$

$$= \frac{30}{12} \times 10^{-3} \times 6 \times 10^{3}$$

$$\boxed{V_0 = 15.0\,V}$$

3.79 Find I_o in the circuit in Fig. P3.79.

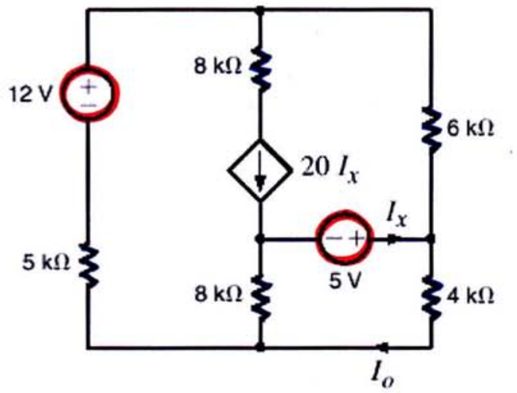
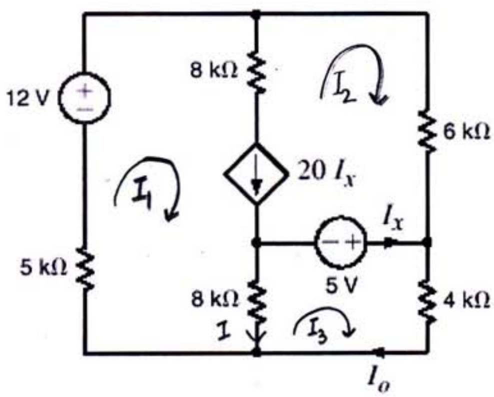


Figure P3.79

SOLUTION:



KVL: $12 = 5kI_1 + 6kI_2 + 4kI_3$

$$\boxed{5kI_1 + 6kI_2 + 4kI_3 = 12}$$

KCL: $I + I_3 = I_1$

$I = I_1 - I_3$

KVL: $5 = 4kI_3 + 8k(-I)$

$4kI_3 - 8k(I_1 - I_3) = 5$

$$\boxed{-8kI_1 + 12kI_3 = 5}$$

KCL: $I_1 = 20I_x + I_2$

$I_1 - I_2 - 20(I_3 - I_2) = 0$

$$\boxed{I_1 + 19I_2 - 20I_3 = 0}$$

$$5kI_1 + 6kI_2 + 4kI_3 = 12$$
$$-8kI_1 + 0I_2 + 12kI_3 = 5$$
$$I_1 + 19I_2 - 20I_3 = 0$$

$$I_1 = 0.66\text{mA}$$
$$I_2 = 0.871\text{mA}$$
$$I_3 = 0.861\text{mA}$$

$$I_0 = I_3$$
$$I_0 = 0.861\text{mA}$$

3.80 Write mesh equations for the circuit in Fig. P3.80 using the assigned currents.

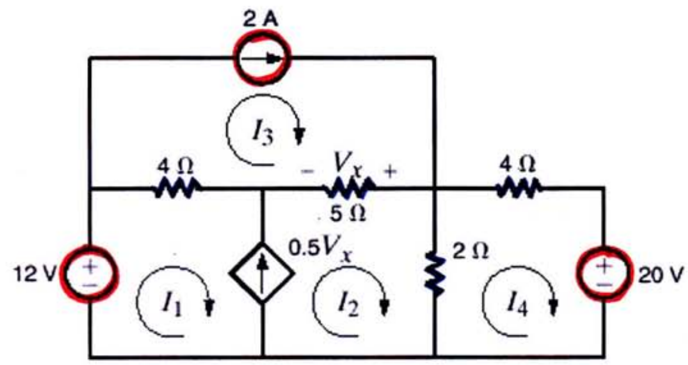
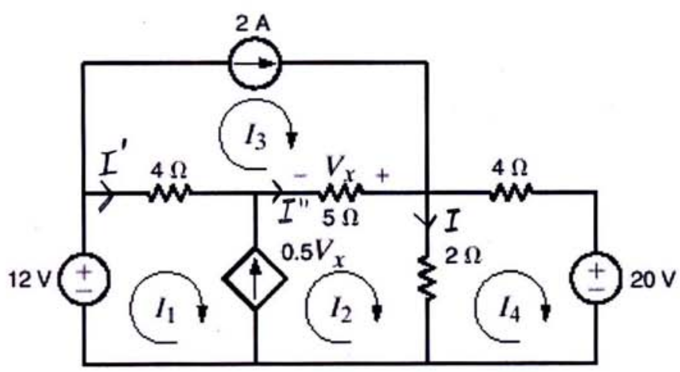


Figure P3.80

SOLUTION:



$$\text{KCL}: I_1 = I' + I_3$$
$$I' = I_1 - I_3$$
$$\text{KCL}: I + I_4 = I_2$$
$$I = I_2 - I_4$$
$$\text{KCL}: I'' + I_3 = I + I_4$$
$$I'' = -I_3 + I_4 + I_2 - I_4$$
$$I'' = I_2 - I_3$$

$$\text{KCL}: I_2 = 0.5V_x + I_1$$
$$-I_1 + I_2 - 0.5V_x = 0$$
$$V_x = -I''(5) = -5(I_2 - I_3)$$

$V_x = -5I_2 + 5I_3$

$-I_1 + I_2 - 0.5(-5I_2 + 5I_3) = 0$

$\boxed{-I_1 + 3.5I_2 - 2.5I_3 = 0}$

$I_3 = 2A$

KVL: $4I_4 + 20 + 2(-I) = 0$

$4I_4 - 2(I_2 - I_4) = -20$

$\boxed{-2I_2 + 16I_4 = -20}$

KVL: $12 = 4I' + 5I'' + 4I_4 + 20$

$4(I_1 - I_3) + 5(I_2 - I_3) + 4I_4 = -8$

$4I_1 + 5I_2 - 9I_3 + 4I_4 = -8$

$\boxed{4I_1 + 5I_2 + 4I_4 = 10}$

$-I_1 + 3.5I_2 - 2.5I_3 = 0$

$-2I_2 + 6I_4 = -20$

$4I_1 + 5I_2 + 4I_4 = 10$

$I_3 = 2A$

$-I_1 + 3.5I_2 = 5$

$-2I_2 + 6I_4 = -20$

$4I_1 + 5I_2 + 4I_4 = 10$

$I_1 = 2.46A$

$I_2 = 2.13A$

$I_4 = -2.62A$

3.81 Find V_o in the network in Fig. P3.81.

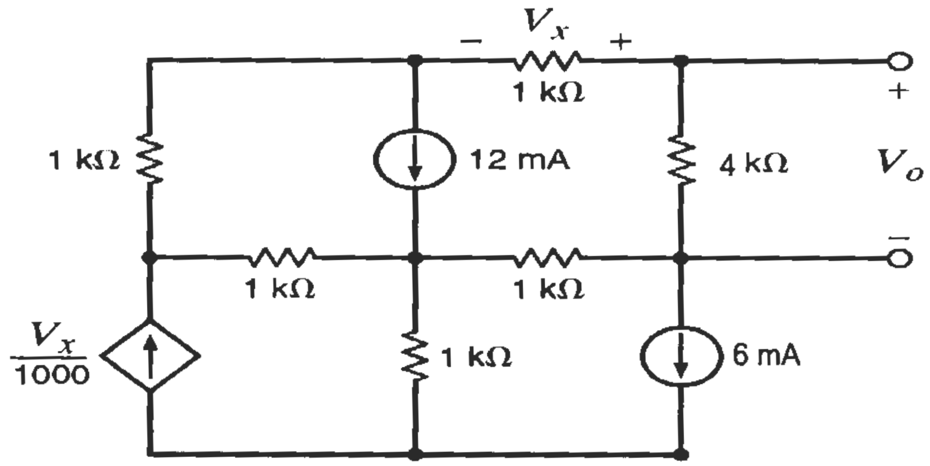
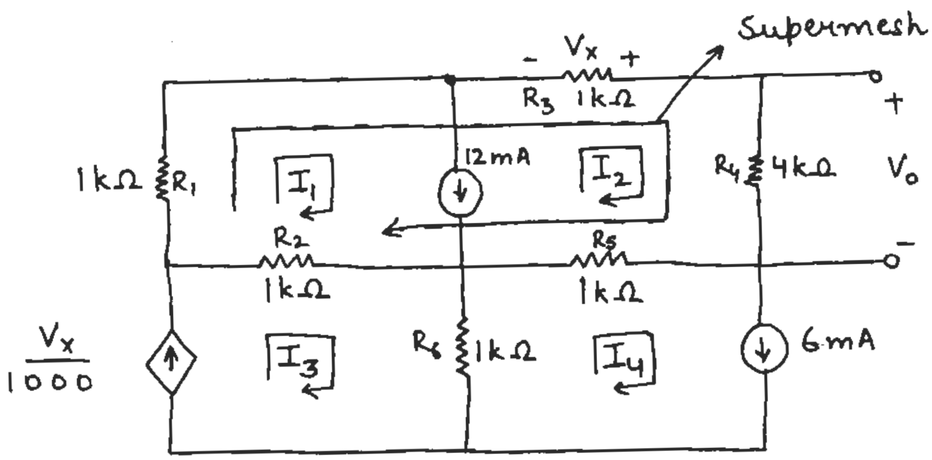


Figure P3.81

SOLUTION: 3.81



$R_1 = R_2 = R_3 = R_5 = R_6 = 1\,k\Omega, \; R_4 = 4\,k\Omega$

$I_1 - I_2 = 12\,mA$ ——— (1)

$I_4 = 6\,mA$

$V_x = -I_2 R_3$

$I_3 = \frac{V_x}{1000}$

$V_o = I_2 R_4$

KVL @ supermesh: $I_1 R_1 + I_2 R_3 + I_2 R_4 + (I_2 - I_4) R_5 + (I_1 - I_3) R_2 = 0$

$I_1 (R_1 + R_2) + I_2 (R_3 + R_4 + R_5) - I_3 R_2 - I_4 R_5 = 0$

$$2\times 10^3 I_1 + 6\times 10^3 I_2 - 10^3 I_3 - 10^3 I_4 = 0$$

$$2I_1 + 6I_2 - I_3 - I_4 = 0$$

Substituting $I_3 = \frac{V_x}{1000}$ and $V_x = -I_2 R_3$

$$2I_1 + 7I_2 = 6\times 10^{-3} \quad \text{—} \quad (2)$$

From equations (1) and (2), we get

$$I_2 = -2\,mA$$

$$V_0 = I_2 R_4$$

$$V_0 = -2\times 10^{-3} \times 4\times 10^3$$

$$\boxed{V_0 = -8.00\ V}$$

3.82 Using nodal analysis, find V_o in the circuit in Fig. P3.82.

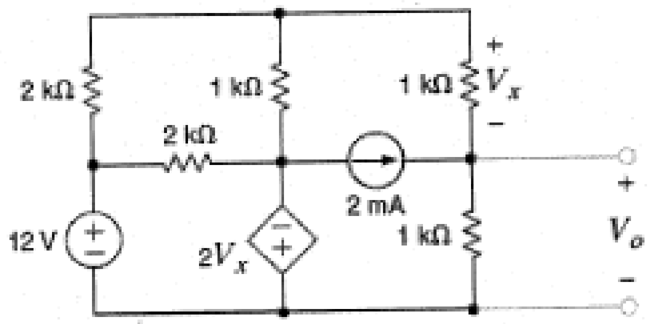
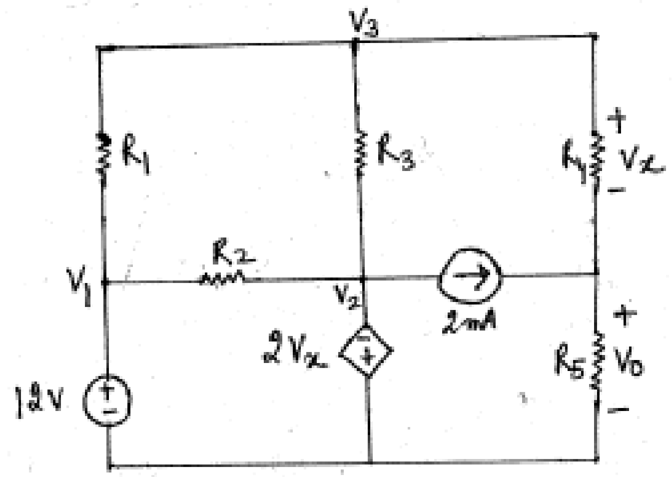


Figure P3.82

Solution : 3.82



$R_1 = R_2 = 2k\Omega$
$R_3 = R_4 = R_5 = 1k\Omega$

$V_x = V_3 - V_0$
$V_1 = 12V$
$V_2 = -2V_x$

at V_3 : $$\frac{V_3 - V_1}{R_1} + \frac{V_3 - V_2}{R_3} + \frac{V_3 - V_0}{R_4} = 0$$

at V_0 : $$\frac{V_3 - V_0}{R_4} + 2\times10^{-3} = \frac{V_0}{R_5}$$

Solve for V_0 : $\boxed{V_0 = 2.5V}$

3.83 Solve for the assigned mesh currents in the network in Fig. P3.83.

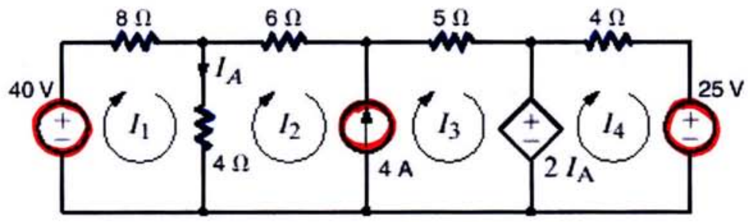
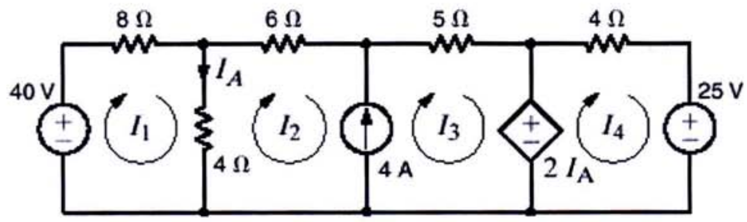


Figure P3.83

SOLUTION:



KCL: $I_1 = I_A + I_2$

$I_A = I_1 - I_2$

KVL: $8I_1 + 4I_A = 40$

$8I_1 + 4(I_1 - I_2) = 40$

$\boxed{12I_1 - 4I_2 = 40}$

KVL: $2I_A = 4I_4 + 25$

$2(I_1 - I_2) = 4I_4 + 25$

$\boxed{2I_1 - 2I_2 - 4I_4 = 25}$

KVL: $8I_1 + 6I_2 + 5I_3 + 4I_4 + 25 = 40$

$\boxed{8I_1 + 6I_2 + 5I_3 + 4I_4 = 15}$

KCL: $I_2 + 4 = I_3$

$\boxed{-I_2 + I_3 = 4}$

$$12I_1 - 4I_2 + 0I_3 + 0I_4 = 40$$
$$2I_1 - 2I_2 + 0I_3 - 4I_4 = 25$$
$$8I_1 + 6I_2 + 5I_3 + 4I_4 = 15$$
$$0I_1 - I_2 + I_3 + 0I_4 = 4$$

$$I_1 = 2.97A$$
$$I_2 = -1.08A$$
$$I_3 = 2.92A$$
$$I_4 = -4.22A$$

3.84 Using the assigned mesh currents shown in Fig. P3.84 solve for the power supplied by the dependent voltage source.

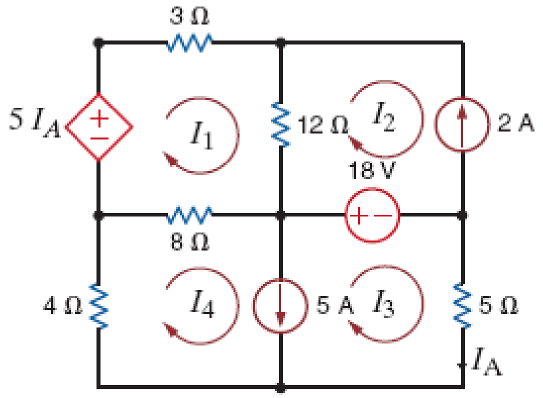
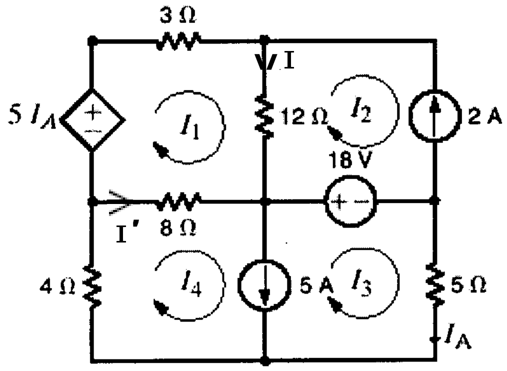


Figure P3.84

SOLUTION:



KCL: $I_1 = I + I_2$

$I = I_1 - I_2$

KCL: $I_4 = I' + I_1$

$I' = I_4 - I_1$

KVL: $3I_1 + 12I + 8(-I') = 5I_A$

$I_A = I_3$

$3I_1 + 12(I_1 - I_2) - 8(I_4 - I_1) = 5I_3$

$\boxed{23I_1 - 12I_2 - 5I_3 - 8I_4 = 0}$

KVL: $8I' + 5I_3 + 4I_4 + 18 = 0$

$8(I_4 - I_1) + 5I_3 + 4I_4 = -18$

$\boxed{-8I_1 + 5I_3 + 12I_4 = -18}$

KCL: $I_3 + 5 = I_4$

$I_2 = -2A$ $\boxed{I_3 - I_4 = -5}$

$\boxed{23I_1 - 5I_3 - 8I_4 = -24}$

$$23I_1 - 5I_3 - 8I_4 = -24$$
$$-8I_1 + 5I_3 + 12I_4 = -18$$
$$0I_1 + I_3 - I_4 = -5$$

$I_1 = -2.59A$

$I_3 = -5.8A$

$I_4 = -0.8A$

and $I_2 = -2A$

$\therefore P_{5IA} = (5 \times -5.8)(2.59) = 75W$

3.85 Determine V_0 in the network in the Fig. P3.85 using loop analysis.

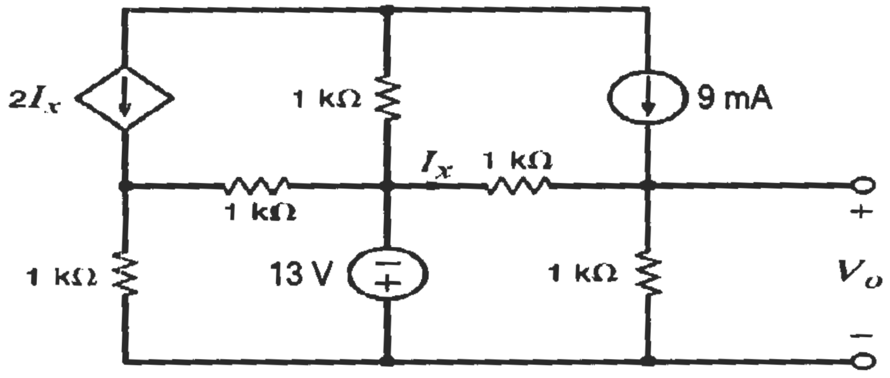
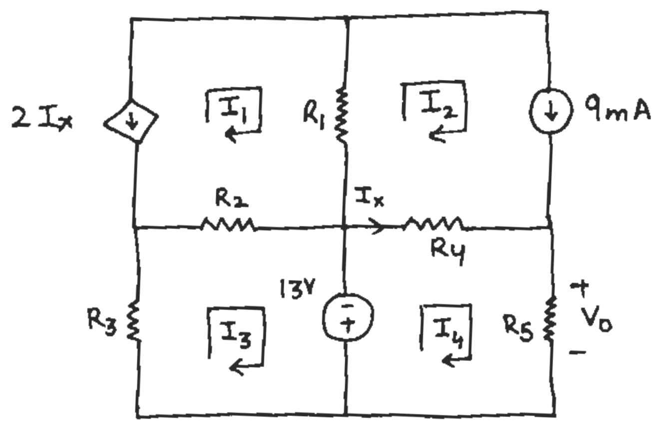


Figure P3.85

Solution: 3.85



$R_1 = R_2 = R_3 = R_4 = R_5 = 1\,k\Omega$

$I_2 = 9\,mA$

$I_x = (I_4 - I_2)$

$I_1 = -2I_x$

$= -2(I_4 - I_2)$

$V_0 = I_4 R_5$

KVL @ I_4: $13 + (I_4 - I_2)R_4 + I_4 R_5 = 0$

$13 + 10^3 I_4 - 10^3 I_2 + 10^3 I_4 = 0$

$I_4 = -2\times10^{-3}\,A$

$V_0 = I_4 R_5 = -2\times10^{-3} \times 1\times10^{3}$

$\boxed{V_0 = -2.00\,V}$

3.86 Using loop analysis, find V_o in the network in Fig. P3.86.

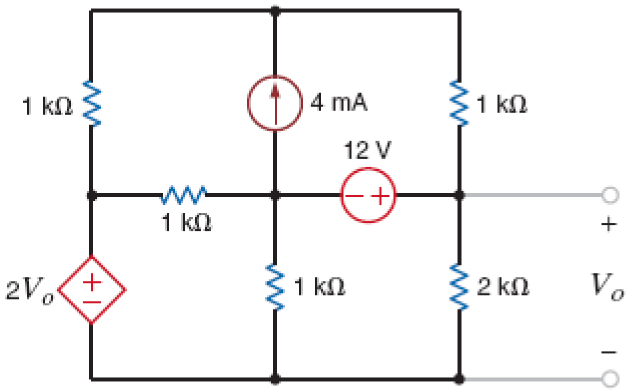
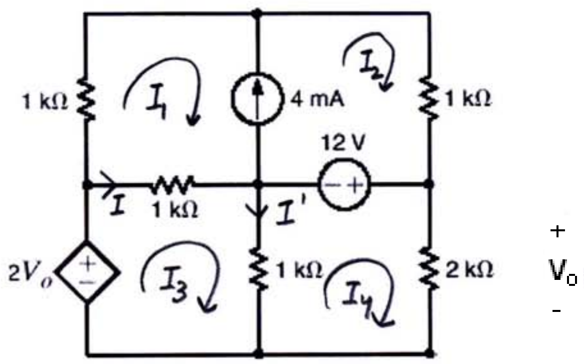


Figure P3.86

SOLUTION:



KCL: $I_1 + 4m = I_2$

$$\boxed{I_1 - I_2 = -4m}$$

KCL: $I_3 = I + I_1$

$I = I_3 - I_1$

KCL: $I' + I_4 = I_3$

$I' = I_3 - I_4$

KVL: $2kI_4 + 1k(-I') = 12$

$-1k(I_3 - I_4) + 2kI_4 = 12$

$$\boxed{-1kI_3 + 3kI_4 = 12}$$

KVL: $1k\,I + 1k\,I' = 2V_0$

$V_0 = 2k\,I_4$

$1k(I_3 - I_1) + 1k(I_3 - I_4) = 2(2k\,I_4)$

$$\boxed{-1k\,I_1 + 2k\,I_3 - 5k\,I_4 = 0}$$

KVL: $2V_0 = 1k\,I_1 + 1k\,I_2 + 2k\,I_4$

$V_0 = 2k\,I_4$

$$\boxed{1k\,I_1 + 1k\,I_2 - 2k\,I_4 = 0}$$

$I_1 - I_2 + 0I_3 + 0I_4 = -4m$

$0I_1 + 0I_2 - 1k\,I_3 + 3k\,I_4 = 12$

$-1k\,I_1 + 0I_2 + 2k\,I_3 - 5k\,I_4 = 0$

$1k\,I_1 + 1k\,I_2 + 0I_3 - 2k\,I_4 = 0$

In the matrix form the equations canbe represented/ restructed as:

$$\begin{bmatrix} 1 & -1 & 0 & 0 \\ 0 & 2 & 0 & -2 \\ 0 & 0 & 4 & -12 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} -4 \\ 4 \\ -4 \\ 44 \end{bmatrix}$$

$V_0 = \infty$

Since there are only 3 independent equations for 4 unknowns (I1 to I4), it can be not be solved for a unique solutions.

This is because current equations are contradictory.

$\therefore V_0 =$ not defined (open circuit).

3.87 Using loop analysis, find V_o in the circuit in Fig. P3.87.

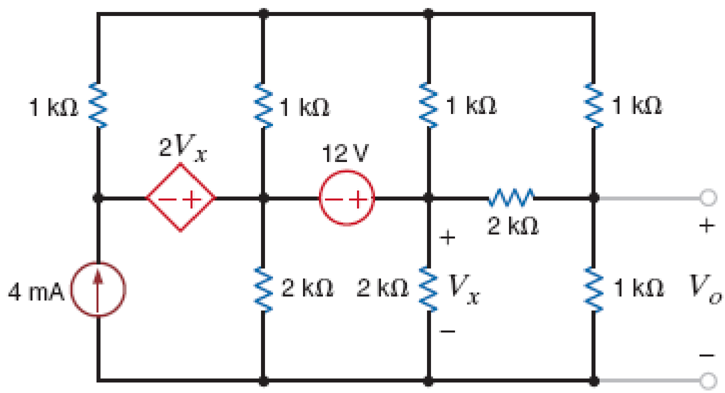
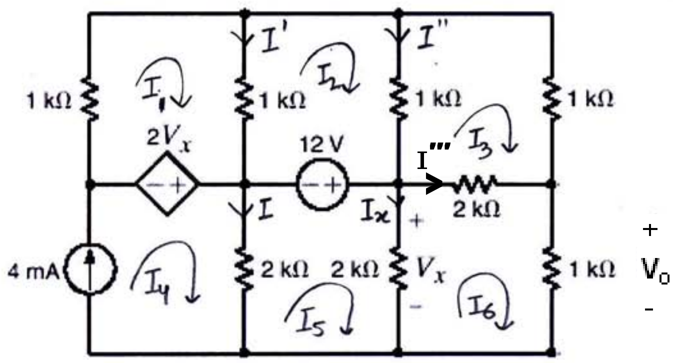


Figure P3.87

SOLUTION:



KCL: $I_1 = I' + I_2$

$I' = I_1 - I_2$

KCL: $I_2 = I'' + I_3$

$I'' = I_2 - I_3$

KCL: $I + I_5 = I_4$

$I = I_4 - I_5$

KCL: $I_x + I_6 = I_5$

$I_x = I_5 - I_6$

KCL: $I_3 + I''' = I_6$

$I''' = I_6 - I_3$

KVL: $2V_x + 1kI_1 + 1kI' = 0$

$$V_x = I_x(2k) = (I_5 - I_6)2k$$

$$2(2k)(I_5 - I_6) + 1kI_1 + 1k(I_1 - I_2) = 0$$

$$4kI_5 - 4kI_6 + 2kI_1 - 1kI_2 = 0$$

$$\boxed{2kI_1 - 1kI_2 + 4kI_5 - 4kI_6 = 0}$$

KVL: $12 + 1k(-I') + 1kI'' = 0$

$$-1k(I_1 - I_2) + 1k(I_2 - I_3) = -12$$

$$-1kI_1 + 2kI_2 - 1kI_3 = -12$$

KVL: $1k(-I'') + 1kI_3 + 2k(-I''') = 0$

$$-1k(I_2 - I_3) + 1kI_3 - 2k(I_6 - I_3) = 0$$

$$\boxed{-1kI_2 + 4kI_3 - 2kI_6 = 0}$$

KVL: $12 = 2k(-I) + 2kI_x$

$$-2k(I_4 - I_5) + 2k(I_5 - I_6) = 12$$

$I_4 = 4mA$

$$\boxed{4kI_5 - 2kI_6 = 20}$$

KVL: $2kI''' + 1kI_6 + 2k(-I_x) = 0$

$$2k(I_6 - I_3) + 1kI_6 - 2k(I_5 - I_6) = 0$$

$$\boxed{-2kI_3 - 2kI_5 + 5kI_6 = 0}$$

$$2kI_1 - 1kI_2 + 0I_3 + 4kI_5 - 4kI_6 = 0$$

$$-1kI_1 + 2kI_2 - 1kI_3 + 0I_5 + 0I_6 = -12$$

$$0I_1 - 1kI_2 + 4kI_3 + 0I_5 - 2kI_6 = 0$$

$$0I_1 + 0I_2 + 0I_3 + 4kI_5 - 2kI_6 = 20$$

$$0I_1 + 0I_2 - 2kI_3 - 2kI_5 + 5kI_6 = 0$$

$I_1 = -18mA$

$I_2 = -17mA$

$I_3 = -4mA$

$I_5 = 5.25mA$

$I_6 = 0.5mA$

$V_0 = 1k(I_6) = 1k(0.5m)$

$V_0 = 0.5V$

3.88 Use loop analysis to determine I_0 in the circuit in the Fig. P3.88.

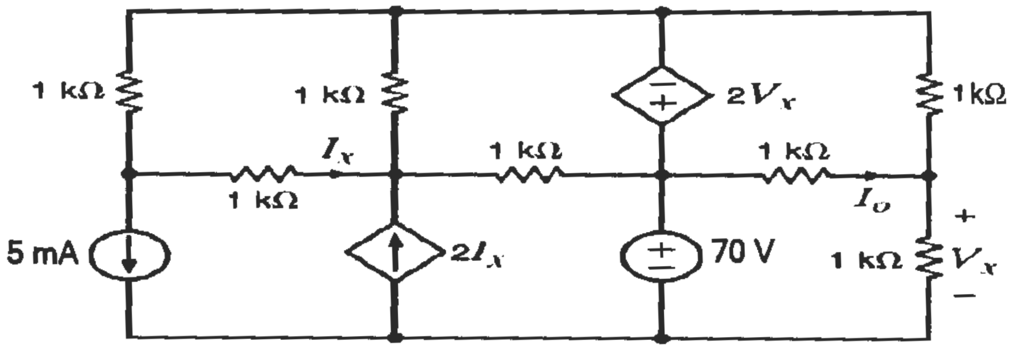
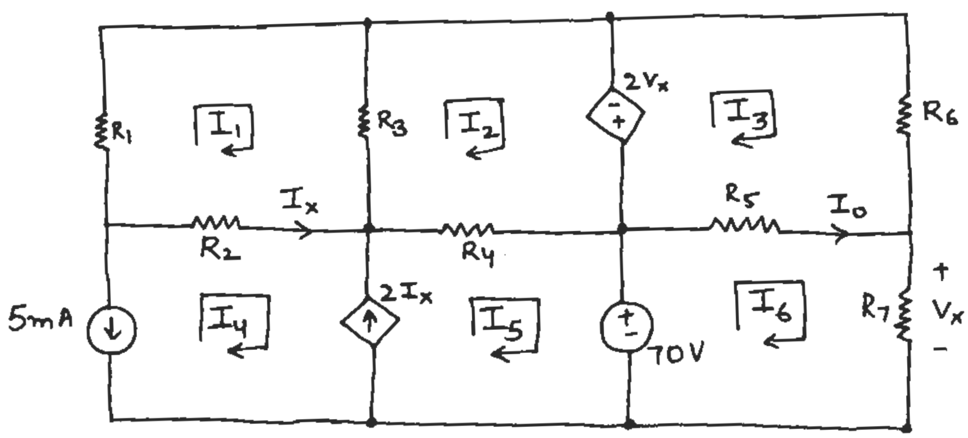


Figure P3.88

Solution: 3.88



$$R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = R_7 = 1\,k\Omega$$

$$I_4 = 5mA$$

$$2I_x = I_5 - I_4$$

$$I_x = I_4 - I_1$$

$$I_0 = I_6 - I_3$$

$$V_x = I_6 R_7$$

KVL @ I_1: $I_1R_1 + (I_1 - I_2)R_3 + (I_1 - I_4)R_2 = 0$

$$3I_1 - I_2 = 5\times10^{-3}$$

KVL @ I_2: $(I_2 - I_1)R_3 - 2V_x + (I_2 - I_5)R_4 = 0$

$$-I_1 + 2I_2 - I_5 - 2I_6 = 0$$

KVL @ I_3: $2V_x + I_3 R_6 + (I_3 - I_6)R_5 = 0$

$$2I_3 + I_6 = 0 \quad \text{——} \quad (1)$$

KVL @ I_6: $-70 + (I_6 - I_3)R_5 + I_6 R_7 = 0$

$$-I_3 + 2I_6 = 70 \times 10^{-3} \quad \text{——} \quad (2)$$

From equations (1) and (2), we get

$$I_6 = 28 \text{ mA}$$

Substituting the value of I_6 in (1), we get

$$2I_3 = -28 \times 10^{-3}$$

$$I_3 = -14 \text{ mA}$$

$$I_0 = I_6 - I_3$$

$$\boxed{I_0 = 42.0 \text{ mA}}$$

3.89 Using loop analysis, find I_o in the circuit in Fig. P3.89.

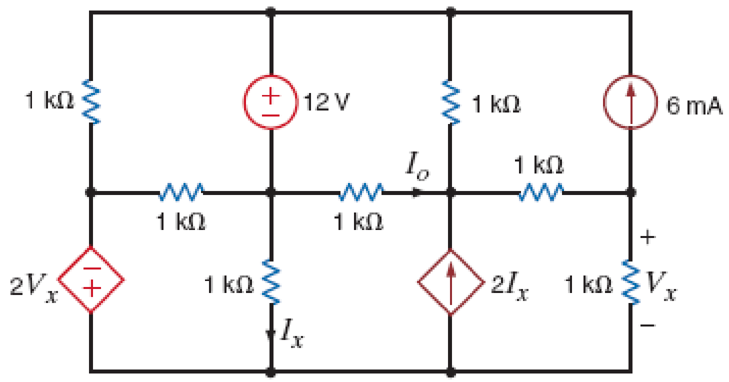
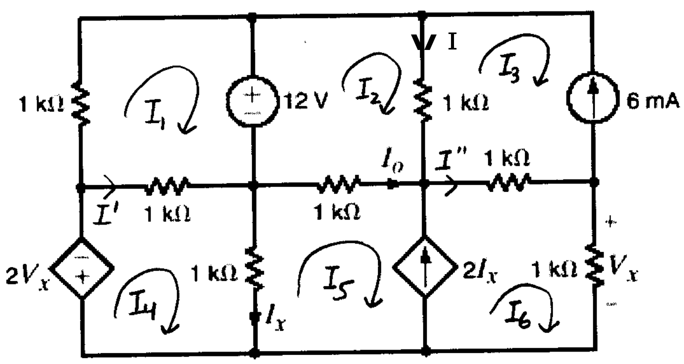


Figure P3.89

SOLUTION:



KCL: $I_2 = I + I_3$

$I = I_2 - I_3$

KCL: $I_4 = I' + I_1$

$I' = I_4 - I_1$

KCL: $I_3 + I'' = I_6$

$I'' = I_6 - I_3$

KCL: $I_5 + I_x = I_4$

$I_x = I_4 - I_5$

KCL: $I_0 + I + 2I_x = I''$

$I_0 = I'' - I - 2I_x = I_6 - I_3 - I_2 + I_3 - 2I_x$

$I_0 = I_6 - I_2 - 2(I_4 - I_5)$

$I_0 = -I_2 - 2I_4 + 2I_5 + I_6$

KVL: $1k\,I_1 + 12 + 1k(-I') = 0$

$1k\,I_1 - 1k\,(I_4 - I_1) = -12$

$\boxed{2k\,I_1 - 1k\,I_4 = -12}$

KVL: $1k\,I + 1k(-I_0) = 12$

$1k(I_2 - I_3) - 1k(-I_2 - 2I_4 + 2I_5 + I_6) = 12$

$\boxed{2k\,I_2 - 1k\,I_3 + 2k\,I_4 - 2k\,I_5 - 1k\,I_6 = 12}$

KVL: $2V_x + 1k\,I' + 1k\,I_x = 0$

$V_x = 1k\,I_6$

$2(1k\,I_6) + 1k(I_4 - I_1) + 1k(I_4 - I_5) = 0$

$\boxed{-1k\,I_1 + 2k\,I_4 - 1k\,I_5 + 2k\,I_6 = 0}$

KCL: $I_6 = 2I_x + I_5$

$I_5 - I_6 + 2(I_4 - I_5) = 0$

$\boxed{2I_4 - I_5 - I_6 = 0}$

KVL: $2V_x + 1k\,I' + 1k\,I_0 + 1k\,I'' + 1k\,I_6 = 0$

$2(1k\,I_6) + 1k(I_4 - I_1) + 1k(-I_2 - 2I_4 + 2I_5 + I_6) + 1k(I_6 - I_3) + 1k\,I_6$

$\boxed{-1k\,I_1 - 1k\,I_2 - 1k\,I_3 - 1k\,I_4 + 2k\,I_5 + 5k\,I_6 = 0}$

$I_3 = -6\,mA$

$\boxed{2k\,I_2 + 2k\,I_4 - 2k\,I_5 - 1k\,I_6 = 6}$

$\boxed{-1k\,I_1 - 1k\,I_2 - 1k\,I_4 + 2k\,I_5 + 5k\,I_6 = -6}$

$$2kI_1 + 0I_2 - 1kI_4 + 0I_5 + 0I_6 = -12$$
$$0I_1 + 2kI_2 + 2kI_4 - 2kI_5 - 1kI_6 = 6$$
$$-1kI_1 + 0I_2 + 2kI_4 - 1kI_5 + 2kI_6 = 0$$
$$0I_1 + 0I_2 + 2I_4 - I_5 - I_6 = 0$$
$$-1kI_1 - 1kI_2 - 1kI_4 + 2kI_5 + 5kI_6 = -6$$

$$I_1 = -6.48mA$$
$$I_2 = 3.12mA$$
$$I_4 = -0.96mA$$
$$I_5 = 0.24mA$$
$$I_6 = -2.16mA$$
$$I_0 = -I_2 - 2I_4 + 2I_5 + I_6$$
$$I_0 = -3.12m - 2(-0.96m) + 2(0.24m) - 2.16m$$
$$I_0 = -2.88mA$$

3.90 Use mesh analysis to determine the power delivered by the independent 3-V source in the network in Fig. P3.90.

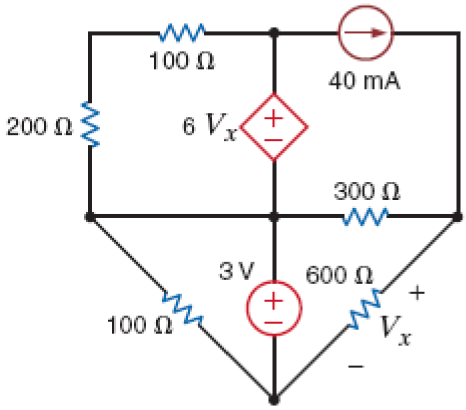
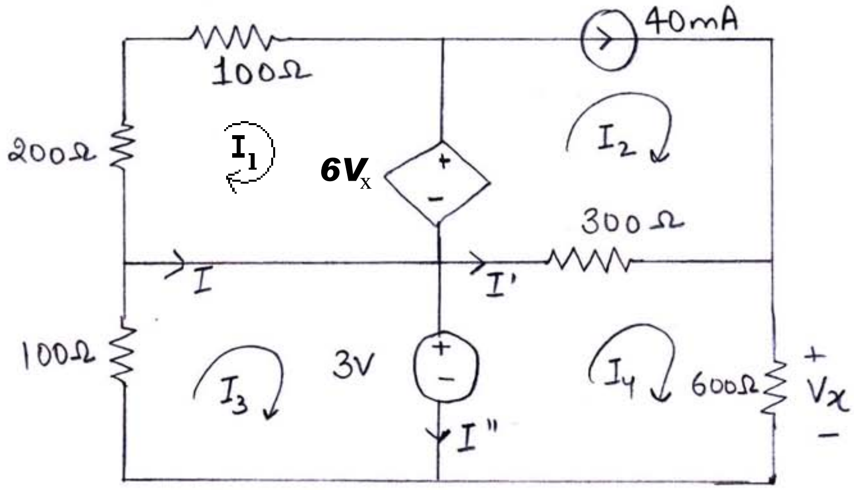


Figure P3.90

SOLUTION:



$I_2 = 40mA$

KCL: $I_3 = I + I_1$

$I = I_3 - I_1$

KCL: $40m + I' = I_4$

$I' = I_4 - 40m$

KVL: $200 I_1 + 100 I_1 + 6V_x = 0$

$V_x = 600 I_4$

$300 I_1 + 3600 I_4 = 0$

KVL: $100 I_3 + 3 = 0$

$I_3 = -30\,mA$

KVL: $3 = 300I' + 600I_4$

$600I_4 + 300(I_4 - 40m) = 3$

$900I_4 = 15$

$I_4 = 16.67\,mA$

KCL: $I_4 + I'' = I_3$

$I'' = I_3 - I_4$

$P_{3V} = I''(3) = 3(I_3 - I_4)$

$P_{3V} = 3(-30m - 16.67\,m)$

$P_{3V} = -140.01\,mW$

$P_{3V} = 140.01\,mW$

3.91 Use mesh analysis to find the power delivered by the current-controlled voltage source in the circuit in Fig. P3.91.

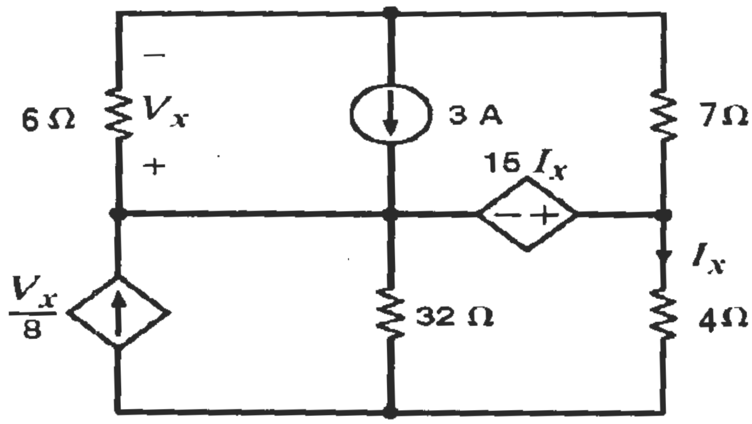
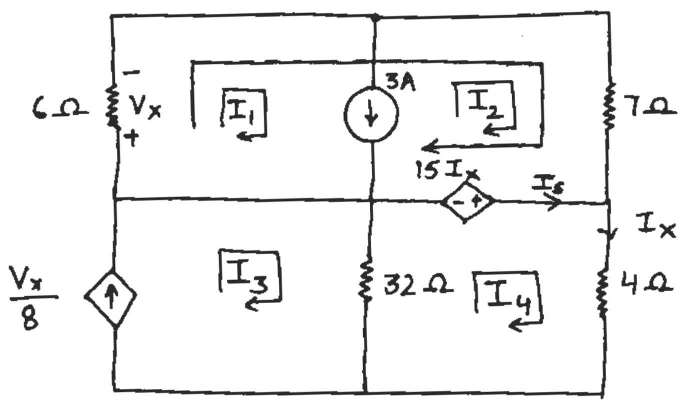


Figure P3.91

Solution: 3.91



$I_1 - I_2 = 3$ — (1)

$V_x = 6 I_1$

$I_s = I_4 - I_2$

$I_x = I_4$

$I_3 = \frac{V_x}{8} = \frac{3}{4} I_1$

KVL @ I_4 : $32(I_4 - I_3) - 15 I_x + 4 I_4 = 0$

$21 I_4 - 32 I_3 = 0$

$I_4 = 1.52 \ I_3$

KVL @ supermesh : $6I_1 + 7I_2 + 15I_x = 0$

$$23.18\, I_1 + 7 I_2 = 0 \quad \text{——} \quad (2)$$

From equations (1) and (2), we get

$$I_1 = 0.696 \text{ A}$$

$$I_3 = \frac{3}{4} I_1 = 0.522 \text{ A}$$

$$I_4 = 1.52\, I_3 = 0.793 \text{ A}$$

$$I_S = I_4 - I_2 = 3.09 \text{ A}$$

$$P_{CCVS} = (15 I_x)\, I_S$$

$$\boxed{P_{CCVS} = 37.0 \text{ W}}$$

3.92 Use nodal analysis to determine I_0 in the circuit in Fig. P3.92.

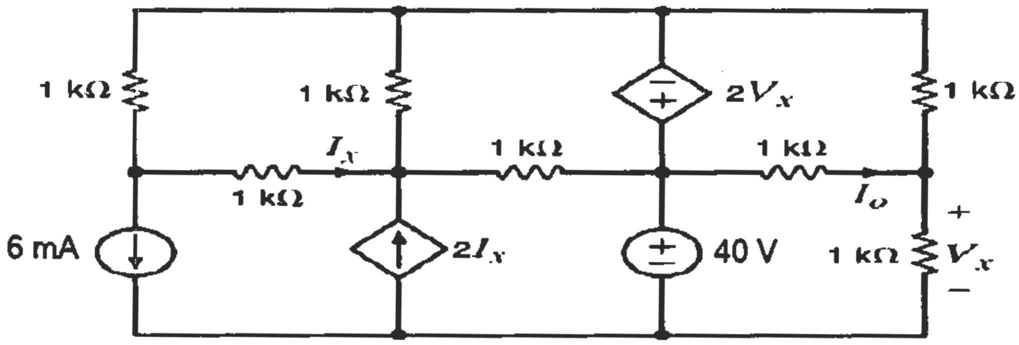
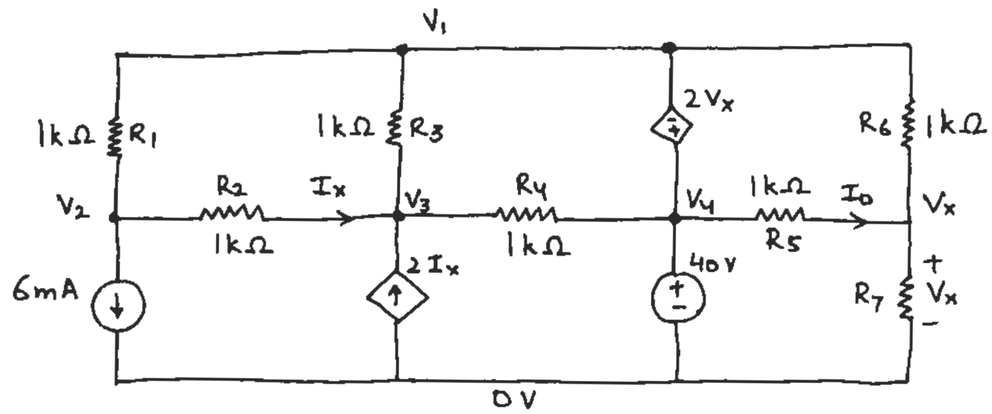


Figure P3.92

Solution: 3.92



$R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = R_7 = 1\,k\Omega$

$V_4 = 40\ V$

$V_4 - V_1 = 2V_x \quad \text{——} \quad (1)$

$$\frac{V_2 - V_3}{R_2} = I_x$$

$$I_0 = \frac{V_4 - V_x}{R_5}$$

$$\text{KCL @ } V_2 : \frac{V_2 - V_1}{R_1} + \frac{V_2 - V_3}{R_2} + 6\times 10^{-3} = 0$$

$$-V_1 + 2V_2 - V_3 = -6$$

KCL @ V_3 : $\frac{V_3 - V_2}{R_2} - 2 I_x + \frac{V_3 - V_1}{R_3} + \frac{V_3 - V_4}{R_4} = 0$

$-V_1 - 3V_2 + 5V_3 = 40$ (Using $V_4 = 40\,V$)

KCL @ V_x : $\frac{V_x - V_4}{R_5} + \frac{V_x - V_1}{R_6} + \frac{V_x}{R_7} = 0$

$3V_x - V_4 - V_1 = 0$ — (2)

Substituting equation (1) in (2), we get

$3\left(\frac{V_4 - V_1}{2}\right) - V_4 - V_1 = 0$

$-\frac{5}{2} V_1 + \frac{1}{2} V_4 = 0$

$-5V_1 + 40 = 0$ (Using $V_4 = 40\,V$)

$V_1 = 8\,V$

$V_x = \frac{V_4 - V_1}{2} = \frac{40 - 8}{2}$

$V_x = 16\,V$

$I_0 = \frac{V_4 - V_x}{R_5}$

$= \frac{40 - 16}{1 \times 10^3}$

$\boxed{I_0 = 24.0\ mA}$

3.93 Use nodal analysis to find V_o in the circuit in Fig. P3.93.

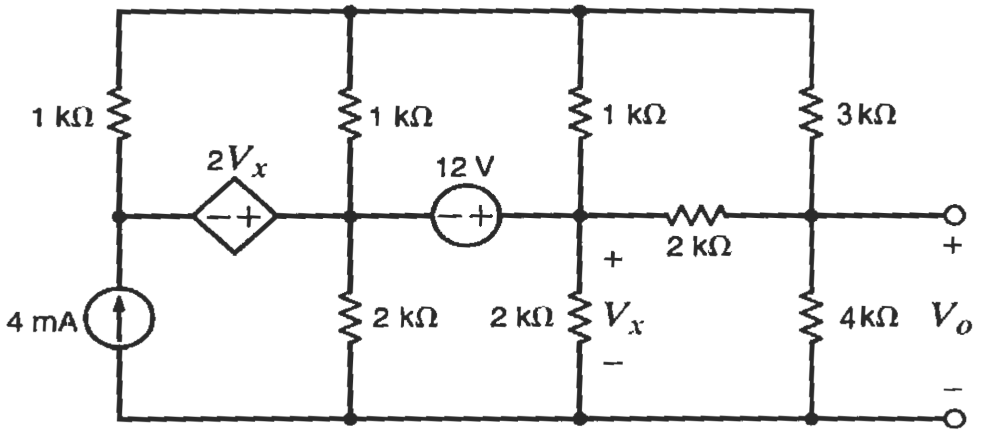
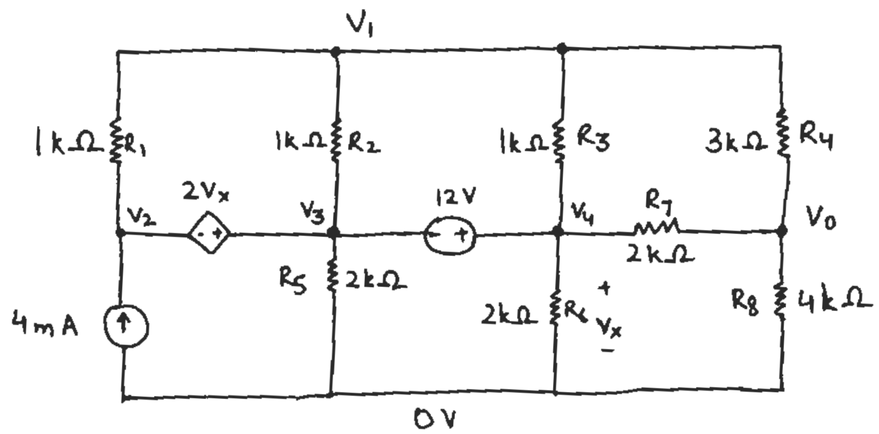


Figure P3.93

SOLUTION: 3·93



$R_1 = R_2 = R_3 = 1\,k\Omega,\ R_4 = 3\,k\Omega,\ R_5 = R_6 = R_7 = 2\,k\Omega,\ R_8 = 4\,k\Omega$

$V_3 - V_2 = 2V_x$ —— ①

$V_4 - V_3 = 12\,V$ —— ②

$V_x = V_4$ —— ③

KCL @ V_1 : $\dfrac{V_1 - V_2}{R_1} + \dfrac{V_1 - V_3}{R_2} + \dfrac{V_1 - V_4}{R_3} + \dfrac{V_1 - V_0}{R_4} = 0$

$-3V_4 - 3V_3 - 3V_2 + 10V_1 - V_0 = 0$ —— ④

KCL @ reference : $\dfrac{V_3}{R_5} + \dfrac{V_4}{R_6} + \dfrac{V_0}{R_8} = 4 \times 10^{-3}$

$4V_3 + V_0 = -8$ —— ⑤

KCL at V_0 : $\frac{V_0 - V_1}{3\times10^3} + \frac{V_0 - V_4}{2\times10^3} + \frac{V_0}{4\times10^3} = 0$

$V_1 = \frac{13V_0 - 6V_4}{4}$ ——— ⑥

Substituting equations ①, ②, ③ and ⑥ in ④, we get

$-3V_4 - 3V_3 - 3V_2 + 10 \cdot \frac{13V_0 - 6V_4}{4} - V_0 = 0$

$-18(12 + V_3) - 3V_3 - 3(V_3 - 2(12 + V_3)) + \frac{63}{2}V_0 = 0$

$-4V_3 + 7V_0 = 32$ ——— ⑦

From equations ⑤ and ⑦ we get

$\boxed{V_0 = 3.00\text{ V}}$

3.94 Find I_o in the network in Fig. P3.94 using nodal analysis.

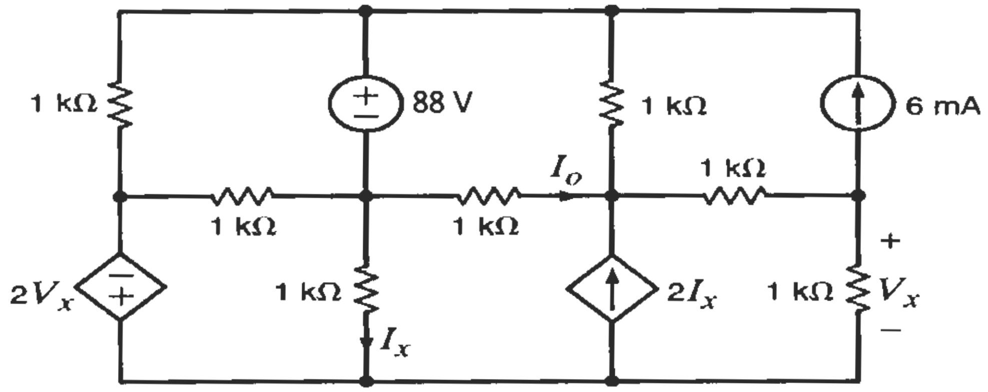
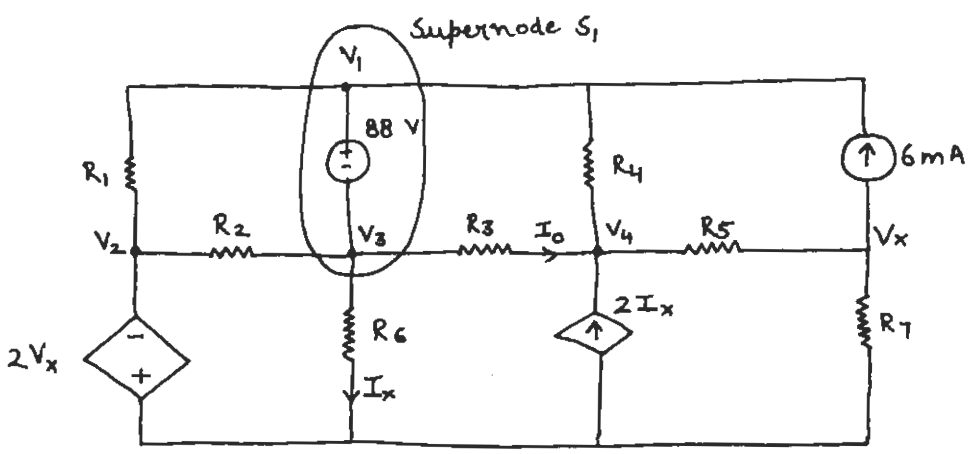


Figure P3.94

SOLUTION: 3.94



$R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = R_7 = 1\,k\Omega$

$$I_x = \frac{V_3}{R_6} \qquad \text{— (1)}$$

$$V_1 - V_3 = 88\text{ V} \qquad \text{— (2)}$$

$$V_2 = -2V_x \implies V_x = -\frac{V_2}{2}$$

$$\text{KCL @ } S_1: \quad \frac{V_1 - V_2}{R_1} + \frac{V_1 - V_4}{R_4} - 6\times10^{-3} + \frac{V_3 - V_2}{R_2} + \frac{V_3}{R_6} + \frac{V_3 - V_4}{R_3} = 0$$

$$2V_1 - 2V_2 + 3V_3 - 2V_4 = 6 \qquad \text{— (3)}$$

$$\text{KCL @ } V_4: \quad \frac{V_4 - V_3}{R_3} - 2I_x + \frac{V_4 - V_x}{R_5} + \frac{V_4 - V_1}{R_4} = 0$$

$$-2V_1 + V_2 - 6V_3 + 6V_4 = 0 \quad \text{—} \quad (4)$$

KCL @ V_x : $\dfrac{V_x - V_4}{R_5} + \dfrac{V_x}{R_7} + 6\times10^{-3} = 0$

$$V_2 + V_4 = 6 \quad \text{—} \quad (5)$$

Substituting equations (2) and (5) in (3), we get

$$2V_1 - 2V_2 + 3V_3 - 2V_4 = 6$$

$$V_3 = -31.6 \text{ V}$$

Substituting equations (2) and (5) in (4), we get

$$-2V_1 + V_2 - 6V_3 + 6V_4 = 0$$

$$V_4 = -16.56$$

$$I_0 = \frac{V_3 - V_4}{R_3}$$

$$= \frac{-31.6 + 16.56}{10^3}$$

$$\boxed{I_0 = -15.04 \text{ mA}}$$