3.12

The KVL loop encircles the entire circuit, and the KVL current is denoted i; its direction is counter-clockwise. We have

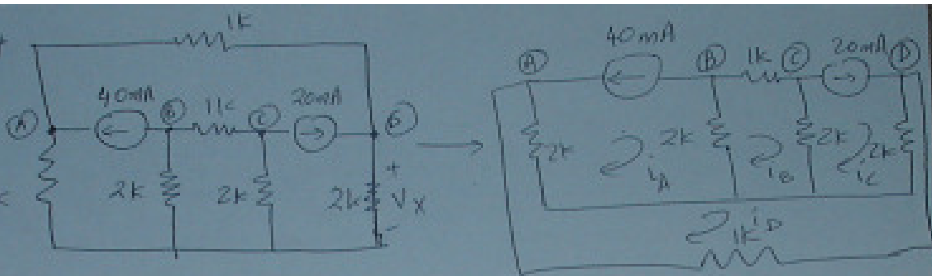
$$(R_1 + R_2 + R_3 + R_4 + R_5)\, i = -v_s + i_s(R_3 + R_4 + R_5).$$

As a result, $i = 25$ mA, which is the current passing through R_1 and R_2; hence, $i_x = 25$ mA. It follows that $v_x = -(i - i_s)R_4 = 18.75$ V. The power dissipated is given by

$$i^2(R_1 + R_2) + iv_s + (i_s - i)^2(R_3 + R_4 + R_5) = 3.75 \text{ W}.$$

Note that the voltage source is absorbing power, so we add it in considering the power dissipated.

3.14



$i_A = -40mA$ $\qquad$ $V_x = 2k(i_c - i_D)$

$i_c = 20mA$

loop B: $1k\, i_B + 2k(i_B - i_c) + 2k(i_B - i_A) = 0$

$5k\, i_B - 2k i_c - 2k i_A = 0$

$5k\, i_B - 2k(20mA) = 2k(-40mA)$

$5k\, i_B - 40 + 80 = 0$

$5k\, i_B = -40$

$i_B = -8mA$

loop D: $2k(i_D - i_A) + 2k(i_D - i_c) + 1k\, i_D = 0$

$5k i_D - 2k i_A - 2k i_c = 0$

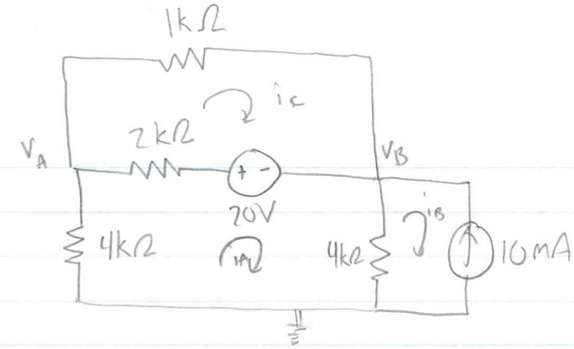
$5k i_D + 80 - 40 = 0$

$i_D = -8mA$

$V_x = 2k(20+8)$

$\boxed{V_x = 2k(28) = 56V}$

3.19



i_A

$$-20 - 4k(i_A + 10mA) - 4k\, i_A - 2k(i_A - i_c) = 0$$

i_B: $i_B = -10mA$

$$-1k(i_c) + 20V - 2k(i_c - i_A) = 0$$

$$\left[\begin{array}{cc|c} -10{,}000 & 2000 & 60 \\ 2000 & -3000 & -20 \end{array}\right]$$

$$\boxed{\begin{array}{l} i_A = -5.385mA \\ i_c = 3.077mA \end{array}}$$

$$20 - 2(3.077 + 5.385) - 4(5.385) - 4(5.385 - 10) = 0 \quad \checkmark$$

$$\frac{V_B - 0}{4} = 10 - 5.385 \Rightarrow \boxed{V_B = 18.46V}$$

$$\frac{V_A - V_B}{1k} = 3.077 \Rightarrow \boxed{V_A = 21.54V}$$

3.20

The mesh equations are given by the following matrix equation:

$$\begin{bmatrix} 14k & -10k & 0 & 0 \\ -10k & 13k & -2k & 0 \\ 0 & -2k & 16k & -6k \\ 0 & 0 & -6k & 6k \end{bmatrix} \begin{bmatrix} i_A \\ i_B \\ i_C \\ i_D \end{bmatrix} = \begin{bmatrix} -10V \\ 0 \\ 0 \\ 15V \end{bmatrix}.$$

Solving this equation, we have $i_A = -1.26$ mA, $i_B = -.76$ mA, $i_C = 1.35$ mA, and $i_D = 3.85$ mA.

Define the top middle and right middle nodes as node a and node b respectively. The matrix describing the nodal voltages is

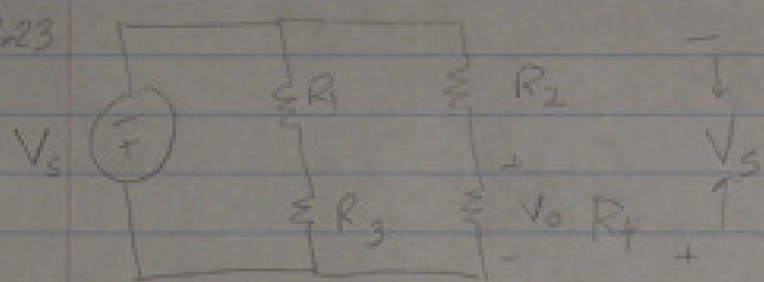
$$\begin{bmatrix} \frac{1}{4k} + \frac{1}{10k} + \frac{1}{1k} & -\frac{1}{1k} \\ -\frac{1}{1k} & \frac{1}{1k} + \frac{1}{2k} + \frac{1}{8k} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \end{bmatrix} \begin{bmatrix} \frac{5}{4k} + \frac{15}{10k} \\ \frac{15}{2k} \end{bmatrix}.$$

We have that $v_A = 10.03$ V and $v_B = 10.79$ V. It is then possible to verify the mesh currents through repeated application of Ohm's law, e.g.

$$i_A = \frac{5 - v_a}{4k} = -1.26 \text{ mA},$$
$$i_B = \frac{v_A - v_B}{1k} = -.76 \text{ mA},$$

and so forth.

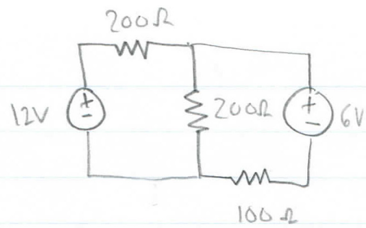
3.23

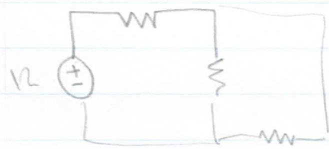


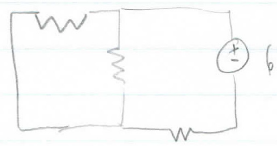
$$V_o = \frac{R_4}{R_4 + R_2}(-V_s)$$ Using voltage divider

$$\boxed{\frac{V_o}{V_s} = \frac{-R_4}{R_2 + R_4}}$$

3.26







$$V_x = 12\left(\frac{200\|100}{200\|100 + 200}\right) \qquad V_x = 6\left(\frac{200\|200}{200\|200 + 100}\right) = 3V$$

$V_x = 3V$

$$\boxed{V_x = 3 + 3 = 6V}$$

Check: $12V - i_A(200) - (i_A + i_B)\,200 = 0$

$6V - (i_A + i_B)\,200 - 100\,i_B = 6$

$$\left.\begin{matrix} 400 & 200 \\ 200 & 300 \end{matrix}\,\right|\,\begin{matrix} 12 \\ 6 \end{matrix} \qquad \begin{matrix} i_A = .03 \\ i_B = 0 \end{matrix}$$

$V_x = 6V$

3.32

Consider, for instance, two ideal voltage sources in series with one another and with the load resistance. We have, for the first voltage source,

$$P = .25 \text{ W} = \frac{v_{s1}^2}{100} \Rightarrow v_{s1} = 5 \text{ V},$$

and for the second,

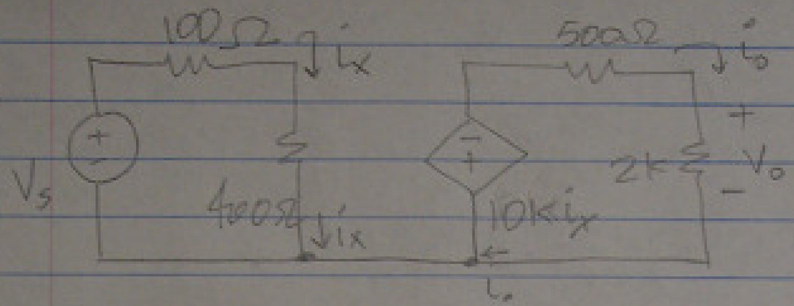
$$P = 4 \text{ W} = \frac{v_{s2}^2}{100} \Rightarrow v_{s2} = 20 \text{ V}.$$

The total power is

$$\frac{(v_{s1} + v_{s2})^2}{100} = 6.25W.$$

Clearly, since power is not linearly related to the i-v characteristics of a circuit, and superposition applies to the i-v characteristics because they are linearly related to one another, superposition does not apply to power computations.

f.1



$$i_x = \frac{V_s}{500}$$

$$i_o = \frac{-10k\, i_x}{2.5k} \quad -(1)$$

Using voltage division

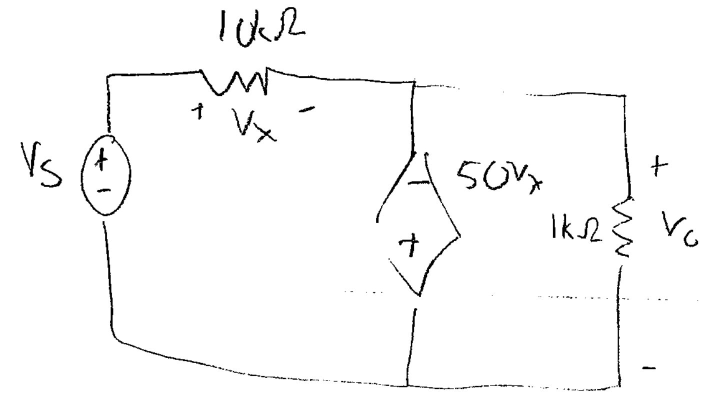
$$V_o = \frac{2k}{2.5k}(-10k\, i_x)$$

$$V_o = -\frac{2k}{2.5k}(10k)\frac{(V_s)}{.5k} \quad -(2)$$

from (i) $$\boxed{\frac{V_o}{V_s} = \frac{-20}{1.25} = -16}$$

from (ii) $$\boxed{\frac{i_o}{i_x} = \frac{-10k}{2.5k} = -4}$$

4.5



$$V_S - V_x - V_o = 0 \qquad -50 v_x = V_o$$

$$V_S - \left(\frac{-V_o}{50}\right) - V_o = 0$$

$$V_S = \frac{50 V_o}{50} - \frac{V_o}{50} = \frac{49 V_o}{50}$$

$$\cancel{\frac{V_S}{V_o} = \frac{49}{50}} \qquad \frac{V_o}{V_S} = \frac{50}{49}$$

4.11

Note that the answer in the book is incorrect. The equivalent resistance listed in the back of the book is R_P, which is an undefined variable.

Consider an arbitrary load resistance connected between the terminals. The voltage drop across the terminals is ri_s, where i_s is given by

$$\begin{aligned} i_s &= \frac{v_s - ri_s}{R_s} \\ i_s(r + R_s) &= v_s \\ i_s &= \frac{v_s}{r + R_s}. \end{aligned}$$

Note that this expression holds no matter the load resistance; hence, the only possible choice for R_{eq} is $R_{eq} = 0$ and v_{Th} is given by

$$v_{Th} = ri_s = \frac{rv_s}{r + R_s}.$$