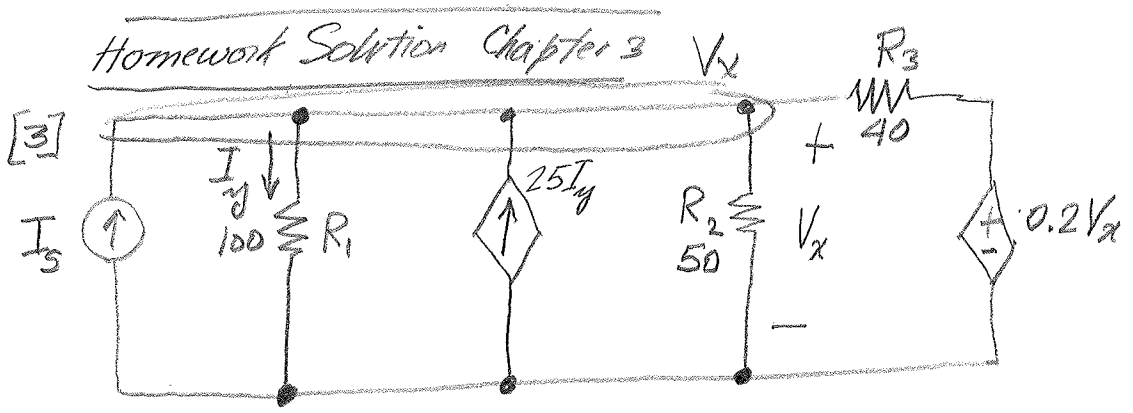
Homework Solution Chapter 3

[3]



$I_s = 1.2A$

$G_1 = 10m$

$G_2 = 20m$

$G_3 = 25m$

Nodal analysis at Node V_x

$$-I_s + I_y - 25I_y + V_x G_2 + (V_x - 0.2V_x) G_3 = 0$$

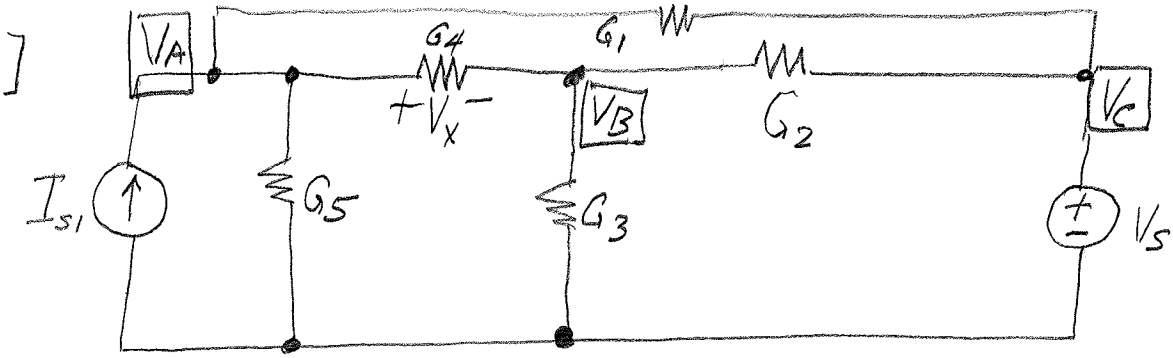
Substitute $I_y = V_x \cdot G_1$

and collect like Terms

$$V_x (G_1 - 25G_1 + G_2 + 0.8 G_3) = I_s$$

$$V_x = \frac{1.2A}{-24(10e{-}3) + 20e{-}3 + 0.8(25e{-}3)} = -6V$$

[6]



$I_{S2} = 8m$
$V_{S2} = 40$
$R_1 = 5K \rightarrow G_1 = 200e\text{-}6$
$R_2 = R_3 = R_4 = 20k$
$\rightarrow G_2 = G_3 = G_4 = 50e\text{-}6$
$R_5 = 10k \rightarrow G_5 = 100e\text{-}6$

Nodal analysis ~~at~~ nodes V_A and V_B.
Not necessary at node V_C because of the power supply V_{S2}.

① @ V_A: $-I_{S1} + V_A G_5 + (V_A - V_B) G_4 + (V_A - V_{S2}) G_1 = 0$

② @ V_B: $(V_B - V_A) G_4 + V_B G_3 + (V_B - V_{S2}) G_2 = 0$

① $V_A(G_5 + G_4 + G_1) - V_B G_4 = I_{S1} + G_1 V_{S2}$

② $V_A(-G_4) + V_B(G_4 + G_3 + G_2) = G_2 V_{S2}$

Put in matrix form @ values

$$\begin{bmatrix} 350e\text{-}6 & -50e\text{-}6 \\ -50e\text{-}6 & 150e\text{-}6 \end{bmatrix} \begin{bmatrix} V_A \\ V_B \end{bmatrix} = \begin{bmatrix} 16m \\ 2m \end{bmatrix}$$

$$\begin{bmatrix} V_A \\ V_B \end{bmatrix} = \left[\frac{1}{(350e\text{-}6)(150e\text{-}6) - (50e\text{-}6)(50e\text{-}6)}\right] \begin{bmatrix} 150e\text{-}6 & 50e\text{-}6 \\ 50e\text{-}6 & 350e\text{-}6 \end{bmatrix} \begin{bmatrix} 16m \\ 2m \end{bmatrix}$$

$$\begin{bmatrix} V_A \\ V_B \end{bmatrix} = 20e6 \begin{bmatrix} 150e\text{-}6 \cdot 16m + 50e\text{-}6 \cdot 2m \\ 50e\text{-}6 \cdot 16m + 350e\text{-}6 \cdot 2m \end{bmatrix}$$

$$\boxed{\begin{bmatrix} V_A \\ V_B \end{bmatrix} = \begin{bmatrix} 50 \\ 30 \end{bmatrix}}$$

$$\boxed{V_x = V_A - V_B = 20\,V}$$

Power in R_4

$$\boxed{P_{R4} = \frac{V_x^2}{R_4} = \frac{20^2}{20000} = 20mW}$$

Power generated from I_{S1}

$$\boxed{P_{I_{S1}}|_{gen} = V_A \cdot I_{S1} = 50(8m) = 400mW}$$

Power generated from V_{S2} Note: $I_{S2} = I_{R1} + I_{R2}$

$$P_{V_{S2}}|_{gen} = V_{S2} \cdot I_{S2} = 40\left[(40-30)50e\text{-}6 + (40-50)2000\text{-}6\right]$$

$$\boxed{P_{V_{S2}}|_{gen} = -60mW}$$

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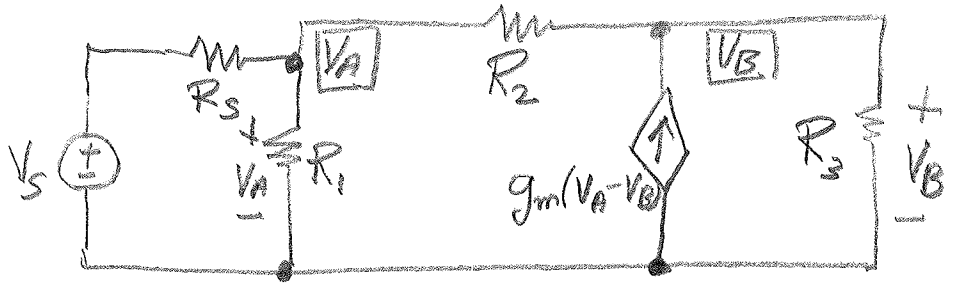

(a) Nodal analysis at nodes V_A and V_B.

① @ V_A: $(V_A - V_S)G_S + V_A G_1 + (V_A - V_B)G_2 = 0$

② @ V_B: $(V_B - V_A)G_2 - g_m(V_A - V_B) + V_B \cdot G_3 = 0$

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① $V_A(G_S + G_1 + G_2) - V_B G_2 = V_S G_S$

$-V_A(G_2 + g_m) + V_B(G_2 + g_m + G_3) = 0$

$$\begin{bmatrix} V_A \\ V_B \end{bmatrix} \begin{bmatrix} G_S + G_1 + G_2 & -G_2 \\ -(G_S + g_m) & G_2 + g_m + G_3 \end{bmatrix} = \begin{bmatrix} G_S V_S \\ 0 \end{bmatrix}$$

(b) $V_S = 150$; $R_S = 1K$; $R_1 = 5K$; $R_2 = 10K$; $R_3 = 10K$; $g_m = 0.0075$

$G_S = 1000e\text{-}6$; $G_1 = 200e\text{-}6$; $G_2 = 100e\text{-}6$; $G_3 = 100e\text{-}6$

$$\begin{bmatrix} V_A \\ V_B \end{bmatrix} \begin{bmatrix} 1300e\text{-}6 & -100e\text{-}6 \\ -7600e\text{-}6 & 7700e\text{-}6 \end{bmatrix} = \begin{bmatrix} 150e\text{-}3 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} V_A \\ V_B \end{bmatrix} = \left[\frac{1}{(1300e\text{-}6)(7700e\text{-}6) - (100e\text{-}6)(7600e\text{-}6)}\right] \begin{bmatrix} 7700e\text{-}6 & 100e\text{-}6 \\ 7600e\text{-}6 & 1300e\text{-}6 \end{bmatrix} \begin{bmatrix} 150m \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} V_A \\ V_B \end{bmatrix} = (108108.1) \begin{bmatrix} 7700e\text{-}6 \cdot 150e\text{-}3 \\ 7600e\text{-}6 \cdot 150e\text{-}3 \end{bmatrix} = \begin{bmatrix} 124.86 \\ 123.24 \end{bmatrix}$$

Power generated by V_S

$P_{V_S}|_{gen} = V_S \cdot I_S$; $I_S = \dfrac{V_S - V_A}{R_S} = \dfrac{150 - 124.86}{1000} = 0.02514$

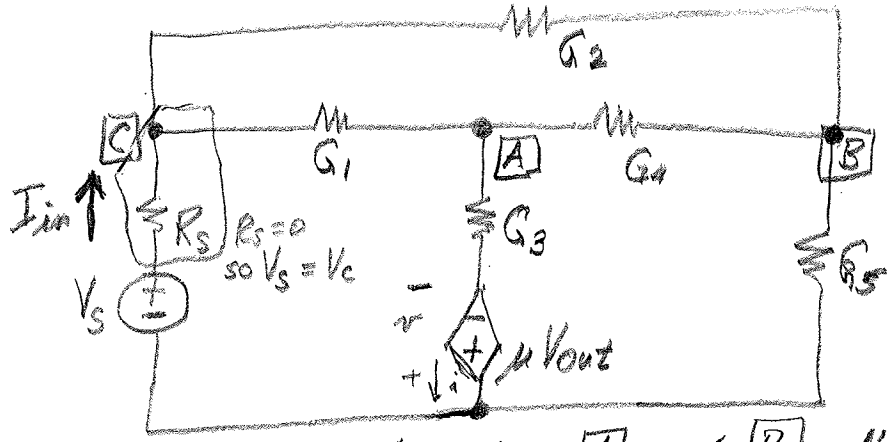
$$P_{V_S}|_{gen} = (150)(0.02514) = 3.771\ W$$

Power absorbed by R_3

$$P_{R_3} = \frac{V_B^2}{R_3} = \frac{(123.24)^2}{10000} = 1.519W$$

(c) $I_2 = \dfrac{V_A - V_B}{R_2} = 162\ \mu A$

[15]



$R_S = 0$; $V_S = 20$

Note: $V_{out} = V_B$

(a) Nodal analysis at nodes [A] and [B], Node [C] collapses into the supply node because $R_S = 0$, so no equation at node [C] is necessary.

① @ [A]; $(V_A - V_S)G_1 + [V_A - (-\mu V_B)]G_3 + (V_A - V_B)G_4 = 0$

② @ [B]; $(V_B - V_A)G_4 + V_B G_5 + (V_B - V_S)G_2 = 0$

① $V_A(G_1 + G_3 + G_4) + V_B(\mu G_3 - G_4) = V_S G_1$

② $V_A(-G_4) + V_B(G_4 + G_5 + G_2) = 0$

(b) $\mu = 6$; $G_1 = 0.5$; $G_2 = 1$; $G_3 = 0.5$ $G_4 = 4$, $G_5 = 1$

$$\begin{bmatrix} V_A \\ V_B \end{bmatrix} \begin{bmatrix} 5 & -1 \\ -4 & 6 \end{bmatrix} = \begin{bmatrix} 10 \\ 20 \end{bmatrix}; \quad \begin{bmatrix} V_A \\ V_B \end{bmatrix} = \left(\frac{1}{26}\right)\begin{bmatrix} 6 & 1 \\ 4 & 5 \end{bmatrix}\begin{bmatrix} 10 \\ 20 \end{bmatrix}$$

$$\begin{bmatrix} V_A \\ V_B \end{bmatrix} = \left(\frac{1}{26}\right)\begin{bmatrix} 60 + 20 \\ 40 + 100 \end{bmatrix} = \begin{bmatrix} 40/13 \\ 70/13 \end{bmatrix}$$

Note that book answer is wrong.

(c) $I_{in} = (V_S - V_B)G_2 + (V_S - V_A)G_1 = \left(20 - \frac{70}{13}\right)\cdot 1 + \left(20 - \frac{40}{13}\right)\cdot \frac{1}{2} = \frac{190}{13} + \frac{220}{26}$

$$\boxed{I_{in} = \frac{500}{26} = 19.23\ A}; \quad \boxed{R_{in} = \frac{V_S}{I_{in}} = \frac{20}{19.23} = 1.04\ W}$$

(d) $\boxed{P_{I_S}|_{gen} = V_S \cdot I_{in} = 20(19.23) = 384.6\ W}$;

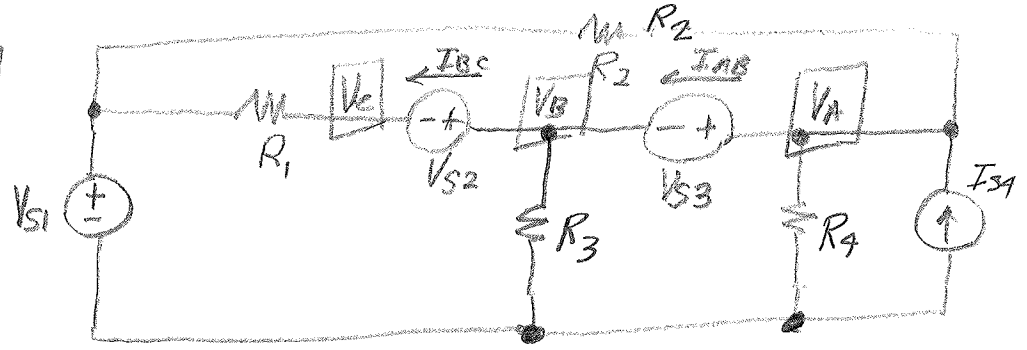
$P_{dep}|_{gen} = v \cdot i$; $v = \mu V_{out}$; $i = [V_A - (-\mu V_{out})]G_3 = \left[\frac{40}{13} + 6\left(\frac{70}{13}\right)\right]0.5$

$v = 6 \cdot \frac{70}{13} = \frac{420}{13}$; $i = \left(\frac{80 + 426}{26}\right) = \frac{253}{13}$

$$\boxed{P_{dep}|_{gen} = \left(\frac{420}{13}\right)\left(\frac{253}{13}\right) = 628.8\ W}$$

(e) $\boxed{P_{R_S} = \frac{V_{out}^2}{R_S} = \left(\frac{70}{13}\right)^2 \cdot 1 = 29.0\ W}$

[26]



$R_1 = 10$ $V_{S1} = 100$
$R_2 = 100$ $V_{S2} = 60$
$R_3 = 100$ $V_{S3} = 100$
$R_4 = 50$ $I_{S4} = 14$

$G_1 = 1000e-3$; $G_2 = 10e-3$; $G_2 = 10e-3$; $G_4 = 20e-3$

Nodal Analysis at V_A, V_B, and V_C nodes give three equations in five unknowns.

① @V_A ; $(V_A - V_{S1})G_2 + I_{AB} + V_A G_4 - I_{S4} = 0$

② @V_B ; $I_{BC} + V_B G_3 - I_{AB} = 0$

③ @V_C $(V_C - V_{S1})G_1 - I_{BC} = 0$

Collect terms

① $V_A(G_2 + G_4) + I_{AB} = G_2 V_{S1} + I_{S4}$

② $V_B G_3 - I_{AB} + I_{BC} = 0$

③ $V_C G_1 - I_{BC} = G_1 V_{S1}$

Need five equation to solve for five unknowns. Make Two more equations by explicitly defining the voltage sources.

④ $V_B - V_C = V_{S2}$; ⑤ $V_A - V_B = V_{S3}$

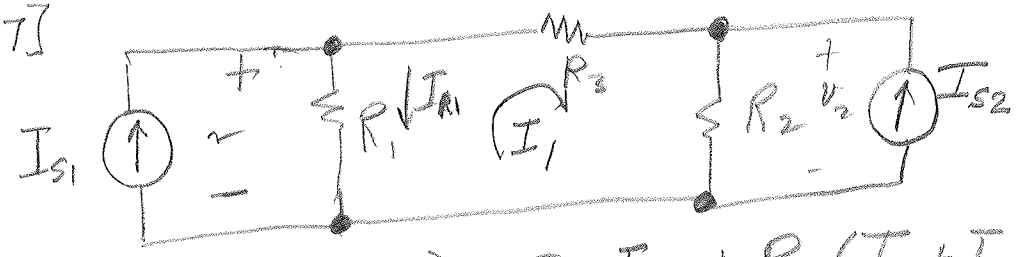
(b) make matrix for MATLAB

$$\begin{bmatrix} G_2+G_4 & 0 & 0 & 1 & 0 \\ 0 & G_3 & 0 & -1 & 1 \\ 0 & 0 & G_1 & 0 & -1 \\ 0 & 1 & -1 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} V_A \\ V_B \\ V_C \\ I_{AB} \\ I_{BC} \end{bmatrix} = \begin{bmatrix} G_2 V_{S1} + I_{S4} \\ 0 \\ G_1 V_{S1} \\ V_{S2} \\ V_{S3} \end{bmatrix}$$

$$\begin{bmatrix} 30e-3 & 0 & 0 & 1 & 0 \\ 0 & 10e-3 & 0 & -1 & 1 \\ 0 & 0 & 1000e-3 & 0 & -1 \\ 0 & 1 & -1 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} V_A \\ V_B \\ V_C \\ I_{AB} \\ I_{BC} \end{bmatrix} = \begin{bmatrix} 15 \\ 0 \\ 10 \\ 60 \\ 100 \end{bmatrix}$$

(c) $P_{VS1}|_{gen} = V_{S1} \cdot I_{S1} = V_{S1}\left[-I_{BC} + (V_{S1} - V_A)G_2\right]$; $P_{VS2} = V_{S2} \cdot I_{BC}$; $P_{VS3} = V_{S3} \cdot I_{AB}$

[37]



$R_1 = 200$ $I_{S1} = 0.75$

$R_3 = 300$ $I_{S2} = 0.1$

$R_2 = 500$

(a) $R_1(I_1 - I_{S1}) + R_3 I_1 + R_2(I_1 + I_{S2}) = 0$

$(R_1 + R_2 + R_3) I_1 = R_1 I_{S1} - R_2 I_{S2}$

$$I_1 = \frac{R_1 I_{S1} - R_2 I_{S2}}{R_1 + R_2 + R_3}$$

$$I_1 = \frac{200(0.75) - 500(0.1)}{1000} = 0.1\,A$$

$P_{I_{S1}}|_{gen} = v \cdot I_{S1}$

Find v; $I_{R_1} = I_{S1} - I_1 = 0.75 - 0.1 = 0.65$

$V_{R_1} = v = 200(0.65) = 130$

$P_{I_{S1}}|_{gen} = 130 \cdot 0.75 = 97.5\,W$

$P_{I_{S2}}|_{gen} = v_2 \cdot I_{S2}$; Find v_2; $I_{R_2} = I_{S2} + I_1 = 0.1 + 0.1 = 0.2\,A$

$v_2 = 0.2(500) = 100\,V$

$P_{I_{S2}}|_{gen} = 100 \cdot 0.1 = 10\,W$

(b) $I_{S1} = 400\,mA$; $I_{S2} = 100\,mA$

$(R_1 + R_2 + R_3) I_1 = R_1 I_{S1} - R_2 I_{S2} \Rightarrow 2000 I_1 = 60$

$\Rightarrow R_1 + R_2 + R_3 = 2000$; $R_1 I_{S1} - R_2 I_{S2} = 60$

Let $R_3 = 600$

① $R_1 + R_2 = 1400$

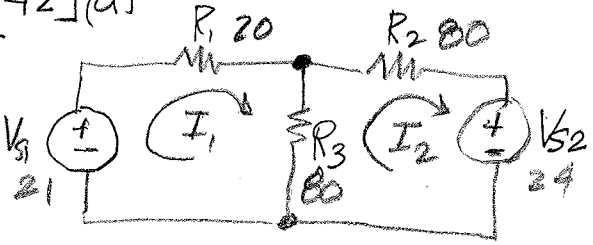
② $0.4 R_1 - 0.1 R_2 = 60$ x10

$4R_1 - R_2 = 600$

$5R_1 = 2000$

$R_1 = 400$; $R_2 = 1000$

[42] (a)



① $R_1 I_1 + (I_1 - I_2) R_3 - V_{S1} = 0$

② $(I_2 - I_1) R_3 + R_2 I_2 - V_{S2} = 0$

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① $I_1 (R_1 + R_3) - I_2 R_3 = V_{S1}$

② $-R_3 I_1 + I_2 (R_2 + R_3) = V_{S2}$

$$\begin{bmatrix} 100 & -80 \\ -80 & 160 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 21 \\ -24 \end{bmatrix}$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \left(\frac{1}{9600}\right) \begin{bmatrix} 160 & 80 \\ 80 & 100 \end{bmatrix} \begin{bmatrix} 21 \\ -24 \end{bmatrix}$$

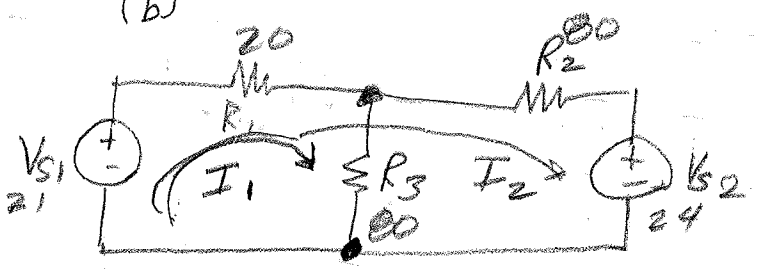
$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \left(\frac{1}{9600}\right) \begin{bmatrix} 3360 - 1920 \\ 1680 - 2400 \end{bmatrix}$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0.15 \\ -0.075 \end{bmatrix}$$

$V_{R3} = (I_1 - I_2) R_3 = 0.225 \cdot 80$

$$P_{R3} = \frac{V_{R3}^2}{R_3} = (0.225)^2 \cdot 80 = 4.05\,W$$

(b)



① $-V_{S1} + R_1 (I_1 + I_2) + R_3 I_1 = 0$

② $-V_{S1} + R_1 (I_1 + I_2) + R_2 I_2 + V_{S2} = 0$

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① $I_1 (R_1 + R_3) + R_1 I_2 = V_{S1}$

② $I_1 (R_1) + I_2 (R_1 + R_2) = V_{S1} - V_{S2}$

$$\begin{bmatrix} 100 & 20 \\ 20 & 100 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 21 \\ -3 \end{bmatrix}$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \left(\frac{1}{9600}\right) \begin{bmatrix} 100 & -20 \\ -20 & 100 \end{bmatrix} \begin{bmatrix} 21 \\ -3 \end{bmatrix}$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \left(\frac{1}{9600}\right) \begin{bmatrix} 2100 + 60 \\ -420 - 300 \end{bmatrix}$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0.225 \\ -0.075 \end{bmatrix}$$

$V_{R3} = I_1 \cdot R_3 = 0.225 \cdot 80$

$P_{R3} = I_1 \cdot V_{R3} = 0.225 \cdot 0.225 \cdot 80$

$P_{R3} = 4.05\,W$

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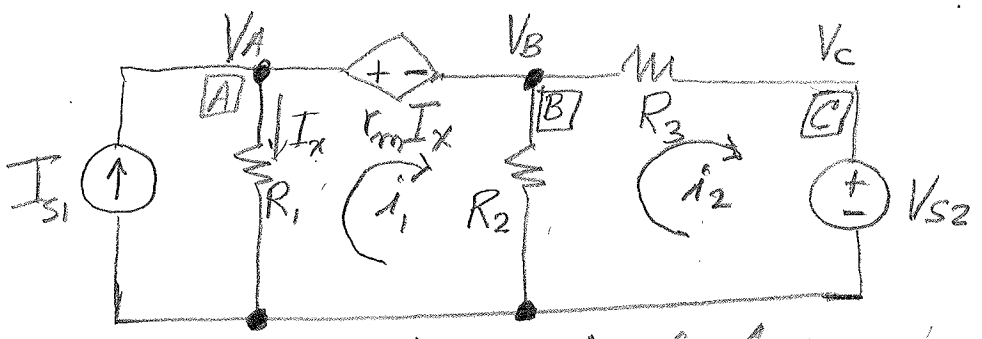


(a) Write mesh equations for loops 1 & 2.

① $R_1(i_1 - I_{S1}) + r_m I_x + R_2(i_1 - i_2) = 0$

Substitute for I_x in terms of i_1 and i_2

$I_x = I_{S1} - i_1$

① $R_1(i_1 - I_{S1}) + r_m(I_{S1} - i_1) + R_2(i_1 - i_2) = 0$

② $R_2(i_2 - i_1) + R_3 i_2 + V_{S2} = 0$

① $i_1(R_1 - r_m + R_2) - i_2 R_2 = (R_1 - r_m) I_{S1}$

② $-i_1 R_2 + i_2(R_2 + R_3) = -V_{S2}$

$$\begin{bmatrix} (R_1 - r_m + R_2) & -R_2 \\ -R_2 & (R_2 + R_3) \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} (R_1 - r_m) I_{S1} \\ -V_{S2} \end{bmatrix}$$

$80 \quad -40 \quad -40 \quad 120$

(b) $R_1 = 100$; $R_2 = 40$; $R_3 = 80$; $r_m = 60$; $I_{S1} = 1A$ $V_{S2} = 40$

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \left\{ \frac{1}{[120 \cdot 80 - (40)(40)]} \right\} \begin{bmatrix} 120 & +40 \\ +40 & 80 \end{bmatrix} \begin{bmatrix} 40 \\ -40 \end{bmatrix}$$

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \left(\frac{1}{8000}\right) \begin{pmatrix} 3200 \\ -1600 \end{pmatrix} = \begin{bmatrix} 0.4 \\ -0.2 \end{bmatrix}$$

(c) $V_A = I_x \cdot R_1 = 0.6(100) = 60$

$V_B = (i_1 - i_2) R_2 = 0.6(80) = 48$

(d) Power generated from I_{S1}

$P_{I_{S1}}|_{gen} = V_A \cdot I_{S1} = 60 \cdot 1 = 60W$

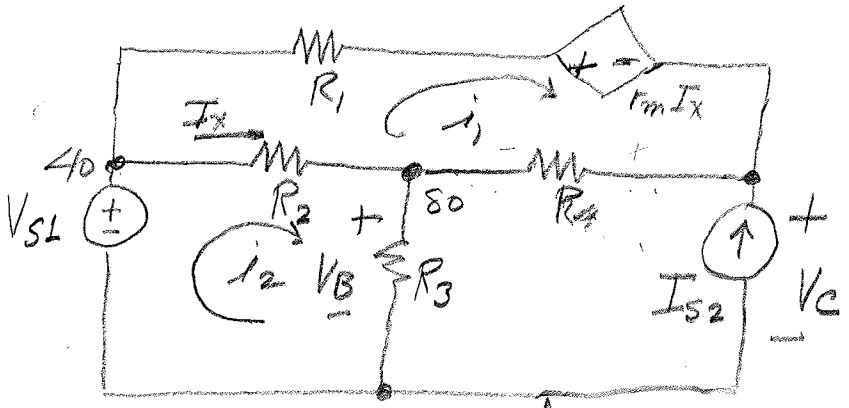
Power generated from V_{S2}

$P_{V_{S2}}|_{gen} = V_C \cdot (-i_2) = 40(+0.2) = 8W$

(e) Power generated by dep. source

$P_{dep}|_{gen} = (V_A - V_B)(-i_1) = (60 - 48)(-0.4) = 4.8W$

[53]



(a) Write mesh equations for loops 1 & 2

① $R_1 i_1 + r_m I_x + (i_1 + I_{S2}) R_4 + R_2 (i_1 - i_2) = 0$ $(I_x = i_2 - i_1)$

② $-V_{S1} + (i_2 - i_1) R_2 + (i_2 + I_{S2}) R_3 = 0$

Subs. $I_x = i_2 - i_1$ into ①

① $i_1 (R_1 - r_m + R_4 + R_2) + i_2 (r_m - R_2) = -R_4 I_{S2} + R_3 I_{S2}$ (80 + 80)

② $-i_1 R_2 + i_2 (R_2 + R_3) = V_{S1} - I_{S2} R_3$ (40, 80)

(b) $R_1 = 100$ $R_2 = 40$ $R_3 = 80$ $R_4 = 80$ $r_m = 60$ $I_{S2} = 1$ $V_{S1} = 40$

① $i_1 (160) + i_2 (20) = -160$

② $-i_1 (40) + i_2 (80) = 40$ (×4)

$-i_1 160 + i_2 320 = 160$

$i_2 \cdot 340 = 0$

$i_2 = 0$

$i_1 = -1$

(c) $V_{R2} = I_x R_2 = (i_2 - i_1) R_2$

$= -40\,V$

$V_B = (i_2 + I_{S2}) R_3 = 80\,V$

$V_c = [i_1 + I_{S2}] R_4 + 80$

$= 80\,V$

(d) $P_{VS_1} = V_{S1} \cdot i_2 = 0$

$P_{IS_2} = V_c \cdot I_{S2} = 80 \cdot 1 = 80\,W$

$P_{dep} = (r_m I_x)(-i_1) = 60(-1)(+1) = -60\,W$