(2.1) #1 : $\frac{V_1 - V_2}{R_1} + \frac{V_1 - V_3}{R_2} + \frac{V_1}{R_3} = 0$

#2 & #4 : $\begin{cases} \frac{V_2 - V_1}{R_1} + \frac{V_2 - V_3}{R_5} + \frac{V_4 - V_3}{R_4} - I_2 = 0 \\ V_2 - V_4 = V_A \end{cases}$

#3 : $\frac{V_3 - V_1}{R_2} + \frac{V_3 - V_2}{R_5} + \frac{V_3 - V_4}{R_4} - I_1 = 0$

(2.2)

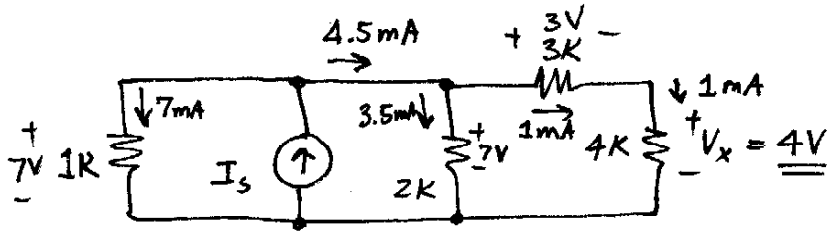
#1 : $R_1 I_1 + R_2 (I_1 - I_2) + V_A + R_3 I_1 = 0$

#2 : $R_4 I_2 + V_B + R_2 (I_2 - I_1) = 0$

#3 : $-V_A - V_B + R_6 (I_3 - I_4) + R_5 I_3 = 0$

#4 : $I_4 = I_A$

(3.1) (a)

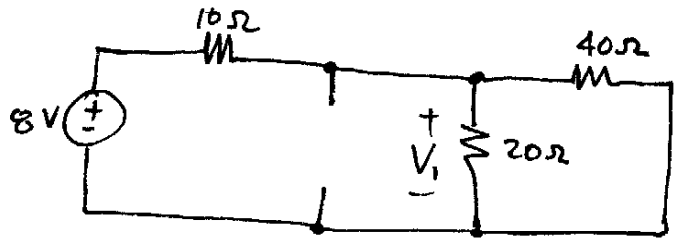


$I_S = 7 + 4.5 = 11.5\,mA$

$K = \frac{V_x}{I_S} = \frac{4\,V}{11.5\,mA} = 348\,\Omega$

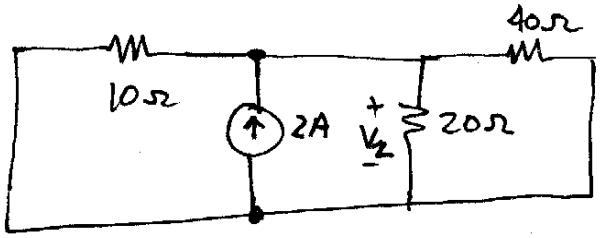
(b) $\boxed{V_x = K I_S = 348\,(50\,mA) = 17.4\,V}$

(3.2)

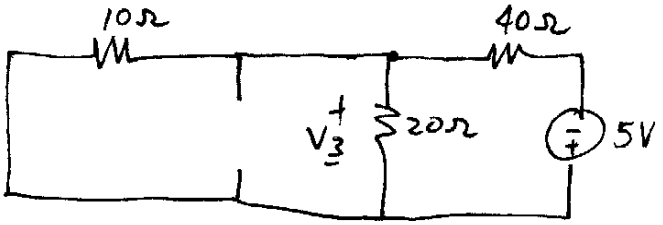


$$V_1 = \frac{20\|40}{20\|40 + 10}\,8 = 4.57\text{V}$$

($20\|40 = 13.3\Omega$)



$$V_2 = 2(10\|20\|40)$$
$$= 2(5.71)$$
$$= 11.4\text{ V}$$



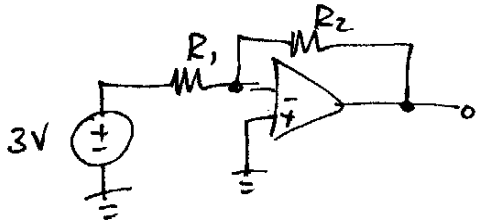
$$V_3 = -\frac{20\|10}{20\|10 + 40}\,5$$

($20\|10 = 6.67\text{V}$)

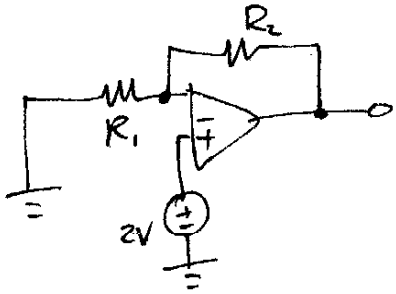
$$= -0.714\text{ V}$$

$$V = V_1 + V_2 + V_3 = 15.3\text{V}$$

(4.1)



$$v_{o_3} = -\frac{R_2}{R_1}3$$

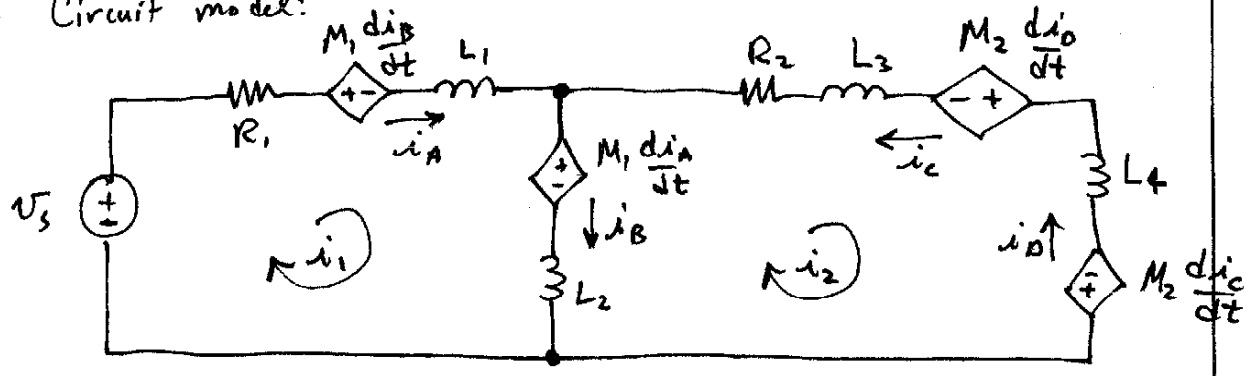


$$v_{o_2} = \left(1 + \frac{R_2}{R_1}\right)2$$

$$v_o = v_{o_3} + v_{o_2} = -\frac{R_2}{R_1}3 + 2 + \frac{R_2}{R_1}2$$

$$v_o = 2 - \frac{R_2}{R_1}$$

(4.2) Circuit model:



$$\#1: \quad -v_s + R_1 i_1 + M_1 \frac{di_B}{dt} + L \frac{di_1}{dt} + M_1 \frac{di_A}{dt} + L_2 \frac{d(i_1 - i_2)}{dt} = 0$$

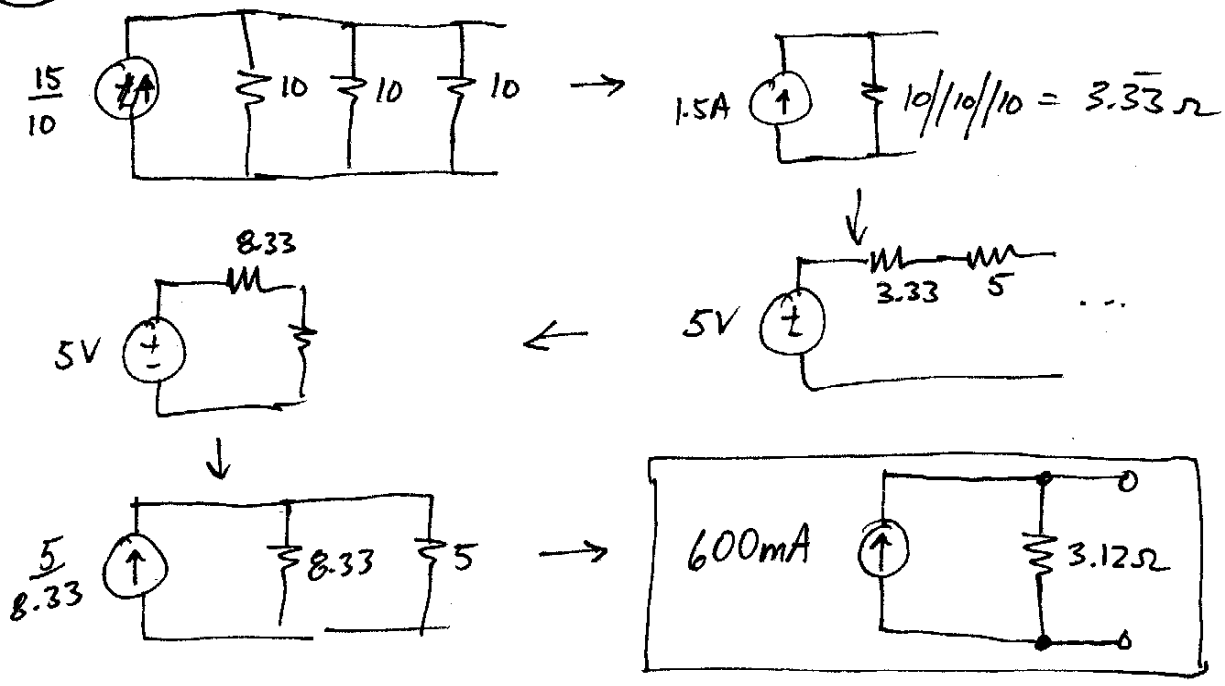
$$\#2: \quad L_2 \frac{d(i_2 - i_1)}{dt} - M_1 \frac{di_A}{dt} + R_2 i_2 + L_3 \frac{di_2}{dt} - M_2 \frac{di_D}{dt}$$

$$+ L_4 \frac{di_2}{dt} - M_2 \frac{di_C}{dt} = 0$$

Control Currents:

$$i_A = i_1$$
$$i_B = i_1 - i_2$$
$$i_C = -i_2$$
$$i_D = -i_2$$

(5.1)

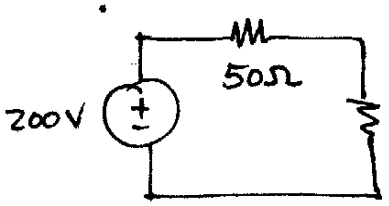


(5.2) $V_{oc} = 200\,V$, $I_{sc} = 4\,A$

$V_{oc} = V_T$, $I_{sc} = I_N$

Since $V_{oc} = R_T I_{sc}$, $R_T = \frac{V_{oc}}{I_{sc}} = \frac{200}{4} = 50\,\Omega$

$$P_{max} = \frac{V_T^2}{4R_T} = \frac{200^2}{4 \cdot 50} = 200\,W$$



$$P_{500} = \underbrace{\left(\frac{200}{500+50}\right)^2}_{\text{current}} 500 = 66.1\,W$$

$$\frac{P_{500}}{P_{max}} \times 100\% = \frac{66.1}{200} \times 100\% = \boxed{33\%}$$