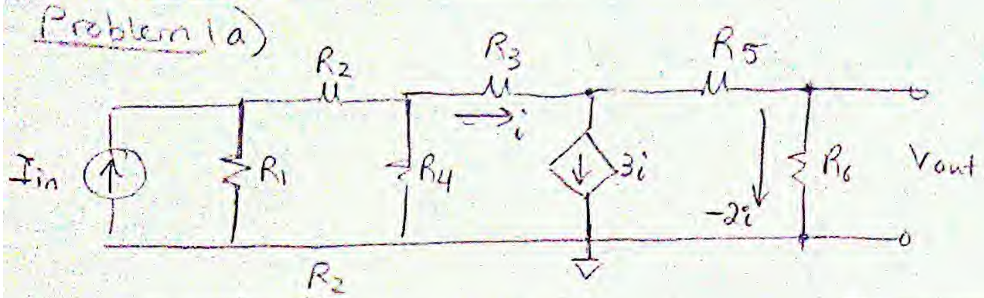
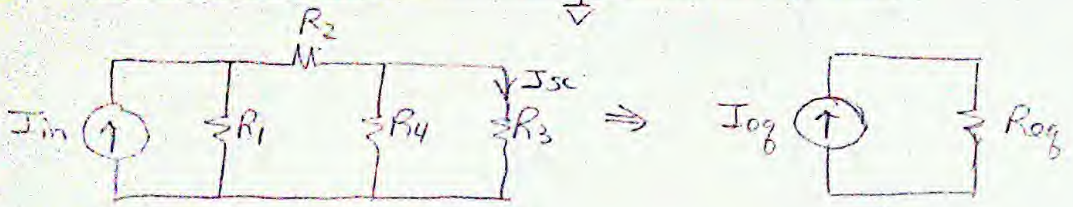
Midterm Solutions, EE40 MT1

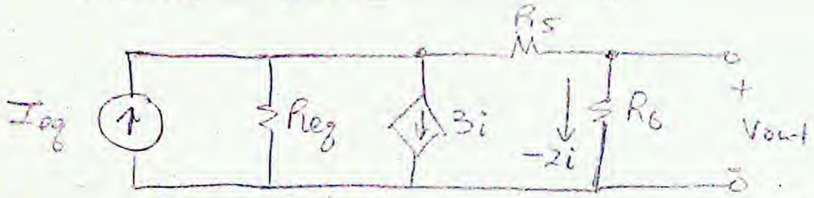
Problem 1(a)





$$R_{eq} = (R_1 + R_2) \| R_4 + R_3$$

$$I_{eq} = \frac{R_3 \| R_4}{R_3 \| R_4 + R_1 + R_2} \cdot R_1 I_{in} \cdot \frac{1}{R_3} = I_{sc}$$



$$-2i = (I_{eq} - 3i)\frac{R_{eq}}{R_{eq} + R_5 + R_6} = \frac{I_{eq} R_{eq}}{R_{eq} + R_5 + R_6} - \frac{3R_{eq}}{R_{eq} + R_5 + R_6} i$$

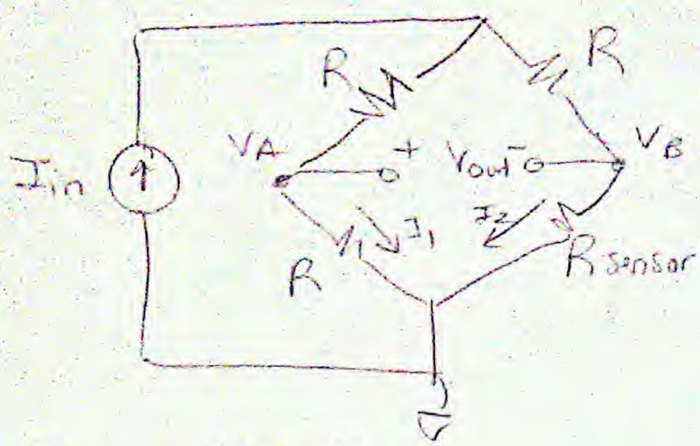
$$i = \frac{I_{eq}\frac{R_{eq}}{R_{eq} + R_5 + R_6}}{\frac{3R_{eq}}{R_{eq} + R_5 + R_6} - 2}$$

$$V_{out} = -2i R_6$$

$$= \frac{\frac{-2R_6 R_{eq}}{R_{eq} + R_5 + R_6}}{\frac{3R_{eq}}{R_{eq} + R_5 + R_6} - 2} I_{eq} = \frac{-2 R_6 R_{eq} I_{eq}}{R_{eq} - 2(R_5 + R_6)}$$

$$\boxed{V_{out} = \frac{-2 R_6 \left[(R_1 + R_2) \| R_4 + R_3\right] \frac{R_3 \| R_4}{R_3 \| R_4 + R_1 + R_2} \cdot \frac{R_1}{R_3} \cdot I_{in}}{(R_1 + R_2) \| R_4 + R_3 - 2(R_5 + R_6)} \; [V]}$$

1b)



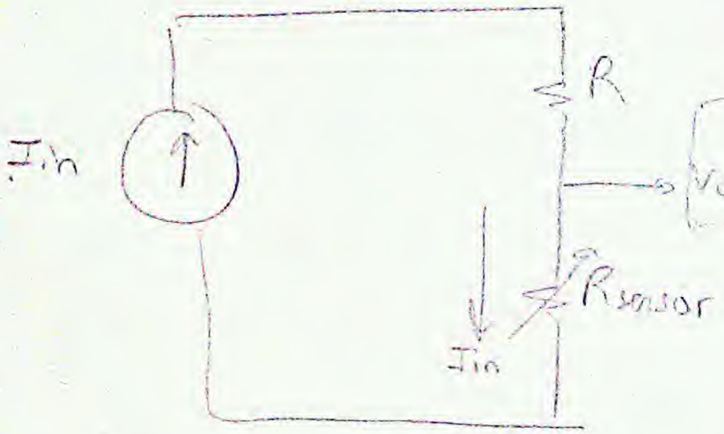
$$V_{out} = V_A - V_B$$

$$= R I_1 - R_{sensor} I_2$$

$$= R I_{in} \frac{R_{sensor} + R}{3R + R_{sensor}} - R_{sensor} I_{in} \frac{2R}{3R + R_{sensor}}$$

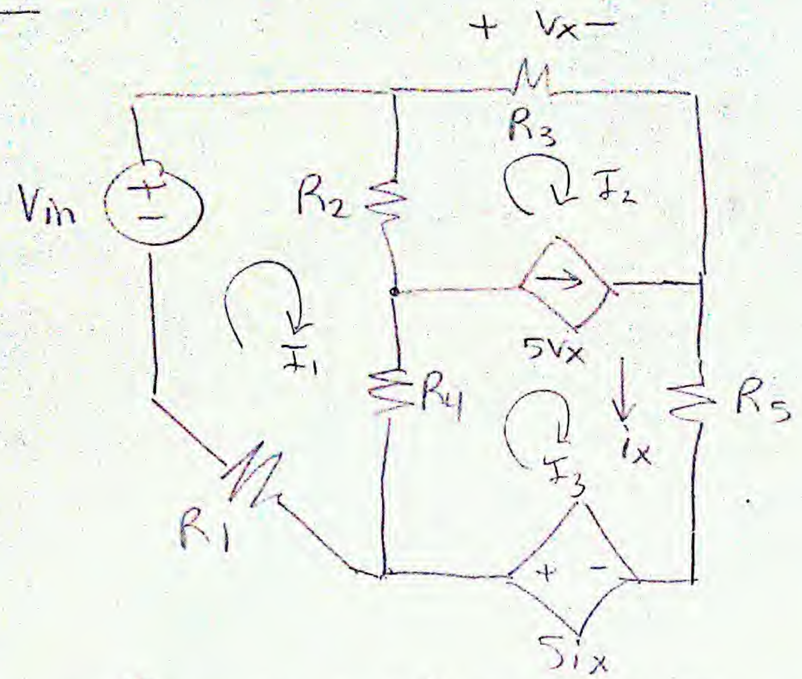
$$= I_{in} \frac{(R R_{sensor} + R^2 - 2R R_{sensor})}{3R + R_{sensor}}$$

$$\boxed{V_{out} = I_{in} \frac{(R^2 - R R_{sensor})}{3R + R_{sensor}} \quad [V]}$$



$$\boxed{V_{out} = I_{in} R_{sensor} \quad [V]}$$

P2



$$0 = (R_1 + R_2 + R_4) I_1 - R_2 I_2 - R_4 I_3 - V_{in}$$

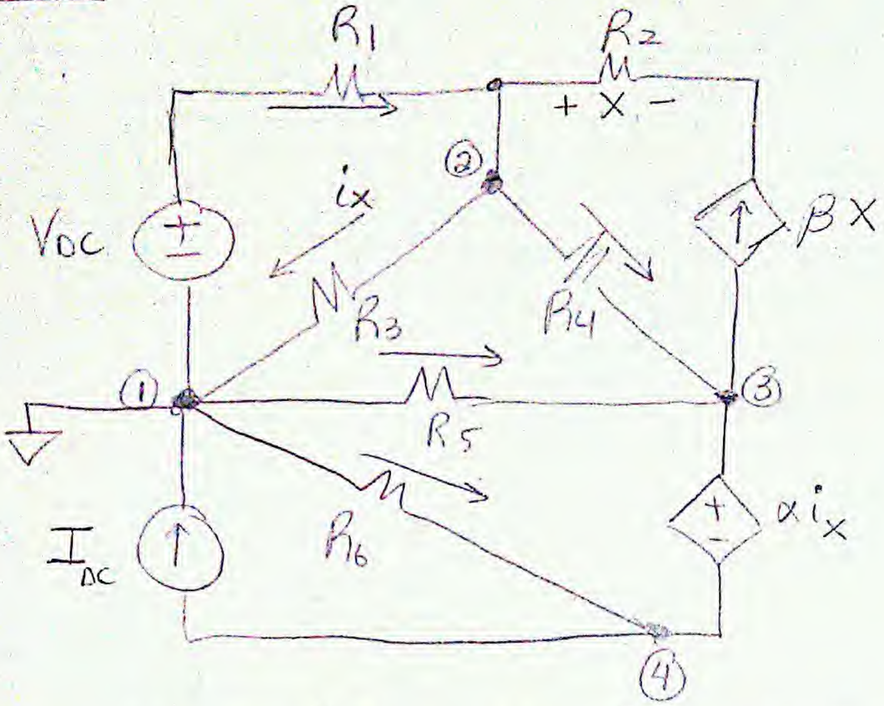
$$0 = (- R_4 - R_2) I_1 + (R_2 + R_3) I_2 + (R_4 + R_5) I_3 - 5 I_3$$

$$5V_x = 5(I_2 R_3) = I_3 - I_2$$

$$0 = (5R_3 + 1) I_2 - I_3$$

$$\boxed{\begin{aligned} (R_1 + R_2 + R_4) I_1 + (-R_2) I_2 + (-R_4) I_3 &= V_{in} \\ (-R_4 - R_2) I_1 + (R_2 + R_3) I_2 + (R_4 + R_5 - 5) I_3 &= 0 \\ 0\, I_1 + (5R_3 + 1) I_2 + (-1) I_3 &= 0 \end{aligned}}$$

P3



$$x = \beta x \quad \text{so let} \quad x = 0$$

$$\frac{V_{DC} - V_2}{R_1} = \frac{V_2 - V_1}{R_3} + \frac{V_2 - V_3}{R_4} \quad (\text{KCL @ ②})$$

$$\therefore \boxed{\frac{V_{DC}}{R_1} = \left(\frac{-1}{R_3}\right)V_1 + \left(\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_1}\right)V_2 + \left(\frac{-1}{R_4}\right)V_3 + 0 \cdot V_4}$$

$$\frac{V_2 - V_3}{R_4} + \frac{(V_1 - V_3)}{R_5} + \frac{V_1 - V_4}{R_6} = I_{DC} \quad (\text{KCL at ③, ④})$$

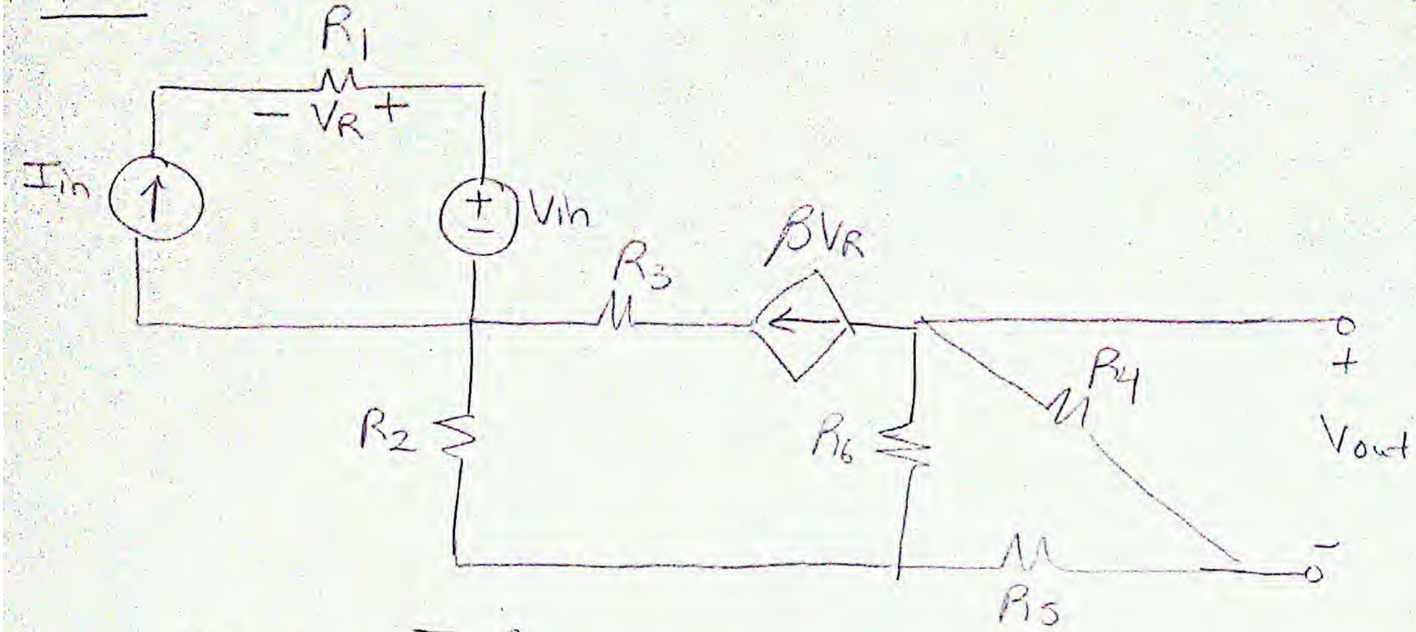
$$\therefore \boxed{I_{DC} = \left(\frac{1}{R_5} + \frac{1}{R_6}\right)V_1 + \frac{1}{R_4} V_2 + \left(\frac{-1}{R_4} - \frac{1}{R_5}\right)V_3 + \left(\frac{-1}{R_6}\right)V_4}$$

$$\alpha i_x = \alpha \frac{(V_2 - V_1)}{R_3} = V_3 - V_4$$

$$\therefore \boxed{0 = \left(-\frac{\alpha}{R_3}\right)V_1 + \left(\frac{\alpha}{R_3}\right)V_2 + (-1)V_3 + 1 \cdot V_4}$$

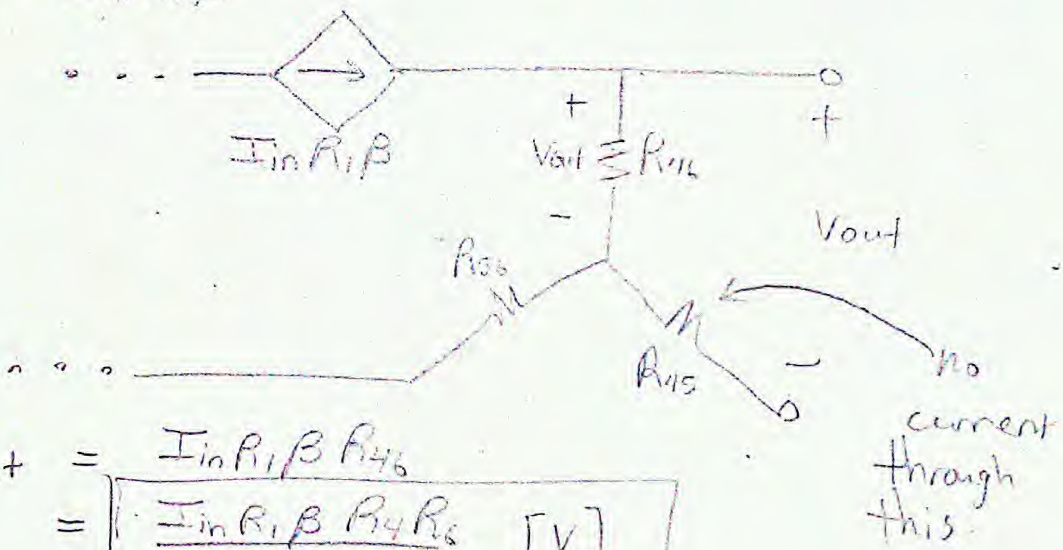
and $\boxed{1 \cdot V_1 + 0 \cdot V_2 + 0 \cdot V_3 + 0 \cdot V_4 = 0}$

P4



$$V_R = -I_{in}R_1$$

$$\beta V_R = -I_{in}R_1\beta$$



$$V_{out} = I_{in}R_1\beta R_{46} = \boxed{\frac{I_{in}R_1\beta R_4 R_6}{R_4+R_5+R_6}\ [V]}$$