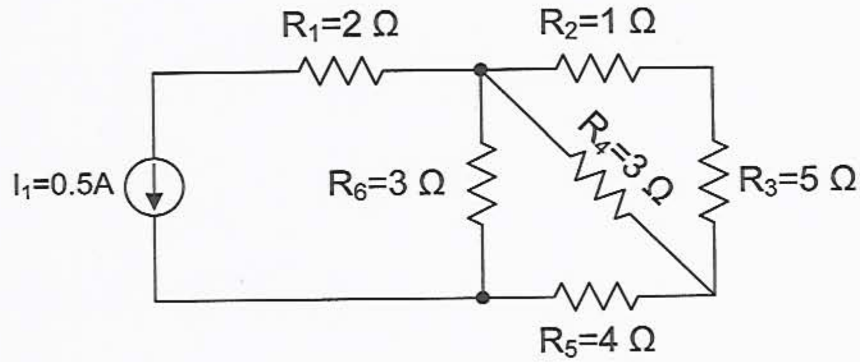
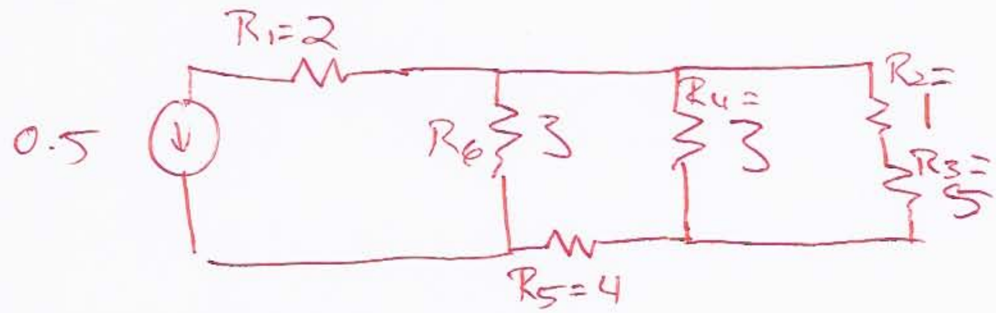
Problem 1 [20 points]



Calculate the numerical value of the power delivered to the circuit by the source I_1. Write down intermediate results and do not forget the unit.

$P =$ 1W



$R_A = R_2 + R_3 = 6\Omega$

$R_B = R_A // R_4 = 2\Omega$

$R_C = R_B + R_5 = 6\Omega$

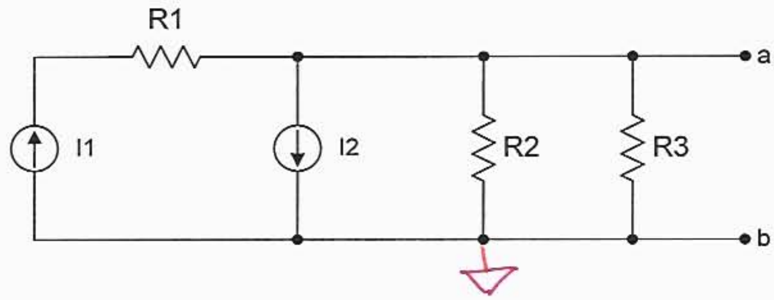
$R_D = R_6 // R_C = 2\Omega$

$R_E = R_1 + R_D = 4\Omega$

$P = I^2 R = 0.5^2 \cdot 4 = 1W$

Problem 2 [20 points]

Find algebraic expressions for the voltage and resistance of a Thevenin equivalent of the circuit below (looking into terminals a-b).



$$V_T = \frac{R_2 R_3}{R_2 + R_3}(I_1 - I_2)$$

$$R_T = \frac{R_2 R_3}{R_2 + R_3}$$

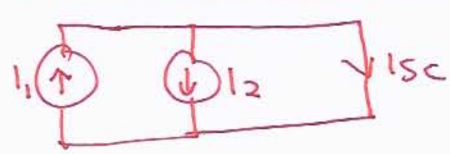
OPEN CIRCUIT VOLTAGE

@ a $\quad I_2 + \frac{V_a}{R_2} + \frac{V_a}{R_3} - I_1 = 0$

$V_a = V_{oc} = V_{TH}$

$(I_1 - I_2)\frac{R_2 R_3}{R_2 + R_3} = V_a$

SHORT CIRCUIT CURRENT

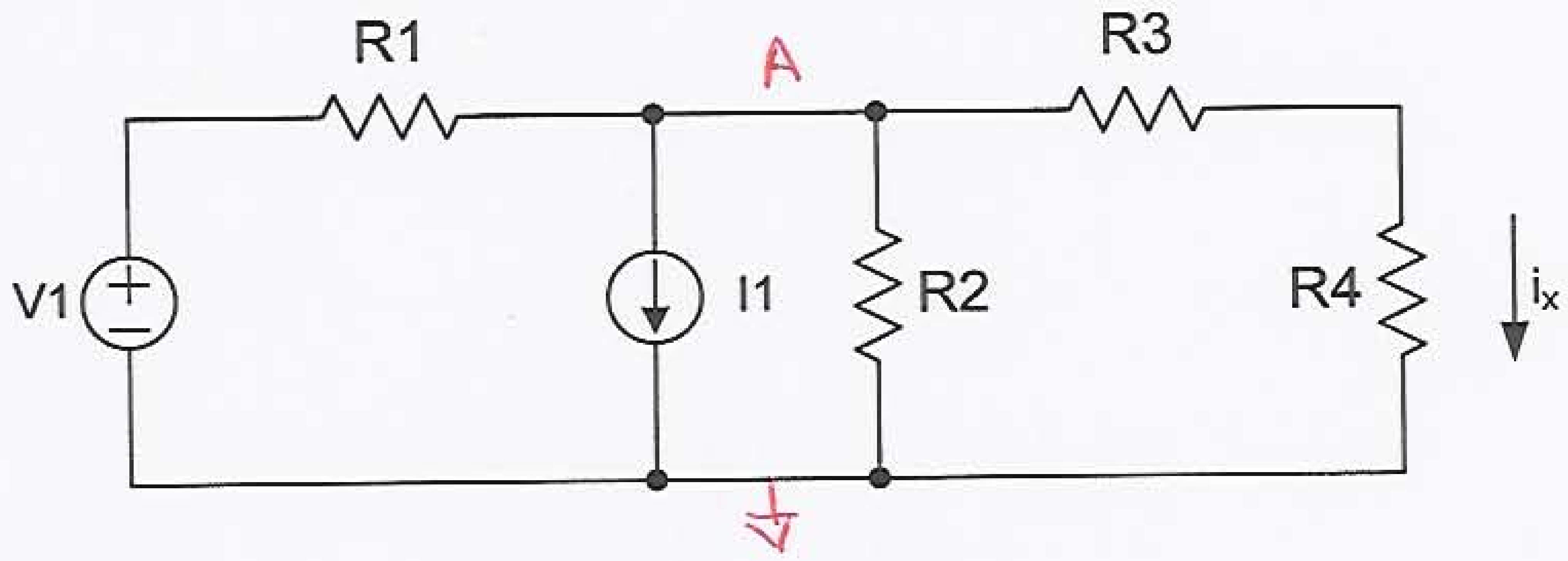


$I_{sc} = I_1 - I_2$

$$R_{TH} = \frac{V_{oc}}{I_{sc}} = \frac{R_2 R_3}{R_2 + R_3}$$

Problem 3 [20 points]

Find an algebraic expression for the current i_x. Simplify as much as possible.



$$i_x = \left(\frac{V_1}{R_1} - I_1\right)\frac{R_1 R_2}{(R_1+R_2)(R_3+R_4)+R_1R_2}$$

@A $$I_1 + \frac{V_A}{R_2} + \frac{V_A - V_1}{R_1} + \frac{V_A}{R_3+R_4} = 0$$

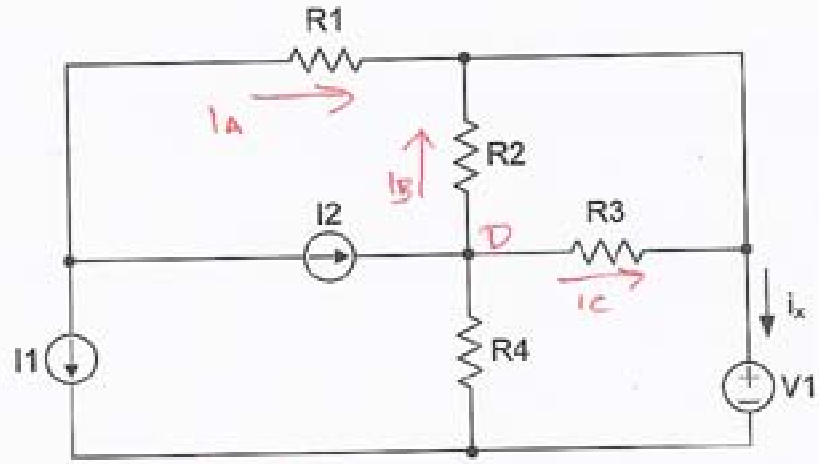
$$I_1 - \frac{V_1}{R_1} + V_A\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3+R_4}\right) = 0$$

$$V_A = \left(\frac{V_1}{R_1} - I_1\right)\frac{R_1R_2(R_3+R_4)}{R_2(R_3+R_4)+R_1(R_3+R_4)+R_1R_2}$$

$$I_x = \frac{V_A}{R_3+R_4} = \left(\frac{V_1}{R_1} - I_1\right)\frac{R_1R_2}{(R_2+R_1)(R_3+R_4)+R_1R_2}$$

Problem 4 [20 points]

Find an algebraic expression for the current i_x. Simplify your result to the extent possible.



$$I_x = I_A + I_B + I_C$$

$$i_x = -I_1 - I_2 + \left(I_2 + \frac{V_1(R_2+R_3)}{R_2R_3}\right)\frac{(R_2+R_3)R_4}{R_2R_3+R_2R_4+R_3R_4} - \frac{V_1(R_2+R_3)}{R_2R_3}$$

$$I_A = -I_1 - I_2$$

@D: $$\frac{V_D}{R_4} + \frac{(V_D-V_1)(R_2+R_3)}{R_2R_3} - I_2 = 0$$

$$V_D\,\frac{R_2R_3+(R_2+R_3)R_4}{R_2R_3R_4} = I_2 + \frac{V_1(R_2+R_3)}{R_2R_3}$$

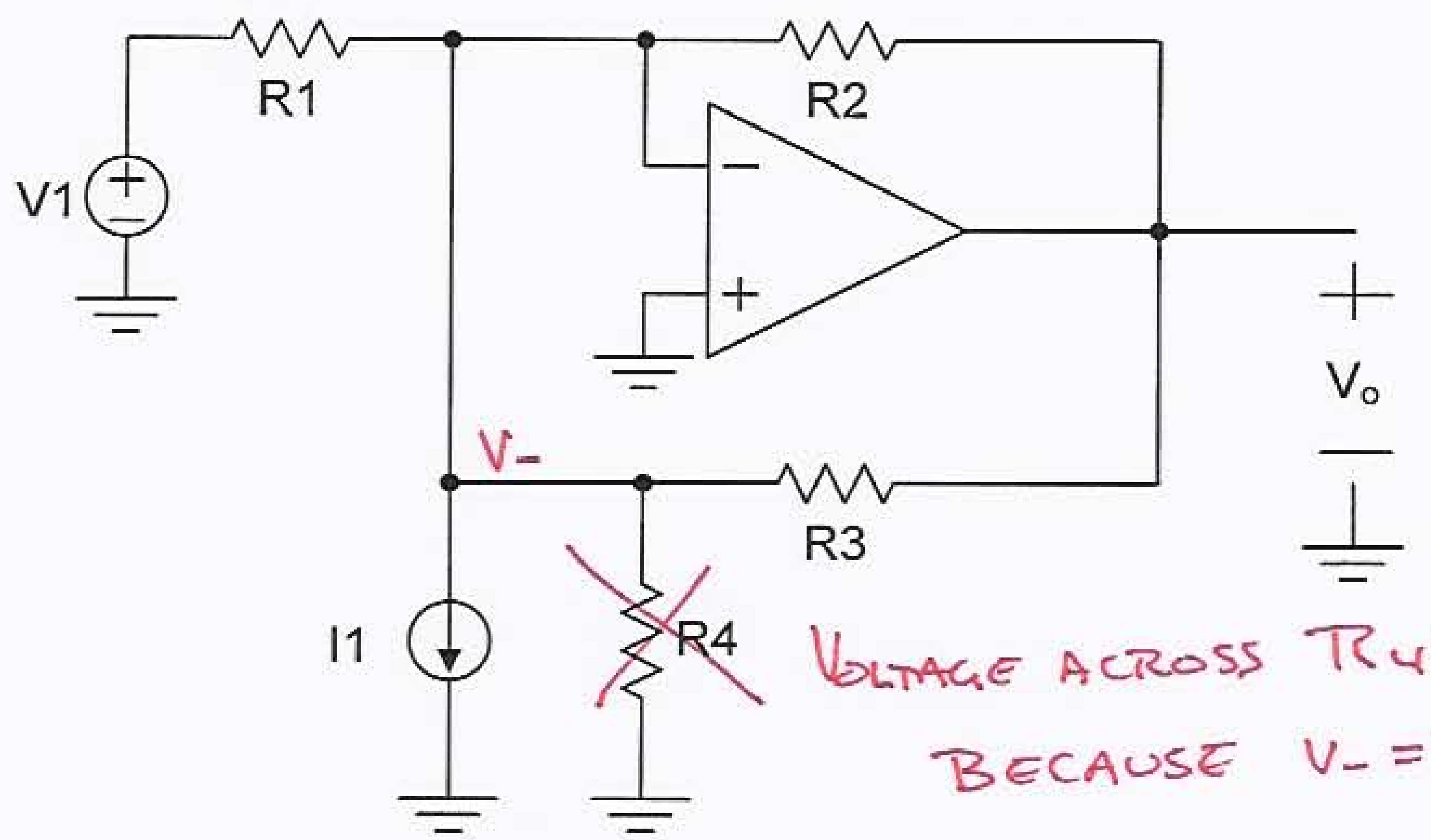
$$V_D = \left(I_2 + \frac{V_1(R_2+R_3)}{R_2R_3}\right)\frac{R_2R_3R_4}{R_2R_3+R_2R_4+R_3R_4}$$

$$I_B + I_C = \frac{V_D - V_1}{R_2 /\!/ R_3} = \left(I_2 + \frac{V_1(R_2+R_3)}{R_2R_3}\right)\frac{\cancel{R_2R_3}R_4}{R_2R_3+R_2R_4+R_3R_4}\cdot\frac{(R_2+R_3)}{\cancel{R_2R_3}} - \frac{V_1(R_2+R_3)}{R_2R_3}$$

$$= \left(I_2 + \frac{V_1(R_2+R_3)}{R_2R_3}\right)\frac{(R_3+R_2)R_4}{R_2R_3+R_2R_4+R_3R_4} - \frac{V_1(R_2+R_3)}{R_2R_3}$$

Problem 5 [20 points]

Find an algebraic expression for V_o as a function of I_1, V_1, and resistor values. Assume that the operational amplifier is ideal.



VOLTAGE ACROSS $R_4 = 0$

BECAUSE $V_- = V_+ = 0$.

$$V_o = \frac{R_2 R_3}{R_2 + R_3}\left(I_1 - \frac{V_1}{R_1}\right)$$

@ V_-: $$I_1 + \frac{V_- - V_o}{R_3 // R_2} + \frac{V_- - V_1}{R_1} = 0$$

$$I_1 + \frac{-V_o (R_2 + R_3)}{R_2 R_3} + \frac{-V_1}{R_1} = 0.$$

$$\frac{V_o (R_2 + R_3)}{R_2 R_3} = I_1 - \frac{V_1}{R_1}$$

$$V_o = \frac{R_2 R_3}{R_2 + R_3}\left(I_1 - \frac{V_1}{R_1}\right)$$