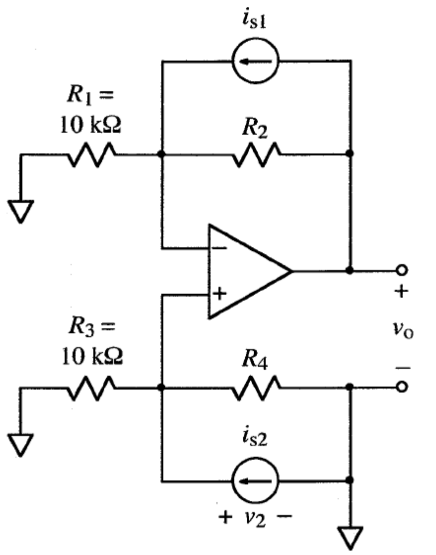
1.



The above circuit operates in linear mode. Derive a symbolic expression for v_o. The expression must contain not more than the parameters i_{s1}, i_{s2}, R_1, R_2, R_3, and R_4.

sol'n: a) First, we calculate v_p. No current flows into the op-amp, leaving a current divider. Equivalently, we have R_3 in parallel with R_4 driven by current source i_{s2}.

$$v_p = i_{s2} \cdot R_3 \| R_4$$

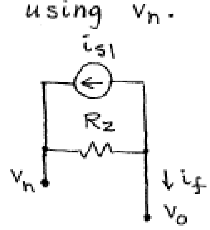
Since the op-amp is operating in linear mode, $v_n = v_p$.

$$v_n = v_p = i_{s2} \cdot R_3 \| R_4$$

Now we the current flowing toward the − input from the left

$$i_s = \frac{0V - v_n}{R_1} = -\frac{v_n}{R_1}$$

Since no current flows into the op-amp, we have the same current flowing in the feedback. We calculate the feedback current, i_f, using v_n.



$$i_f = -i_{s1} + \frac{v_n - v_o}{R_2}$$

We set $i_s = i_f$ and solve for v_o.

$$-\frac{v_n}{R_1} = -i_{s1} + \frac{v_n - v_o}{R_2}$$

or

$$\frac{v_o}{R_2} = -i_{s1} + \frac{v_n}{R_2} + \frac{v_n}{R_1}$$

or

$$v_o = -i_{s1} R_2 + v_n \left(1 + \frac{R_2}{R_1}\right)$$

or

$$v_o = -i_{s1} R_2 + i_{s2} \cdot R_3 \| R_4 \cdot \left(1 + \frac{R_2}{R_1}\right)$$

2.

If $i_{s1} = 10\ \mu A$ and $i_{s2} = 0\ \mu A$, find the value of $R_2 = R_4$ that will yield an output voltage of $v_o = 1$ V.

If $i_{s2} = 0\ \mu A$, then $v_p = 0$ V and $v_n = v_p = 0$ V. It follows that all of i_{s1} must flow thru R_2.
Thus,

$$v_o = -i_{s1} R_2$$

or

$$R_2 = \frac{v_o}{-i_{s1}} = \frac{1V}{-10\ \mu A}$$

or

$$R_2 = -100\ k\Omega$$

3.

Write a formula for the circuit's input resistance, R_{in}, as seen by source i_{s2}. In other words, write a formula for voltage, v_2, across i_{s2} divided by i_{s2}:

$$R_{in} \equiv \frac{v_2}{i_{s2}}$$

Write R_{in} in terms of not more (and possibly less) than R_1, R_2, R_3, and R_4.

v_2 is the voltage across i_{s2}, as shown in the diagram. $v_2 = v_p$, (the voltage at the + input).

$$v_2 = i_{s2} \cdot R_3 \| R_4 \quad \text{(see answer to part (a))}$$

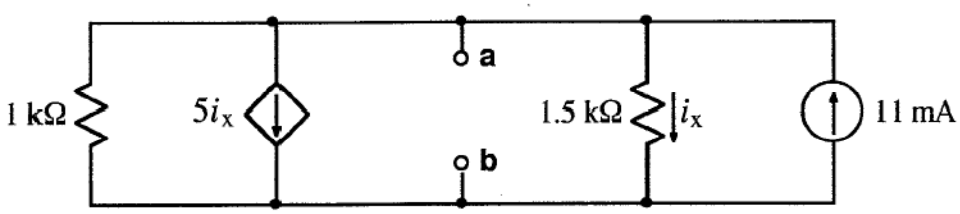
Using this result, we find R_{in}:

$$R_{in} = \frac{v_2}{i_{s2}} = \frac{i_{s2} R_3 \| R_4}{i_{s2}}$$

or

$$R_{in} = R_3 \| R_4$$

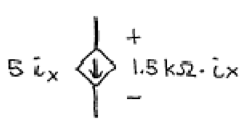
4.



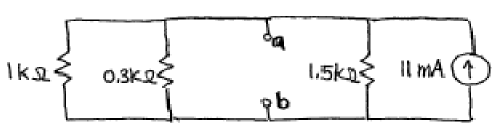
Find the Thevenin equivalent of the above circuit relative to terminals a and b.

We observe that the voltage across all the components is the same, and it is equal to $i_x \cdot 1.5\,k\Omega$.

For the dependent source, we may find an equivalent resistance:



$$R_{eq} = \frac{v}{i} = \frac{1.5\,k\Omega \cdot \cancel{i_x}}{5\,\cancel{i_x}} = 0.3\,k\Omega$$



The v_{Th} is the voltage across a, b and is equal to the 11 mA current times the combined parallel impedance.

$$v_{Th} = 11\,mA \cdot 1k\Omega \| 1.5k\Omega \| 0.3k\Omega$$

we have $1.5k\Omega \| 0.3k\Omega = 0.3k\Omega \cdot 5 \| 1$

$$= 0.3\,k\Omega \cdot \frac{5}{6}$$

$$= 250\Omega$$

and $1k\Omega \| 250\Omega = 250\Omega \cdot 4 \| 1$

$$= 250\Omega \cdot \frac{4}{5}$$

$$= 200\Omega$$

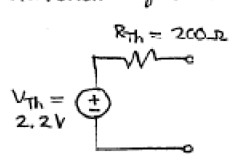
$$v_{Th} = 11\,mA \cdot 200\Omega = 2.2\,V$$

To find R_{Th}, we turn off the independent 11 mA source and look into a, b. We have

$$R_{Th} = 1k\Omega \| 1.5k\Omega \| 0.3k\Omega$$

or $R_{Th} = 200\,\Omega$

Thevenin equivalent:



5. a)

If we attach R_L to terminals **a** and **b**, find the value of R_L that will absorb maximum power.

b)

Calculate the value of that maximum power absorbed by R_L.

For max pwr transfer, we use

$$R_L = R_{Th} = 200\Omega.$$

When $R_L = R_{Th}$, we achieve the max pwr transfer:

$$P_{max} = \frac{V_{Th}^2}{4 R_{Th}}$$

$$'' = \frac{(2.2V)^2}{4(200\Omega)}$$

$$P_{max} = 6.05 \text{ mW}$$