Include units in your answers where appropriate.

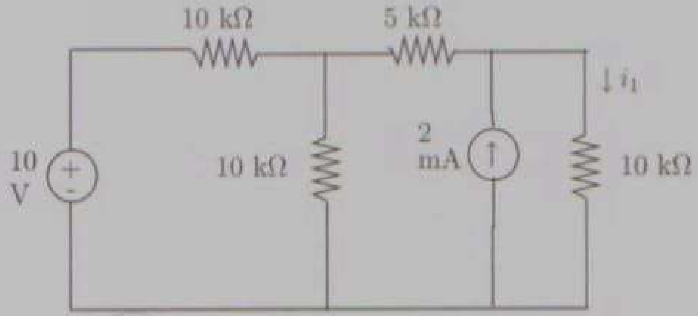
1. Circle T (true) or F (false) for each of these Boolean equations.

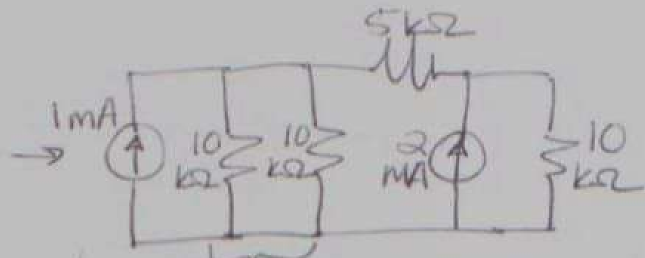
(a). T **F** A mesh is a loop with other loops inside it.
(b). **T** F A voltage source with series R transforms to a current source with R in parallel.
(c). **T** F The Thévenin equivalent voltage V_{TH} is the open-circuit voltage.
(d). **T** F Superposition sums the individual responses due to each independent source.
(e). T **F** Ideal op amps operate in saturation.

2. Source Transformations:

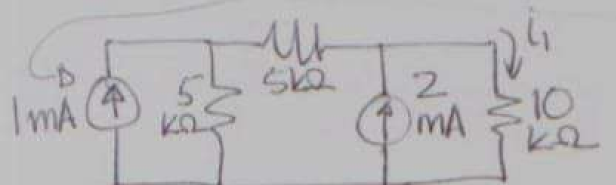
Using source transformation, find the current i_1 flowing through the 10 kΩ resistor in the circuit given below. Draw a small sketch of each transformation you make.

$$I_{S_1} = \frac{10\,V}{10\,k\Omega} = 1\,mA$$

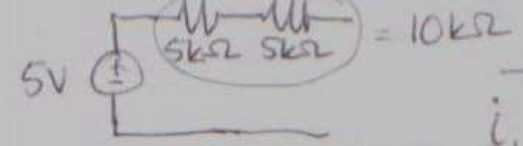


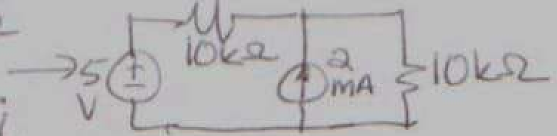


$10k\Omega \| 10k\Omega = 5k\Omega$

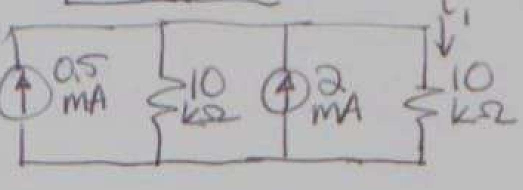


$$V_{S_2} = I_{S_1}(5k\Omega) = 1mA(5k\Omega) = 5V$$

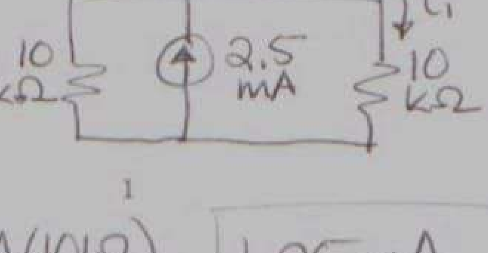




$$I_{S_3} = \frac{V_{S_2}}{10k\Omega} = \frac{5V}{10k\Omega} = 0.5\,mA$$



• Current sources in || add:
$0.5mA + 2mA = 2.5mA$

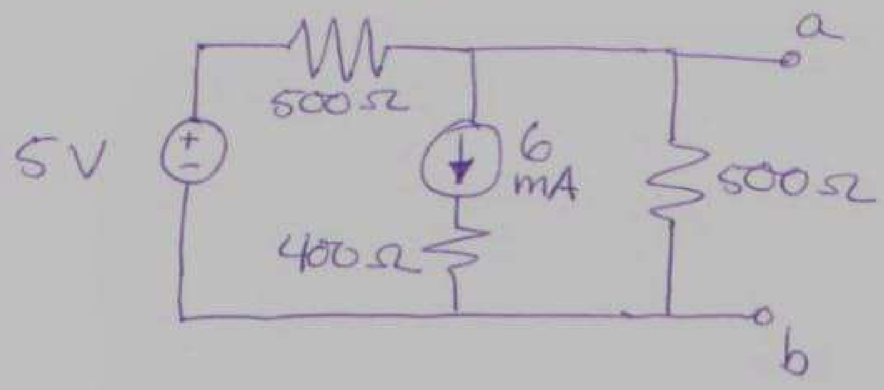


$\boxed{i_1 = 1.25mA}$

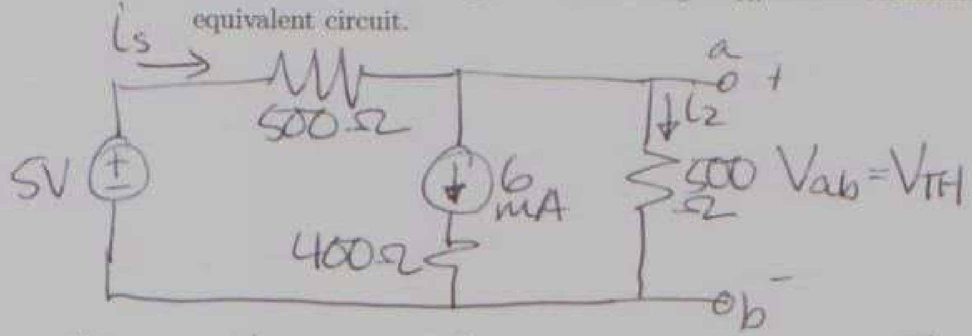
Use Current Divider:

$$i_1 = \frac{I_S(10k\Omega)}{10k + 10k\Omega} = \frac{2.5mA(10k\Omega)}{20k\Omega} = \boxed{1.25mA}$$

3. Thévenin's Equivalent Circuit with Independent Sources:
Given the resistive circuit below:



3(a). Find the open-circuit voltage V_{TH} across terminals a and b of the Thévenin equivalent circuit.



- Ohm's Law: $V_{TH} = 500 i_2$ or $i_2 = V_{TH}/500$
- KVL: $-5V + 500 \cdot i_s + V_{TH} = 0$

$i_s = (5 - V_{TH})/500$

- KCL at node a: $-i_s + 6mA + i_2 = 0$

Plug in values for $i_s + i_2$:

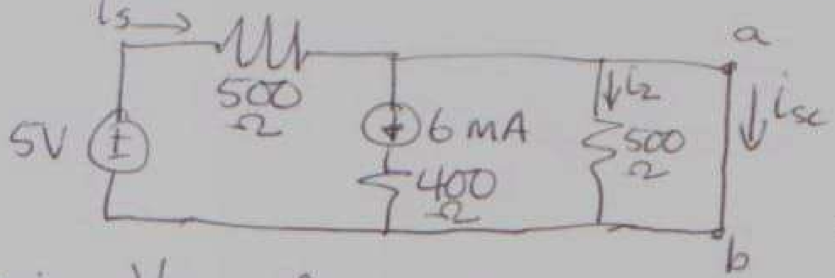
$-(5 - V_{TH})/500 + 6mA + V_{TH}/500 = 0$

$V_{TH}\left(\frac{1}{500} + \frac{1}{500}\right) = \frac{5}{500} - 6mA = (10-6)mA = 4mA$

$V_{TH} = 4mA\left(\frac{500}{2}\Omega\right) = 1000mV = 1V$

$\boxed{V_{TH} = 1V}$

3(b). Find the short-circuit current i_{sc} between terminals a and b of the circuit.



+
$V_{ab} = 0$ (only a wire connecting nodes a+b; no voltage drop btw a+b)
−

- $i_2 = \frac{V_{ab}}{500} = \frac{0}{500} = 0\ A$
- KVL: $-5 + 500 i_s + \underbrace{V_{ab}}_{=0} = 0$; $i_s = 5/500\ A = 10\ mA$

Node A:
- KCL: $-i_s + 6\ mA + \underbrace{i_2}_{=0} + i_{sc} = 0$

$i_{sc} = i_s - 6\ mA = (10-6)\ mA = 4\ mA$

$i_{sc} =$ 4 mA

3

3(c). Find the Thévenin resistance R_{TH} of the Thévenin equivalent circuit, using your results for parts 3(a) and 3(b) above.

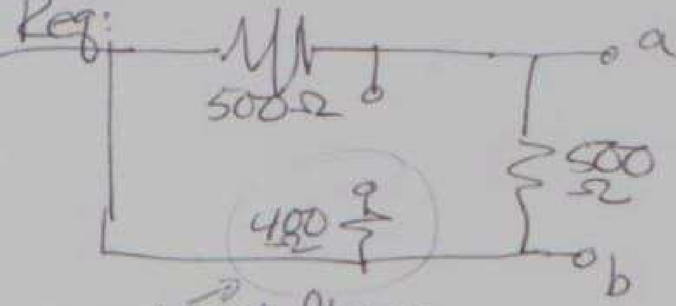
$$R_{TH} = V_{TH}/i_{sc} = \frac{1\ V}{4\ mA} = 250\ \Omega$$

$R_{TH} =$ 250 Ω

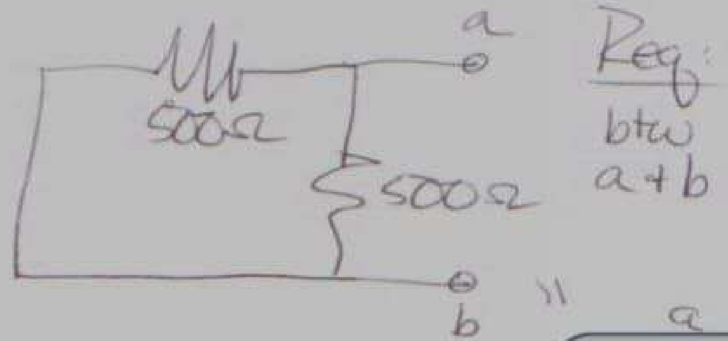
3(d). Find the Thévenin resistance R_{TH} of the Thévenin equivalent circuit by finding the equivalent resistance R_{eq} with respect to terminals a and b when all independent sources are removed (deactivated).

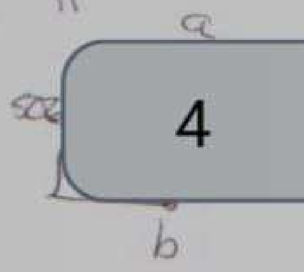
To deactivate voltage source → short circuit
To deactivate current source → open circuit

Req:



=





no current flows through 400Ω, so it has no effect

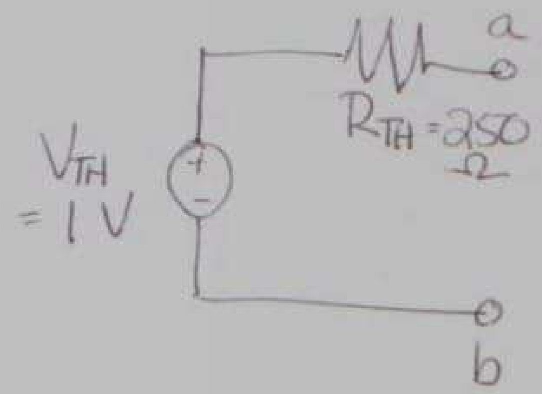
$$R_{eq} = 500 \| 500 \ \Omega = \frac{500(500)}{500+500}\ \Omega = \frac{500(\cancel{500})}{2(\cancel{500})} = 250\ \Omega$$

$\boxed{R_{TH} = 250\ \Omega}$

3(e). Are your results for R_{TH} in parts 3(c) and 3(d) the same?
(circle one): Yes No

Should they be the same?
(circle one): Yes No

3(f). Draw your Thévenin equivalent circuit below.



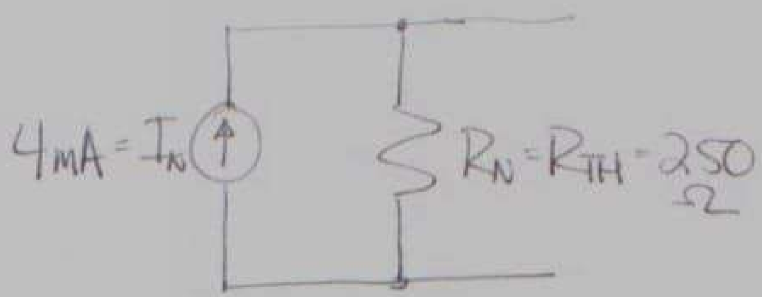
5. Norton's Equivalent Circuit:

5(a). Find the Norton equivalent circuit for the circuit given in problem 4. What is the Norton current source, I_N?

$$I_N = V_{TH}/R_{TH} = \frac{1\text{ V}}{250\,\Omega} = 4\text{ mA}$$

$\boxed{I_N = 4\text{ mA}}$

5(b). Draw your Norton equivalent circuit below.



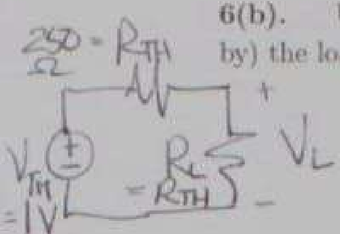
6. Maximum Power Transfer:

6(a). Using the circuit in problem 4, what value of load resistance R_L will provide the maximum power transferred to the load R_L? You don't have to prove what value will provide maximum power, just use the appropriate value of R_L that does provide maximum power.

$$R_L = R_{TH} = 250\,\Omega$$

$\boxed{R_L = 250\,\Omega}$

6(b). Using the value of R_L obtained above, find the power P_L transferred to (or absorbed by) the load R_L.



$$P_L = \cancel{\tfrac{1}{2}}V_L^2/R_L = V_L^2/R_{TH} \;;\; V_L = \frac{V_{TH}R_L}{R_{TH}+R_L} = \frac{V_{TH}R_{TH}}{2R_{TH}} = \frac{V_{TH}}{2}$$

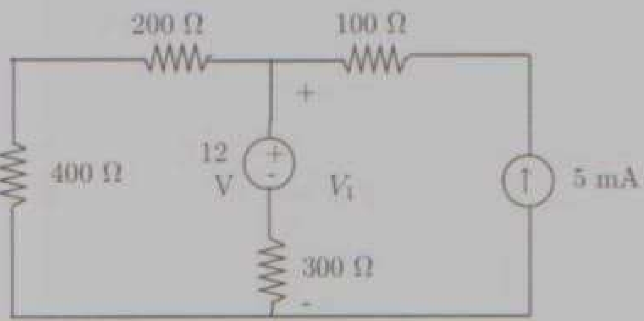
(voltage divider)

$$P_L = \frac{(V_{TH}/2)^2}{R_{TH}} = \frac{V_{TH}^2}{4R_{TH}} = \frac{1}{4(250)} = \frac{1}{1000} = 1\text{ mW}$$

$\boxed{P_L = 1\text{ mW}}$

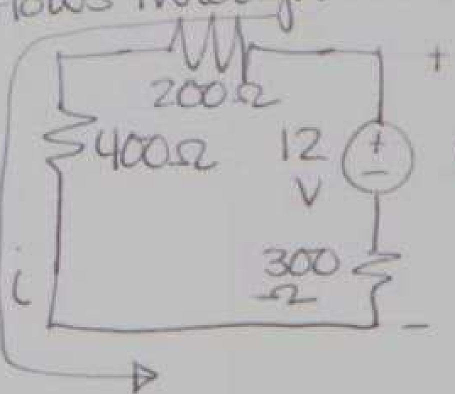
7. Superposition:

Use superposition on the circuit below to find the voltage V_1.



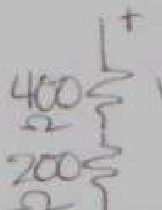
7(a). Find the voltage V_1' due to the 12 V voltage source alone.

• Deactivate current source: becomes open circuit; no current flows through 100Ω R so can ignore it



• Current i flows from + to − terminal of 12 V source

• V_1' = voltage across 12 V source − 300Ω·i
= voltage across 400 + 200 Ω resistors



• Use voltage divider:

$V_S = 12V$

$$V_1' = \frac{V_S(400+200)}{400+200+300} = \frac{V_S(600)}{900} = \frac{12(2)}{3} = 8V$$

6

$\boxed{V_1' = 8V}$

or use KVL

• $-i(400+200) + V_1' = 0;\ V_1' = 600i$

• $-i(400+200) + 12 - i(300) = 0;\ 900i = 12;\ i = 12/900$

$V_1' = 600\left(\frac{12}{900}\right) = 8V$ (same eqn as voltage divider)