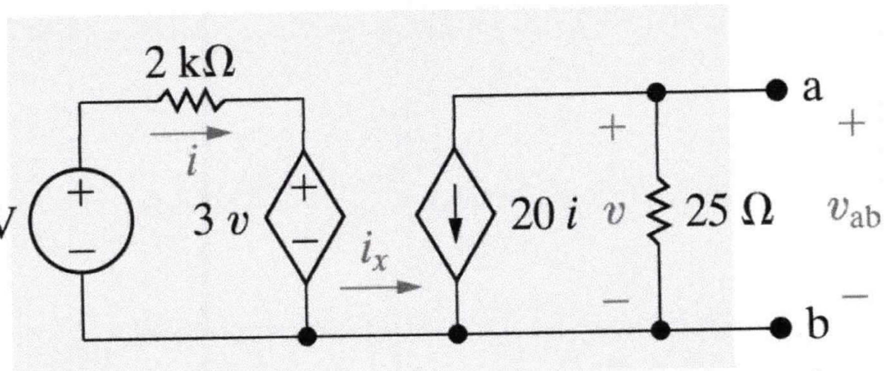
Problem 1

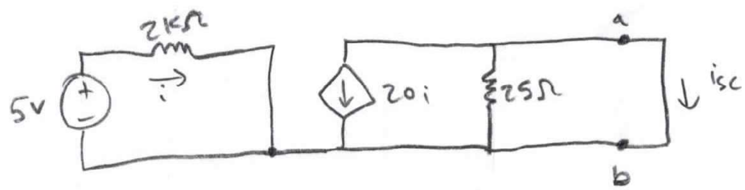
Find the Thévenin equivalent for the circuit containing dependent sources shown below:



$i_x = 0 \Rightarrow V_{Th} = v_{ab} = (-20i)(25) = -500i$ $\quad i = \frac{5-3v}{2000} = \frac{5-3V_{Th}}{2000} \Rightarrow 2000i = -4V_{Th} = 5-3V_{Th}$

$\Rightarrow \boxed{V_{Th} = -5V}$

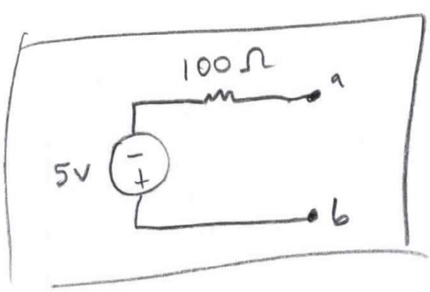
Next find short-circuit circuit



$i_{sc} = -20i \qquad i = \frac{5}{2000} = 0.0025 \Rightarrow i_{sc} = -20(0.0025) = -0.050$

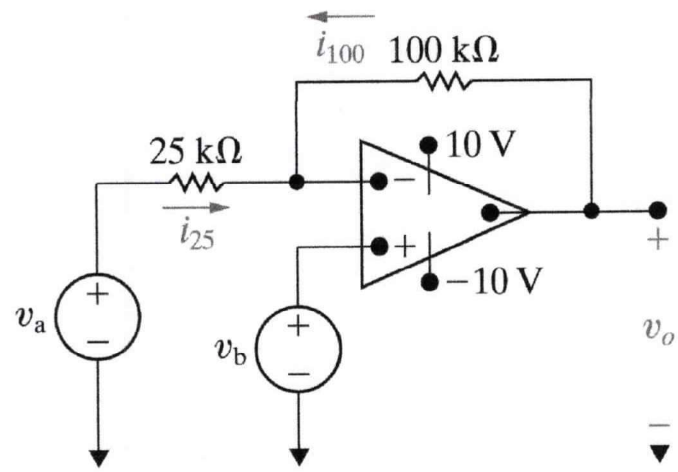
$R_{Th} = \frac{V_{Th}}{i_{sc}} = \frac{-5}{-0.050} = 100\Omega$

Thus,



Problem 3

The op amp shown is ideal. Calculate v_0 if $v_a = 1V$ and $v_b = 0V$. Repeat for $v_a = 1V$ and $v_b = 2V$. If $v_a = 1.5V$, specify the range of v_b that avoids amplifier saturation.



$$\frac{0 - V_o}{100000} + \frac{0 - 1}{25000} = 0 \Rightarrow \frac{V_o}{100} = \frac{-1}{25} \Rightarrow \boxed{V_o = -4V}$$

$$\frac{2 - V_o}{100000} + \frac{2 - 1}{25000} = 0 \Rightarrow \frac{2}{100} - \frac{V_o}{100} + \frac{1}{25} = 0 \Rightarrow \frac{3}{50} = \frac{V_o}{100} \Rightarrow \boxed{V_o = 6V}$$

$$\frac{V_b - 1.5}{25000} + \frac{V_b - V_o}{100000} = 0 \Rightarrow V_b\left(\frac{1}{25} + \frac{1}{100}\right) = \frac{1.5}{25} + \frac{V_o}{100}$$

$$V_b = \frac{4}{5} \cdot \frac{3}{2} + \frac{V_o}{5} = \frac{1}{5}(6 + V_o)$$

$$5V_b - 6 = V_o$$

$$-10 \le V_o \le 10$$

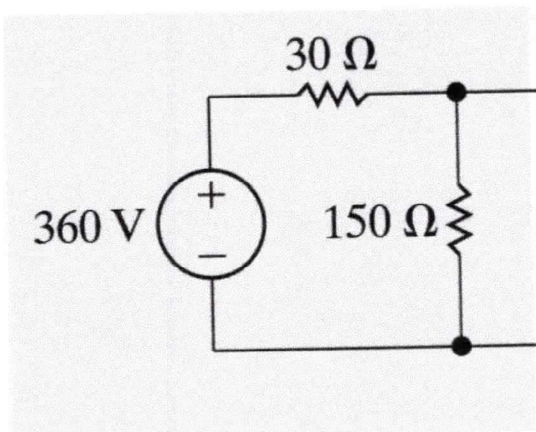
$$-10 \le 5V_b - 6 \le 10$$

$$-4 \le 5V_b \le 16$$

$$\boxed{-0.8 \le V_b \le 3.2}$$

Problem 4

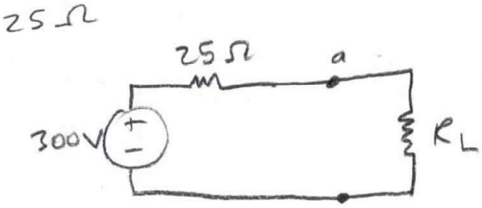
For the circuit shown below, find the value of R_L that results in maximum power being transferred to R_L. Calculate the maximum power that can be delivered to R_L. When R_L is adjusted for maximum power transfer, what percentage of the power delivered by the 360V source reaches R_L?



V_{Th} for shaded part of circuit $\quad V_{Th} = \frac{150}{150+30}(360) = 300V$

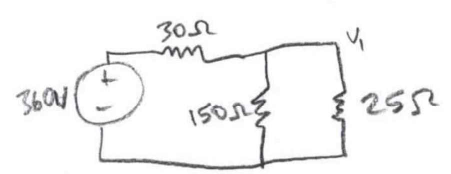
$R_{Th} = \frac{150 \cdot 30}{150+30} = 25\Omega$

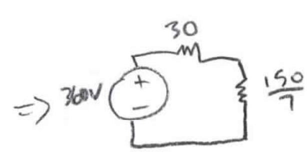
Now we have



R_L must equal R_{Th} for max power transfer $\Rightarrow \boxed{R_L = 25\Omega}$

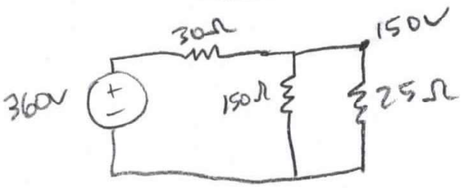
$P_{max} = \frac{V_{Th}^2}{4R_L} = \frac{300^2}{100} = \boxed{900W}$





$\frac{150 \cdot 25}{150+25} = \frac{150}{7}$

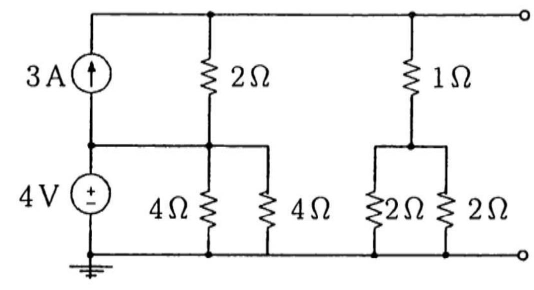
$\Rightarrow V_1 = \frac{\frac{150}{7}}{30 + \frac{150}{7}} \cdot 360 = 150$

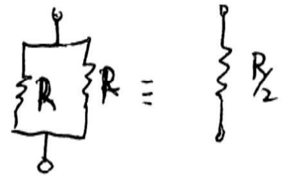


Total power is $\frac{(360-150)^2}{30} + \frac{150^2}{150} + \frac{150^2}{25} = 1470 + 150 + 900$

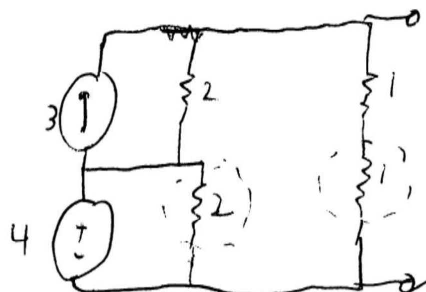
Percentage in R_L is $\frac{900}{2520} \cdot 100 = \boxed{35.71\%}$

(d) (10 pt) Reduce the following circuit to its Thevenin Equivalent, that is find V_T , R_T .

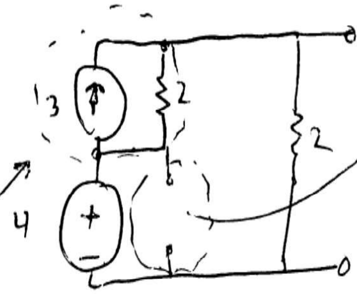




since $R_{\|} = \frac{1}{\frac{1}{R}+\frac{1}{R}} = \frac{1}{\frac{2}{R}} = \frac{R}{2}$, so the circuit above simplifies to



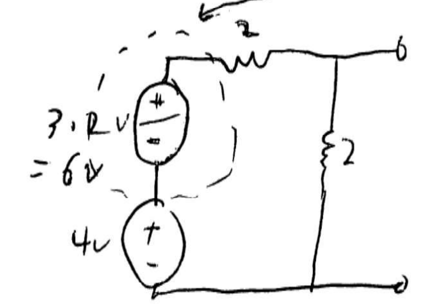
$\equiv$



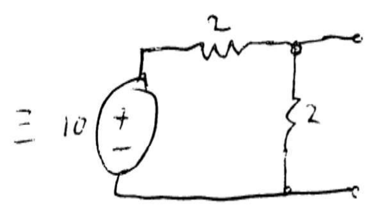
This resistor does not affect output at all, because it's in parallel with a voltage source that will maintain a fixed voltage and current across it regardless!

Thevenin to Norton transformation

$\equiv$

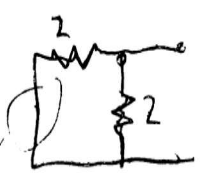


$\equiv$



$V_{\text{open circuit}} = \frac{2}{2+2} \cdot 10v = 5v$ (voltage divider)

$R_{Thev} \rightarrow$

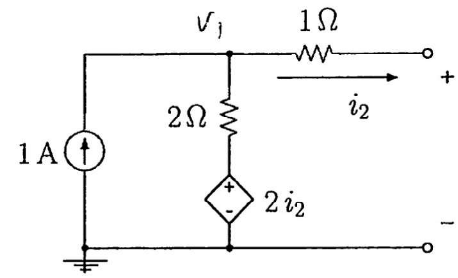


$= 2\|2 = \frac{1}{\frac{1}{2}+\frac{1}{2}} = \frac{1}{1} = 1$

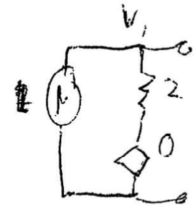
replace independent voltage source with short circuit

$V_T =$ 5 v
$R_T =$ 1 Ω

(b) (15pt) Find the Thevenin Equivalent Circuit.

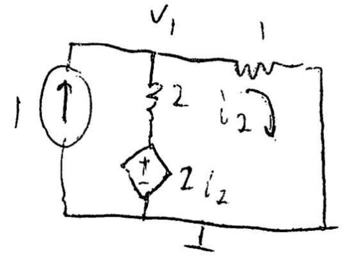


(i) $V_{\text{open circuit}} = V_{Thev}$ $i_2 = 0$ so $v_1 = V_{o.c.}$



$1 = \frac{v_1}{2} \rightarrow v_1 = 2 = V_{oc} = \boxed{V_{THEV} = 2}$

(ii) $i_{\text{short circuit}} = i_{sc}$:



$i_2 = i_{sc} = \frac{v_1}{1} = v_1$

KCL at v_1:

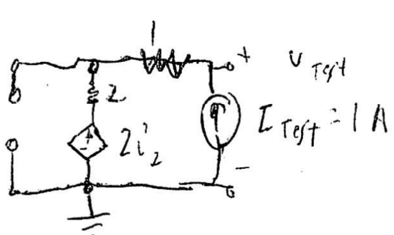
$1 = \frac{v_1 - 2i_2}{2} + \frac{v_1}{1} = \frac{v_1 - 2v_1}{2} + \frac{v_1}{1} = \frac{-v_1}{2} + v_1 = \frac{v_1}{2}$

$v_1 = 2 \cdot 1 = 2$

$i_{sc} = \frac{2}{1} = \boxed{2 = i_N}$

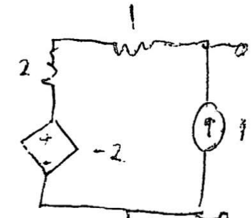
(iii) $R_{Thev} = \frac{V_{oc}}{i_{sc}} = \frac{2}{2} = \boxed{1\Omega = R_{Thev}}$

Alternatively, use test method



$i_2 = -1A$

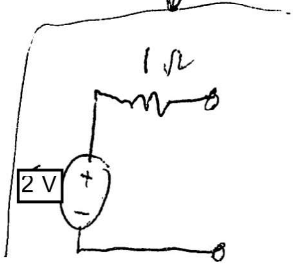
so dependent source



$V_{Test} = 1 \cdot I_{test} + 2 \cdot I_{test} - 2I_{test} = I_{test} = 1$

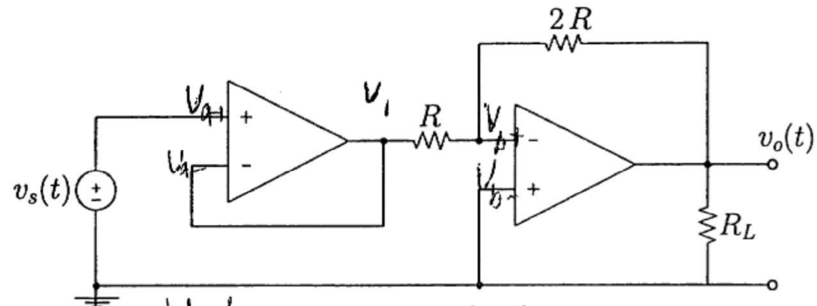
$R_{Thev} = \frac{1}{1} = 1$

Thevenin equivalent circuit



3. Problem 3 (25 points)

(a) (19 pt) Analyze the following circuit and find v_0/v_s . Use the ideal op-amp approximations.



ideal op-amp approximation

Step 1: find v_1: $V_{a+} = V_{a-} = V_s(t)$

But $V_1 = V_{a-} \rightarrow V_1 = V_s(t)$

Step 2: $V_{b-} = 0 = V_{b+}$

KCL at V_{b-} gives

$$\frac{V_1}{R} = \frac{0 - v_0(t)}{2R} = \frac{V_s}{R} \quad \text{So} \quad \frac{V_0}{V_s} = \frac{-2R}{R} = -2$$

$\boxed{\frac{v_0}{v_s} = -2}$

(b) Find the power absorbed/supplied in R_L if

i. (2pt) $R_L = 3\,\Omega$

$$P_L = V_0(t)\, i_L(t) = \frac{v_0^2(t)}{R_L} = \frac{(2V_s(t))^2}{3} = \frac{4}{3} V_s^2(t)$$

$\boxed{p = \frac{4}{3} V_s^2(t)}$

ii. (2pt) $R_L = 0\,\Omega$

$V_0(t) = 0$ [Deviates from ideal op-amp approximations; Power consumed internally across $R_{b,out}$]

So $V_0(t) \cdot i_L(t) = 0$; $i_L(t) = 0$

$\boxed{p = 0}$

iii. (2pt) $R_L = \infty\,\Omega$

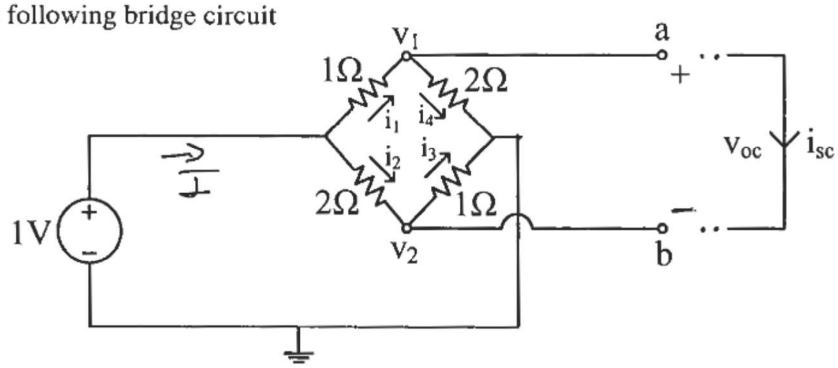
$$V_0(t) = 2V_s(t), \quad i_L(t) = \frac{2V_s(t)}{\infty} = 0$$

$\boxed{p = 0}$

$p = v \cdot i = v \cdot 0 = 0$

Problem 2 *(25 points)*

Analyze the following bridge circuit



(a) The terminal v_1 and v_2 are open. Calculate v_1, v_2, and v_{oc}.

$v_1 = \frac{1}{3} \cdot 2 = \frac{2}{3}$ $\quad v_2 = \frac{1}{3} \cdot 1$

$v_{oc} = v_1 - v_2$

$v_1 =$ $2/3$

$v_2 =$ $1/3$

$v_{oc} =$ $1/3$

(b) The terminals v_1 and v_2 are shorted together calculate i_1, i_2, i_3, i_4, and i_{sc}.

$I = \dfrac{1}{\frac{2}{3} + \frac{2}{3}} = \dfrac{3}{4}$ $\quad i_1 = \frac{3}{4} \cdot \frac{2}{3} = \frac{1}{2}$

$i_2 = \frac{3}{4} \cdot \frac{1}{3} = \frac{1}{4}$

$i_3 = \frac{1}{2}$

$i_4 = 1/4$

$i_1 =$ $1/2$

$i_2 =$ $1/4$

$i_3 =$ $1/2$

$i_4 =$ $1/4$

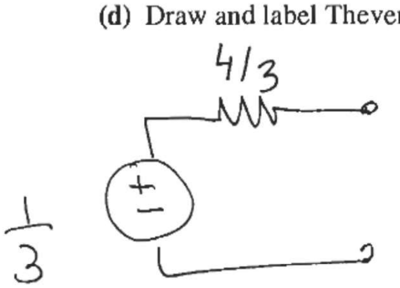
$i_{sc} =$ $i_1 - i_4 = \frac{1}{2} - \frac{1}{4} = \frac{1}{4}$

(c) Compute the Thevenin resistance of the circuit between a and b.

$$R_T = \frac{V_T}{I_{sc}} = \frac{1/3}{1/4} = \frac{4}{3}$$

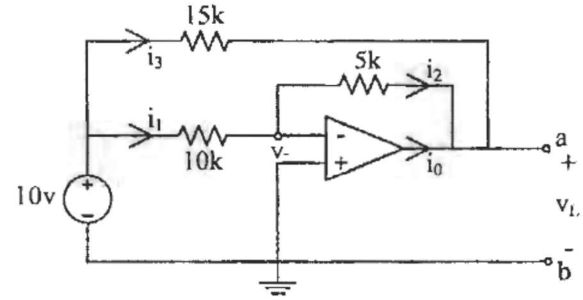
$R_T =$ $\frac{4}{3}$

(d) Draw and label Thevenin and Norton equivalent circuits between a and b.



Problem 3 *(25 points)*

Consider the following op-amp circuit.



(a) Find v_-, i_1, i_2, i_3, i_0, and v_L.

$V_+ = V_- = 0\,V$ (given)

$\therefore I_1 = \frac{10V - 0}{10k\Omega} = 1mA$

$\therefore I_2 = I_1 = 1mA$ (because current cannot enter input of op amp)

$\therefore$ For 5K resistor, $\frac{0 - V_{OUT}}{5K} = I_2 = 1mA$

$\therefore V_{OUT} = -5V$

$\therefore$ For 15K resistor, $\frac{10V - (-5V)}{15K} = 1mA = I_3$

Finally, $I_0 = I_2 + I_3 = -2mA$

$v_- =$ 0 V (+3)

$i_1 =$ 1 mA (+3)

$i_2 =$ 1 mA (+3)

$i_3 =$ 1 mA (+3)

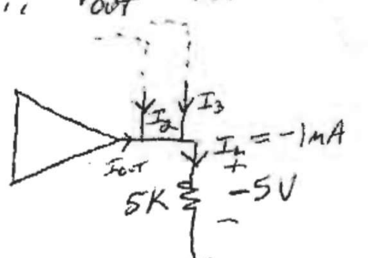
$i_0 =$ −2 mA (+3)

$v_L =$ −5 V (+3)

(b) If you connect $R_L = 5k\Omega$ between a and b, what is v_L and i_0?

Connection of a $5k\Omega$ load does not affect I_1 & I_2. Neither does I_3 change.

$\therefore V_{OUT}$ remains at −5V.



$\therefore$ with the load,

$I_{OUT} = -[I_2 + I_3 - I_L]$

$= -[1mA + 1mA - (-1mA)]$

$= -3mA$

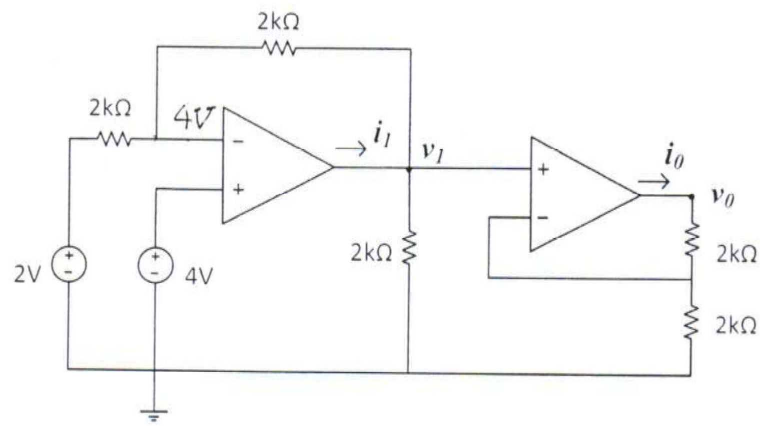
$i_0 =$ − 3 mA (+3)

$v_L =$ − 5 V (+4)

(Problem 3 cont'd)

(b) In the following circuit, assuming linear operation and ideal op-amp approximation, determine the node voltages v_0, v_1, and the currents i_0, i_1.

10 Pts



$v_0 =$ 12 V

$v_1 =$ 6 V

$i_0 =$ 3 mA

$i_1 =$ 4 mA

Apply KCL at the "−" input of the first op-amp.

$$\frac{4-2}{2k} = \frac{v_1-4}{2k} \longrightarrow v_1 = 6\,V$$

Apply KCL at the output of the first op-amp.

$$i_1 = \frac{v_1}{2k} + \frac{v_1-4}{2k} = 4\,mA.$$

Apply KCL at the "−" input of the second op-amp.

$$\frac{v_0-v_1}{2k} = \frac{v_1}{2k} \longrightarrow v_0 = 2v_1 = 12\,V$$

Apply KCL at the output of the second op-amp

$$i_0 = \frac{v_0}{4k} \longrightarrow i_0 = 3\,mA$$