Exam #2

Student **FULL** Name: ____

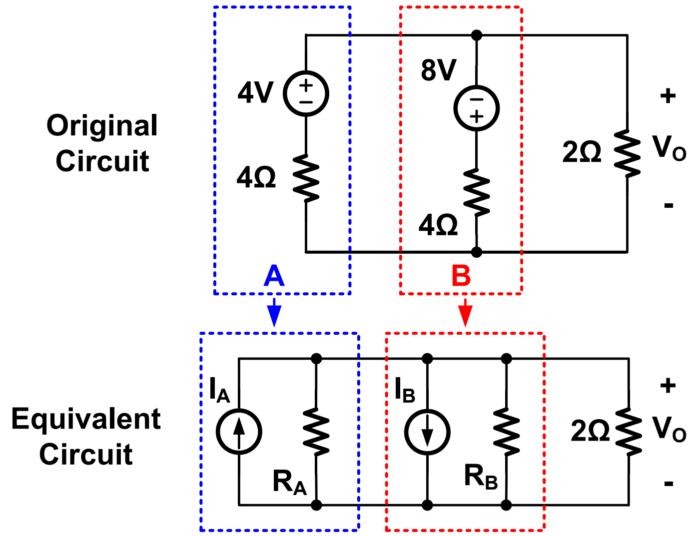
Lab Section: ____

Write your FULL name (the same as how you put in the system) as CLEAR as possible!

You are allowed one 8.5” × 11” sheet of prepared notes, a pen or pencil, and a calculator. No internet connected devices are allowed. Write legibly. For maximum credit, state all assumptions and show all work in a clear manner.

Problem #	Points Possible	Points Earned
1	10	
2	30	
3	15	
4	35	
Submitted Note Sheets and Scratch Papers	10	

Problem 1 Source Transformation: (10 pts)



Use the source transformation method to convert the original circuits at the top to the equivalent circuit at the bottom.

a) Find I_A and R_A. [4 pts]

R_A remain the same : $R_A = 4\Omega$ ※

$I_A = \frac{4V}{4\Omega} = 1A$ ※

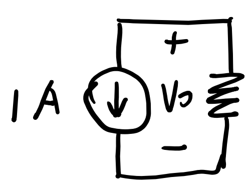
b) Find I_B and R_B. [4 pts]

$R_B = 4\Omega$

$I_B = \frac{8V}{4\Omega} = 2A$ ※

c) Combine the current sources and resistors in the equivalent circuit, Find V_O. [2 pts]

I_B goes down, I_A goes up, $I_B > I_A$:

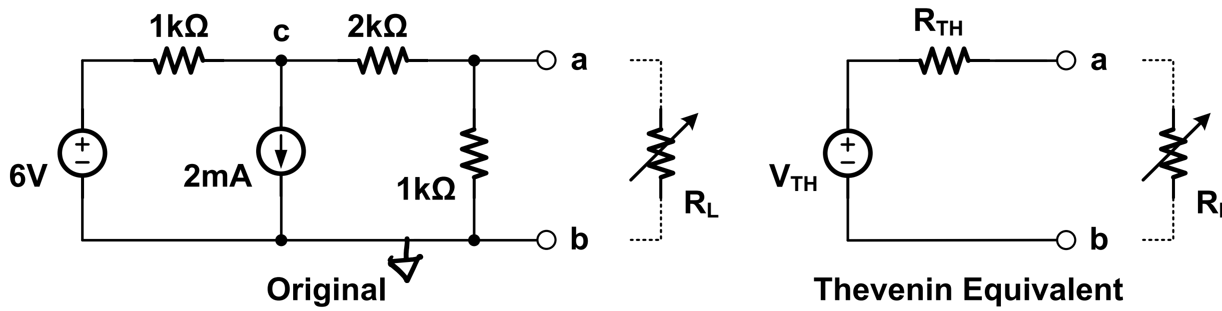


$R_{eq} = (4 // 4) // 2 = 1\Omega$

$V_o = -1 \times 1 = -1V$ ※

↑ mind the direction

Problem 2: Thevenin and Norton Equivalent (30 pts)



The above figure shows the original circuit, and its Thevenin Equivalent circuit. Nodes "a" and "b" is the two terminals that loading will be attached to.

a) Find V_{TH}. (Node-voltage method recommended, but you may use any other methods of your choice.) [10 pts]

$$\frac{V_c - 6}{1k} + 2m + \frac{V_c}{3k} = 0$$

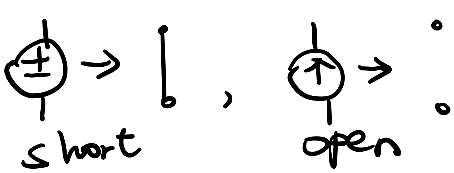
$$3V_c - 18 + 6 + V_c = 0$$

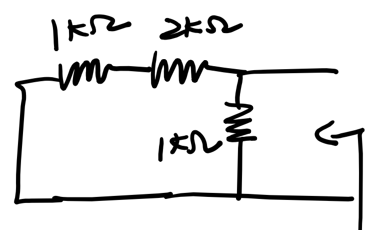
$$4V_c = 12, \quad V_c = 3\,V$$

$$V_{TH} = V_a = V_c \times \frac{1k}{2k + 1k} = 3 \times \frac{1}{3} = 1\,V$$

b) Find R_{TH}. (You can use any method that applies.) [10 pts]

No dependent sources: Deact (Method 2)





$$3k \,//\, 1k = R_{eq} = \frac{3 \times 1}{4}\,k\Omega = 750\,\Omega$$

c) In order to extract the maximum power, how much should the load resistor (R_L) be attached between nodes "a" and "b"? [3 pts] What is the maximum power delivered to that R_L? [2 pts]

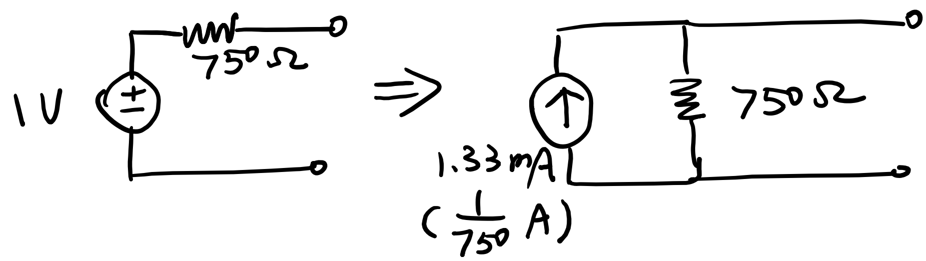
$R_L = R_{TH}$ for maximum power,

so $R_L = 750\,\Omega$.

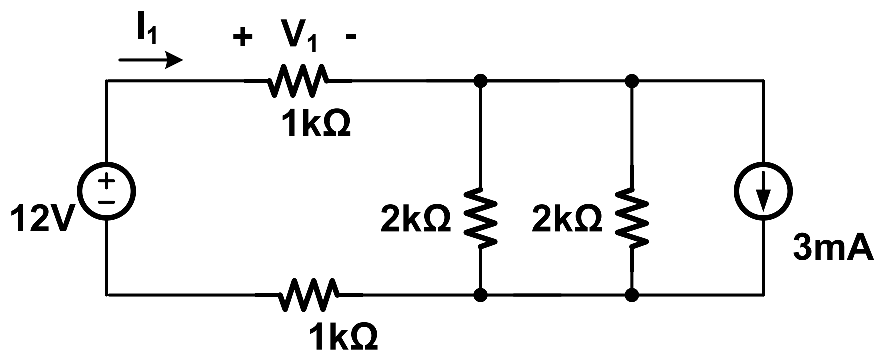
$$P_{max} = \frac{\left(\frac{1}{2}V_{TH}\right)^2}{R_L} = \frac{0.5^2}{750} = 0.333\,mW$$

or $\frac{1}{3}\,mW$.

d) Draw the Norton equivalent circuit of the original circuit. Find out the value of each elements (I_N and R_N) [5 pts]



Problem 3: Superposition (15 pts)

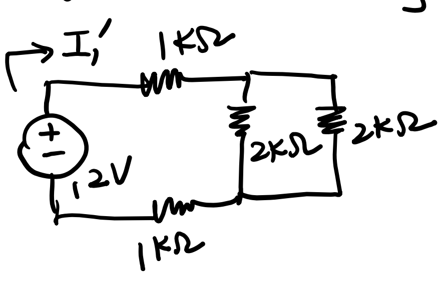


a) When deactivating an independent voltage source, should it be shorted or opened? [2 pts]

b) When deactivating an independent current source, should it be shorted or opened? [2 pts]

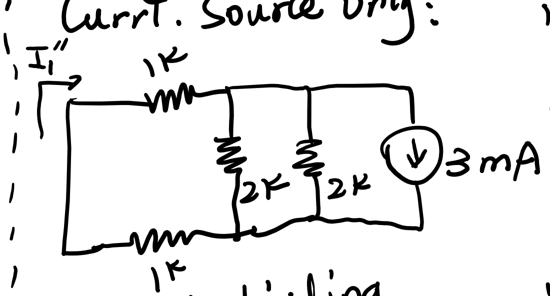
c) Find I_1 of the above circuit using superposition method (Looking at one source at a time by deactivating the other sources. **No other methods!**). [11 pts]

Volt. Source only:



$$I_1' = \frac{12}{1K + 1K + 2K // 2K} = \frac{12}{3K} = 4mA$$

Curr. Source only:



Current dividing in 3 identical paths (1KΩ each)

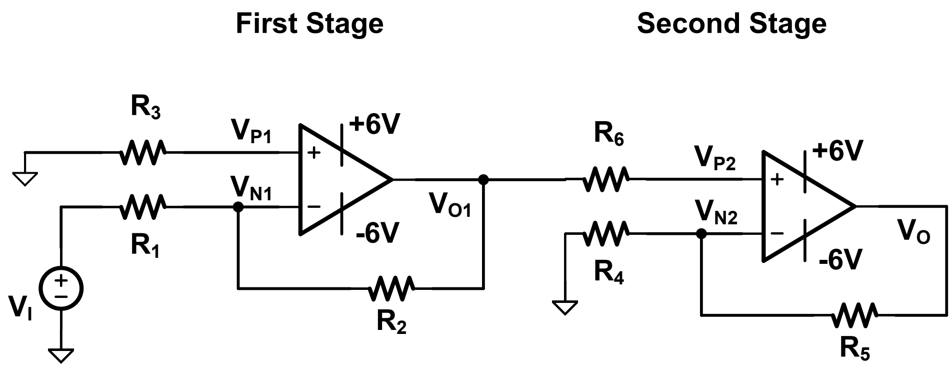
$I_1'' = 1mA$

Combined

$I_1 = I_1' + I_1''$

$= 5mA$

Problem 3: Op-amp circuits (35 pts)



Two op-amp circuits are connected in series. The op-amps are ideal. The supplies are +/- 6V.

a) Find the voltage gain equation of the **first stage** V_{O1}/V_I. (10 pts)

R_3 is a dummy Resistor, no current is pass it.

$V_{N1} = V_{P1} = 0\,V$, $\frac{0 - V_I}{R_1} = \frac{0 - V_{01}}{R_2} \Rightarrow \frac{V_{01}}{V_I} = -\frac{R_2}{R_1}$ ※

(inverting Amp.)

b) Find the voltage gain equation of the **whole circuit** V_O/V_I. (10 pts)

R_6 is a dummy as well, as no current goes into V_{P2}.

$V_{P2} = V_{01}$, $\frac{V_{N2}}{R_4} + \frac{V_{N2} - V_0}{R_5} = 0$, $\frac{V_{01}}{R_4} + \frac{V_{01} - V_0}{R_5} = 0$,

$V_{N2} = V_{P2} = V_{01}$. $\frac{V_0}{V_{01}} = 1 + \frac{R_5}{R_4}$, $\frac{V_0}{V_I} = \frac{V_0}{V_{01}} \times \frac{V_{01}}{V_I} = -\frac{R_2}{R_1}\left(1 + \frac{R_5}{R_4}\right)$ ※

c) If $R_1=R_4=1k\Omega$, $R_2=R_5=2k\Omega$, $R_3=R_6=3k\Omega$, find V_{O1} and V_O when $V_I=2V$. (*Don't forget to check whether the output voltage is valid or not by comparing with the supply voltages.*) (6 pts)

$V_{01} = V_I \times \left(-\frac{R_2}{R_1}\right) = 2 \times \left(-\frac{2k}{1k}\right) = -4\,V.$

$-6 \le -4 \le 6\,V \Rightarrow$ Valid ※.

$V_0 = V_I \times \left(-\frac{R_2}{R_1}\right)\left(1 + \frac{R_5}{R_4}\right) = 2 \times \left(-\frac{2k}{1k}\right)\left(1 + \frac{2k}{1k}\right) = 2 \times (-2) \times 3 = -12\,V$

$-12V < -6$, so invalid! $V_0 = -6\,V$ ※.

d) If $R_1=R_4=1k\Omega$, $R_2=R_5=2k\Omega$, $R_3=R_6=3k\Omega$, what is the maximum input voltage (V_I) to ensure that neither of the amplifiers is saturated? (*Hint: you will need to look at both V_{O1} and V_O.*) (9 pts)

$-6V \le V_{01} \le 6V$ $\quad$ $-6V \le V_0 \le 6V$

$-6V \le -2V_I \le 6V$, $\quad$ $-6V \le (-2) \times 3\, V_I \le 6V$

$-3V \le V_I \le 3V$ $\quad$ & $\quad$ $-1V \le V_I \le 1V$,

so to satisfy both conditions,

$-1V \le V_I \le 1V$ ※