Name: Solution Student ID:

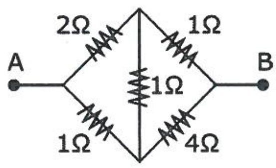
Solution attached

National Taiwan Normal University
Department of Computer Science and Information Engineering

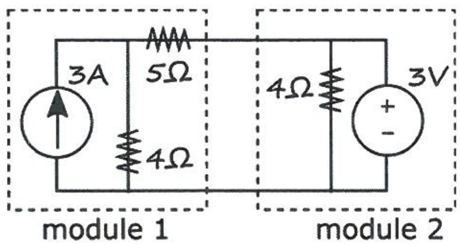
CSU0007 - Basic Electronics
Midterm Exam (Nov. 13, 2020)

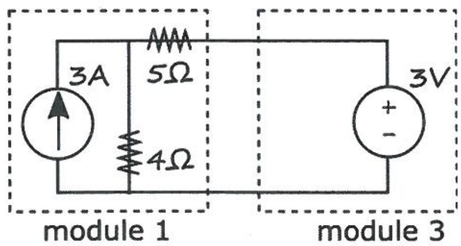
Exam time: 2 hours (3:30pm-5:30pm)
Clearly label your answer, and clearly state each step of your answer.

1. (20 points) **KCL and KVL.** For the following circuit, determine the equivalent resistance from the view of A-B. (Hint: attach a testing voltage source).



2. (30 points) **Circuit Transformation.** For the following circuits, answer two questions.
   2a. (20 points) Is it true that module 2 and module 3 are equivalent from the view of module 1? Explain you answer.
   2b. (10 points) In Homework 3, we have discussed a plausible approach of determining the Thévenin equivalent resistance by using only a multimeter. Now, think about the circuits given here and give one reason why in reality we may still choose to use a potentiometer (i.e., a variable resistor) to determine the Thévenin equivalent resistance.

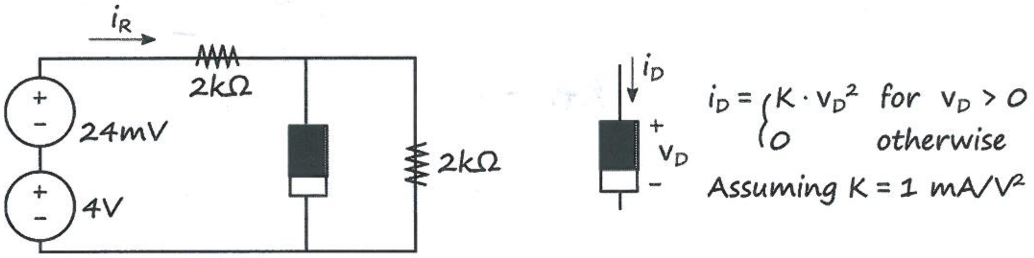




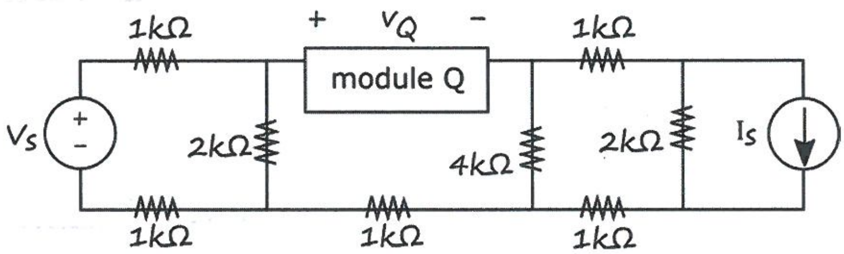
3. (15 points) **Static Discipline.** Consider the following specification: $V_{IL}=1.8V$, $V_{IH}=3.3V$, $V_{OL}=1.2V$, and $V_{OH}=4.3V$. Answer two questions.
   3a. (5 points) What is the noise margin for a logic 1?
   3b. (10 points) Can the following electronic module meet the above specification? Why or why not? The module produces voltage level $V_{OUT}=1V$ for sending a logic 0 and $V_{OUT}=4.5V$ for sending a logic 1. The module can interpret input signals between 0V and 2V as a logic 0 and input signals higher than 3V as a logic 1.

Name: ______________________ Student ID: ______________________

4. (15 points) **Small-Signal Analysis.** For the following circuit,
   4a. (5 points) Compute the small-signal linear resistance r_d.
   4b. (10 points) Compute current i_R.



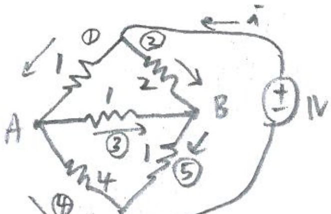
5. (20 points) **Comprehensive Analysis**. Consider the following electronic module, called module Q. Module Q will work correctly only if the voltage across it is higher than or equal to 2V. When it is working, module Q is equivalent to a linear resistor with resistance 4kΩ from the view of the rest of the circuit. Now, in the following configuration, given V_S=2V, what is the minimum value of I_S to make module Q work correctly?



This is the end of the exam questions.

Start your answer here:

① Solution 1: Symbolic Computation



$$\begin{cases} i_1 = i_3 + i_4 & A \\ i_2 = i_5 - i_3 & B \\ i_1 + 4i_4 = 2i_2 + i_5 \\ 4i_4 = i_3 + i_5 \\ 2i_2 = i_1 + i_3 \end{cases}$$

$$R_{eq} = \frac{1V}{i} = \frac{i_1 + 4i_4}{i}$$

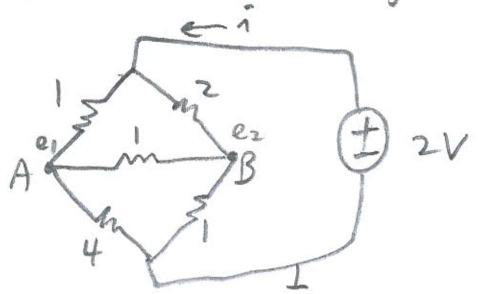
$$\left[\begin{array}{ccccc|c} 1 & 0 & -1 & -1 & 0 & 0 \\ 0 & 1 & 1 & 0 & -1 & 0 \\ 1 & -2 & 0 & 4 & -1 & 0 \\ 0 & 0 & 1 & -4 & 1 & 0 \\ \cancel{1} & \cancel{-2} & \cancel{1} & \cancel{0} & \cancel{0} & \cancel{0} \end{array}\right] \rightarrow \text{dependent}$$

Solve the matrix using Gaussian's elimination method

$$\Rightarrow \begin{cases} i_1 = \frac{13}{17} i_5 \\ i_2 = \frac{10}{17} i_5 \\ i = i_1 + i_2 = \frac{23}{17} i_5 \\ i_4 = \frac{6}{17} i_5 \end{cases}$$

$$\Rightarrow R_{eq} = \frac{i_1 + 4i_4}{i} = \frac{37}{23}\,\Omega \quad ※$$

Solution 2: Node Analysis



$$\text{node } A: \quad \frac{2-e_1}{1} = \frac{e_1 - e_2}{1} + \frac{e_1 - 0}{4}$$

$$\text{node } B: \quad \frac{2-e_2}{2} = \frac{-(e_1 - e_2)}{1} + \frac{e_2 - 0}{1}$$

$$\Rightarrow e_1 = \frac{48}{37}, \quad e_2 = \frac{34}{37}$$

$$\Rightarrow i = \frac{2-e_1}{1} + \frac{2-e_2}{2} = \frac{46}{37}$$

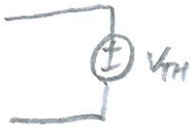
$$\Rightarrow R_{eq} = \frac{v}{i} = \frac{37}{23}\,\Omega \quad ※$$

Name: ______________________ Student ID: ______________________

(2) 2a. Yes. According to Thévenin's Theorem,

$V_{TH} = 3V$

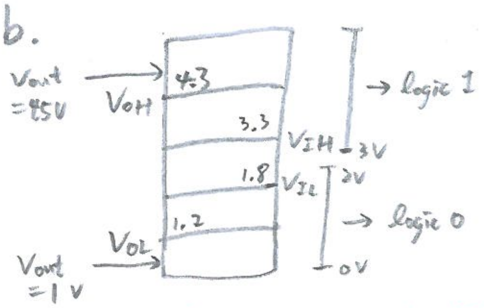
$R_{TH} = 0\Omega$

⇒


2b. The internal resistance could be very small, and therefore the current flowing through the multimeter could be very large and could burn out the multimeter. ☆

(3) 3a. Noise margin is $4.3 - 3.3 = 1V$, from 3.3V to 4.3V

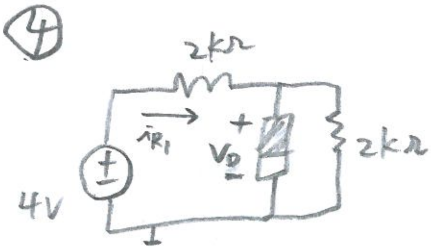
3b.



Also, refer to Example 5.1 in the textbook ~

Yes. ∵
① Vout for logic 1 is higher than V_{OH}
② Vout for logic 0 is lower than V_{OL}
☆ ③ Vin higher than V_{IH} can be intepreted as logic 1
☆ ④ Vin lower than V_{IL} can be interpreted as a logic 0.

(4)



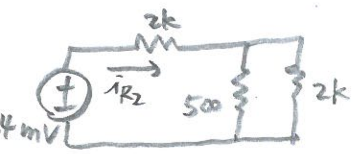
Clearly, $V_D > 0$

KCL ⇒ $\frac{4 - V_D}{2} = 1K V_D^2 + \frac{V_D}{2}$

$\Rightarrow 2V_D^2 + 2V_D - 4 = 0$

$\Rightarrow V_D = 1V \Rightarrow i_{R_1} = \frac{3}{2} = 1.5 \text{ mA}$

$r_d = \frac{1}{f'(V_D)|_{V_D = V_D}} = \frac{1}{2 1K V_D} = 500\,\Omega$ ✱



$i_{R_2} = \frac{24}{2 + \frac{0.5 \times 2}{0.5 + 2}} = 10\ \mu A$

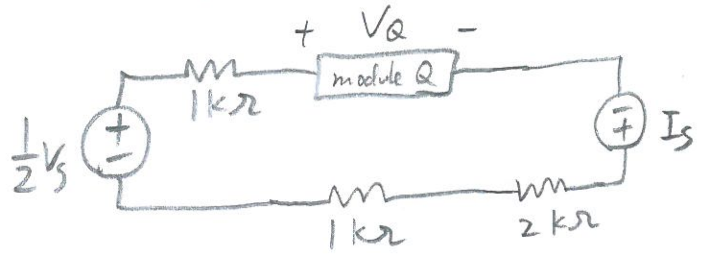
$\Rightarrow i = i_{R_1} + i_{R_2} = 1.51 \text{ mA}$

Also, refer to the exercise ②# on P57 in the lecture note ~

Name: ____________________ **Student ID:** ____________________

(5) The original circuit is equivalent to the following:

(Use Thévenin's Theorem)



Important take-home message from this problem is the "load effect", as we've discussed last week in class.

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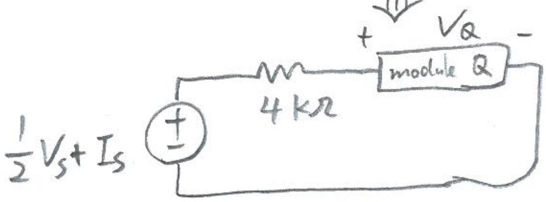

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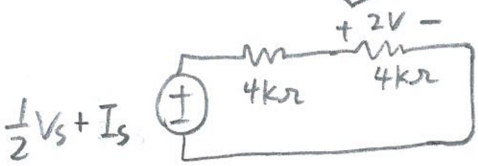

$\frac{1}{2}V_s + I_s = 4$

given $V_s = 2V \Rightarrow \underline{I_s = 3\ mA}$ #