

# Intro to ECSE

## Quiz 1 Solutions

Spring 2023

<b>1.</b>	<b>/18</b>
<b>2.</b>	<b>/16</b>
<b>3.</b>	<b>/12</b>
<b>Total</b>	<b>/46</b>

Name \_\_\_\_\_

Notes:

**SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS.** No credit will be given for numbers that appear without justification. Use the backs of pages if there is not enough room on the front.

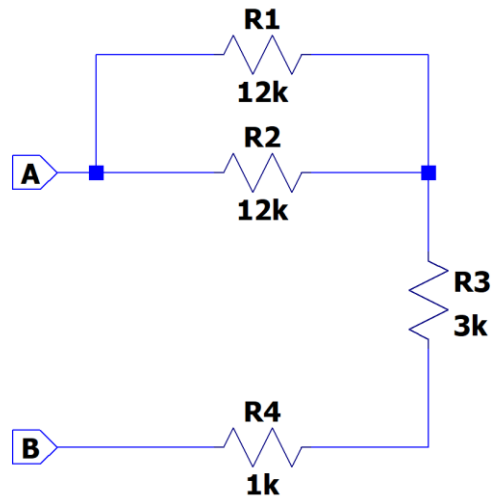
For partial credit on some questions, you may want to re-draw circuit diagrams as you simplify the circuits.

Many problems can be solved using more than one method. check your answers by using a second method.

At least skim through the entire quiz before you begin and then start with the problems you know best. The proctor will only answer clarification questions where wording is unclear or where there may be errors/typos. No other questions will be responded to.

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**Problem 1 (18 Points): Combining Resistors, Circuit Reduction, Voltage Dividers**



**Figure 1**

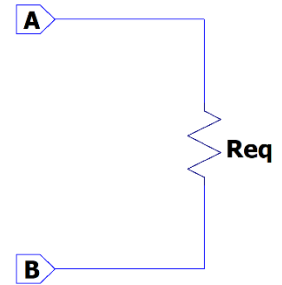
a) (2 pts) In the circuit diagram above, which of the resistors (if any) are in series?

R3 and R4 are in series. (2 pts)

b) (2 pts) In the circuit diagram above, which of the resistors (if any) are in parallel?

R1 and R2 are in parallel. (2 pts)

- c) (6 pts) What is the equivalent resistance ( $R_{eq}$ ) between terminals A and B in the circuit above, such that the circuit simplifies to the circuit diagram to the right?



Step 1: combine R1 and R2 in parallel to obtain  $R_{12} = 6k\Omega$

(2 pts: 1 for correct formula; 1 for correct calculation)

Step 2: combine R3 and R4 in series to obtain  $R_{34} = 4k\Omega$  (2 pts)

(2 pts: 1 for correct formula; 1 for correct calculation)

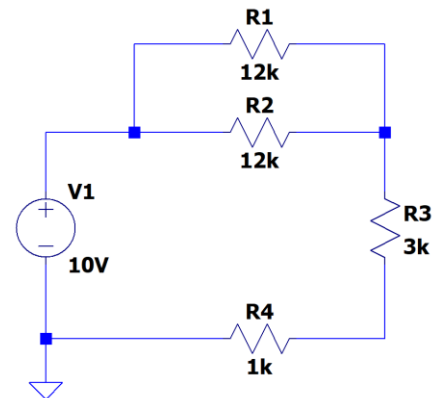
Step 3: combine  $R_{12}$  and  $R_{34}$  in series to obtain  $R_{eq} = 10k\Omega$  (2 pts)

(2 pts: 1 for correct formula; 1 for correct calculation)

- d) (2 pts) If a voltage source with a value of 10V is added between terminals A and B of the original circuit to create the circuit to the right, what is the current flowing through R3?

Since the same current flows through R12, R3, and R4, due to them all being in series, the same current flows through the sum of R12, R3, and R4, which is  $R_{eq}$ . Therefore  $I_{R4} = V_1/R_{eq} = 10V/10k\Omega = 1mA$ .

(2 pts: 1 for correct formula or approach; 1 for correct calculation)



e) (2 pts) In the same circuit as above (in part d), what is the voltage across R2?

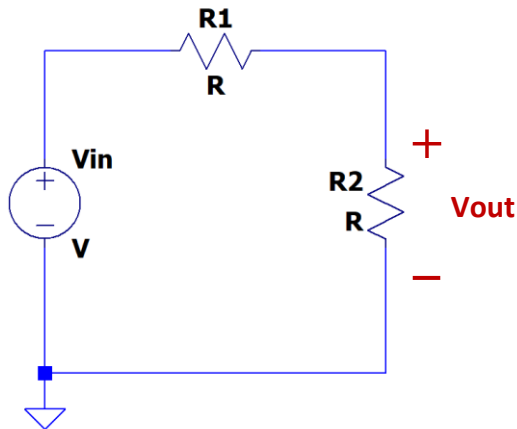
The voltage across R2 can be determined via 2 methods:

1) Ohm's Law: since  $I = 1\text{mA}$  and  $V_{R2} = V_{R12} = I * R_{12} = 1\text{mA} * 6\text{k}\Omega = 6\text{V}$

2) Voltage divider:  $V_{R2} = V_1 \frac{R_{12}}{(R_{12}+R_3+R_4)} = 10\text{V} \frac{6\text{k}\Omega}{6\text{k}\Omega+3\text{k}\Omega+1\text{k}\Omega} = 6\text{V}$

(2 pts: 1 pt for valid approach; 1 pt for calculation)

f) (4 pts) You are tasked with designing a circuit whose output voltage is 20% of its input voltage (i.e.  $V_{out} = 0.2V_{in}$ ), using the circuit design below and the resistor values in the table below. Choose values for R1 and R2 to satisfy the design requirement of  $V_{out} = 0.2V_{in}$ . You may use each resistor value only once, but you may combine resistors to provide equivalent values for R1 or R2 if you wish (for example  $R_1 = 1\text{k}\Omega + 2\text{k}\Omega$ ).



1kΩ	2kΩ
4kΩ	8kΩ

$$V_{out} = V_{in} \frac{R_2}{R_1 + R_2} = 0.2V_{in}$$

So, the ratio of resistances must equal 0.2.

$$\frac{R_2}{R_1 + R_2} = 0.2 \rightarrow 0.2R_1 = 0.8R_2 \rightarrow R_1 = 4R_2$$

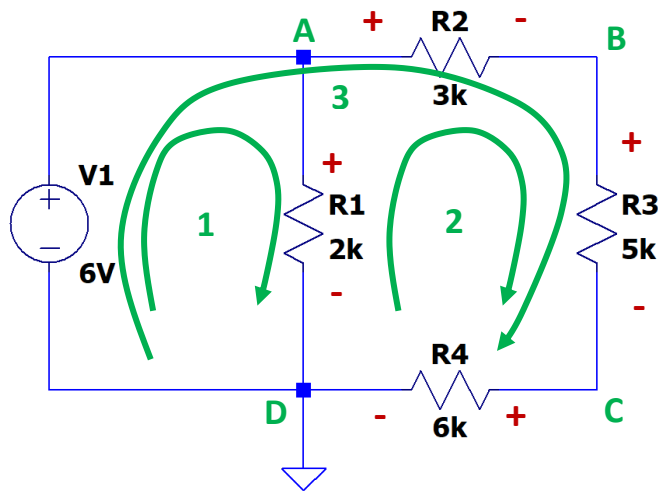
As a result, any two values of R1 and R2 such that  $R_1 = 4R_2$  will work, such as

$$R_1 = 4\text{k}\Omega \text{ and } R_2 = 1\text{k}\Omega$$

$$R_1 = 8\text{k}\Omega \text{ and } R_2 = 2\text{k}\Omega$$

(4 pts: 2 pts for correct approach using voltage divider; 1 pt for correct relationship between R1 and R2; 1 pt for correct choice of R1 and R2)

**Problem 2 (16 pts): KVL/KCL/Ohm's Law Method of Circuit Analysis**



- a) (4 pts) How many nodes are in the circuit above? How many loops are there? Label all nodes and loops on the circuit diagram.

# of nodes: 4; # of loops: 3

(4 pts: 1 pt for # of nodes; 1 pt for # of loops; 1 pt for all nodes labeled correctly; 1 pt for all loops labeled correctly)

- b) (2 pts) How many unknowns are there in this circuit as it is drawn (i.e. do not combine resistances)?

Since the unknowns in this circuit analysis method are the voltages across the resistors OR currents through the resistors, the number of resistors is the number of unknowns, so 4.

(2 pts)

- c) (2 pts) Draw reference marks on your circuit diagram.

(2 pts for reference marks on all resistors)

- d) (4 pts) Write the linearly-independent equations that will solve for all unknowns in the circuit in terms of **voltage** (i.e. in the final form of your equations, the unknowns must be expressed in terms of voltage).

The best nodes to choose are B and C (since they are not adjacent to the voltage source or ground) and the best loops to choose are 1 and 2 (since they don't include any other loops). If the current flowing through each resistor (from + to -) is denoted as  $I_{\text{Resistor\_name}}$ , the equations are:

$$\text{Node B: } I_{R2} - I_{R3} = 0 \rightarrow \frac{V_{R2}}{R_2} - \frac{V_{R3}}{R_3} = 0$$

$$\text{Node C: } I_{R3} - I_{R4} = 0 \rightarrow \frac{V_{R3}}{R_3} - \frac{V_{R4}}{R_4} = 0$$

$$\text{Loop 1: } -V1 + V_{R1} = 0$$

$$\text{Loop 2: } -V_{R1} + V_{R2} + V_{R3} + V_{R4} = 0$$

(4 pts: 1 pt for each equation)

- e) (4 pts) Write the equations in matrix form, giving your final answer in terms of numerical values for circuit elements. Note: You do not have to solve the matrix equation to obtain a numerical answer for the unknowns, but you may if you'd like to check your answer. If you do choose to solve the matrix equation, that work will not be graded.

$$\begin{bmatrix} 0 & \frac{1}{R_2} & -\frac{1}{R_3} & 0 \\ 0 & 0 & \frac{1}{R_3} & -\frac{1}{R_4} \\ 1 & 0 & 0 & 0 \\ -1 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} V_{R1} \\ V_{R2} \\ V_{R3} \\ V_{R4} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ V1 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 0 & \frac{1}{3000} & -\frac{1}{5000} & 0 \\ 0 & 0 & \frac{1}{5000} & -\frac{1}{6000} \\ 1 & 0 & 0 & 0 \\ -1 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} V_{R1} \\ V_{R2} \\ V_{R3} \\ V_{R4} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 6 \\ 0 \end{bmatrix}$$

(4 pts: 2 pts for correct coefficients matrix; 1 pt for correct voltages array; 1 pt for correct sources array)

**Problem 3 (12 pts): Electrical Engineering Fundamentals, Proof of Skills, and Coming to Class**





a) (2 pts) Circle one: current is defined as the flow of:

- (A) voltage
- (B) power
- (C) charge
- (D) potential energy

b) (2 pts) What is the name of the reference point with respect to which all node voltages are measured in an electrical circuit?

Ground

c) (4 pts) Write the names of the following circuit elements on the lines next to their symbols:

i)		<u>Current Source</u>
ii)		<u>Resistor</u>
iii)		<u>Voltage Source</u>
iv)		<u>Ground</u>

(4 pts: 1 pt for each)

d) (2 pts) What does it mean to be able to “optimize” an assignment in Intro to ECSE?

Labs and proof of skills can be resubmitted with changes in response to feedback from the course staff, so that students can learn from “failure” (and improve their grade).

e) (2 pts) What is the purpose of proof of skills?

Proof of skills is meant to give all students the skills and knowledge they need to be prepared to do the labs in the course (and to help prepare for success in ECSE).