Intro to ECSE

Quiz 1

Spring 2025

1.	**/12**
2.	**/10**
3.	**/13**
Total	**/35**

Name Solutions

RIN ______________________

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. Work through a problem in terms of variables, then substitute numerical values when you are ready to solve it.

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.

Problem 1 [12 pts]: Circuit Analysis – Circuit Reduction Method

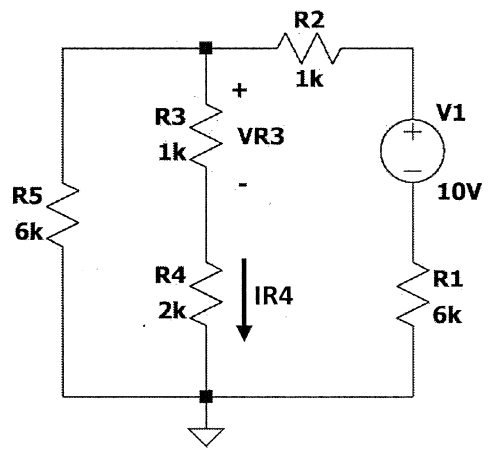


Figure 1

a) [2 pts] In the circuit above, which resistors are in *series* with each other? Do not combine resistors before answering this question. If no resistors are in series, write "none".

Resistors in series:

R3 & R4

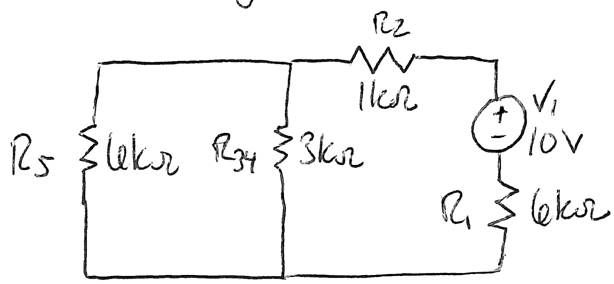
b) [2 pts] In the circuit above, which resistors are in *parallel* with each other? Do not combine resistors before answering this question. If no resistors are in parallel, write "none".

Resistors in parallel:

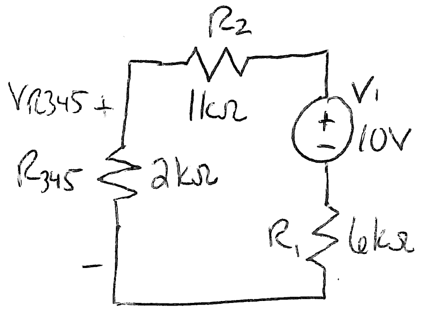
none

c) [4 pts] Using the circuit reduction method, calculate the value of V_{R3}, as shown in the circuit in Figure 1 above. Redraw your circuit for each step of the circuit reduction process for full credit.

· Combining R3 and R4 in series: $R_{34} = R_3 + R_4 = 3k\Omega$



· Combining R5 and R34 in parallel: $\underbrace{R_5 \| R_{34}}_{R_{345}} = \dfrac{1}{\frac{1}{6k\Omega} + \frac{1}{3k\Omega}} = 2k\Omega$



· Calculating V_{R345} via a voltage divider

$$V_{R345} = V_1 \frac{R_{345}}{R_{345} + R_2 + R_1} = 10V \frac{2k\Omega}{2k\Omega + 1k\Omega + 6k\Omega} = 10V \cdot \frac{2}{9} = 2.22V$$

· Calculating V_{R3} via a voltage divider

$$V_{R3} = V_{R345} \frac{R_3}{R_3 + R_4} = 2.22V \frac{1k\Omega}{1k\Omega + 2k\Omega} = \frac{2.22V}{3} = 0.741V$$

$V_{R3} =$ 0.741V

d) [2 pts] Calculate *IR*4, the current flowing through resistor *R*4, as shown in Figure 1.

$$I_{R3} = \frac{V_{R3}}{R_3} = \frac{0.741V}{1k\Omega} = 0.741mA$$

Since R_3 and R_4 are in series, $I_{R3} = I_{R4}$

***IR*4 =** 0.741mA

e) [2 pts] Calculate *PR*4, the power consumed by resistor *R*4.

$V_{R4} = 2.22V - 0.741V = 1.479V$

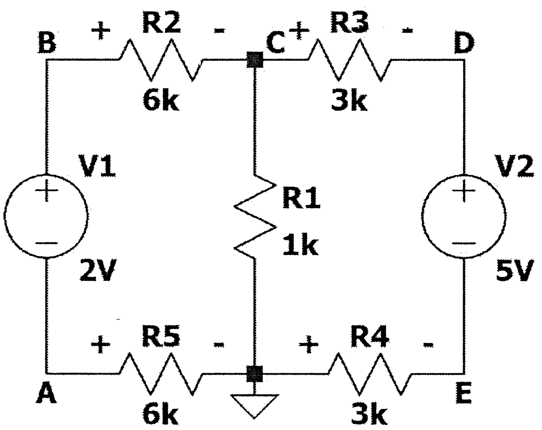
$I_{R4} = 0.741mA$

$P_{R4} = V_{R4} \cdot I_{R4} = 1.479V \cdot 0.741 \times 10^{-3}A = 0.0011W = 1.1mW$

***PR*4 =** 1.1mW

Problem 2 [10 Points]: Short Answer

2.1 [4 pts] The results of an LTSpice DC operating point simulation are shown below. Calculate the voltages across the specified resistors, as shown in the schematic.



--- Operating Point ---

V(b):	1.4	voltage
V(a):	-0.6	voltage
V(d):	2.9	voltage
V(e):	-2.1	voltage
V(c):	0.8	voltage

VR2: 0.6V

$V_{R2} = V_B - V_C = 1.4V - 0.8V = 0.6V$

VR3: -2.1V

$V_{R3} = V_C - V_D = 0.8V - 2.9V = -2.1V$

VR4: 2.1V

$V_{R4} = 0 - V_E = 0V - (-2.1V) = 2.1V$

VR5: -0.6V

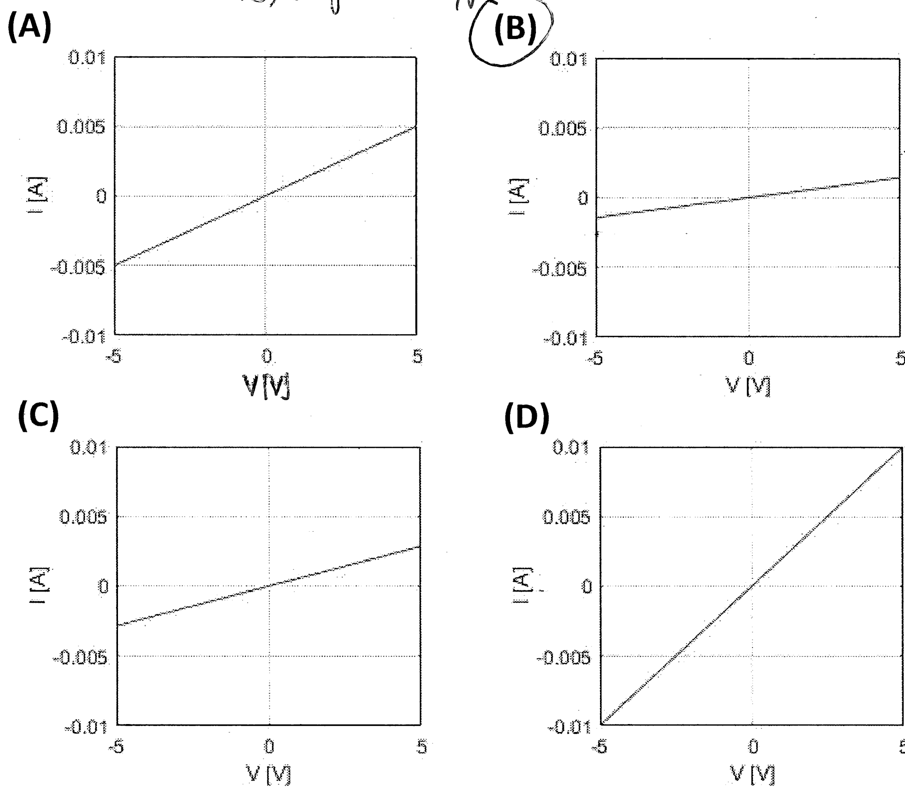
$V_{R5} = V_A - 0V = -0.6V$

2.2 [2 pts] Does the *passive sign convention* apply to all types of circuit elements (resistors, voltage sources, current sources) that you have seen in circuits so far or only some of them? Explain.

The passive sign convention only applies to passive elements (ones that use energy), not active ones (ones that provide energy), so only resistors must follow it in the circuits we have seen so far.

2.3 [2 pts] The I-V characteristics of four resistors are shown below. Which resistor has the largest resistance? Circle one:

Slope ∝ 1/R



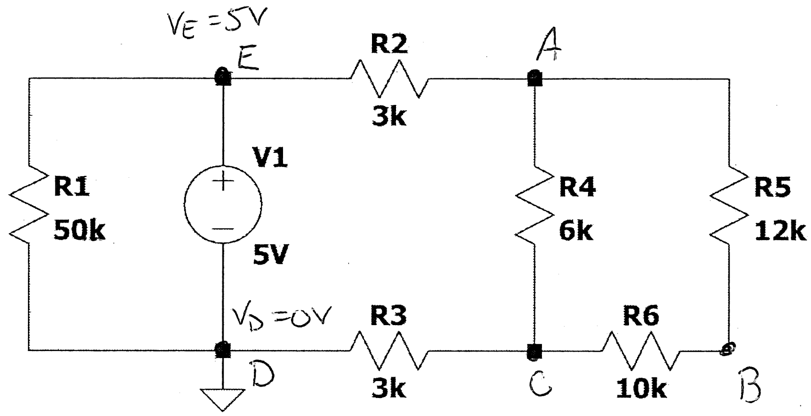
smallest slope = largest R

2.4 [2 pts] Why is it necessary to measure voltage with both the "+" and "-" leads (i.e. the 1+ and 1- wires) of your instrumentation board?

Voltage is always measured between two points, as a difference, so both leads are always needed

$V_{meas} = V_+ - V_-$

Problem 3 [13 Points]: Nodal Analysis



a) [2 pts] How many voltage nodes in total (both known and unknown) are in this circuit? Label them on the circuit schematic.

Total Number of Nodes:	5

b) [2 pts] Which of these nodal voltages are already known (if any)? Write their numerical values on the circuit schematic.

$V_E = 5V$, $V_D = 0V$

c) [2 pts] How many linearly independent equations are needed to solve for all unknowns in this circuit?

3 unknowns

Total Number of Equations Needed:	3

d) [3 pts] Write down the KCL equation for each node in terms of the nodal voltages you labeled on the schematic in 3.a and 3.b.

Node A: $\frac{V_A - V_E}{R_2} + \frac{V_A - V_C}{R_4} + \frac{V_A - V_B}{R_5} = 0$ (V_E = 5V)

$V_A(1/R_2 + 1/R_4 + 1/R_5) + V_B(-1/R_5) + V_C(-1/R_4) = 5/R_2$

Node B: $\frac{V_B - V_A}{R_5} + \frac{V_B - V_C}{R_6} = 0$

$V_A(-1/R_5) + V_B(1/R_5 + 1/R_6) + V_C(-1/R_6) = 0$

Node C: $\frac{V_C - V_B}{R_6} + \frac{V_C - V_A}{R_4} + \frac{V_C - V_D}{R_3} = 0$ ($V_D = 0$)

$V_A(-1/R_4) + V_B(-1/R_6) + V_C(1/R_6 + 1/R_4 + 1/R_3) = 0$

KCL Equations:

$V_A(1/R_2 + 1/R_4 + 1/R_5) + V_B(-1/R_5) + V_C(-1/R_4) = 5/R_2$

$V_A(-1/R_5) + V_B(1/R_5 + 1/R_6) + V_C(-1/R_6) = 0$

$V_A(-1/R_4) + V_B(-1/R_6) + V_C(1/R_6 + 1/R_4 + 1/R_3) = 0$

e) [4 pts] Write the equations from 3.d in matrix form with numerical values for circuit elements inserted (i.e. numbers for all resistances, known voltages, and known currents). You do not need to numerically solve the matrix equation.

$R_2 = 3000\Omega$

$R_3 = 3000\Omega$

$R_4 = 6000\Omega$

$R_5 = 12000\Omega$

$R_6 = 10000\Omega$

Matrix A =

$$\begin{bmatrix} (1/3000 + 1/6000 + 1/12000) & (-1/12000) & (-1/6000) \\ (-1/12000) & (1/12000 + 1/10000) & (-1/10000) \\ (-1/6000) & (-1/10000) & (1/10000 + 1/6000 + 1/3000) \end{bmatrix}$$

Vector x =

$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix}$$

Vector b =

$$\begin{bmatrix} 5/3000 \\ 0 \\ 0 \end{bmatrix}$$