University ☺f P☺rtland
Sch☺☺l ☺f Engineering

EE 271–Electrical Circuits Laboratory
Fall 2016

<u>Lab Experiment #4: Electrical Circuit Theorems</u>

Electrical Circuit Theorems

I. Objective

In this experiment, the students will analyze, construct and test dc resistive circuits to gain further insight and hands-on experience on electrical circuits as well as to verify some of the circuit theorems they learn in class such as the ***Superposition Principle***, ***Thevenin*** and ***Norton Equivalent Circuits*** and ***Maximum Power Transfer Theorem***.

II. Procedure

PART A: Superposition Principle

Pre-lab Assignment A.1: For the circuit shown in Fig. 1, calculate the voltage V_2 across the resistor R_2 using the superposition principle. Provide your work step by step and box your answers.

Pre-lab Assignment A.2: For the circuit shown in Fig. 1, reverse the polarity of the 5 V dc voltage source and redo pre-lab assignment A.1. (Hint: You can use the results of Pre-lab 1.a.) Box your answers.

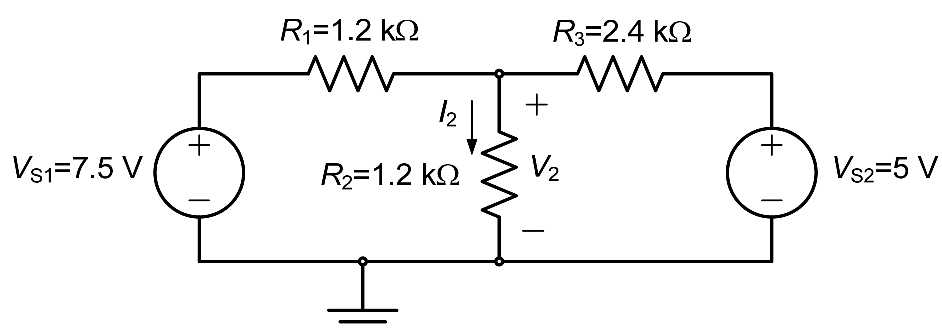

Figure 1. A resistive circuit excited by two dc voltage sources.

Lab Experiment A.1: Construct the resistive circuit shown in Fig. 1. Using the *LCR* meter, measure and record the actual values of the resistors R_1, R_2, and R_3 used in your circuit. To verify the superposition principle, measure and record the voltage V_2 for the following three cases (record your measurements in Table 1 form as provided below):

(a) When V_{s1} voltage is on and V_{s2} is off. (Voltage source "off" means you disconnect the voltage source from the circuit and short the terminals where this voltage source was connected. Warning: Do not short the terminals of the voltage source itself!)
(b) When V_{s1} voltage is off and V_{s2} is on.
(c) When both V_{s1} and V_{s2} voltages are on.

Table 1. Measured V_2 values in the circuit shown in Figure 1.

V_2 (V) (V_{s1} on and V_{s2} off)	V_2 (V) (V_{s1} off and V_{s2} on)	V_2 (V) (Both V_{s1} and V_{s2} on)

Check to see if superposition holds. Also check to see if your measured V_2 values agree with the V_2 values calculated in your pre-lab assignment A.1 (i.e., calculate percentage error between the calculated and the measured V_2 values).

Lab Experiment A.2: Reverse the polarity of the 5 V voltage source in your circuit and repeat the same V_2 measurements done in Lab Experiment A.1, parts (a), (b) and (c). Again record your measurements in Table 2 form as provided below.

Table 2. Measured V_2 values in the circuit shown in Figure 1 where the polarity of the 5 V voltage source is reversed.

V_2 (V) (V_{s1} on and V_{s2} off)	V_2 (V) (V_{s1} off and V_{s2} on)	V_2 (V) (Both V_{s1} and V_{s2} on)

Check to see if superposition holds. Also check to see if your measured V_2 values agree with the V_2 values calculated in your pre-lab assignment A.2.

PART B: Thevenin, Norton & the Maximum Power Transfer Theorem

Pre-lab Assignment B.1: For the circuit shown in Fig. 2, find the Thevenin and Norton equivalent circuits seen between terminals **A** and **B**. Draw each equivalent circuit separately with the appropriate values provided. Provide your work step by step and box your results.

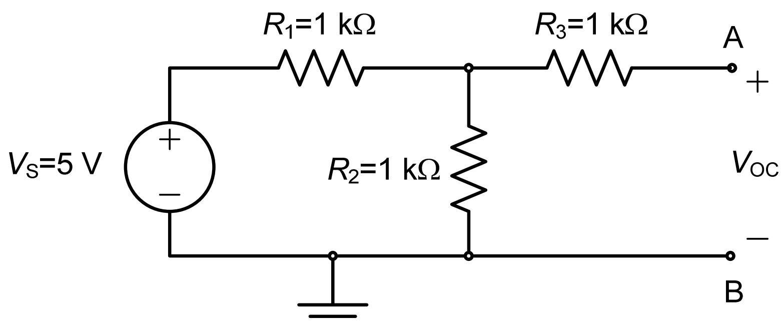

Figure 2. A resistive circuit excited by a dc voltage source.

Pre-lab Assignment B.2: For the circuit shown in Fig. 2, find the optimum value of the external load resistance $R_{L,opt}$ to be connected between the terminals **A** and **B** so that it receives maximum power from the circuit. What is $P_{L,max}$? (Hint: Use the results of pre-lab assignment B.1.)

Lab Experiment B.1: Construct the circuit shown in Fig. 2. Using the *LCR* meter, measure and record the actual values of the resistors used in your circuit. Verify the Thevenin and Norton equivalent circuits obtained in pre-lab assignment B.1 by measuring the open-circuit voltage V_{OC} and short-circuit current I_{SC} between terminals **A** and **B**.

Table 3. Measured values of V_{OC}, I_{SC} and V_L, and calculated value of R_T (or R_N) and P_L in the circuit shown in Figure 2.

V_{OC} (V)	I_{SC} (mA)	R_T or R_N (Ω)	V_L (V)	P_L (mW)

Lab Experiment B.2: Connect a load resistance with the optimum value $R_{L,opt}$ between terminals **A-B** in the original circuit shown in Fig. 2. Measure the voltage V_L across $R_{L,opt}$ and use it to verify the $P_{L,max}$ value calculated in pre-lab assignment B.2.

PART C: Maximum power to a load resistance with fixed value

Pre-lab Assignment C: In Fig. 3, assume that the load resistance R_L has a fixed value given by R_L=1 kΩ.

(a) How much power is being delivered to R_L? Show your work step by step.

(b) Your job is to introduce a single external resistor R_{ext} into the circuit with an appropriate value to maximize power delivery to the 1 kΩ load. What is the value of R_{ext}? (Hint: The external resistor could even be a piece of wire.) Where should it be connected? With the external resistor properly connected to the circuit, what is $P_{L,max}$? (Note that this problem is different than the maximum power transfer theorem.) Show your work and box your results!

Lab Experiment C: Verify the results of pre-lab assignment 3 experimentally. Measure and record the load voltage V_L and the current I_L with and without the external resistance connected and calculate the load power using $P_L = V_L I_L$ in each case. Approximately how much percent did the load power increase due to the introduction of the external resistance R_{ext} into the circuit?

Table 4. Measured values of V_L and I_L, and calculated values of P_L in the circuit shown in Figure 3.

V_L (V) (no R_{ext})	V_L (V) (with R_{ext})	I_L (mA) (no R_{ext})	I_L (mA) (with R_{ext})	P_L (mW) (no R_{ext})	P_L (mW) (with R_{ext})	% P_L increase

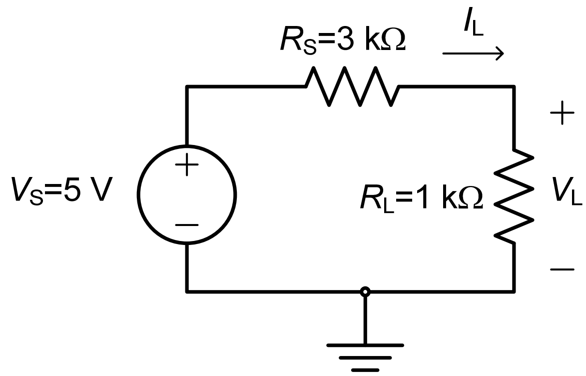

Figure 3. A circuit with a fixed load resistance having a value R_L=1 kΩ.

III. Discussions & Conclusion

In this section, discuss the various aspects of Experiment #4 and make some conclusions. In your write-up, you should at least address the following questions:

1. What was the objective of this experiment and was the objective achieved?
2. Did any of your measurements have more than 5% error? What was your maximum % error?
3. What sources of error may have contributed to the differences between the theoretical values and the measured values?
4. Other comments relevant to this experiment.