Introduction:

Building on what you have learned in lab 1, this experiment deals with resistive circuits as well. This time, the emphasis is on how circuits, which may potentially be large and complicated, can be described by simple equivalent circuit models. You will investigate how a real voltage source such as a battery deviates from its ideal circuit model. In addition, you will use the load line method to analyze a linear circuit.

In the design part, you will see that you don’t need to know details about the internal structure of a circuit in order to draw the maximum power from it. Thevenin’s and Norton’s theorems will allow you to determine the right load with two quick measurements.

The goals for this experiment are:
1. Understand real voltage sources
2. Replace an unknown circuit with a simple equivalent circuit
3. Match a resistive load to an unknown circuit for maximum power transfer
4. Understand graphical methods for linear circuits

Topics from the lecture you need to be familiar with:
1. Thevenin’s and Norton’s equivalents
2. Power transfer to a load resistor

Pre-lab questions (hand in before lab starts):
1. What are the two simplest equivalent circuits that a linear network can be reduced to? Explain how we can go from one configuration to the other? (with figures and formulas or words)
2. What distinguishes an ideal voltage source from a realistic one?
3. How can you model a realistic voltage source with a current source? (i.e., what is the Norton equivalent of a real voltage source?)
4. In a simple Thevenin equivalent circuit, for what load resistance does the load dissipate the maximum power? Show how you come to this conclusion. (Start by finding the equation for power of the circuit in terms of Rload).
5. Explain what open circuit voltage and short circuit current mean and how they relate to the Thevenin and Norton equivalents.
MainLab-2: Thevenin, Norton, and Matching

1. **Introduction (a paragraph, 10pts)**

2. **Basics of Equivalent Circuits**

   2.1. **Equivalent circuit for a resistive network**

   (a) Rebuild your voltage divider circuit from lab 1, as shown below.

   Set the supply voltage, \( V_{in} \), such that the voltage at the output terminals \( (V_{out}) \) is 5V.

   ![Circuit Diagram]

   (b) Measure the open circuit voltage \( (V_{OC}) \) and the short circuit current \( (I_{SC}) \) at the output terminals and determine the Thevenin and Norton equivalent for your circuit. Draw the Thevenin and Norton equivalents.

   (c) Take a 10 KΩ potentiometer \( (R_{load}) \) and set it to 1 KΩ. Connect the potentiometer in parallel with \( R_3 \). Calculate the power dissipated in \( R_{load} \), \( (P_L=V_{out}^2/R_{load}) \).

   (d) Vary your load resistance by setting the trimpot to different values \( (0Ω~10KΩ) \). Determine the dissipated power for each value (Hint: You can use Excel as well). Plot the power versus load (trimpot resistance). At what resistance does the load dissipate the maximum power? (Make sure you have enough data points around the maximum.)

   (e) Compare and verify your experiment result against the theoretically expected optimum \( R_{load} \) value. How large is the discrepancy (absolute in mW and relative in percent) and what could be the reasons for the discrepancy?
2.2. Realistic voltage source

(a) Obtain a 9V battery from the TA and determine its Thevenin equivalent where the actual source voltage and internal resistance of the battery are respectively the Thevenin voltage and resistance. NOTE: DO NOT short the battery terminals to measure \( I_{sc} \). This may damage the battery. Instead you will have to measure the “open circuit” voltage and the current through a “non-zero” load resistance. Do this by directly measuring the “open circuit” voltage of the battery, and by connecting a resistor across the battery terminals and measuring the current through it. Then, calculate the internal resistance using the voltage division principle.

\[
\frac{V_{battery}}{R_{battery}} = \frac{V_{Resistor}}{R1} = \frac{1}{Kohm}
\]

2.3. Matching a load to an unknown circuit

(a) Obtain one of the numbered ‘black’ boxes from the TA. Record the number in your report.

(b) Find its Thevenin equivalent through your experiment. You can connect circuit elements to the black box by clamping a wire under the output terminals screws and tightening the screws. Then turn on the power by flipping the switch on the box. (Turn switch off when finished using the box.)

(c) Determine the matching load resistance for maximum power transfer.

(d) Connect the matching load across the output terminals of the box and measure the actual dissipated power in the load. Compare with your expectations.

3. Conclusion (10pts)