Lab 2: DC Circuits
Lab Assignment

1. I-V curve for various components
Source: Curtis, 1.2.1. (HH 1.1, 1.2, 1.3)

A passive element is a two-contact device that contains no source of power or energy; an element that has a power source is called an active element. In the first part of the laboratory, you are to measure and plot the I-V curve for various passive circuit elements. You are also to plot the power dissipation in each element vs. applied voltage.

You need to decide which of the circuit elements are resistive and which are not resistive. For those elements that are resistive, determine the resistance, R. To do these measurements, you will connect the device under test to a variable voltage power supply and measure I and V as you vary the voltage control of the power supply. Make a table of all your data points and plot them as you go along. Reverse the polarity of the applied voltage by reversing the orientation of the element; this allows you to do measurements from -15 to +15 volts on the supply.

Measure the I-V curves and the power dissipation of the following elements. When making these measurements, record the applied voltage from the supply, the voltage across the device from the voltmeter, and the current through the device:

- 10k resistor
- 1k resistor
- #47 lamp: Follow instructions and answer all questions from HH 1.2
- diode: Follow instructions from HH 1.3 carefully. Answer/do all parts on page 27. Do not answer the questions on page 28.

Plot the power dissipation vs. applied voltage. Indicate the equation used to calculate power.
2. Effects of instruments on your readings

Source: http://www2.hawaii.edu/~jrand/EE211/Labs/01_analog_measuring_equipment.doc (HH 1.1)

Part A - Voltmeter

An ideal voltmeter has infinite resistance: It is an open circuit. Although it is impossible to make a physical voltmeter with infinite resistance, a well-designed voltmeter exhibits a very large internal input resistance. In some experiments, it is important to take into account the finite, non-ideal, internal resistance. To determine the internal resistance of the voltmeter, set up the circuit shown in Figure 1. The voltmeter reads the voltage across itself, which includes its internal resistance. Since the circuit has only a single branch, the current flowing through the resistor also flows through the voltmeter. The current is given by the equation:

\[ I = \frac{V_{\text{source}} - V_{\text{meter}}}{R} \]  

(1)

From Ohm's Law, if we know the current (I) and the voltage of the meter (V_m) we can compute R_m.

\[ R_m = \frac{R \times V_m}{V_s - V_m} \]  

(2)

![Figure 1: Circuit for measuring the resistance of the voltmeter.](image)

1. Select a 1MΩ resistor, and measure its value using the multimeter.
2. Set the power supply to provide 10 V (Remember, always measure the voltage provided by the power supply with either the voltmeter or the scope. Do not rely on the digital display on the front panel of the power supply.)
3. Record the voltage measured by the voltmeter.
4. Compute the internal resistance of the voltmeter.

What is the total resistance of the voltmeter?
Part B - Ammeter

An ideal ammeter has zero resistance so that the circuit in which it has been placed is not disturbed. An ideal ammeter is a short circuit. However, as with the voltmeter, no ammeter can ever be ideal, and therefore all ammeters have some small internal resistance. To determine the resistance of the ammeter, we will use the circuit in Figure 2.

![Diagram of circuit](image)

Figure 2. Circuit for measuring the resistance of the Ammeter

The total resistance in this circuit is:

\[ R_{\text{total}} = R + R_{\text{meter}} \quad (3) \]

According to Ohm's Law, the current in this circuit can be found using the equation:

\[ I = \frac{V_s}{R_{\text{total}}} \quad (4) \]

By using the known quantities I, Vs and R, we can solve for the unknown quantity \( R_m \).

In the procedure that follows it is extremely important that you take precise and accurate measurements. Record each measurement as precisely as the instrument will allow.

1. Select a 100 \( \Omega \) resistor. Measure and record its actual value.
2. Assemble the circuit in Figure 2. Set the multimeter to the ammeter mode for DC current measurement.
3. Use the oscilloscope to measure the voltage across the DC power supply.
4. Measure the value of the current using the ammeter.
5. Determine the value of \( R_m \) from the above equations.

What is the total resistance of the ammeter?
3. Voltage Dividers
Source: Eyler lab 1 (HH 1.4, 1.6)

In its general form Thévenin’s theorem tells us that any two-terminal network of passive linear components can be replaced by a single voltage source in series with a single impedance - it’s impossible to tell the difference by any external measurement. The most direct way to find the Thévenin equivalent voltage $V_{th}$ is to measure the open-circuit voltage between terminals 1 and 2 when no load is connected. Next, you can measure the short-circuit current $I_{sc}$ by connecting a low-resistance ammeter directly between the terminals. The Thévenin equivalent resistance $R_{th}$ is found from the ratio,

$$R_{th} = \frac{V_{th}}{I_{sc}}$$

There are obvious pitfalls in doing this in the laboratory. Voltmeters have finite input impedance and so may alter the open-circuit voltage. Ammeters not only exhibit a finite resistance, but may also cause trouble if the short-circuit current is so high that it blows a fuse (or something explodes). For this reason the short-circuit current is rarely measured directly, but we’ll make an exception today by choosing a circuit that’s relatively benign. Normally a gentler approach would be used.

1. Construct the resistive bridge network shown in the above figure on your breadboard. This classic circuit is a non-trivial network, for which both of Kirchoff’s laws must be used in a direct analysis. Measure the behavior of this circuit by connecting at least four different resistors between terminals 1 and 2, measuring the load current and voltage in each case. Values for the load resistor $R_L$ between about 100Ω and 10KΩ are recommended. After the first few measurements you will notice that the load current can be calculated much more
accurately than it can be measured, so you may as well stop measuring it. Why is this the case?

2. Measure the open-circuit voltage and short-circuit current of your bridge circuit, then construct the Thévenin equivalent circuit using a variable dc power supply. Use a series combination of resistors or a variable resistor (potentiometer) to approximate the required value $R_{th}$ within 5%. Now repeat the measurements of part 1 on this equivalent circuit.

Use Kirchhoff’s laws to solve directly for the voltage and current as a function of the load resistance $R_L$. Compare the results with your measurements from part 1.

Comment on the accuracy of your results from part 2. What contribution to the error comes from the inexact value you used for $R_{th}$? From the finite resistance of the voltmeter? From the finite resistance of the current meter?

4. Resistor Power Rating
Source: Hands-on 2.2.1

**Caution: In the following exercise, care must be taken to prevent burns.**

The resistor in the following exercise will become very hot and may even catch fire (briefly). Keep the body of the resistor well above the breadboard. Do not touch the resistor with your fingers. Remove the destroyed resistor using pliers or a similar tool.

Be sure that the power is turned off, and construct the circuit shown using a 1/4 watt carbon-film resistor.
This circuit can be used to demonstrate destructive power loading. Note that the resistor will heat up rapidly. You may substitute a 100 Ω resistor if we don’t have any 68’s. You must use the variable DC power supply for this exercise!

Turn on the power and observe the effect on the resistor. Be sure to turn off the power as soon as the resistor begins to smoke. Record your observations and comments.

Calculate the power that was dissipated by the resistor before it burned out. What is the minimum resistor value that can be safely used in this circuit? (Assume that only 1/4 watt resistors are available.)

Calculate the current that flowed through the resistor (before it burned out).

Note that even though the voltage was low and the current was well under 1 A, damage was nevertheless done! Because your body’s resistance is large, low voltages can’t give you a shock, but in the wrong circumstances they can still cause trouble. The key to safe work in electronics is always to estimate power dissipations in components before turning on the power, and to make sure you are not exceeding the ratings.