

Laboratory 1

Application of Algebra in Engineering: The One-Loop Circuit

1.1 Laboratory Objective

The objective of this laboratory is to illustrate linear and quadratic applications utilized in engineering. Supplementary information includes basic MATLAB commands and functions.

1.2 Educational Objectives

After performing this experiment, students should be able to:

1. Perform basic algebraic manipulations with linear equations.
2. Perform basic algebraic manipulations with quadratic equations.
3. Measure and understand the relationship between voltage, current, and resistance.
4. Apply basic functions in MATLAB toward the solution of engineering equation using the command window.
5. Using MATLAB for plotting data.

1.3 Background

It is essential that all engineers have an understanding of the fundamental laws of electricity. Ohm's Law and Kirchhoff's Voltage Law are two such laws that are presented in this lab. In addition, knowledge of the equipment and instrumentation that employ these laws is comparably important. Some of these include ammeters, voltmeters, wattmeters, breadboards, and circuitry components such as resistors. The implementation of these instruments is introduced in this lab.

1.3.1 Ohm's Law

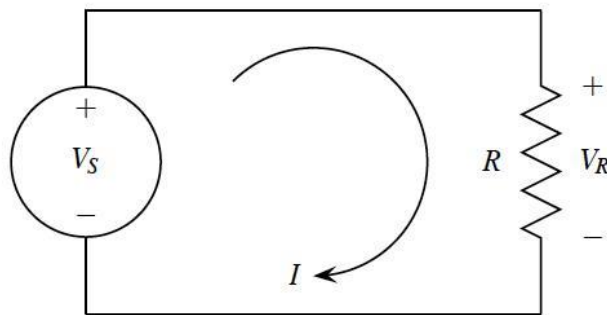


Figure 1.1: An Electrical Circuit Consisting of a Voltage Source V_S and Resistive Element R

Ohm's Law is a linear equation stating the voltage across a resistor is equal to the current flowing through that resistor multiplied by the value of that resistor. The following equation relates to Figure 1.1:

$$V_R = IR$$

The value of V_R is the voltage across the resistor in volts (V), I is the current flowing through the resistor in amperes (A), and R is the resistance in ohms (Ω).

1.3.2 Kirchhoff's Voltage Law

Kirchhoff's Voltage Law states that the sum of the voltage rises is equal to the sum of the voltage drops in a circuit.

$$\Sigma \text{Voltage Rises} = \Sigma \text{Voltage Drops}$$

Therefore, for the circuit shown in Figure 1.1:

$$V_S = V_R = IR$$

1.3.3 Equipment

A breadboard and resistors are two electrical components presented in this lab. The function of breadboards along with identification of resistor values will be reviewed. In addition, three types of measuring devices are introduced in this lab. These include an ammeter, voltmeter, and wattmeter. Lastly, multiple power supplies will be utilized in the circuit construction.

1.3.3.1 Breadboard

A breadboard is a medium to prototype a circuit. Circuit components are attached to the breadboard by inserting wires or leads into the small holes arranged in grids on the board. Since these components are not soldered in place, the pieces can be removed and the circuit easily changed. A standard breadboard is shown in Figure 1.2.

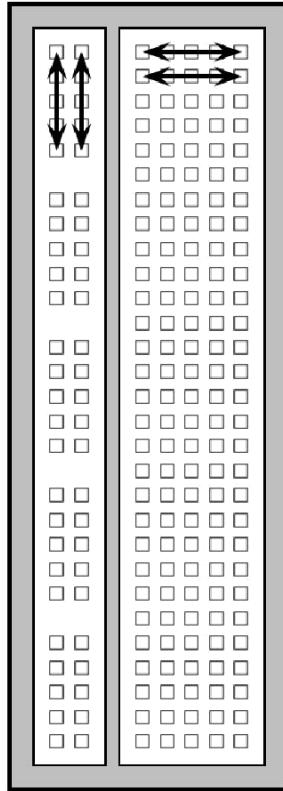


Figure 1.2: A standard Breadboard Layout

Inside the breadboard are metal contacts that connect the holes. These metal contacts join clusters of five holes together and are connected per the arrows shown in Figure 1.2. These clusters of five holes can be considered as one node.

1.3.3.2 Resistors

Resistors are electrical components that dissipate power by consuming current. This enables engineers to regulate the amount of current allowed to flow into succeeding components in the circuit. All resistors have a maximum power limit. The tiny resistors used in lab are quarter-watt resistors and the larger ones are ten-watt resistors. Because of the physical size limitations for printing, a standard for defining resistor values has been developed. For the larger resistors, the value is printed right on the casing. This standard uses color-coded bands that, in conjunction with a chart, yield the resistor value. Figure 1.3 shows an example of a typical resistor defined by colored bands.

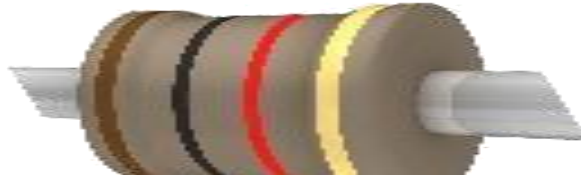


Figure 1.3: A 1000Ω Resistor

The colored bands of this resistor correspond to Table 1.1 and Table 1.2. Reading from left to right, the first two bands give the first two digits of the resistor value. The third colored band is the multiplier. This value tells to what power of ten we multiply the first two digits. The resistor value in Figure 1.3 is found using Tables 1.1 and 1.2 as follows:

- The Brown band corresponds to a 1.
- The Black band corresponds to a 0.
- The Red band indicates multiplying by 10^2 .
- The next Gold band indicates a tolerance of 5%

The value of this resistor is 10 times 10^2 resulting in 1000Ω with a tolerance of +/- 5%.

Table 1.1 Resistor Color Band Values

Number	0	1	2	3	4	5	6	7	8	9
Color	Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Grey	White

Table 1.2 Resistor Tolerance Color Band Values

Tolerance	±1%	±2%	±5%	±10%
Color	Brown	Red	Gold	Silver

An ammeter is a device that measures the current flowing in a circuit. Because it measures a quantity moving through the circuit, it must be connected in series as shown in Figure 1.4.

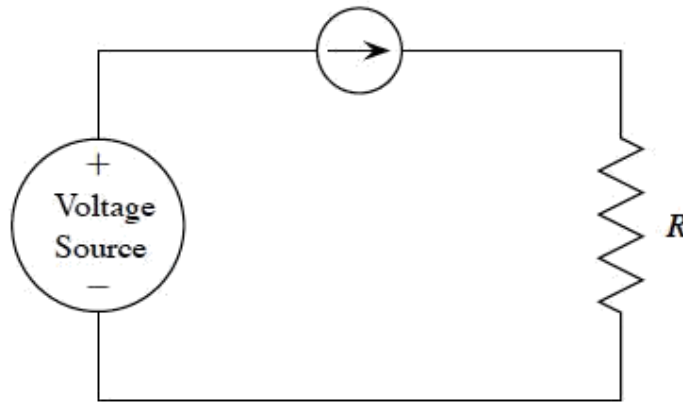


Figure 1.4: Placement of an Ammeter in a Circuit

1.3.3.4 Voltmeter

A voltmeter is a device that measures the voltage potential across an electrical component. Because of this, it is placed in parallel with the component whose voltage drop is being measured. A voltmeter is used to measure the voltage drop across the resistor in Figure 1.5.

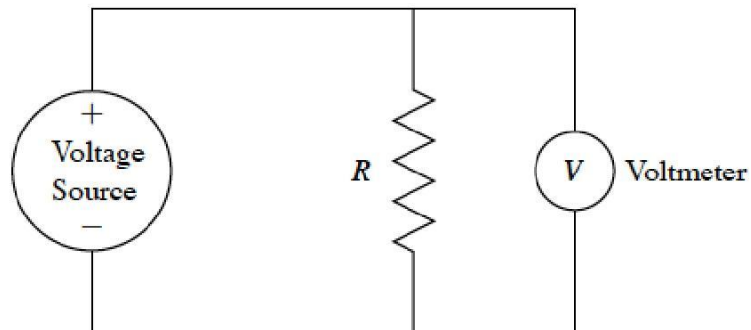


Figure 1.5: Placement of a Voltmeter in a Circuit

1.3.3.5 Wattmeter

A wattmeter is a device that measures the power used by an electrical component. The power delivered or absorbed is given by some basic equations related by Ohm's Law:

$$P = VI = I^2R = V^2/R$$

A wattmeter functions by simultaneously measuring the current that passes through, and the voltage that drops across the component. In practice, this requires four connections to a circuit. The current nodes will be connected in series while the voltage nodes will be connected in parallel. The wattmeter that is connected in Figure 1.6 is set up to measure the power dissipated by the resistor R .

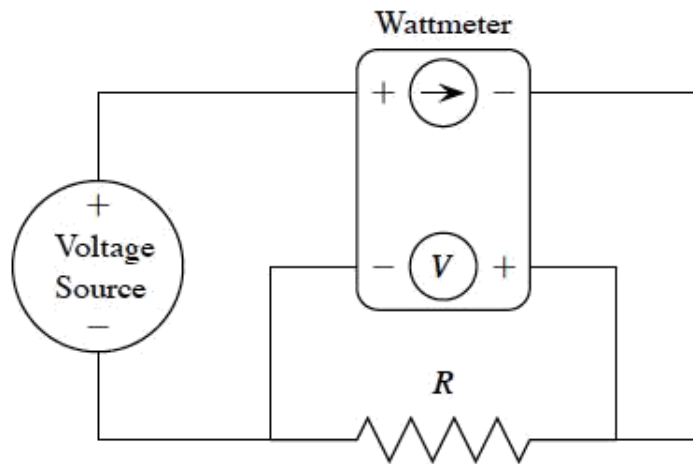


Figure 1.6: Placement of a Wattmeter in a Circuit

1.4 Procedure

Follow the steps outlined below after the Lab Instructor has explained how to use the web portal.

1.4.1 Circuit Number 1

1. The value of the resistor in Figure 1.7 is unknown. Construct the circuit with a resistor and use the web app to find this value. Complete Table 1.3 and record the current value measured on the ammeter.

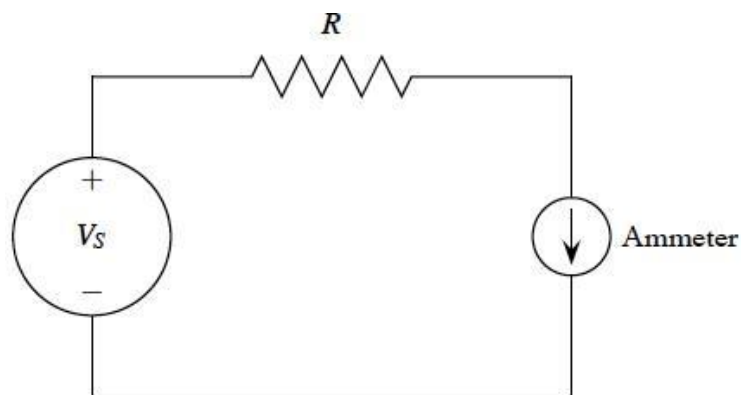


Figure 1.7: Circuit for Section 1.4.1

Table 1.3 Circuit 1 Measurements

Voltage V_S (volts)	Measured Current I (amps)	Calculated Resistance R (ohms)
0	0	0
5		
12		
15		
18		

2. Calculate the resistance R in the last column using Ohm's Law. (Pay close attention to units!)

$$R = V_S / I$$

3. Attach these hand calculations at the end of the lab.
4. Plot V_S vs. I using MATLAB.

NOTE: Standard notation is y vs. x . Place V_S on y -axis and I on the x -axis. Use MATLAB syntax that is given in Section 1.5.

5. Using MATLAB's Basic Fitting tool, find the slope of the graph.
6. Print the graph.

1.4.2 Circuit Number 2

1. The value of the resistor in Figure 1.8 below is unknown. Construct the circuit and use the web app to find this value. Complete Table 1.4 and record the current value measured on the ammeter.

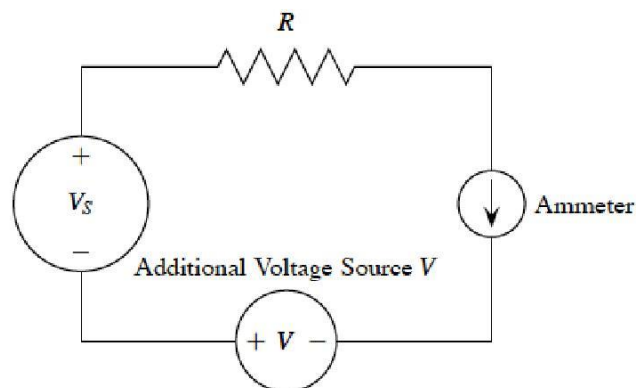


Figure 1.8: Circuit for 1.4.2

Table 1.4 Circuit 2 Measurements

Voltage V_s ,(volts)	Add. Voltage V ,(volts)	Measured I , (amps)	Calculated R ,(ohms)
0	6		
5	6		
7	6		
9	6		

2. Calculate the resistance R in the last column using Ohm's Law. (Pay close attention to UNITS!)

$$R = (V_s + V) / I$$

3. Attach these hand calculations at the end of the lab.
4. Plot V_s vs. I in MATLAB using the syntax in Section 1.5.
5. Using MATLAB's Basic Fitting tool, find the slope and y-intercept of the graph.
6. Print the graph.

1.4.3 Circuit Number 3

1. The value of the current flowing through the circuit in Figure 1.9 is unknown. Construct the circuit using the given resistors and use the web app to find it. Complete Table 1.5 and record the power and current from the wattmeter.

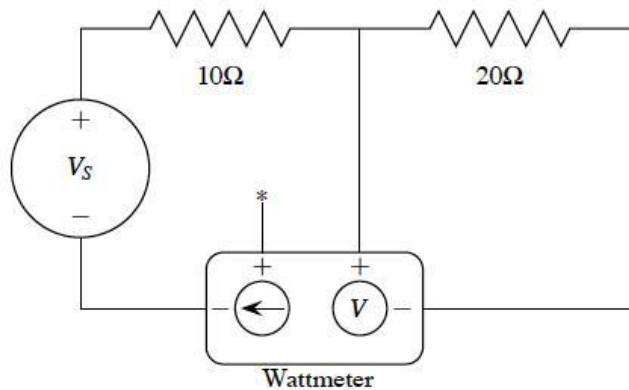


Figure 1.9: Circuit for Section 1.4.3

Table 1.5 Circuit 3 Measurements

Voltage V_s , (volts)	Power P , (watts)	Measured I , (amps)	Calculated I_{calc} , (amps)
7			
9			
11			

2. Use the following quadratic equation to calculate the theoretical current and record that value in the last column in Table 1.5. (Pay close attention to UNITS!)

NOTE: The value for R in the equation below is 10, not 20. P in this equation is the power dissipated by the 20Ω resistor.

$$R I_{\text{calc}}^2 - V_s I_{\text{calc}} + P = 0$$

3. Attach these hand calculations at the end of the lab.

1.5 MATLAB Commands

`x=[];` This command defines a row vector x . Place real numbers within the square brackets separated by spaces or commas.

`plot(x,y,'o')` This command plots the data in vectors x and y and does not connect lines between each point.

To fit a curve to the data:

1. On the figure, go to the “Tools” drop down menu.
2. Highlight “Basic Fitting”.
3. Check the “Linear” box.
4. Check the “Show Equations” box.

This will fit a linear curve to the data and place the equation of that line on the plot.

1.6 Lab Requirements

1. Complete Tables 1.3, 1.4, and 1.5 (2 points each)
2. Write an abstract for this lab and attach with this report. (required to pass course) (10 pts.)
3. Show hand calculations for all three tables. Insert after this page. (2 points each)
4. Insert both plots after this page. (Don't forget axis labels and title!)(2 points each)
5. Answer the following questions:
 - a) To what component of circuit one does the slope of plot one correspond? (1 point)
 - b) To what component of circuit two does the y-intercept of plot two correspond? (2 points)
 - c) Refer to circuits one and two for the following questions:
 - i. For circuits one and two, the calculated R should be relatively close to what value? (1 point)
 - ii. By how much do these values differ from the theoretical resistance as a percentage (calculate for the maximum voltage case of circuits #1 and #2)? Show work. (Hint: Use percent-error equation) (2 points)
 - iii. Is this within the tolerance of the resistor? (1 point)
 - d) How do the values for the measured current and calculated current from circuit three compare? What are some reasons for this? (2 points)