

Experiment 3

Resistance

The output terminals of the power supply constitute an *open circuit*. The test circuit, or load, of effective resistance R is connected across the power supply to establish a *closed circuit* through which a current I can flow. This load may be one or more resistors in parallel or series, a diode, light bulb, motor or any other electrical component or system.

To monitor the amount of current flowing in this closed circuit at a set voltage V , the power supply includes a current meter (ammeter) connected in *series* between the voltage source and the resistive load. Refer to Figure 3.1 for the schematic diagram for the circuit.

The digital meters have a measurement error of $\pm 0.5\%$ plus one least significant digit (LSD) on the display.

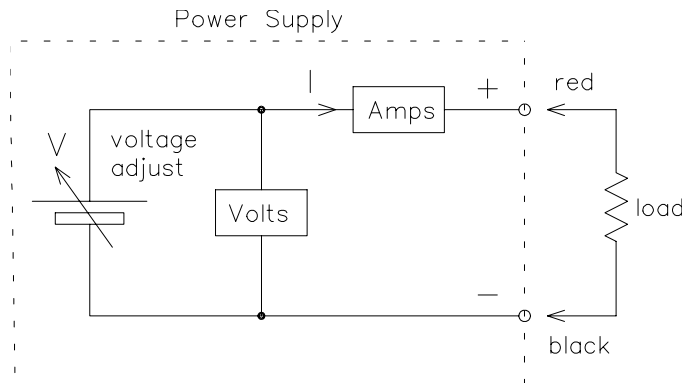


Figure 3.1: Experimental setup

Part 1: Single resistors

In this exercise, you will determine R for a resistor from the slope of a line of best fit through a series of (I, V) data points. You will then compare the result with the nominal resistance of the component.

- Your workstation is equipped with either a single HP power supply unit (PSU) or a double MPJA PSU that can be shared by two workstations. With the PSU turned off, rotate the **Voltage** adjust knob(s) fully *counterclockwise* to set the output voltage to 0 V.

1. For the HP PSU, check that the **Range** is *pressed*, then turn on the power supply. Press and hold the **CC set** button and use the current adjust knob to set a maximum current to 2.0 A. This will limit the power supply current in case of a short circuit.
 2. For the MPJA PSU, check that the **Tracking** buttons are set to **INDEP** and that the **Current** knobs are turned fully clockwise to set a current limit to 3.0 A, then turn on the PSU.
- Connect the circuit as shown in Figure 3.1 with resistor R_1 as the load resistor. Resistors R_1 and R_2 are similar, with a nominal resistance of $40\ \Omega$ and an error, or tolerance, of $\pm 5\%$.
 - With the voltage adjust knob, set the output voltage from 1 V to 10 V in nominal increments of ≈ 1 V and at each step record in Table 3.1 the magnitude of the current flowing through the resistor.
- ?** With $V \approx 10$ V and a current of about 0.25 A flowing through the resistor, occasionally touch the resistor. What do you note?
- ?** Does the current value change if this voltage is applied to the resistor for an extended period of time? Why might be the cause of this change? How should the current change?

V (V)	1									10
$\delta(V)$ (V)										
I (A)										
$\delta(I)$ (A)										

Table 3.1: Experimental results for resistor R_1

- Perform a sample calculation of $\delta(V)$ and $\delta(I)$, the errors in V and I , at $V = 5$ V and enter these results for all the values of V in Table 3.1.

$$\delta(V) = \dots\dots\dots = \dots\dots\dots = \dots\dots\dots$$

$$\delta(I) = \dots\dots\dots = \dots\dots\dots = \dots\dots\dots$$

- Close any open Physicalab programs, then start a new Physicalab session and enter the emails of the group members. Enter the data pairs and their associated errors ($I, V, \delta(V), \delta(I)$) in the data window. Select **scatter plot**. Click **Draw** to generate a graph of your data. The graph should approximate a straight line. Select **fit to: y=** and enter **A*x+B** in the fitting equation box. Click **Draw** to perform a linear fit on your data. Label the axes and enter your name and a description of the data as part of the graph title. Click **Send to** to email yourself a copy of your graph for later inclusion in your lab report.
- Enter below the experimental values for R_1 and $\delta(R)$ from the slope of the graph. Also include for comparison the nominal value R_1 and tolerance $\delta(R)$ of resistor R_1 .

$$(\text{slope})R_1 = \dots\dots\dots \pm \dots\dots\dots \Omega$$

$$(\text{nominal})R_1 = \dots\dots\dots \pm \dots\dots\dots \Omega$$

- Repeat the above steps by connecting the circuit shown in Figure 3.1 using the resistor R_2 as the load resistance. Enter your findings in Table 3.2.

V (V)	1									10
$\delta(V)$ (V)										
I (A)										
$\delta(I)$ (A)										

Table 3.2: Experimental results for resistor R_2

- Summarize below the values of R_2 from the slope of the graph and the the value displayed on the resistor R_2 .

$$(\text{slope})R_2 = \dots\dots\dots \pm \dots\dots\dots \Omega$$

$$(\text{nominal})R_2 = \dots\dots\dots \pm \dots\dots\dots \Omega$$

Part 2: Resistors in series

- Replace the single resistor used in Part 1 by the two resistors connected in series as shown in Figure 3.5. Set $V \approx 5$ V and measure the corresponding value of I .

$$V = \dots\dots\dots \pm \dots\dots\dots \text{ V} \qquad I = \dots\dots\dots \pm \dots\dots\dots \text{ A}$$

- Use Equation 3.1 to determine the experimental effective resistance R_s . Apply the proper error propagation rule to evaluate the error $\delta(R_s)$ of the two resistors in series.

$$R_s = \dots\dots\dots = \dots\dots\dots = \dots\dots\dots$$

$$\delta(R_s) = \dots\dots\dots = \dots\dots\dots = \dots\dots\dots$$

$$R_s(\text{Ohm's law}) = \dots\dots\dots \pm \dots\dots\dots \Omega$$

- Use the nominal component values for R_1 and R_2 and Equation 3.2 to calculate the theoretical effective resistance R_s and error $\delta(R_s)$ of the two resistors in series:

$$R_s = \dots\dots\dots = \dots\dots\dots = \dots\dots\dots$$

$$\delta(R_s) = \dots\dots\dots = \dots\dots\dots = \dots\dots\dots$$

$$R_s(\text{Series Law}) = \dots\dots\dots \pm \dots\dots\dots \Omega$$

Part 3: Resistors in parallel

- Connect the two resistors in parallel. Set $V \approx 5 \text{ V}$ and measure the corresponding value of I . Calculate the experimental effective resistance R_p and error $\delta(R_p)$ of the two resistors in parallel.

$$V = \dots \pm \dots \text{ V} \qquad I = \dots \pm \dots \text{ A}$$

- Use Equation 3.1 to determine the experimental effective resistance R_p and the error $\delta(R_p)$ of the two resistors in parallel.

$$R_p = \dots = \dots = \dots$$

$$\delta(R_p) = \dots = \dots = \dots$$

$$R_p(\text{Ohm's law}) = \dots \pm \dots \Omega$$

- Use the nominal component values and Equation 3.4 to calculate the theoretical resistance R_p and the error $\delta(R_p)$ of the two resistors in parallel:

$$R_p = \dots = \dots = \dots$$

$$\delta(R_p) = R_p^2 \sqrt{\left(\frac{\delta R_1}{R_1^2}\right)^2 + \left(\frac{\delta R_2}{R_2^2}\right)^2} = \dots = \dots$$

$$R_p(\text{parallel law}) = \dots \pm \dots \Omega$$

Part 4: IV characteristics of a diode

As mentioned in the Theory, many electrical devices do not obey Ohm's law. A diode is a semiconducting device whose resistance not only depends on the voltage V applied across its terminals, but also on the polarity, or direction of the applied voltage.

The diode has a positive and a negative terminal. The negative terminal is identified by a band at that end of the diode body. A diode is:

- **forward biased** when the band end is connected to the negative (-) terminal of the power supply;
- **reverse biased** when the band end is connected to the positive (+) terminal of the power supply.

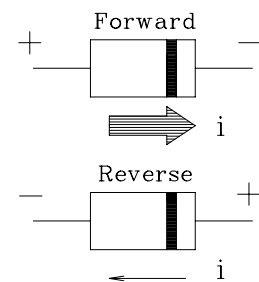


Figure 3.2: Current flow in a diode, showing the polarity of the applied voltage

A diode behaves like a voltage-controlled on/off switch.

For all applied negative voltages and positive voltages that are less than the diode turn-on voltage V_{on} , the diode is in an *off* state. The diode resistance is very large and the current flow is approximately zero.

Above V_{on} , the diode current increases exponentially with increasing voltage as the diode resistance drops to nearly zero. In this *on* state, an excessive current will flow through the diode, destroying it, unless you **always have a current-limiting resistor placed in series with a diode!**

- Set $V = 0$ V. Connect a resistor in series with the diode and the PSU so that the diode is *forward biased*. Measure the current in the circuit over a range of voltages from 1 V to 10 V in nominal steps of ≈ 1 V. Present your results in Table 3.3.

V (V)	1									10
$\delta(V)$ (V)										
I (A)										
$\delta(I)$ (A)										

Table 3.3: Experimental results for forward biased diode

V (V)	-1									-10
$\delta(V)$ (V)										
I (A)										
$\delta(I)$ (A)										

Table 3.4: Experimental results for reverse biased diode

? Is it difficult to read the current as the voltage is set to +10 V? Why? What would you think is happening? Does this effect eventually disappear? Why?

- Rearrange the diode so that it is connected in the *reverse biased* direction. Repeat the series of measurements and enter your data in Table 3.4.
- On the same graph, plot I as a function of $-10 \leq V \leq 10$ using the two data sets from Tables 3.3 and 3.4. Check **Line between points** to display the trend of your data points.
- To determine the turn-on voltage of the diode, fit a straight line $\mathbf{y}=\mathbf{A}*\mathbf{x}+\mathbf{B}$ to the positive voltage points (V, I). Check the **Constrain to:** box and enter $\mathbf{x}>1$ to fit only this range of data. The turn-on voltage V_{on} is given approximately by the X-intercept of the line, at $I = 0$. Properly label and title the graph, then email a copy.

? Is a straight line the proper function to fit your data to? Why? What does the slope of the straight line represent? What are the units of this quantity?

Part 5: Resistance characteristics of a heated filament

In this exercise you are going to explore the temperature dependence of a resistor. The resistor in this case is the tungsten filament of a low voltage light bulb. As the voltage applied across the filament is increased,

the current causes the filament to increase in temperature and eventually begin to glow.

NOTE: applying more than 5 V to the light bulb will destroy the Tungsten filament!

V (V)										5
I (A)										

Table 3.5: Experimental results for tungsten filament

- Connect the light bulb to the PSU. Measure I for a range of voltages from 0 V to -5 V and enter the results in Table 3.5. Estimate the voltage when the filament begins to glow.

$$V_{on1} = \dots\dots\dots V, \quad V_{on2} = \dots\dots\dots V, \quad V_{on3} = \dots\dots\dots V, \quad \langle V_{on} \rangle = \dots\dots\dots V$$

- Plot the $(V, \langle I \rangle)$ results for the tungsten filament. Also include a point at $(0,0)$. Connect the points with line segments as before, then save a copy of the graph.

? As you analyse the graph, what do you note in the behaviour of the V, I curve in the region where the light bulb begins to glow? How would you explain this feature of the graph?

! Important! Be sure to have this printout signed and dated by a TA before you leave at the end of the lab session. All your work needs to be kept for review by the instructor, if so requested.

Lab report

Go to the “Lab Documents” web page to access the online lab report template for this experiment. Complete the template as instructed and submit it to Turnitin before the lab report submission deadline, late in the evening six days following your scheduled lab session. Do not wait until the last minute. Turnitin will not accept overdue submissions. Unsubmitted lab reports are assigned a grade of zero.