

Ohm's Law

Introduction

When a potential difference is applied across an assortment of devices made from different materials, the resulting currents, passing through the devices, are, generally, different. The microscopic property of the material responsible for this behavior is called resistivity. A related macroscopic property is resistance. The resistance R of a device is defined as

$$R \equiv \frac{V}{I}, \quad (1)$$

where V is the potential difference (voltage) applied between two points on the device, and I is the current passing between the two points. According to Eq. 1 the resistance, in general, is functionally dependent on the applied voltage; however, for some devices the resistance is a constant independent of the applied voltage, i.e. the current is directly proportional to the potential difference. Such devices are called Ohmic and are said to obey Ohm's Law.

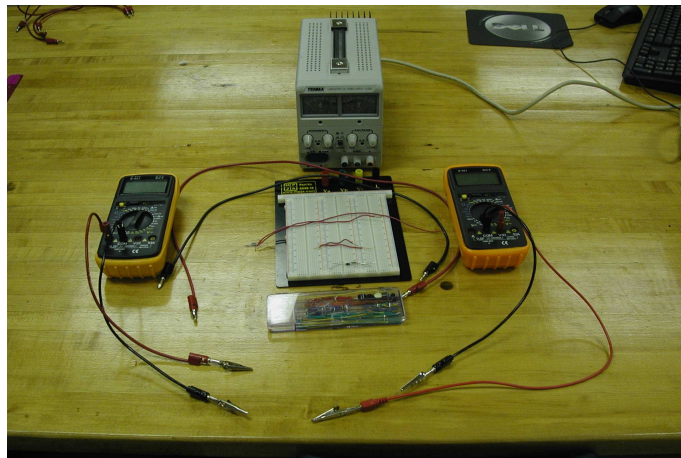


Figure 1: Shown is the equipment used in performing the experiment. It includes two multimeters, a power supply, a breadboard, a 2700Ω resistor and a diode rated for a maximum current of one amp at 250 volts.

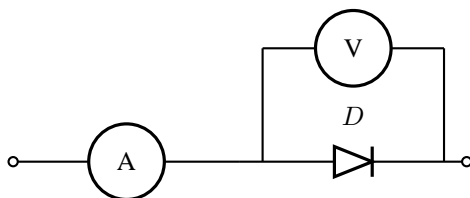


Figure 2: Electric Circuit with Diode.

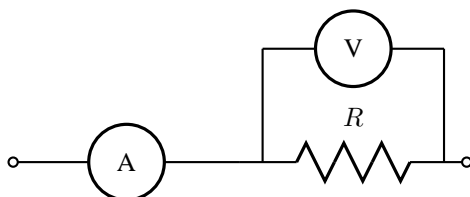


Figure 3: Electric Circuit with Resistor.

Procedure

1. Using the diode, construct the circuit shown in Fig. 2. Obtain five different voltage and current readings for the diode. The voltage readings should range between 0 and 0.8 volts.¹ The voltmeter should be set to the 2 volt scale, and the ammeter should be set to the 200 milliamp scale (or the 2 milliamp scale, as appropriate). Record your data in Table 1.
2. Using Microsoft Excel plot a graph of voltage vs. current for the diode (Voltage is the ordinate, and current is the abscissa.). Does the diode appear to be an ohmic device?
3. Remove the diode from the circuit and insert the resistor, as shown in Fig. 3. Obtain five different voltage and current readings for the resistor. The voltage readings should range between 0 and 8 volts. The voltmeter should be set to the 20 volt scale, and the ammeter should be set to the 200 milliamp scale (or the 2 milliamp scale, as appropriate). Record your data in Table 1.
4. Using Microsoft Excel plot a graph of voltage vs. current for the resistor (Voltage is the ordinate, and current is the abscissa.). Does the resistor appear to be an ohmic device? Perform a linear regression of the data, setting the intercept to zero. Report the value of the squared correlation coefficient, r^2 , obtained from the regression in Table 2.

¹If using a light emitting diode the voltages should range from 0 to 3 volts.

5. Measure the resistance of the resistor using the multimeter. Report its value in Table 2.
6. Using Eq. 3 calculate the standard error of the slope, δm . Report the value of the slope m and its standard error, in Table 2.
7. According to Eq. 1, for an Ohmic device the slope of the graph corresponds to the resistance of the device. Compare the value of resistance measured directly using the multimeter to that obtained from the slope of the graph. Consider the value of resistance measured with the multimeter to be the true value of the resistance. Then, using the criterion stated in Eq. 5 determine whether the value of resistance obtained from the slope is consistent with that obtained using the multimeter.

Appendix

Consider two sets of data y_i and x_i ($i = 1 \dots N$) where the y_i are assumed to be linearly related to the x_i according to the relationship

$$y_i = mx_i + \epsilon_i . \quad (2)$$

The ϵ_i is a set of uncorrelated random errors. The slope m of the regression line can be estimated using a variety of techniques, such as the method of least squares estimation. It can be shown that the standard error of the slope, σ is given as

$$\sigma = \sqrt{\frac{1 - r^2}{N - 1} \frac{\sigma_y}{\sigma_x}} , \quad (3)$$

where r is the estimated correlation coefficient between the y_i and x_i , σ_y and σ_x are the standard deviations of the y_i and x_i , respectively. The quantities σ_y and σ_x can straightforwardly be calculated using function keys on a scientific calculator or defined functions in Excel. Note that if the regression equation, Eq. 2, includes a y-intercept as an additional parameter to be estimated, then the term $N - 1$ in Eq. 3 is replaced by $N - 2$, reflecting the extra degree of freedom in the estimation process.

To reflect its statistical uncertainty the slope is typically reported as

$$m \pm \sigma , \quad (4)$$

which can be understood informally to mean that with high probability the true value of the slope lies within the interval

$$[m - 1.96\sigma, m + 1.96\sigma] , \quad (5)$$

and its best estimate is m .

	Diode		Resistor	
	I (amps)	V (volts)	I (amps)	V (volts)
1				
2				
3				
4				
5				

Table 1: Data

	Resistor
r^2	
Slope ($m \pm \delta m$)	
Resistance (multimeter)	
Are the values obtained by the two methods in agreement? (y or n)	

Table 2: Results