5 Power in DC Circuits

OBJECTIVES:

After performing this experiment, you will be able to:

1. Find the power in a resistor using each of the three basic power equations.
2. Indirectly measure the power in a variable resistor at various settings of resistance.
3. Plot the power dissipated as a function of resistance for the variable resistor of objective 2.

READING:

Floyd and Buchla, *Principles of Electric Circuits,* Sections 4–1 through 4–4 and Application Activity

MATERIALS NEEDED:

One 2.7 kΩ resistor
One 10 kΩ potentiometer
One 0–10 mA ammeter
For Further Investigation: One LED

SUMMARY OF THEORY:

In physics, the unit for measuring energy or work is the joule. One joule is equivalent to the energy expended (or work accomplished) when a one newton weight (about 3.6 oz) is lifted over a distance of one meter. For electrical circuits, voltage represents the energy expended when a unit of positive charge is moved from one point to another point of higher potential. Alternatively, it is the energy released when one coulomb of charge moves from a point of higher potential to one of lower potential.

When current is in a resistor, energy is dissipated. In a resistance, this energy is dissipated in the form of heat. The power dissipated is defined as the energy given up per unit of time. Power in an electrical circuit is defined by the equation

$$P = IV$$

This equation says that energy dissipated per time is equal to the charge per time (I) times the energy per charge (V). Power is measured in joules per second, which defines a unit called the **watt.** In an electrical circuit, one watt is the power developed when one volt is across one ohm of resistance. By applying Ohm's law to the defining law for power, two more useful equations for power can be found:

$$P = I^2R$$

and

$$P = \frac{V^2}{R}$$

The physical size of a resistor is related to the amount of heat it can dissipate. Therefore, larger resistors are rated for more power than smaller ones. Carbon composition resistors are available with standard power ratings ranging from ⅛ W to 2 W. For most typical low voltage applications (15 V or less and at least 1 kΩ of resistance) a ¼ W resistor is satisfactory.

In this experiment, you will find the power dissipated in a fixed resistor and verify that each of the three preceding equations gives you the same result. Then you will find what happens to the power dissipated in a variable resistor as resistance is varied. Later, when you study the maximum power transfer theorem, you will find out more about the theory behind this experiment.

PROCEDURE:

1. Measure the actual resistance of R_1. The color-coded value is 2.7 kΩ. Enter the measured resistance (in kΩ) in Table 5–1 and in the first column of Table 5–2.

2. Construct the circuit shown in Figure 5–1. The ammeter is connected in series. Have your instructor check your circuit before applying power if you are not sure of your connections.

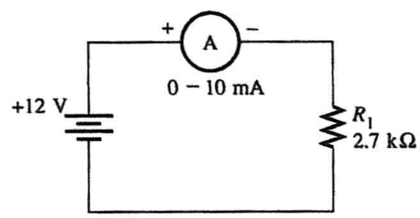

Figure 5–1

3. Using your DMM, set the power supply voltage to 12.0 V. This voltage also appears across R_1 (ignoring the very small voltage drop across the ammeter). Record the voltage and current (in mA) in the top portion of Table 5–2.

4. Using the measured resistance, voltage, and current, compute the power dissipated in R_1. Use each of the three forms of the power law and enter your results in the bottom portion of Table 5–2. You should find reasonable agreement between the three methods.

Determining Power in a Variable Resistance

5. Modify the circuit by removing the ammeter and adding a 10 kΩ potentiometer in series with R_1, as shown in Figure 5–2. R_2 is the 10 kΩ potentiometer. Connect the center (variable) terminal to one of the outside terminals. Use this and the remaining terminal as a variable resistor. Adjust the potentiometer for 0.5 kΩ. (Always remove the power source when measuring resistance).

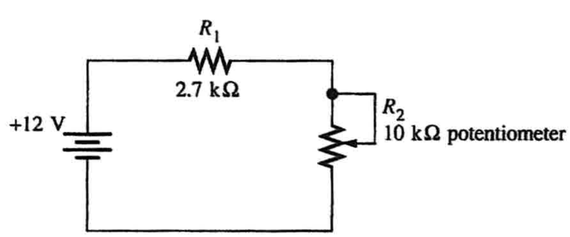

Figure 5–2

6. Measure the voltage across R_1 and the voltage across R_2. Enter the measured voltages in Table 5–3. As a check, make sure that the sum of V_1 plus V_2 is equal to 12.0 V. Then compute the power dissipated in R_2 using the equation

$$P_2 = \frac{(V_2)^2}{R_2}$$

Note that if the resistance is entered in kilohms, the power will be in milliwatts. Enter the computed power in Table 5–3.

7. Disconnect the power supply and set R_2 to the next value shown in Table 5–3. Reconnect the power supply and repeat the measurements made in step 2. Continue in this manner for each of the resistance settings shown in Table 5–3.

8. Using the data in Table 5–3, graph the relationship of the power, P_2, as a function of resistance R_2 on Plot 5–1. Since resistance is the independent variable, plot it along the x-axis and plot power along the y-axis. An *implied* data point can be plotted at the origin because there can be no power dissipated in R_2 without resistance. A smooth curve can then be drawn to the origin.

FOR FURTHER INVESTIGATION:
A series circuit has the same current throughout the circuit. Find this current for each setting of R_2 by applying Ohm's law to R_1 by dividing the voltage across R_1 by the resistance of R_1. Then, on Plot 5–2, graph the current as a function of the resistance of R_2. On the same graph, plot the voltage measured across R_2 as a function of the resistance of R_2. Where is the product of the current times the voltage a maximum?

APPLICATION PROBLEM:
Figure 5–3 shows a variation of the circuit in this experiment in which a light-emitting diode (LED) is used in place of R_2. The LED is a polarized component and must be put in the circuit in the correct direction. Design a measurement procedure that will enable you to determine the power in the LED as the power supply is varied. Start V_S at 1.0 V and increase it in 1.0 V increments to +12 V. Graph the power in the LED as a function of the power supply voltage in Plot 5–3. What can you conclude from this circuit?

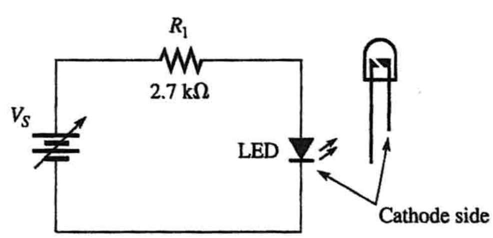

Figure 5–3

Report for Experiment 5

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ABSTRACT:

DATA:

Table 5–1

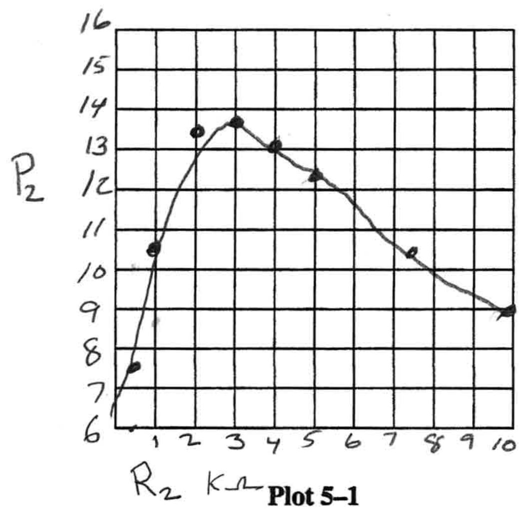
Component	Listed Value	Measured Value
R_1	2.7 kΩ	2.661 kΩ

Table 5–2

Measured value of		
Resistance	Voltage	Current
2.661 kΩ	12.03 V	4.494 mA
Computed Power		
$P = IV$	$P = I^2R$	$P = \frac{V^2}{R}$
54.063 mW	53.742 mW	54.386 mW

Table 5–3

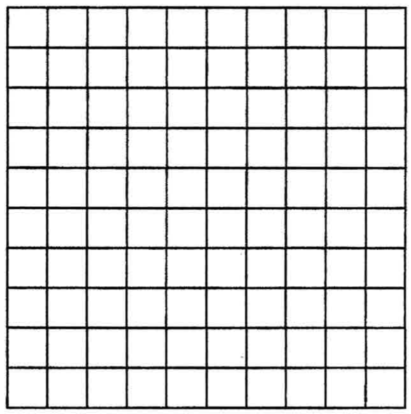
Variable Resistance Setting (R_2)	V_1 (measured)	V_2 (measured)	Power in R_2 $P_2 = \frac{V_2^2}{R_2}$
0.5 kΩ	10.05 V	1.95 V	7.605 mW
1.0 kΩ	8.740 ✓	3.282 V	10.772 mW
2.0 kΩ	6.882 V	5.190 ✓	13.468 mW
3.0 kΩ	5.680 V	6.387 ✓	13.598 mW
4.0 kΩ	4.826 V	7.238 ✓	13.097 mW
5.0 kΩ	4.191 V	7.870 V	12.384 mW
7.5 kΩ	3.160 V	8.904 V	10.571 mW
10.0 kΩ	2.549 V	9.509 V	9.042 mW



Plot 5–1

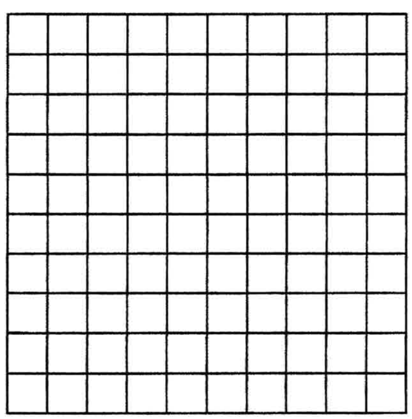
RESULTS AND CONCLUSION:

FURTHER INVESTIGATION RESULTS:



Plot 5–2

APPLICATION PROBLEM RESULTS:



Plot 5–3

EVALUATION AND REVIEW QUESTIONS:

1. In the first part of the experiment, you computed the power in a resistor using three different equations. Why might the results in each case be slightly different?

The values for V_1, V_2 + R_2 are not exact.

2. For the circuit in Figure 5–1, assume a student accidentally set the power supply to 24 V instead of 12 V.

   (a) How much power would be dissipated in the resistor? $\frac{24^2}{2.7\,k\Omega}$

   (b) Would a ¼ W resistor be adequate for this case? 213.333mW

3. For the circuit in Figure 5–2, what was happening to the *total power* in the circuit as the resistance of R_2 was increasing? Explain your answer.

The total amount was decreasing. The total resistance was increasing while the total voltge remains constant.

4. A 1.5 kΩ resistor is found to have 22.5 V across it.

   (a) What is the current in the resistor? 15mA

   (b) What is the power dissipated in the resistor? 337.5mW

   (c) Could a ¼ W resistor be used in this application? Explain your answer.

   1/4W = 250mW. As this is less than the power dissipated by the resistor

5. What physical characteristic determines the power rating of a resistor?

The material the resistor is created from and the surface area.

6. What is the smallest value of resistance that can be used across 10 V if the power dissipated is not to exceed 0.5 W?

$$P = \frac{V^2}{R} = \quad R = \frac{V^2}{P} = 200\,\Omega$$