

# Experiment VI—Voltage, Current and Resistance

## Introduction

Our world is filled with devices that contain electrical circuits in which various voltage sources cause currents to flow. We use radios, telephones, computers, flashlights, irons, heaters, stoves, motors — the list is long. Each of these contain circuits which take electrical energy from some power supply and turn it into other forms: the light of a lamp, the heat of a stove, stereo sound or mechanical work.

In general, electrical currents generate heat and magnetic fields, and produce chemical effects. Any of these phenomena can be used to measure current. One of the simplest ways is to let the current flow through a coil of wire that is in a magnetic field and to measure the resulting torque on the coil by observing the deflection of a torsion spring. This is how your multimeter works, which we call a magnetic multimeter (MMM), in contrast to the standard term ‘analog’. Look at the meter itself. You can see the copper colored coil and one of the two spiral torsion springs (the other is at the back; they also lead current in and out of the moving coil). The MMM is a current meter with a range selector switch and appropriate resistors and other parts that can measure voltage and resistances.

One of the earliest and most widely used electrical devices is the incandescent lamp, of which there are hundreds of different kinds. They all work because current flowing through a tungsten filament in a glass bulb heats that filament to “incandescence” —visibly hot, so that light is emitted, along with heat.

In this experiment you will use meters, power supplies, resistors and lamps in various circuits. You will make measurements to get some intuition and knowledge of circuit behavior.

## Equipment

You will need your LVPS; two multimeters; three  $43\Omega$ , (power rating  $1/2W$ ) resistors; one  $2.4\Omega$ ,  $2W$  resistor; one length of #16 bare resistance wire ( $1.02\Omega$  per meter); one #47 miniature incandescent lamp, nominal rating  $0.15A$  at  $6.3V$  (called pilot, panel or indicator lamp); and one #1157 auto tail and stop lamp (tail lamp filament with a nominal rating of  $8W$  at  $12.6V$ ; stop lamp filament with a nominal rating of  $27W$  at  $12.6V$ ). Look closely at your lamps and notice the filament, conducting leads and glass insulator. Throughout this experiment you will need clip leads.

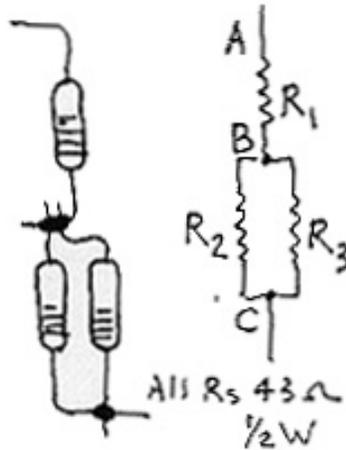
## Measurements

Arrange the experimental apparatus as directed and record your measurements on the separate RESULTS sheet in the problem set. You may wish to add brief comments, as appropriate.

**1 ---Resistors and Lamps:** Measure the resistance of each of the three  $43\Omega$  resistors,  $R_1$ ,  $R_2$ , and  $R_3$ . Solder together resistors  $R_2$  and  $R_3$  in parallel. Then solder resistor  $R_1$  in series with the other two as shown in Figure 1. Measure the resistances between the points A and B, B and C, and A and C in Figure 2. Measure the 'cold' resistances (not connected to a power supply) of the #47 lamp and the two #1157 lamp filaments.



**Figure 1: Three  $43\Omega$  Resistors, one in series with two in parallel**



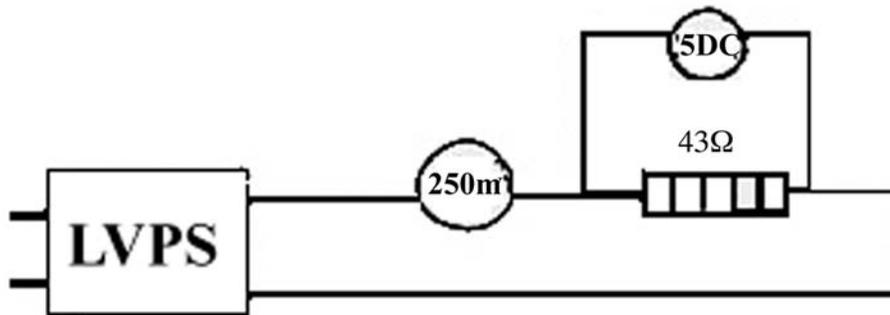
**Figure 2: Circuit Diagram: Three  $43\Omega$  Resistors, one in series with two in parallel**

**2a---Voltage Divider:** Connect the arrangement of the three resistors in Figure 1 to your LVPS with the output set at 5 volts. Measure the voltage differences between the points A and B, B and C, and A and C in Figure 2. Calculate the current through each resistor using Ohm's Law and calculate the power dissipated in each resistor.

**2b---Voltage and Current:** Connect the arrangement of the three resistors in Figure 1 to your LVPS with the output set at 5 volts. Use a clip lead to short the two resistors ( $R_2$  and  $R_3$ ) that are connected in parallel, (connect B to C in Figure 2). Measure the voltage between A and B. Calculate the current and power dissipated through the remaining resistor  $R_1$ . Observe the warming of resistor  $R_1$  by feeling it with your fingers.

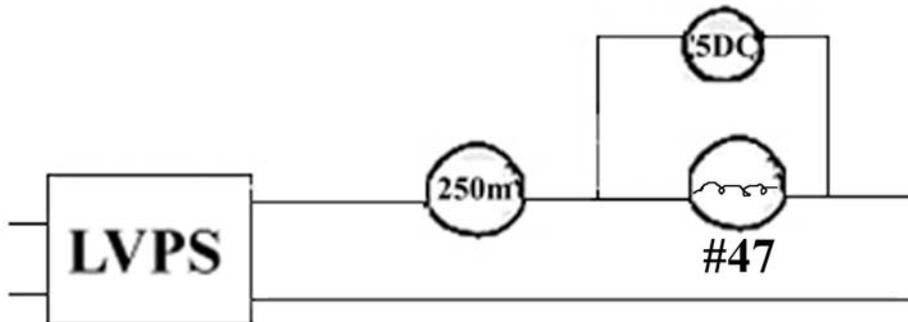
**2c---Voltage and Current:** Connect the arrangement of the three resistors in Figure 1 to your LVPS with the output set at 5 volts. Now use the clip lead to short resistor  $R_1$  by connecting A to B. Measure the voltage between B and C. Calculate the current and power dissipated through the resistors  $R_2$  and  $R_3$ . Observe the warming of the two resistors in parallel by feeling them with your fingers.

**3a---Voltage-Current (V-I) Characteristics:** Set your LVPS to its lowest output voltage (around 1.5V). Connect one MMM on the 250mDCA range in series with one  $43\Omega$  resistor across the LVPS output (Figure 3a). Be careful of shorts that might damage the MMM. (If your MMM suddenly stops working you probably blew the fuse. Open the back and replace the fuse with one of your spare fuses.) Connect the other MMM on the 5DCV range across the resistor (Figure 3a). Adjust the voltage output (turn the pot) of the LVPS so that your MMM on the 5DCV range across the resistor reads 1.5V, 2V, 3V, 4V, and 5V. Record the values of the current for each voltage setting.



**Figure 3a: Voltage-Current (V-I) Characteristics for the  $43\Omega$  resistor**

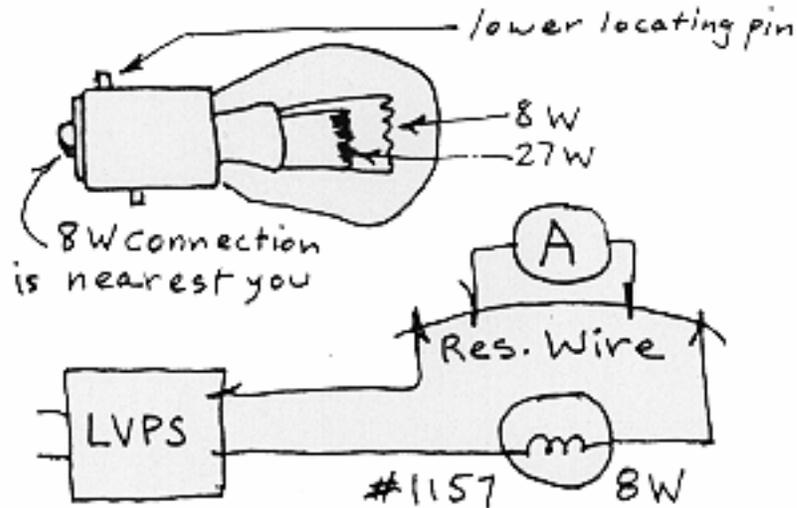
**3b---#47 Lamp:** Set your LVPS to its lowest output voltage and repeat the  $V - I$  measurements with the #47 lamp instead of the  $43\Omega$  resistor. You can use one of the sockets provided to connect the #47 lamp. Use your clip leads to connect to the socket tabs.



**Figure 3b: Voltage-Current (V-I) Characteristics for #47 lamp**

**3c---#1157 Lamp:** Set your LVPS to its lowest output voltage. Identify the 8W filament lead (it's the one with the higher resistance---use your ohmmeter to determine this; sometimes the contact is not good initially when the lamp is plugged into the socket. Try cleaning the contacts with a screwdriver blade). Use a clip lead to connect the positive terminal of the LVPS to one

end of the foot long piece of resistance wire that can be found in the top tray your Red Box. Use a second clip lead to connect the other end of the resistance wire to the shell of the lamp socket. Connect the 8W filament lead to the minus terminal of the LVPS (see Figure 3c).



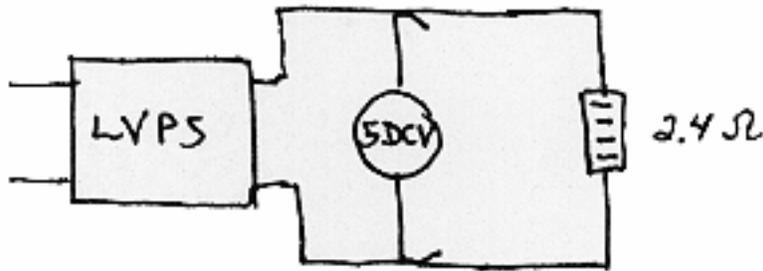
**Figure 3c: Voltage-Current (V-I) Characteristics for #1157 lamp**

Connect one MMM on the 25DCV range (not shown in Figure 3c) across the #1157 lamp. Connect the other MMM set on the  $50\mu(250mV)$ DCA range across a measured length of the resistance wire ( $0.2m$  is a good choice). The wire has resistance  $1.02\Omega$  per meter so a length of  $0.2m$  between the MMM probes corresponds to a resistance of  $0.2\Omega$ . When a current of  $0.5A$  flows through the resistance wire then there will be a voltage drop

$$V = IR = (0.5A)(0.2\Omega) = 100mV.$$

This will give almost a half scale reading on the  $50\mu(250mV)$ DCA setting. (On the  $50\mu(250mV)$ DCA range the MMM will measure between  $0V$  and  $250mV$  on the black DC scale.) Adjust the voltage across the #1157 lamp to  $2V$ ,  $4V$ ,  $6V$ ,  $8V$ ,  $10V$ . Record the values of the voltage across the resistance wire for each voltage setting. Calculate the current through the resistance wire for each voltage setting. Note the LM315T regulator may overheat and shut down; if this happens simply disconnect the lamp for a minute to let things cool down.

**4a--- Some LVPS Properties** A full characterization of the LVPS is a lot of work, but a few measurements will show some of its behavior. Connect a MMM on the 5DCV range across the output of the LVPS. Set your LVPS to  $1.5V$  (no load voltage). Use clip leads to connect the  $2.4\Omega$ ,  $2W$  resistor (from LVPST kit) across the LVPS output just long enough to see if the MMM reading changes (Figure 4a). Record the output voltage (load voltage) of the LVPS with the  $2.4\Omega$  resistor load attached. Disconnect the resistor load and adjust the LVPS (no load voltage) for  $2V$ ,  $3V$ ,  $4V$ , and  $5V$ .. Record the output voltages with the  $2.4\Omega$  resistor load for each setting of the LVPS. Then switch the MMM range to 25DCV, for setting of the LVPS of  $10V$  and  $15V$ . Record the output voltages with the  $2.4\Omega$  resistor load for each setting of the LVPS.



**Figure 4a: Measuring LVPS Properties**

Notice that for low voltages there isn't much change when the load is applied --- estimate the readings as best as you can. At any voltage much over  $2V$  you will be overloading the resistor, so that's why you shouldn't leave it connected for long.

**4b--- LVPS Short Circuit Current:** Set your LVPS to its lowest output voltage. Connect the two ends of the resistance wire across the LVPS output. Connect a MMM on the  $50\mu(250mV)$  DCA range across  $100mm$  of the resistance wire. This is pretty close to a short circuit so calculate the short circuit  $I_{sc}$  by measuring the voltage across the  $100mm$  of resistance wire (resistance  $0.1\Omega$ ). Turn the adjusting pot on the LVPS to see if the  $I_{sc}$  varies.

**5--- Charging a Capacitor:** Carefully zero a MMM on the RX1K range by connecting the leads together and adjusting the red OHMS ADJUST dial. Set the range switch to 'OFF'. You will only be able to make this measurement once so please follow directions carefully. Connect the  $1000\mu F$  capacitor with the red positive lead of the meter going to the negative lead of capacitor, and the black negative lead of the meter going to the positive lead of the capacitor. As soon as you turn the MMM range to RX1K start your clock. Measure the time at which the pointer reaches 4.5, 4, 3, 2, 1, and 0.5 on the black DC scale with 5 as maximum. Record your results. If you are unable to get data during the first run, on the next run the meter will only point between 1 and 3 on the black DC scale. You can still measure the time it takes the pointer to reach 2.5, 2, 1.5, 1 on the black DC scale.

## Parts List

You will be using parts from several different parts kits and the Red Box.

### LVPS

#### Red Box

- 2 MMM
- 1 transformer 120 V ac to 12 V ac
- 1' 800 wire
- 1 lamp socket (#1157)
- 1 clip lead kit (CLK)

#### LVPST Test Kit

- 1 resistor,  $2.4\ \Omega$  2W
- 1 lamp #1157 automotive

#### Experiment VI: Voltage and Current

- 3 lamps, #47 6.3V 0.15 A
- 3 lamp holders
- 3 resistors,  $43\ \Omega$  1/2W
- 1 electrolytic capacitor, 1000  $\mu F$
- 1 ft wire, #22 insulated stranded

# Report Experiment VI: Voltage and Current

## Data and Analysis

Arrange experimental apparatus as directed in the Experiment VI: Measurements p.13 and record results on the appropriate tables below.

### 1 ---Resistors and Lamps (all values in ohms)

Resistance of three  $43\ \Omega$  resistors:

$R_1 = \underline{\hspace{2cm}}$ ,  $R_2 = \underline{\hspace{2cm}}$ , and  $R_3 = \underline{\hspace{2cm}}$ .

$R_{AB} = \underline{\hspace{2cm}}$ ,  $R_{BC} = \underline{\hspace{2cm}}$ , and  $R_{AC} = \underline{\hspace{2cm}}$ .

Resistance of Lamps:

#47 =  $\underline{\hspace{2cm}}$ , #1157, 8W =  $\underline{\hspace{2cm}}$ , #1157, 27W =  $\underline{\hspace{2cm}}$ .

### 2.Voltage Measurements

2a---Voltage Divider

Voltages (in volts):

$V_{AB} = \underline{\hspace{2cm}}$ ,  $V_{BC} = \underline{\hspace{2cm}}$ ,  $V_{AC} = \underline{\hspace{2cm}}$ .

Current (in amperes) through Resistors:  $I_1 = \underline{\hspace{2cm}}$ ,  $I_2 = \underline{\hspace{2cm}}$ ,  $I_3 = \underline{\hspace{2cm}}$ .

Power (in watts) dissipated by Resistors:  $P_1 = \underline{\hspace{2cm}}$ ,  $P_2 = \underline{\hspace{2cm}}$ ,  $P_3 = \underline{\hspace{2cm}}$ .

2b---Voltage and Current

Current (in amperes) through Resistor  $R_1$ :  $I_1 = \underline{\hspace{2cm}}$ .

Power (in watts) dissipated by Resistor  $R_1$ :  $P_1 = \underline{\hspace{2cm}}$ ,

2c---Voltage and Current

Current (in amperes) through Resistors  $R_2$  and  $R_3$ :  $I_2 = \underline{\hspace{2cm}}$ ,  $I_3 = \underline{\hspace{2cm}}$ .

Power (in watts) dissipated by Resistors  $R_2$  and  $R_3$ :  $P_2 = \underline{\hspace{2cm}}$ ,  $P_3 = \underline{\hspace{2cm}}$ .

### 3---Voltage-Current (V-I) Characteristics

3a)	3a)	3b)	3b)	3c)	3c)	3c)
$43\ \Omega$	$43\ \Omega$	#47	#47	#1157 8W	#1157 8W	#1157 8W
Voltage [V] across $43\ \Omega$	Current [A]	Voltage [V] across #47	Current [A]	Voltage [V] across #1157	Res. Wire [mV]	Current [A]

Length of resistance wire (in mm) =  $\underline{\hspace{2cm}}$ ,

Resistance of wire (in  $\Omega$ ) =  $\underline{\hspace{2cm}}$ .

#### 4--- Some LVPS Properties

No Load Voltage $V_{\text{no load}}$ [V]	Voltage with Load $V_{\text{load}}$ [V]	$V_{\text{no load}} - V_{\text{load}}$ [V]

4b--- LVPS Short Circuit Current (in amperes)  $I_{\text{SC}} = \underline{\hspace{2cm}}$ .

#### 5--- Charging a Capacitor

MMM reading	Time [s]
5.0	
4.5	
4.0	
3.5	
3.0	
2.5	
2.0	
1.5	
1.0	
0.5	

**Problem 1: *Internal resistance of the LVPS***

When the output voltage of the LVPS is between 1.5V and 12.0V, the output voltage does not noticeably change when a reasonable load is connected. This means that the internal resistance is very small, in the range between  $0.01\Omega$  and  $0.001\Omega$ . However when the output voltage of the LVPS is above 12.0V, the internal resistance increases substantially.

- a) How can you determine the internal resistance as a function of load?
- b) From your data from the LVPS with the #1157 lamp as the load, determine the internal resistance as a function of load?

**Problem 2: *Calculating the internal resistance of an AA cell.***

An AA cell when there is no load connected to it, has a terminal to terminal voltage of 1.50V. When a  $2.4\Omega$  resistor is connected in series to an AA cell, the terminal voltage drops to 1.33V. What is the current in the circuit? What is the internal resistance of the AA cell? What is the short-circuit current if the terminals are connected by a wire with negligible resistance assuming that the internal resistance is constant? What power is lost to the internal resistance?