Includes Teacher's Notes and Typical Experiment Results

Instruction Manual and Experiment Guide for the PASCO scientific Model EM-8622

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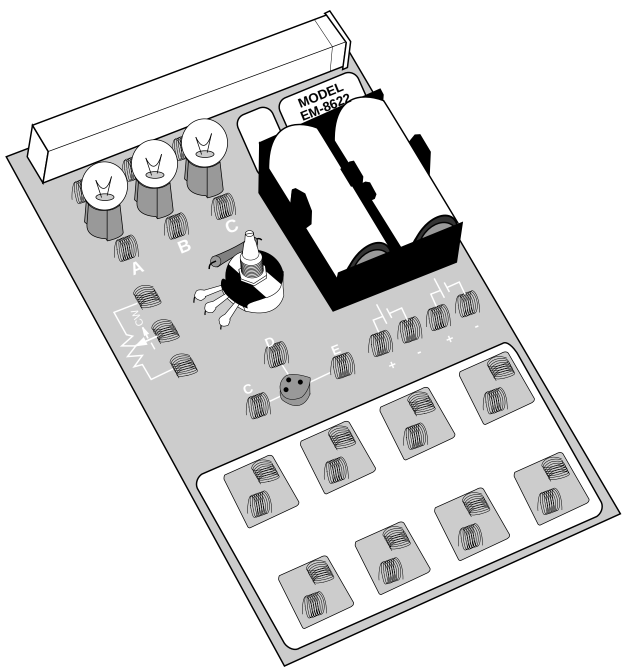
BASIC ELECTRICITY



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Introduction

The PASCO Circuits Experiment Board is designed to implement a large variety of basic electrical circuits for experimentation. The Circuits Experiment Board can be used for experiments beginning with a simple complete circuit and continuing on to a study of Kirchhoff's Laws and characteristics of diodes and transistors. A labeled pictorial diagram of the Experiment Board appears in Figure 1.2 of Experiment 1.

Equipment

The PASCO Model EM-8622 Circuits Experiment Kit includes the following materials:

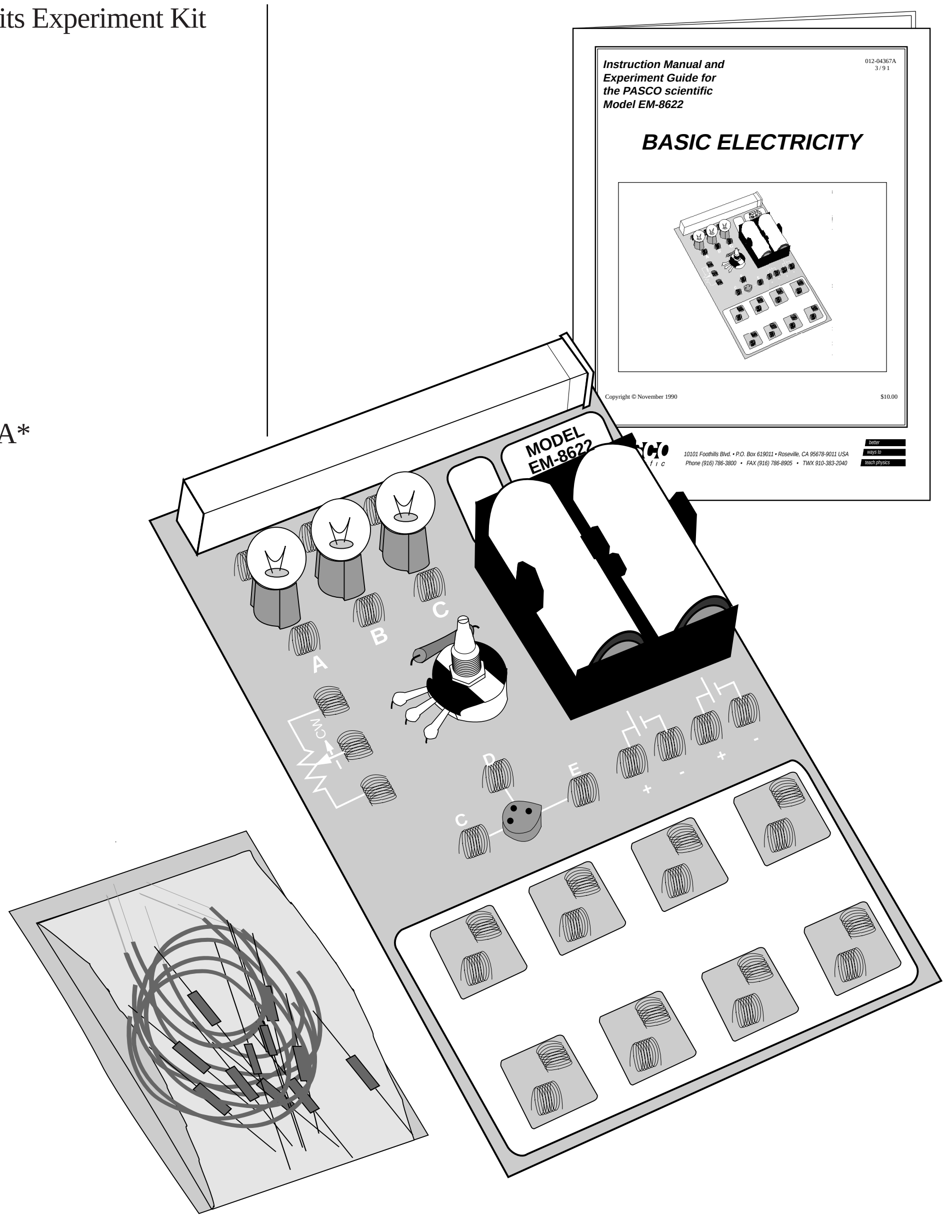
(2) Circuits Experiment Boards,

- (1) Resistor— 3.3 Ω, 2W, 5%
- (1) Potentiometer— 25 Ω, 2W
- (1) Transistor Socket
- (32) Springs
- (1) Battery Holder
- (3) Light Sockets
- (3) #14 Light Bulbs – 2.5 V, 0.3 A*
- (1) Storage Tube

(1) Component Bag

- Resistors
  - (2) 10 Ω— 1 watt
  - (3) 100 Ω— 1/2 watt
  - (8) 330 Ω— 1/2 watt
  - (3) 560 Ω— 1/2 watt
  - (3) 1000 Ω— 1/2 watt
  - (2) 100 K Ω— 1/2 watt
  - (2) 220 K Ω— 1/2 watt
- (2) Diodes 1N-4007
- (2) Transistors 2N-3904
- Capacitors
  - (2) 100 μ F— 16 volts
  - (2) 330 μ F— 16 volts
- Wire Leads— 22 ga.

(1) Experiment Manual



* **NOTE:** Due to manufacturer's tolerances, wattage may vary by 15-30% from bulb to bulb.

Getting Started

① Open the zip-lock bag containing the resistors and other components. Distribute the following resistors and wires to each of the boards, storing them in the plastic holder at the top of the board:

(3) 5" Wire Leads (12.7 cm)

(4) 10" Wire Leads (25.4 cm)

(1) 100 Ω Resistor (brown, black, brown, gold)

(3) 330 Ω Resistors (orange, orange, brown, gold)

(1) 560 Ω Resistor (green, blue, brown, gold)

(1) 1000 Ω Resistor (brown, black, red, gold)

Store the remainder of the components in the zip-lock bag until needed in future experiments.

② Students will need to use the same resistors, same batteries, etc. from one experiment to another, particularly during experiments 4 to 6. Labeling of the boards and your meters will enable students to more easily have continuity in their work. A pad has been included on the board for purposes of labeling individual boards. Use of a removable label or using a permanent marker are two alternatives.

The Experiments

The experiments written up in this manual are developmental, starting from an introduction to the Circuits Experiment Board and complete circuits, through series and parallel circuits, ultimately resulting in diode and transistor characteristics. These experiments can be used in combination with existing labs that the teacher employs, or may be used as a complete lab unit.

Experiment 1	Circuits Experiment Board
Experiment 2	Lights in Circuits
Experiment 3	Ohm’s Law
Experiment 4	Resistances in Circuits
Experiment 5	Voltages in Circuits
Experiment 6	Currents in Circuits
Experiment 7	Kirchhoff’s Rules
Experiment 8	Capacitors in Circuits
Experiment 9	Diode Characteristics
Experiment 10	Transistor Characteristics

Additional Equipment needed:

Experiments 3-10	Digital Multimeter, VOM or VTVM (See discussion on page 3)
Experiments 8-10	The Meter needs at least 10^6 Ω input impedance
Experiment 8	A timing device is needed, 0.1 second resolution.
Experiment 9	A.C. Power Supply and an Oscilloscope (optional)

Comments on Meters

VOM:

The Volt-Ohm-Meter or VOM is a multiple scale, multiple function meter (such as the PASCO SB-9623 Analog Multimeter), typically measuring voltage and resistance, and often current, too. These usually have a meter movement, and may select different functions and scales by means of a rotating switch on the front of the unit.

Advantages: VOM's may exist in your laboratory and thus be readily accessible. A single meter may be used to make a variety of measurements rather than needing several meters.

Disadvantages: VOM's may be difficult for beginning students to learn to read, having multiple scales corresponding to different settings. VOM's are powered by batteries for their resistance function, and thus must be checked to insure the batteries are working well. Typically, VOM's may have input resistances of 30,000 Ω on the lowest voltage range, the range that is most often used in these experiments. For resistances in excess of 1,000 Ω, this low meter resistance affects circuit operation during the taking of readings, and thus is not usable for the capacitor, diode and transistor labs.

DMM:

The Digital Multimeter or DMM is a multiple scale, multiple function meter (such as the PASCO SB-9624 Basic Digital Multimeter or the SE-9589 General Purpose DMM), typically measuring voltage and resistance, and often current, too. These have a digital readout, often with an LCD (Liquid Crystal Display). Different functions and scales are selected with either a rotating switch or with a series of push-button switches.

Advantages: DMM's are easily read, and with their typically high input impedances ($>10^6$ Ω) give good results for circuits having high resistance. Students learn to read DMM's quickly and make fewer errors reading values. Reasonable quality DMM's can be purchased for $60 or less. PASCO strongly recommends the use of DMM's.

Disadvantages: DMM's also require the use of a battery, although the lifetime of an alkaline battery in a DMM is quite long. The battery is used on all scales and functions. Most DMM's give the maximum reading on the selector (i.e., under voltage, "2" means 2-volt maximum, actually 1.99 volt maximum). This may be confusing to some students.

VTVM:

The Vacuum Tube Voltmeter or VTVM is a multiple scale, multiple function meter, typically measuring voltage and resistance. They do not usually measure current. The meter is an analog one, with a variety of scales, selected with a rotating switch on the front of the meter.

Advantages: VTVM's have high input resistances, on the order of 10^6 Ω or greater. By measuring the voltage across a known resistance, current can be measured with a VTVM.

Disadvantages: VTVM's have multiple scales. Students need practice to avoid the mistake of reading the incorrect one. An internal battery provides the current for measuring resistance, and needs to be replaced from time to time. Grounding problems can occur when using more than one VTVM to make multiple measurements in the same circuit.

Panelmeters:

Individual meters, frequently obtained from scientific supply houses, are available in the form of voltmeters, ammeters, and galvanometers (such as PASCO's SE-9748 Voltmeter 5 V, 15 V , SE-9746 Ammeter 1 A, 5 A and SE-9749 Galvanometer ± 35 mV). In some models, multiple scales are also available.

Advantages: Meters can be used which have the specific range required in a specific experiment. This helps to overcome student errors in reading.

Disadvantages: Using individual meters leads to errors in choosing the correct one. With limited ranges, students may find themselves needing to use another range and not have a meter of that range available. Many of the individual meters have low input impedances (voltmeters) and large internal resistances (ammeters). Ohmmeters are almost nonexistent in individual form.

Light Bulbs

The #14 bulbs are nominally rated at 2.5 V and 0.3 A. However, due to relatively large variations allowed by the manufacturer, the wattage of the bulbs may vary by 15 to 30%. Therefore, supposedly "identical" bulbs may not shine with equal brightness in simple circuits.

Notes on the Circuits Experiment Board

The springs are securely soldered to the board and serve as a convenient method for connecting wires, resistors and other components. Some of the springs are connected electrically to devices like the potentiometer and the D-cells. In the large Experimental Area, the springs are connected in pairs, oriented perpendicular to each other. This facilitates the connection of various types of circuits.

If a spring is too loose, press the coils together firmly to tighten it up. The coils of the spring should not be too tight, as this will lead to bending and/or breaking of the component leads when they are inserted or removed. If a spring gets pushed over, light pressure will get it straightened back up.

The components, primarily resistors, and small wires can be stored in the plastic container at the top of the board. Encourage students to keep careful track of the components and return them to the container each day following the lab period.

When connecting a circuit to a D-cell, note the polarity (+ or -) which is printed on the board. In some cases the polarity is not important, but in some it will be imperative. Polarity is very important for most meters.

Connections are made on the Circuits Experiment Board by pushing a stripped wire or a lead to a component into a spring. For maximum effect, the stripped part of the wire should extend so that it passes completely across the spring, making contact with the spring at four points. This produces the most secure electrical and mechanical connection.

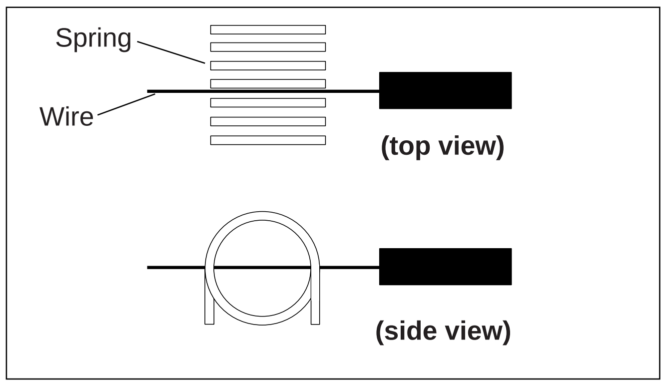


Figure 1 Diagram of wires and springs

Experiment 1: Circuits Experiment Board

EQUIPMENT NEEDED:

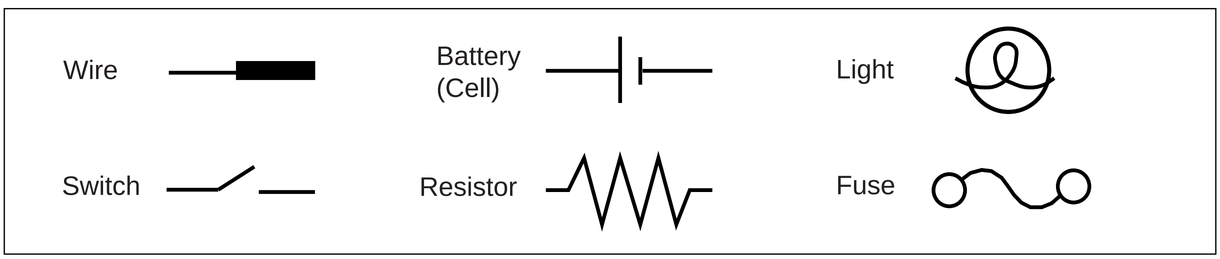
-Circuits Experiment
-D-cell Battery
-Graph
-Board
-Wire Leads
-Paper

Purpose

The purpose of this lab is to become familiar with the Circuits Experiment Board, to learn how to construct a complete electrical circuit, and to learn how to represent electrical circuits with circuit diagrams.

Background

① Many of the key elements of electrical circuits have been reduced to symbol form. Each symbol represents an element of the device's operation, and may have some historical significance. In this lab and the ones which follow, we will use symbols frequently, and it is necessary you learn several of those symbols.



② The Circuits Experiment Board has been designed to conduct a wide variety of experiments easily and quickly. A labeled pictorial diagram of the Experiment Board appears on page 6. Refer to that page whenever you fail to understand a direction which mentions a device on the board itself.

③ **Notes on the Circuits Experiment Board:**

a) The springs are soldered to the board to serve as convenient places for connecting wires, resistors and other components. Some of the springs are connected electrically to devices like the potentiometer and the D-cells.

b) If a spring is too loose, press the coils together firmly to enable it to hold a wire more tightly. If a spring gets pushed over, light pressure will get it straightened back up. If you find a spring which doesn't work well for you, please notify your instructor.

c) The components, primarily resistors, are contained in a plastic case at the top of the board. Keep careful track of the components and return them to the storage case following each lab period. This way you will get components with consistent values from lab to lab.

d) When you connect a circuit to a D-cell (each "battery" is just a cell, with two or more cells comprising a battery) note the polarity (+ or -) which is printed on the board. Although in some cases the polarity may not be important, in others it may very important.

e) Due to normal differences between light bulbs, the brightness of "identical" bulbs may vary substantially.

Procedure

① Use two pieces of wire to make connections between the springs on one of the light bulbs to the springs on the D-cell in such a way that the light will glow. Discuss with your lab partner before you begin actually wiring your circuit which connections you intend to make, and why you think you will be successful in activating the light. If you are not successful, try in order: changing the wiring, using another light, using another cell, asking the instructor for assistance.

a) Sketch the connections that the wires make when you are successful, using the symbols from the first page of this lab.

b) Re-sketch the total circuit that you have constructed, making the wires run horizontally and vertically on the page. This is more standard in terms of drawing electrical circuits.

② Reverse the two wires at the light. Does this have any effect on the operation? Reverse the two wires at the cell. Does this have any effect on the operation?

③ In the following steps, use a vacant spring connection such as one of the three around the transistor socket as shown on the right as a "switch." Connect one lead from the battery to this spring and then take a third wire from the spring to the light. You can now switch the power "on" and "off" by connecting or not connecting the third wire.

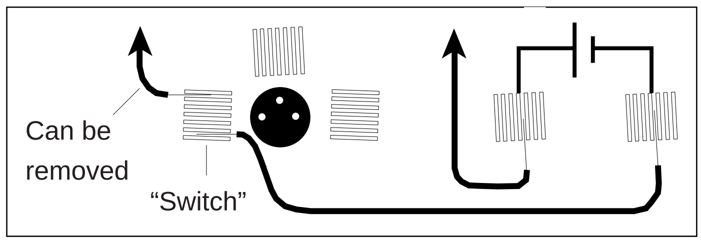


Figure 1.1

④ Use additional wires as needed to connect a second light into the circuit in such a way that it is also lighted. (Use a "switch" to turn the power on and off once the complete wiring has been achieved.) Discuss your plans with your lab partner before you begin. Once you have achieved success, sketch the connections that you made in the form of a circuit diagram. Annotate your circuit diagram by making appropriate notes to the side indicating what happened with that particular circuit. If you experience lack of success, keep trying.

➤ **NOTE:** Is your original light the same brightness, or was it brighter or dimmer that it was during step 1? Can you explain any differences in the brightness, or the fact that it is the same? If not, don't be too surprised, as this will be the subject of future study.

⑤ If you can devise another way of connecting two lights into the same circuit, try it out. Sketch the circuit diagram when finished and note the relative brightness. Compare your brightness with what you achieved with a single light by itself.

⑥ Disconnect the wires. Return the components and wires to the plastic case on the Circuits Experiment Board. Return the equipment to the location indicated by your instructor.

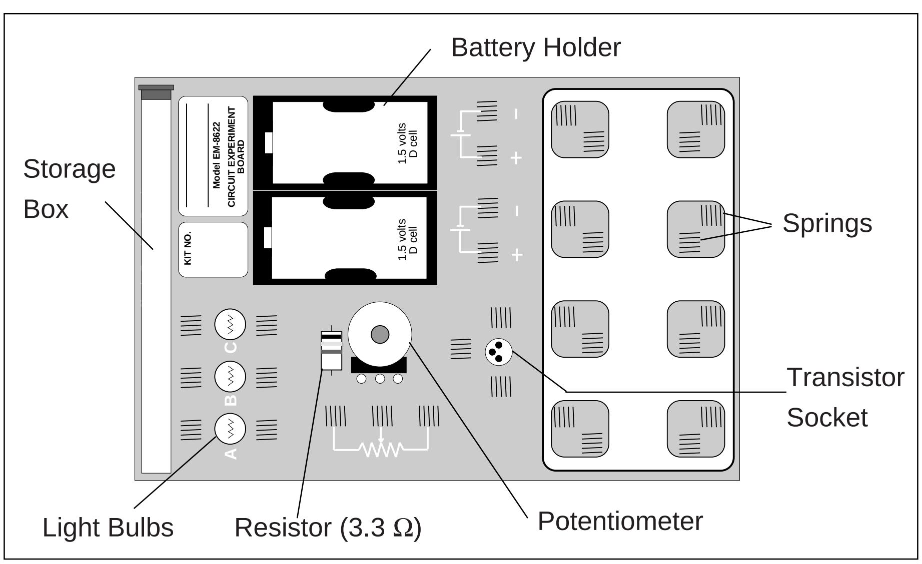


Figure 1.2

Experiment 2: Lights in Circuits

EQUIPMENT NEEDED:

-Circuits Experiment Board
-Wire Leads
-Two D-cell Batteries
-Graph Paper.

Purpose

The purpose of this lab is to determine how light bulbs behave in different circuit arrangements. Different ways of connecting two batteries will also be investigated.

Procedure

PART A

➤ **NOTE:** Due to variations from bulb to bulb, the brightness of one bulb may be substantially different from the brightness of another bulb in “identical” situations.

① Use two pieces of wire to connect a single light bulb to one of the D-cells in such a way that the light will glow. Include a “switch” to turn the light on and off, preventing it from being on continuously. (You should have completed this step in Experiment 1. If that is the case, review what you did then. If not, continue with this step.)

② Use additional wires as needed to connect a second light into the circuit in such a way that it is also lighted. Discuss your plans with your lab partner before you begin. Once you have achieved success, sketch the connections that you made in the form of a circuit diagram using standard symbols. Annotate your circuit diagram by making appropriate notes to the side indicating what happened with that particular circuit.

➤ **NOTE:** Is your original light the same brightness, or was it brighter or dimmer than it was during step 1? Can you explain any differences in the brightness, or why it is the same?

③ If one of the light bulbs is unscrewed, does the other bulb go out or does it stay on? Why or why not?

④ Design a circuit that will allow you to light all three lights, with each one being equally bright. Draw the circuit diagram once you have been successful. If you could characterize the circuit as being a series or parallel circuit, which would it be? What happens if you unscrew one of the bulbs? Explain.

⑤ Design another circuit which will also light all three bulbs, but with the bulbs all being equally bright, even though they may be brighter or dimmer than in step 4. Try it. When you are successful, draw the circuit diagram. What happens if you unscrew one of the bulbs? Explain.

⑥ Devise a circuit which will light two bulbs at the same intensity, but the third at a different intensity. Try it. When successful, draw the circuit diagram. What happens if you unscrew one of the bulbs? Explain.

➤ **NOTE:** Are there any generalizations that you can state about different connections to a set of lights?

PART B

⑦ Connect a single D-cell to a single light as in step 1, using a spring clip "switch" to allow you to easily turn the current on and off. Note the brightness of the light.

⑧ Now connect the second D-cell into the circuit as shown in Figure 2.1a. What is the effect on the brightness of the light?

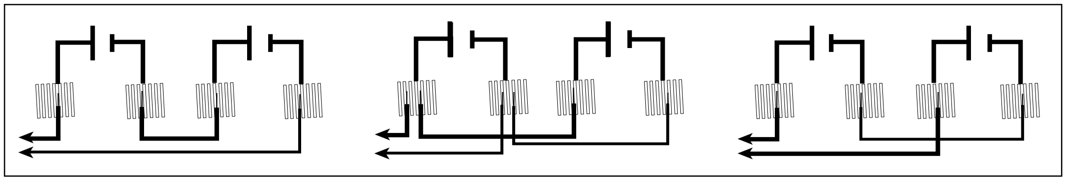


Figure 2.1a Figure 2.1b Figure 2.1c

⑨ Connect the second D-cell as in Figure 2.1b. What is the effect on the brightness?

⑩ Finally, connect the second D-cell as in figure 2.1c. What is the effect on the brightness?

➤ **NOTE:** Determine the nature of the connections between the D-cells you made in steps 8-10. Which of these was most useful in making the light brighter? Which was least useful? Can you determine a reason why each behaved as it did?

PART C

⑪ Connect the circuit shown in Figure 2.2. What is the effect of rotating the knob on the device that is identified as a "Potentiometer?"

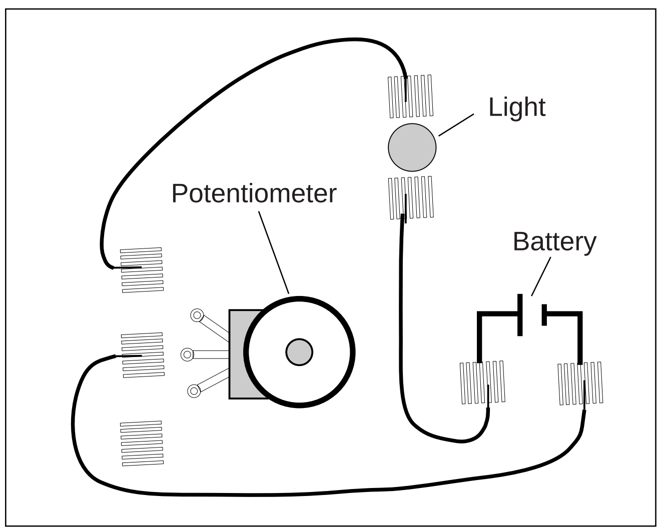


Figure 2.2 (Not to scale)

Discussion

① Answer the questions which appear during the experiment procedure. Pay particular attention to the **"NOTED:"** questions.

② What are the apparent rules for the operation of lights in series? In parallel?

③ What are the apparent rules for the operation of batteries in series? In parallel?

④ What is one function of a potentiometer in a circuit?

Experiment 3: Ohm’s Law

EQUIPMENT NEEDED:

-Circuits Experiment Board
-Multimeter
-Graph Paper.
-D-cell Battery
-Wire Leads

Purpose

The purpose of this lab will be to investigate the three variables involved in a mathematical relationship known as Ohm’s Law.

Procedure

① Choose one of the resistors that you have been given. Using the chart on the back, decode the resistance value and record that value in the first column of Table 3.1.

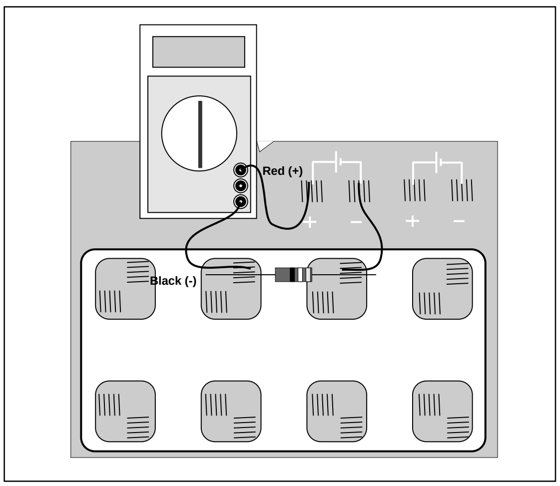


Figure 3.1a

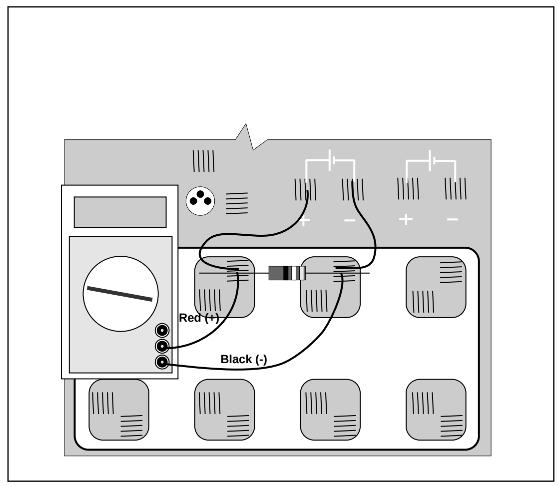


Figure 3.1b

② **MEASURING CURRENT:** Construct the circuit shown in Figure 3.1a by pressing the leads of the resistor into two of the springs in the Experimental Section on the Circuits Experiment Board.

③ Set the Multimeter to the 200 mA range, noting any special connections needed for measuring current. Connect the circuit and read the current that is flowing through the resistor. Record this value in the second column of Table 3.1.

④ Remove the resistor and choose another. Record its resistance value in Table 3.1 then measure and record the current as in steps 2 and 3. Continue this process until you have completed all of the resistors you have been given. As you have more than one resistor with the same value, keep them in order as you will use them again in the next steps.

⑤ **MEASURING VOLTAGE:** Disconnect the Multimeter and connect a wire from the positive lead (spring) of the battery directly to the first resistor you used as shown in Figure 3.1b. Change the Multimeter to the 2 VDC scale and connect the leads as shown also in Figure 3.1b. Measure the voltage across the resistor and record it in Table 3.1.

⑥ Remove the resistor and choose the next one you used. Record its voltage in Table 3.1 as in step 5. Continue this process until you have completed all of the resistors.

Data Processing

① Construct a graph of Current (vertical axis) vs Resistance.

② For each of your sets of data, calculate the ratio of Voltage/Resistance. Compare the values you calculate with the measured values of the current.

Resistance, Ω	**Current, amp**	**Voltage, volt**	**Voltage/Resistance**

Table 3.1

Discussion

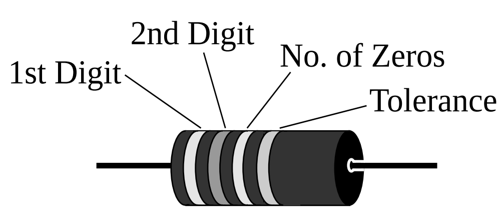
① From your graph, what is the mathematical relationship between Current and Resistance?

② Ohm's Law states that current is given by the ratio of voltage/resistance. Does your data concur with this?

③ What were possible sources of experimental error in this lab? Would you expect each to make your results larger or to make them smaller?

Reference

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



Fourth Band	
None	±20%
Silver	±10%
Gold	±5%
Red	±2%

Figure 3.2

Experiment 4: Resistances in Circuits

EQUIPMENT NEEDED:

-Circuits Experiment Boar
- Multimeter
-Resistors.

Purpose

The purpose of this lab is to begin experimenting with the variables that contribute to the operation of an electrical circuit. This is the first of a three connected labs.

Procedure

① Choose the three resistors having the same value. Enter those sets of colors in Table 4.1 below. We will refer to one as #1, another as #2 and the third as #3.

② Determine the coded value of your resistors. Enter the value in the column labeled "Coded Resistance" in Table 4.1. Enter the Tolerance value as indicated by the color of the fourth band under "Tolerance."

③ Use the Multimeter to measure the resistance of each of your three resistors. Enter these values in Table 4.1.

④ Determine the percentage experimental error of each resistance value and enter it in the appropriate column.

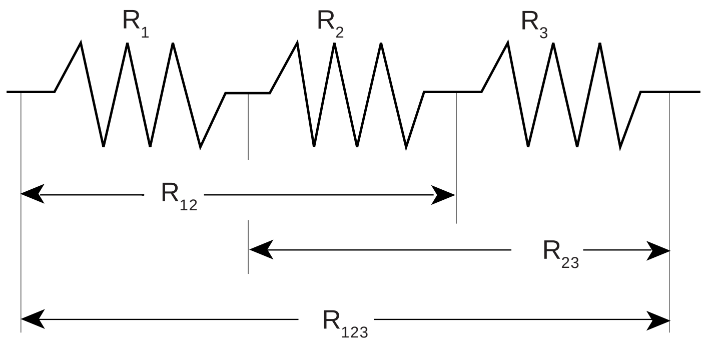
Experimental Error = [(|Measured - Coded|) / Coded] x 100%.

	Colors 1st	2nd	3rd	4th	Coded Resistance	Measured Resistance	% Error	Tolerance
#1								
#2								
#3								

Table 4.1

⑤ Now connect the three resistors into the SERIES CIRCUIT, figure 4.1, using the spring clips on the Circuits Experiment Board to hold the leads of the resistors together without bending them. Measure the resistances of the combinations as indicated on the diagram by connecting the leads of the Multimeter between the points at the ends of the arrows.

Series



R_{12}= ______________

R_{23}= ______________

R_{123}= ______________

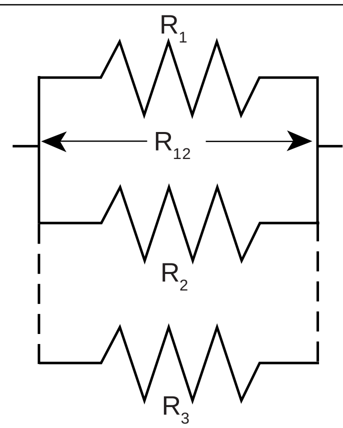
Figure 4.1

⑥ Construct a PARALLEL CIRCUIT, first using combinations of two of the resistors, and then using all three. Measure and record your values for these circuits.

Parallel

> ➤ **NOTE:** Include also $\mathbf{R_{13}}$

⑦ Connect the COMBINATION CIRCUIT below and measure the various combinations of resistance. Do these follow the rules as you discovered them before?



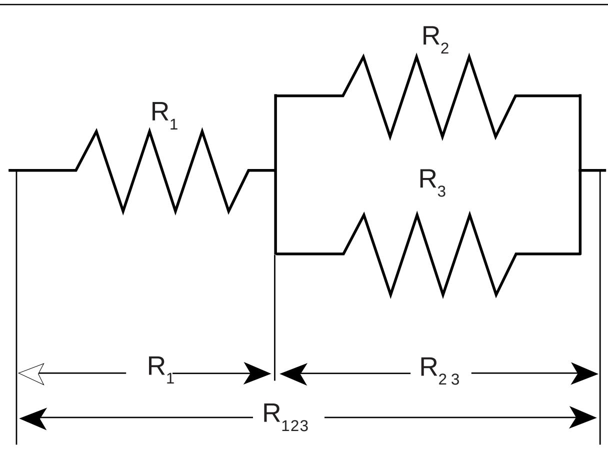
R_{12}= ______________

R_{23}= ______________

R_{123}= ______________

Figure 4.2

Combination



R_1 = ______________

R_{23} = ______________

R_{123}= ______________

Figure 4.3

⑧ Choose three resistors having different values. Repeat steps 1 through 7 as above, recording your data in the spaces on the next page. Note we have called these resistors A, B and C.

	Colors 1st	2nd	3rd	4th	Coded Resistance	Measured Resistance	% Error	Tolerance
A								
B								
C								

Table 4.2

Series

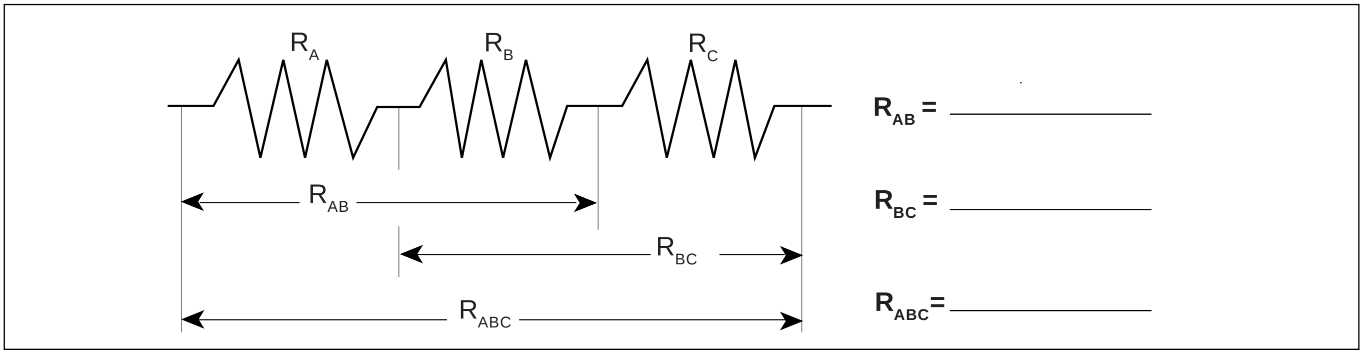


Figure 4.4

Parallel

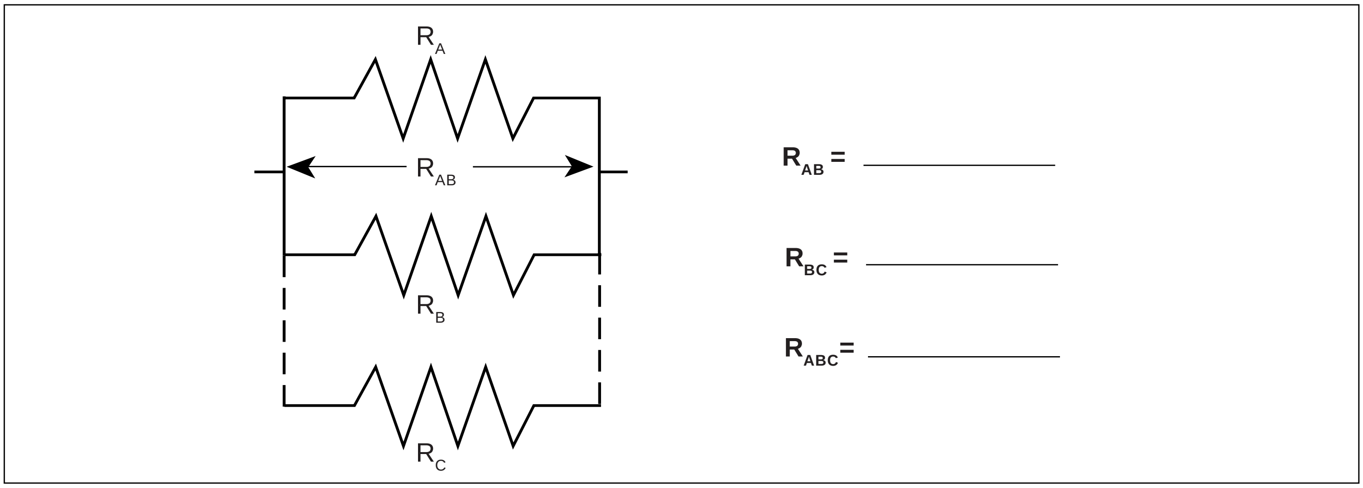


Figure 4.5

➤ **NOTE:** Include also R_{AC}

Combination

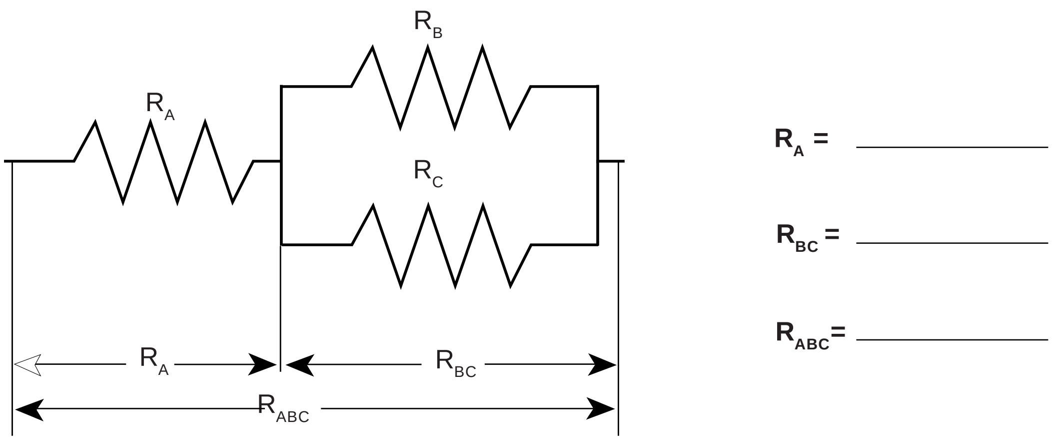


Figure 4.6

Discussion

① How does the % error compare to the coded tolerance for your resistors?

② What is the apparent rule for combining equal resistances in series circuits? In parallel circuits? Cite evidence from your data to support your conclusions.

③ What is the apparent rule for combining unequal resistances in series circuits? In parallel circuits? Cite evidence from your data to support your conclusions.

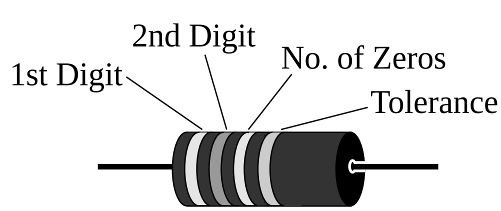
④ What is the apparent rule for the total resistance when resistors are added up in series? In parallel? Cite evidence from your data to support your conclusions.

Extension

Using the same resistance values as you used before plus any wires needed to help build the circuit, design and test the resistance values for another combination of three resistors. As instructed, build circuits with four and five resistors, testing the basic concepts you discovered in this lab.

Reference

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



Fourth Band	
None	±20%
Silver	±10%
Gold	±5%
Red	±2%

Figure 4.7

PASCO scientific

Experiment 5: Voltages in Circuits

EQUIPMENT NEEDED:

- -Circuits Experiment Board
- -D-cell Battery
- -Wire Leads
- -Multimeter
- -Resistors

Purpose

The purpose of this lab will be to continue experimenting with the variables that contribute to the operation of an electrical circuit. You should have completed Experiment 4 before working on this lab.

Procedure

① Connect the three equal resistors that you used in Experiment 4 into the series circuit shown below, using the springs to hold the leads of the resistors together without bending them. Connect two wires to the D-cell, carefully noting which wire is connected to the negative and which is connected to the positive.

② Now use the voltage function on the Multimeter to measure the voltages across the individual resistors and then across the combinations of resistors. Be careful to observe the polarity of the leads (red is +, black is -). Record your readings below.

Series

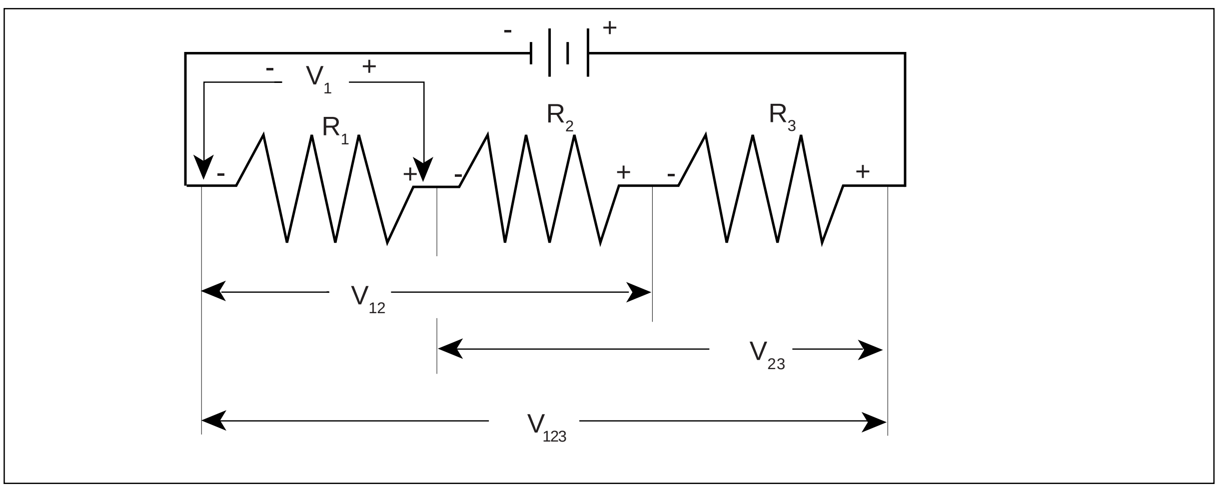


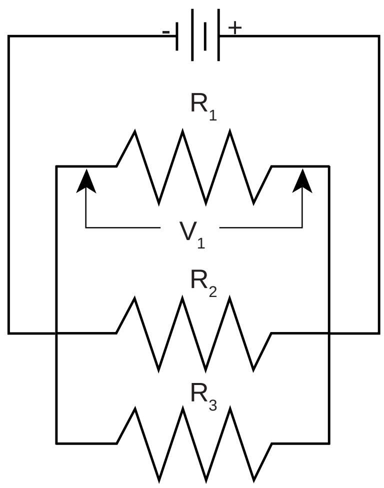
Figure 5.1

R_1 =	________	V_1 =	________
R_2 =	________	V_2 =	________
R_3 =	________	V_3 =	________
R_{12} =	________	V_{12} =	________
R_{23} =	________	V_{23} =	________
R_{123} =	________	V_{123} =	________

③ Now connect the parallel circuit below, *using all three resistors*. Measure the voltage across each of the resistors and the combination, taking care with the polarity as before.

➤**NOTE:** Keep all three resistors connected throughout the time you are making your measurements. Write down your values as indicated below.

Parallel



R_1 = ________ V_1 = ________

R_2 = ________ V_2 = ________

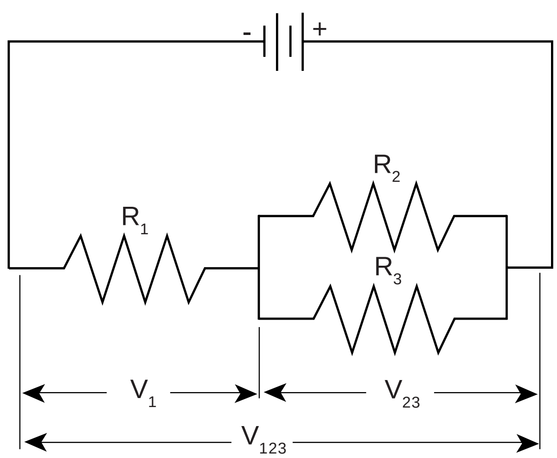
R_3 = ________ V_3 = ________

R_{123}= ________ V_{123}= ________

Figure 5.2

④ Now connect the circuit below and measure the voltages. You can use the resistance readings you took in Experiment 4 for this step.

Combination



R_1 = ________ V_1 = ________

R_{23} = ________ V_{23} = ________

R_{123} = ________ V_{123} = ________

Figure 5.3

⑤ Use the three unequal resistors that you used in Experiment 4 to construct the circuits shown below. Make the same voltage measurements that you were asked to make before in steps 1 to 4. Use the same resistors for A, B and C that you used in Experiment 4.

Series

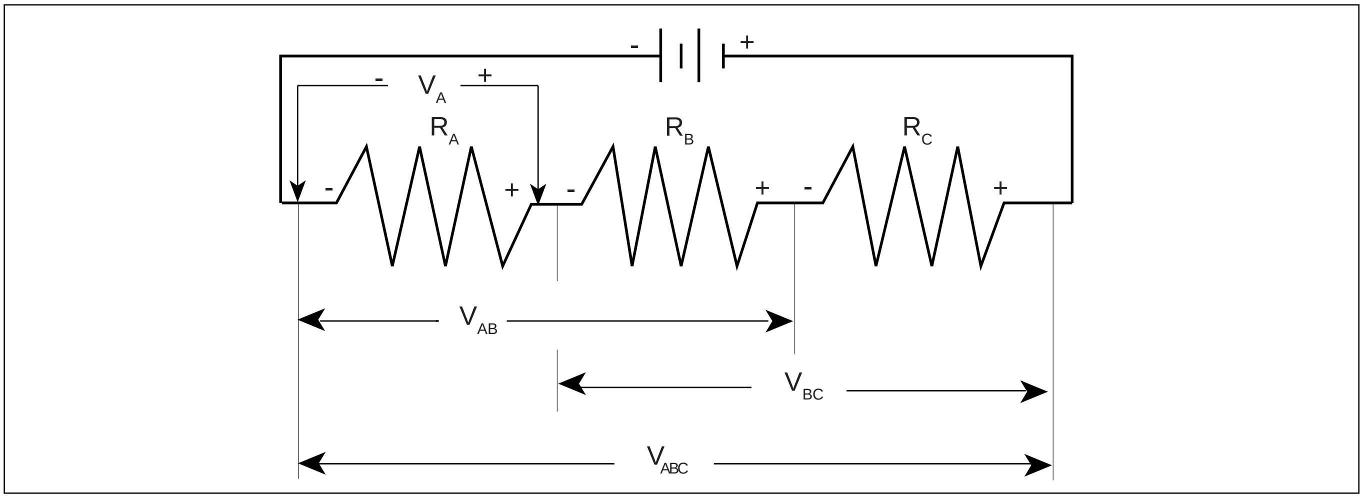


Figure 5.4

R_A = ________ V_A = ________

R_B = ________ V_B = ________

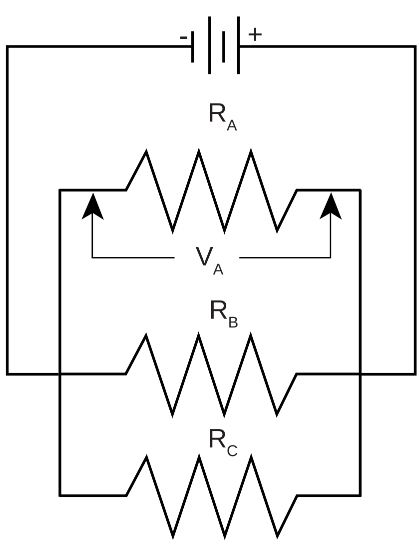
R_C = ________ V_C = ________

R_{AB} = ________ V_{AB} = ________

R_{BC} = ________ V_{BC} = ________

R_{ABC} = ________ V_{ABC} = ________

Parallel



R_A = ________ V_A = ________

R_B = ________ V_B = ________

R_C = ________ V_C = ________

R_{ABC} = ________ V_{ABC} = ________

Figure 5.5

Combination

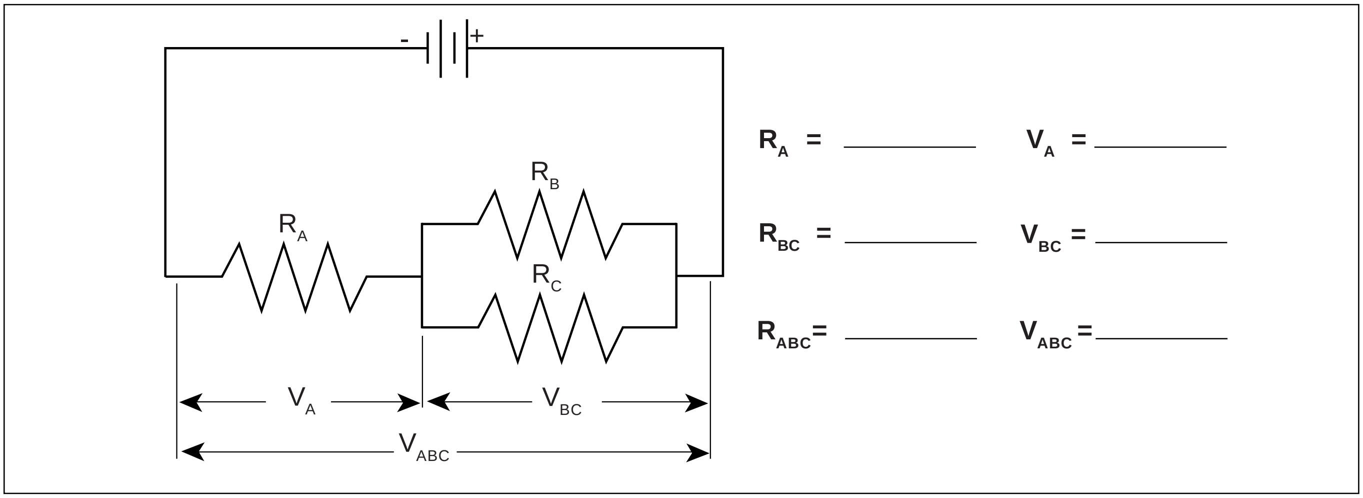


Figure 5.6

Discussion

On the basis of the data you recorded on the table with Figure 5.1, what is the pattern for how voltage gets distributed in a series circuit with equal resistances? According to the data you recorded with Figure 5.4, what is the pattern for how voltage gets distributed in a series circuit with unequal resistances? Is there any relationship between the size of the resistance and the size of the resulting voltage?

Utilizing the data from Figure 5.2, what is the pattern for how voltage distributes itself in a parallel circuit for equal resistances? Based on the data from Figure 5.5, what is the pattern for how voltage distributes itself in a parallel circuit for unequal resistances? Is there any relationship between the size of the resistance and the size of the resulting voltage?

Do the voltages in your combination circuits (see Figures 5.3 and 5.6) follow the same rules as they did in your circuits which were purely series or parallel? If not, state the rules you see in operation.

Experiment 6: Currents in Circuits

EQUIPMENT NEEDED:

-Circuits Experiment Board
-Resistors
-Wire Leads.
-Digital Multimeter
-D-cell Battery

Purpose

The purpose of this lab will be to continue experimenting with the variables that contribute to the operation of electrical circuits.

Procedure

① Connect the same three resistors that you used in Experiments 3 and 4 into the series circuit shown below, using the springs to hold the leads of the resistors together without bending them. Connect two wires to the D-cell, and carefully note which lead is negative and which is positive.

Series

② Now change the leads in your DMM so that they can be used to measure current. You should be using the scale which goes to a maximum of 200 mA. Be careful to observe the polarity of the leads (red is +, black is -). In order to measure current, the circuit must be interrupted, and the current allowed to flow through the meter. Disconnect the lead wire from the positive terminal of the battery and connect it to the red (+) lead of the meter. Connect the black (-) lead to $\mathbf{R_1}$, where the wire originally was connected. Record your reading in the table as $\mathbf{I_o}$. See Figure 6.2.

③ Now move the DMM to the positions indicated in Figure 6.3, each time interrupting the circuit, and carefully measuring the current in each one. Complete the table on the top of the back page.

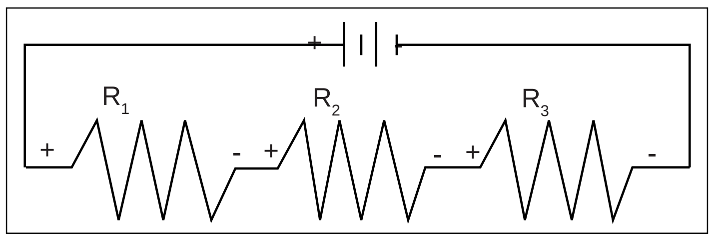


Figure 6.1

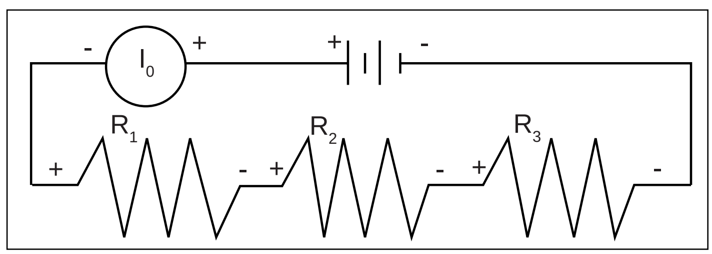


Figure 6.2

➤ **NOTE:** You will be carrying values from Experiments 3 and 4 into the table on the back.

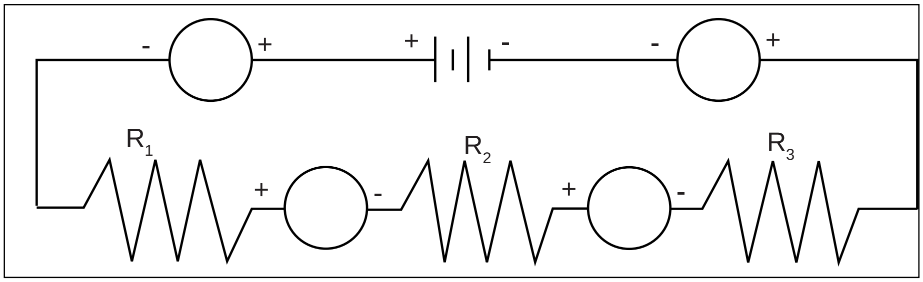


Figure 6.3

R_1 = ______________	I_0 = ______________	V_1 = ______________
R_2 = ______________	I_1 = ______________	V_2 = ______________
R_3 = ______________	I_2 = ______________	V_3 = ______________
R_{12} = ______________	I_3 = ______________	V_{12} = ______________
R_{23} = ______________		V_{23} = ______________
R_{123} = ______________		V_{123} = ______________

④ Connect the parallel circuit below, using all three resistors. Review the instructions for connecting the DMM as an ammeter in step 2. Connect it first between the positive terminal of the battery and the parallel circuit junction to measure $\mathbf{I_0}$. Then interrupt the various branches of the parallel circuit and measure the individual branch currents. Record your measurements in the table below.

Parallel

R_1 = ______________	I_0 = ______________	V_1 = ______________
R_2 = ______________	I_1 = ______________	V_2 = ______________
R_3 = ______________	I_2 = ______________	V_3 = ______________
R_{123} = ______________	I_3 = ______________	V_{123} = ______________
	I_4 = ______________	

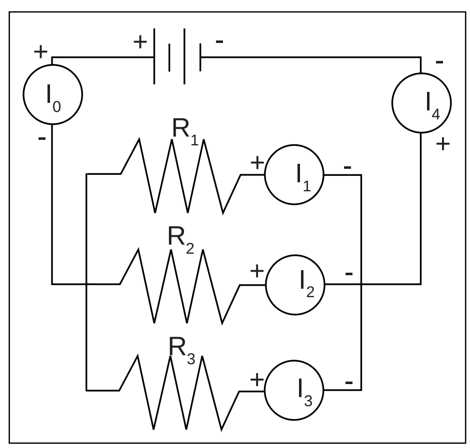


Figure 6.4

Discussion

On the basis of your first set of data, what is the pattern for how current behaves in a series circuit? At this point you should be able to summarize the behavior of all three quantities - resistance, voltage and current - in series circuits.

On the basis of your second set of data, are there any patterns to the way that currents behave in a parallel circuit? At this time you should be able to write the general characteristics of currents, voltages and resistances in parallel circuits.

Experiment 7: Kirchhoff's Rules

EQUIPMENT NEEDED:

- -Circuits Experiment Board
- -Wire Leads
- -Resistors.
- -Two D-cell Batteries
- -Digital Multimeter (DMM)

Purpose

The purpose of this lab will be to experimentally demonstrate Kirchhoff's Rules for electrical circuits.

Procedure

① Connect the circuit shown in Figure 7.1a using any of the resistors you have except the 10 Ω one. Use Figure 7.1b as a reference along with 7.1a as you record your data. Record the resistance values in the table below. With no current flowing (the battery disconnected), measure the total resistance of the circuit between points **A** and **B**.

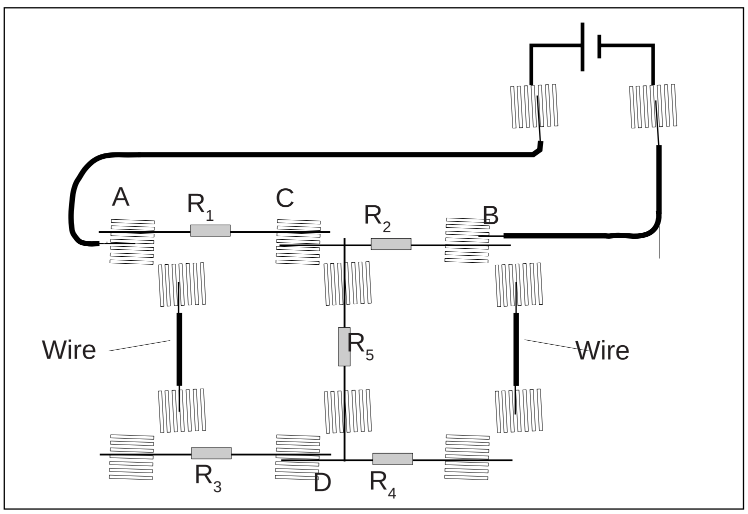


Figure 7.1a

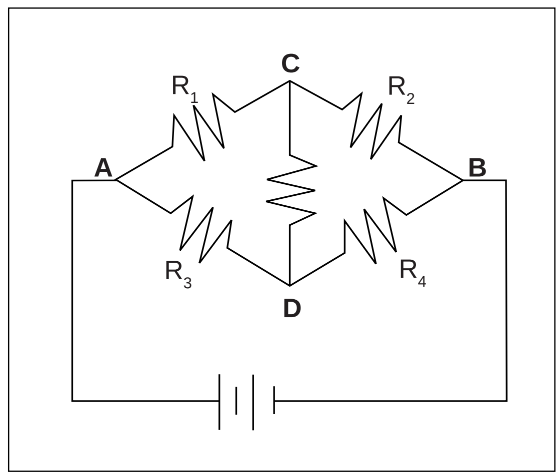


Figure 7.1b

② With the circuit connected to the battery and the current flowing, measure the voltage across each of the resistors and record the values in the table below. On the circuit diagram in Figure 7.1b, indicate which side of each of the resistors is positive relative to the other end by placing a "+" at that end.

③ Now measure the current through each of the resistors. Interrupt the circuit and place the DMM in series to obtain your reading. Make sure you record each of the individual currents, as well as the current flow into or out of the main part of the circuit, $\mathbf{I_T}$.

Resistance, Ω	Voltage, volts	Current, mA
R_1	V_1	I_1
R_2	V_2	I_2
R_3	V_3	I_3
R_4	V_4	I_4
R_5	V_5	I_5
R_T	V_T	I_T

Table 7.1

Analysis

① Determine the net current flow into or out of each of the four "nodes" in the circuit.

② Determine the net voltage drop around at least three (3) of the six or so closed loops. Remember, if the potential goes up, treat the voltage drop as positive (+), while if the potential goes down, treat it as negative (-).

Discussion

Use your experimental results to analyze the circuit you built in terms of Kirchhoff's Rules. Be specific and *state the evidence* for your conclusions.

Extension

Build the circuit below and apply the same procedure you used previously. Analyze it in terms of Kirchhoff's Rules. If possible, try to analyze the circuit ahead of time and compare your measured values with the theoretically computed values.

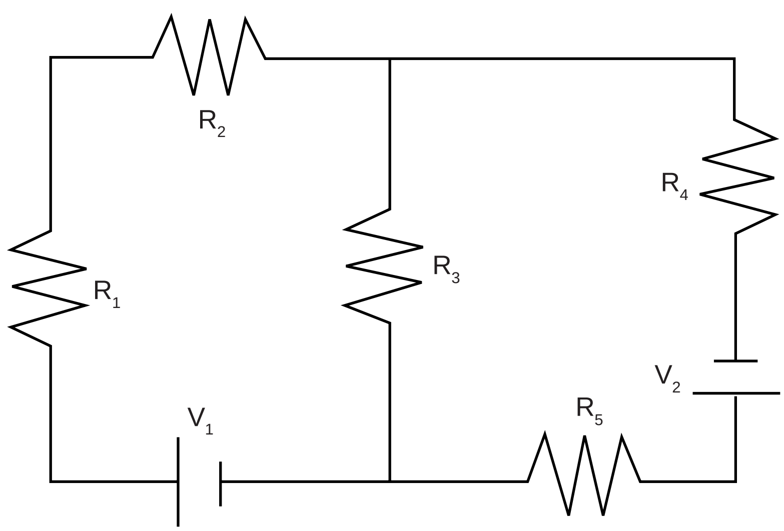


Figure 7.2

Experiment 8: Capacitors in Circuits

EQUIPMENT NEEDED:

– Vacuum Tube Voltmeter (VTVM) or Electrometer (ES-9054B) or Digital Multimeter (DMM) that has an input impedance of 10 MΩ or greater.

– Circuits Experiment Board
– Capacitors, Resistors
– Wire Leads
– D-cell Battery
– Stopwatch or timer with 0.1 sec resolution.

Purpose

The purpose of this lab will be to determine how capacitors behave in R-C circuits. The manner in which capacitors combine will also be studied.

Procedure

① Connect the circuit shown in Figure 8.1, using a 100-K Ω resistor and a 100-μF capacitor. Use one of the spring clips from the transistor socket as a "switch" as shown. Connect the VTVM so the black "ground" lead is on the side of the capacitor that connects to the negative terminal of the battery and set it so that it reads to a maximum of 1.5 V DC.

② Start with no voltage on the capacitor and the wire from the "switch" to the circuit disconnected. If there is a remaining voltage on the capacitor, use a piece of wire to "short" the two leads together, draining any remaining charge. (Touch the ends of the wire to points **B** and **C** as shown in Figure 1 to discharge the capacitor.)

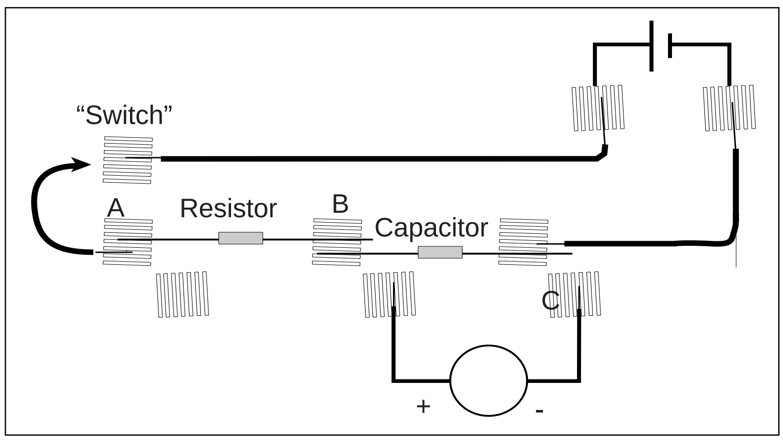


Figure 8.1

③ Now close the "switch" by touching the wire to the spring clip. Observe the voltage readings on the VTVM, the voltage across the capacitor. How would you describe the manner in which the voltage changes?

④ If you now open the "switch" by removing the wire from the spring clip, the capacitor should remain at its present voltage with a very slow drop over time. This indicates that the charge you placed on the capacitor has no way to move back to neutralize the excess charges on the two plates.

⑤ Connect a wire between points **A** and **C** in the circuit, allowing the charge to drain back through the resistor. Observe the voltage readings on the VTVM as the charge flows back. How would you describe the manner in which the voltage falls? (It would be reasonable to sketch a graph showing the manner in which the voltage rose over time as well as the manner in which it fell over time.)

⑥ Repeat steps 3-5 until you have a good feeling for the process of charging and discharging of a capacitor through a resistance.

⑦ Now repeat steps 3-5, this time recording the time taken to move from 0.0 volts to 0.95 volts while charging, $\mathbf{t_C}$, and the time taken to move from 1.5 volts to 0.55 volts while discharging, $\mathbf{t_D}$. Record your times along with the resistance and capacitance values in Table 8.1 at the top of the back page.

Trial	Resistance	Capacitance	t_C	t_D
1				
2				
3				
4				
5				
6				
7				
8				

Table 8.1

⑧ Replace the 100-µF capacitor with a 330-µF capacitor. Repeat step 7, recording the charging and discharging times in Table 8.1. If a third value is available, include it in the data table, too.

⑨ Return to the original 100-µF capacitor, but put a 220-K Ω resistor in the circuit. Repeat step 7, recording your data in Table 8.1. If a third resistor is provided, use it in the circuit, recording the data.

➤ **NOTE:**

① What is the effect on charging and discharging times if the capacitance is increased? What mathematical relationship exists between your times and the capacitance?

② What is the effect on charging and discharging times if the resistance of the circuit is increased? What mathematical relationship exists between your times and the resistance?

⑩ Return to the original 100-K Ω resistor, but use the 100-µF capacitor in series with the 330-µF capacitor. Repeat step 7, recording your results in Table 8.2.

⑪ Now repeat step 7, but with the 100-µF and the 330-µF capacitors in parallel.

R = __________ C_1 = __________ C_2 = __________

Type of Circuit	t_C	t_D
Series		
Parallel		

Table 8.2

➤ **NOTE:** What is the effect on the total capacitance if capacitors are combined in series? What if they are combined in parallel? (Refer to Table 8.2).

Experiment 9: Diodes

EQUIPMENT NEEDED:

-Circuits Experiment Board
-Wire Leads
-1000-Ω Resistor
-330-Ω Resistor.
-Digital Multimeter (DMM)
-Two D-cell Batteries
-1N4007 Diode

Purpose

The purpose of this lab will be to experimentally determine some of the operating characteristics of semiconductor diodes.

Procedure

① Connect the circuit shown in Figure 9.1a using the 1N4007 diode you've been supplied and the 1000-Ω resistor. Use Figure 9.1b as a reference along with Figure 9.1a as you record your data. Note the direction that the diode is oriented, with the dark band closer to point **B**.

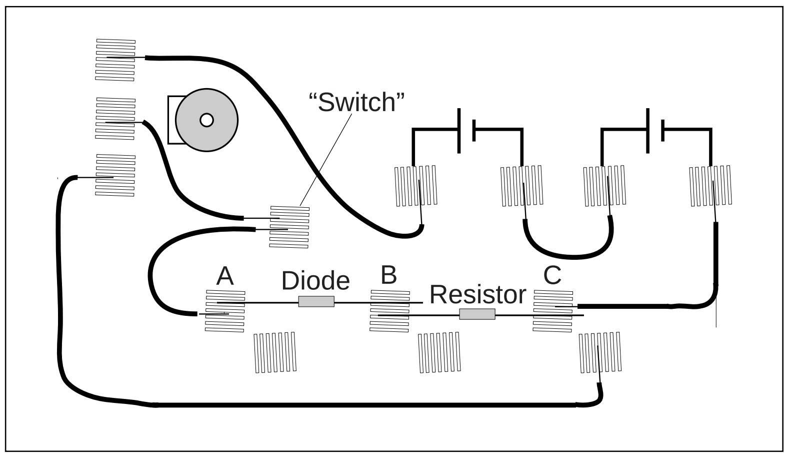


Figure 9.1a

② With the "switch" closed and the current flowing, adjust the potentiometer until there is a voltage of 0.05 volt between points **B** and **C** ($\mathbf{V_{BC}}$). Measure the voltage across the diode ($\mathbf{V_{AB}}$). Record your values in the left-hand side of Table 9.1under "Forward Bias".

③ Adjust the potentiometer to attain the following values for $\mathbf{V_{BC}}$: 0.1, 0.2, 0.3,.....2.0 volts. Record the two voltages for each case.

④ Remove the 1000-Ω resistor and replace it with a 330-Ω resistor. Repeat steps 3 & 4, going from a voltage of 0.3, 0.4,.....2.0 volts. Record the two voltages in each case.

⑤ Reverse the orientation of the diode. Set the diode voltage ($\mathbf{V}_{AB}$) to the values 0.5, 1.0,....3.0 volts. Measure the resistor voltage ($\mathbf{V}_{BC}$) in each case. Record these values in the columns labeled "Reverse Bias".

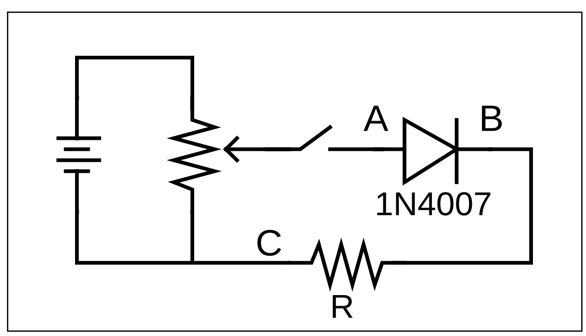


Figure 9.1b

Analysis

① Determine the current flow (**I**) in each setting by dividing the voltage across the resistor ($\mathbf{V}_{BC}$) by the resistance. Where you switched resistors, be sure to change the divisor.

② Construct a graph of Current (vertical axis) vs the Voltage across the diode, with the graph extending into the 2nd quadrant to encompass the negative voltages on the diode.

Discussion

Discuss the shape of your graph and what it means for the operation of a semiconductor diode. Did the diode operate the same in steps 3 and 4 as it did in step 5? In steps 3 and 4 the diode was "Forward Biased", while it was "Reverse Biased" in step 5. Based on your data, what do you think these terms mean? What use might we have for diodes?

Sample Data Table

Diode Type ____________

Forward Bias				Reverse Bias			
R, Ω	V_{AB}, volts	V_{BC}, volts	I, mA	R, Ω	V_{AB}, volts	V_{BC}, volts	I, mA

Table 9.1

Extensions

① If your instructor has a zener diode, carry out the same investigations that you did above. What differences are there in basic diodes and zener diodes?

② Use an LED (light emitting diode) to carry out the same investigations. What differences are there between basic diodes and LED's?

Experiment 10: Transistors

EQUIPMENT NEEDED:

-Circuits Experiment Board
-Wire Leads
-1000-Ω Resistor
-100-Ω Resistor.
-Two D-cell Batteries
-Digital Multimeter (DMM)
-2N3904 Transistor (NPN)

Purpose

The purpose of this lab will be to experimentally determine some of the operating characteristics of a transistor.

Procedure

① Connect the circuit shown in Figure 10.1a using the 2N3904 Transistor you've been supplied. Resistor $\mathbf{R_1}$ = 1000 Ω and resistor $\mathbf{R_2}$ = 100 Ω. Use Figure 10.1b as a reference along with Figure 10.1a as you record your data. Note the leads on the transistor as marked next to the socket in the drawing.

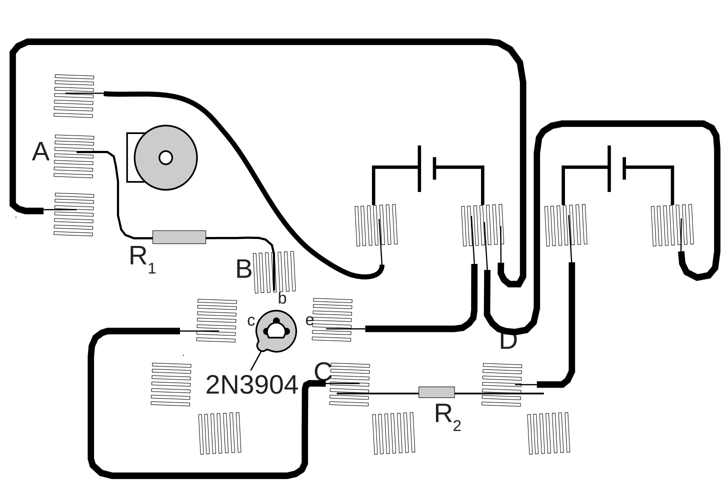


Figure 10.1a

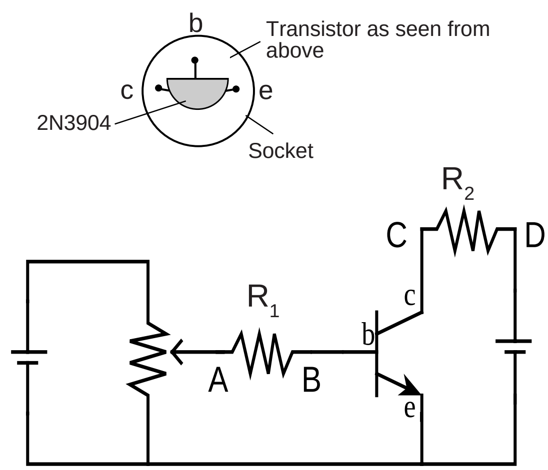


Figure 10.1b

② Adjust the potentiometer carefully until the reading between points **A** and **B** is approximately 0.002 volt (2.0 mv). Now read the voltage between points **C** and **D**. Record these readings in your data table. Note that $\mathbf{V_{AB}}$ divided by $\mathbf{R_1}$ gives the current flowing to the base of the transistor, while $\mathbf{V_{CD}}$ divided by $\mathbf{R_2}$ gives the current flowing in the collector part of the circuit.

③ Adjust the potentiometer to give $\mathbf{V_{AB}}$ the following readings, each time reading and recording the corresponding $\mathbf{V_{CD}}$: 0.006, 0.010, 0.015, 0.020, 0.025, 0.030, 0.035, 0.040, 0.045, 0.050, 0.055, 0.060, 0.080, 0.100, 0.150, 0.200, 0.250 volts. Also set $\mathbf{V_{AB}}$ to 0.000 volts.

Analysis

① For each of your sets of readings, calculate:

$$\mathbf{I_B = V_{AB} / R_1} \text{ and } \mathbf{I_C = V_{CD} / R_2}$$

Record all of your current readings in mA.

② Plot a graph of $\mathbf{I_C}$ (vertical axis) vs $\mathbf{I_B}$. If you find an area or areas where you need more points to fill out any curves or sudden changes, simply return to step 2 and make the appropriate measurements.

③ What is the general shape of the graph? Is there a straight-line region? Does it go through the origin? Why or why not? Relate the behavior of the transistor at the beginning of the graph to the behavior of the diode in Experiment 9.

④ What does the leveling off of the graph indicate? Electronics people refer to the transistor as being "saturated". How would you describe saturation based on your experiment?

⑤ Find the slope of the straight-line region of the graph. This ratio - $\mathbf{I_C / I_B}$ is referred to as the current amplification of the transistor. It describes how many times greater changes in the collector current are than the changes in the base current. Report the current amplification of your transistor.

Discussion

Discuss the graph and the calculations you did in the Analysis section.

Sample Data Table

Transistor Type ____________

R_1, Ω	V_{AB}, volts	I_B, mA	R_2, Ω	V_{CD}, volts	I_C, mA

Table 10.1

Extensions

① What effect would changing the resistance in the collector circuit ($\mathbf{R_2}$) make? Try changing the value to 330 Ω or 560 Ω. Does the graph have the same shape? Is the current amplification the same as before? How does the amplification depend on $\mathbf{R_2}$?

② Obtain a different transistor and repeat the measurements you made in steps 2 & 3. If it is a PNP transistor, you will need to reverse the wires coming from the D-cells as the emitter needs to be positive, not negative, and the collector will be negative.

Appendix: Tips and Troubleshooting

Correct Circuit, Doesn't Work

- Check to see if the circuit is indeed connected correctly and completely.
- Check to see if the battery is giving full voltage.
- Check to see if each wire is making contact with the spring. If magnet wire is used, the enamel coating on the outside will prevent electrical connection and needs to be removed. In some cases, students may try to make a complete circuit through the insulation.

Surprising Results

In some cases, there will be no difference in the measurements from one point in the circuit to another. This doesn't mean the measurement is trivial or unimportant, rather it is what we hope the student will learn from his/her lab work. Not all measurements have to be different.

Making a "switch"

In the several labs, students are asked to use a "vacant" spring connection such as one of the three around the transistor socket as shown on the right as a "switch." By connecting one lead from the battery there and then taking a third wire to the circuit, you can effectively switch the power "on" and "off" by simply connecting or not connecting the third wire. This duplicates the action in a real switch.

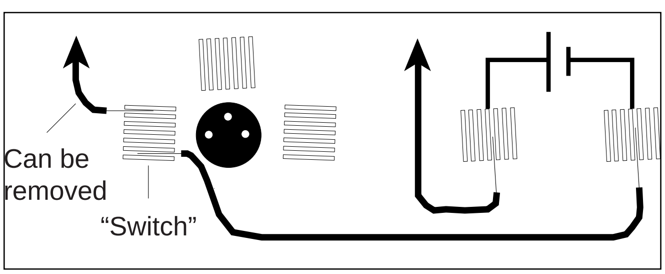


Figure 2

Lights and Relative Brightness

The lights for this experiment board, #14 bulbs, are designed for 2.5 volts and 0.3 amperes. A single D-cell will not light a bulb to maximum brightness, but two cells in series will give a very bright light.

The labs asking for relative brightness ask students to judge relative brightness only, not an absolute brightness. This part of the experiment would be aided by having the room mostly darkened. Additional bulbs can be purchased from PASCO, at Radio Shack, an electronics store, at auto supplies stores, or possibly a local discount store.

Batteries

The Circuits Experiment Board is designed to use one or two D-cells. The voltage delivered by a D-cell is 1.5 volts ±. In practice, alkaline cells give the longest life, but the less expensive zinc-carbon cells will give adequate results. A single set of batteries was used successfully by ten different classes to complete labs 1,3,4,5, 6 and 7 before being replaced.

Resistors

The resistors supplied are listed under Materials on page 1 of this manual. The values have been chosen for clear results and for helping to extend the life of the D-cells. If resistors are lost or broken, replacements can be purchased from PASCO, or at any electronics store, including Radio Shack. Other values can be substituted, but for Experiments 3 through 7, the values should be between 100 Ω and 1500 Ω for best results.

> ➤**NOTE:** Using the 330 Ω, 560 Ω and 1000 Ω resistors gives approximate ratios of 1:2:3 for working towards semi-quantitative understanding of d.c. circuits.

The diagram below shows the resistor color code. For example, a resistor having the colors Orange-Orange-Brown-Silver has the value 330 Ω ± 10%.

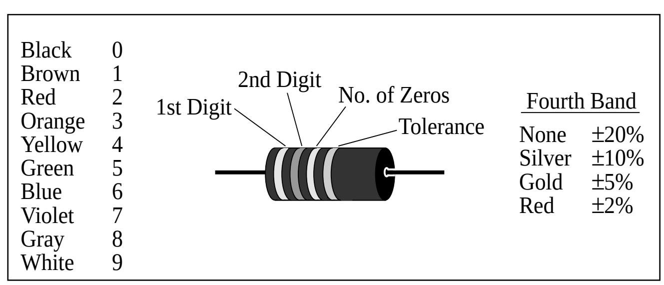


Figure 3

Wires

The Circuits Experiment Board can be used with a large variety of wire types and sizes. We recommend 20 or 22 gauge solid wire with colorful insulation. This will help students to follow their work more easily and minimize difficulties in making the transition from paper circuit to actual circuit on the Circuits Experiment Board.

Stripping Your Own Wire

The wire included with the Basic Electricity Lab is 22 gauge insulated, solid wire in 5" and 10" lengths. The lengths are stripped at each end.

If you choose to strip your own additional wires, a commercially available wire stripper can be used to remove the insulation from each end. The jaws of the wire stripper are placed on the wire 3/8" from the end. By squeezing the handles together, the jaws will close on the wire and cut only as deep as the insulation.

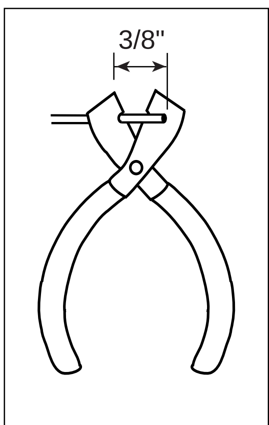


Figure 3a

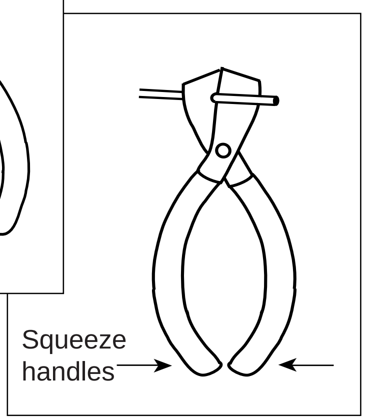


Figure 3b

Pulling the wire away from the stripper (Figure 3c) causes the cut end of the insulation to slip off of the wire, leaving 3/8" of exposed wire.

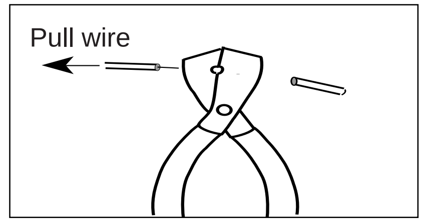


Figure 3c

If you do not have access to a wire stripper, the wire may also be stripped by carefully using a knife. Place the wire on a solid surface. Set the knife blade on the insulation about 3/8" from the end. With the blade at an angle so it cannot cut downward into the wire, use the knife to shave off the insulation.

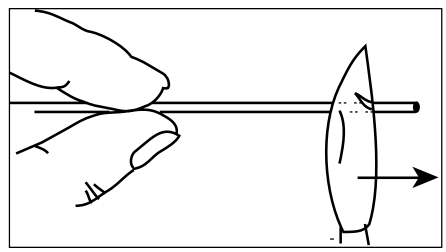


Figure 4

After one part of the insulation is removed, turn the wire and continue shaving off the rest of the insulation.

Replacement Parts List

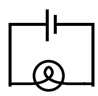
Item	PASCO Part #
P.C.B. ASSY, BASIC ELECT	004-04340
MANUAL EM-8622	012-04367
RES, 10 OHM, 1W, 5%	111-100
RES, 100 OHM, 1/2W, 5%	112-101
RES, 1K, 1/2W, 5%	112-102
RES, 100K, 1/2W, 5%	112-104
RES, 220K, 1/2W, 5%	112-224
RES, 330 OHM, 1/2W, 5%	112-331
RES, 560 OHM, 1/2W, 5%	112-561
CAP, ELECT-100mF, 16V AXIAL	222-039
CAP, ELECT 330MF, 16V AXIAL	222-040
DIODE-1N4007, 1000PIV, 1A	410-002
TRANSISTOR-2N3904 NPN	420-002

➤**NOTE:** Replacement parts can be purchased from PASCO or at most electronic stores including Radio Shack.

Notes

Teacher's Guide

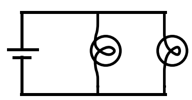
Exp 1 - Circuits Experiment Board

① 

② Reversing things at either end had no effect.

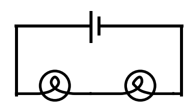
④⑤ There are two different ways of putting two lamps into the circuit: parallel and serial.

Parallel:



With this method, the lights will each be approximately the same brightness as in part 1.

Serial:

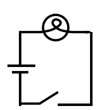


Using this circuit, the lights will be dimmer than in part 1.

Exp 2 - Lights in Circuits

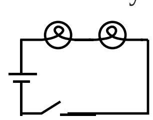
➤**NOTE:** It is best to do these experiments with both batteries, rather than just one. Connect them in series, as shown in figure 2.1a. This will make the lights brighter and easier to see when some of the dimmer circuits are built.

Procedure

① 

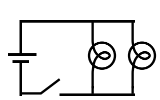
②③ There are two ways of making the circuit so that both lights are on with the same intensity.

Series



The lights will be dimmer than in part 1. The electric current must go through one bulb to reach the other, so disconnecting a bulb will cause both to go out. (This is how those maddening “if-one-goes-out-they-all-die-so-Merry-Christmas” lights are wired.)

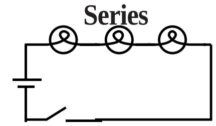
Parallel



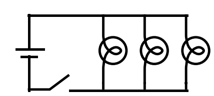
The lights will show the same intensity as in part 1. The electric current is going through both bulbs at the same time, so disconnecting one does not affect the other. (This is how the Christmas lights you wish you had bought are wired.)

④⑤ Again, the circuit may be series or parallel.

Series



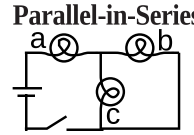
Parallel



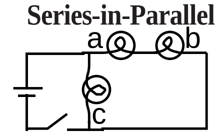
These circuits have the same characteristics as the ones in part 2-3

⑥ There are two ways of doing this as well.

Parallel-in-Series



Series-in-Parallel



(The parallel portion of the first circuit will be very dim.)

What happens if you unscrew one of the bulbs depends on which bulb you unscrew. In the first circuit, unscrewing (a) will turn everything off. Unscrewing (b) or (c) will make (a) dimmer and leave the other one unaffected. In the second circuit, unscrewing (c) will make (a) and (b) brighter; while unscrewing (a) or (b) will make (c) brighter and turn the other one off.

⑦-⑩ Putting the batteries in series (2.1a) will make things the brightest, because then the voltage to the lights is the highest. Batteries in parallel (2.1b) will have the same effect as one battery. Batteries opposed (2.1c) will have no effect at all unless one of the batteries is nearly dead.

⑪ The potentiometer, when used this way, adjusts the brightness of the lamp. (For best results, use the batteries in series for this part of the lab.)

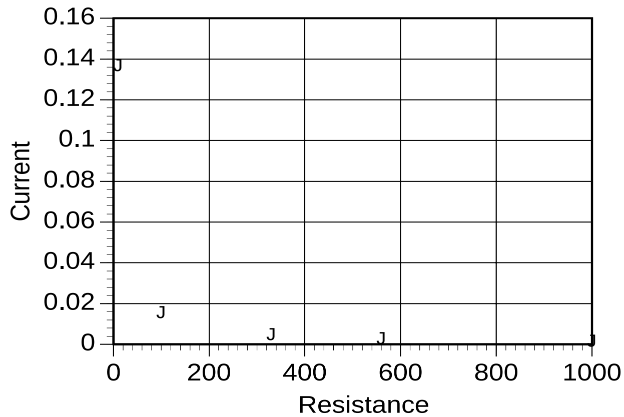
Exp 3- Ohm's Law

Procedure

②-⑥)Warn the students to be particularly careful when setting up the multimeter to measure current. Attaching an ammeter the wrong way can damage the meter.

Data Processing

Resistance	Current	Voltage	V/R	% difference
100	0.02	1.579	0.02	-1.87%
560	0.00	1.582	0.00	-2.73%
330	0.00	1.582	0.00	-3.32%
1000	0.00	1.583	0.00	-9.17%
10	0.14	1.549	0.15	-13.31%



Discussion

① Current is inversely proportional to R

② Yes. A curve fit of the graph above gives Current = 1.36 x Resistance$^{-0.98}$, which is quite close to the theoretical equation.

③) The greatest source of error is caused by the meter itself. Because the ammeter has some internal resistance, the measured current is less than the current when the meter is not there.

Exp 4- Resistances in Circuits

Procedure

①-④

	Colors	coded	measured	% error	tolerance
#1	brown-black-brown-gold	100	98.9	-1.10%	±0.05%
#2	brown-black-brown-gold	100	99.6	-0.40%	±0.05%
#3	brown-black-brown-gold	100	99.7	-0.30%	±0.05%

⑤ **Series**

R_{12} = 198.3Ω
R_{23} = 199.1Ω
R_{123} = 298Ω

⑥ **Parallel**

R_{12} = 49.7Ω
R_{23} = 49.9Ω
R_{123} = 33.3Ω
R_{13} = 49.8Ω

⑦ **Combination**

R_1 = 98.9Ω
R_{23} = 49.9Ω
R_{123} = 148.7Ω

⑧ **Series**

R_{AB} = 428Ω
R_{BC} = 891Ω
R_{ABC} = 989Ω

Parallel

R_{AB} = 76.1Ω
R_{BC} = 207Ω
R_{ABC} = 67.0Ω
R_{AC} = 84.1Ω

Combination

R_A = 98.9Ω
R_{BC} = 207Ω
R_{ABC} = 306Ω

	Colors	coded	measured	% error	tolerance
A	brown-black-brown-gold	100	98.9	-1.10%	±0.05%
B	orange-orange-brown-gold	330	330	0.00%	±0.05%
C	green-blue-brown-gold	560	561	0.18%	±0.05%

Discussion

① The actual value matches the coded value much more closely than required by the tolerances.

②-④ In series, the resistances are added. $R = R_1 + R_2 + R_3 + ...$In parallel, the reciprocals of the resistances are added. $1/R = 1/R_1 + 1/R_2 + 1/R_3 +...$ This is evidenced in all the data sets above.

Exp 5- Voltages in Circuits

Procedure

Equal Resistors:

Series

measurement	Resistance	Voltage
1	100	0.523
2	100	0.528
3	100	0.527
12	200	1.051
23	200	1.055
123	300	1.578

Parallel

measurement	Resistance	Voltage
1	33.33	1.565
2	33.33	1.565
3	33.33	1.565
123	33.33	1.565

Combination

measurement	Resistance	Voltage
1	100	1.049
23	50	0.529
123	150	1.578

Different Resistors:

Series

measurement	Resistance	Voltage
A	100	0.157
B	330	0.526
C	560	0.897
AB	430	0.685
BC	890	1.423
ABC	990	1.581

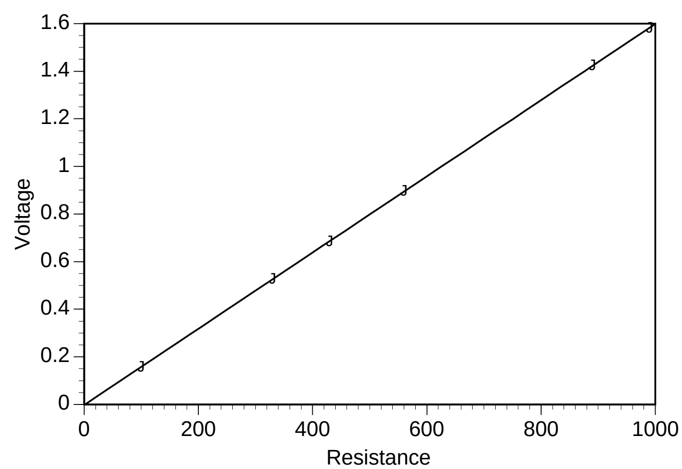
Parallel

measurement	Resistance	Voltage
A	67.49	1.574
B	67.49	1.574
C	67.49	1.574
ABC	67.49	1.574

Combination

measurement	Resistance	Voltage
A	100.00	0.509
BC	207.64	1.07
ABC	307.64	1.579

Discussion



In any series circuit, the voltage is distributed according to the size of the resistors. (Notice that the graph above, of the data from the second series circuit, shows this direct relationship.)

In any parallel circuit, the voltage is the same across all elements.

In the combination circuit, the voltage acts as if the parallel resistors were actually one resistor, which is then in series with the first. The rules are the same.

Exp 6- Currents in Circuits

➤**NOTE:** The resistors used were:

R_1 = 100Ω
R_2 = 330Ω
R_3 = 560Ω

These are the same resistors as were used in the previous lab, and some of the data here originates in lab 5.

Procedure

Series:

The current was the same—1.5 mA—no matter where it was measured in the circuit.

Parallel:

Measurement	Resistance	Current	Voltage
1	100	0.0156	1.574
2	330	0.0047	1.574
3	560	0.0028	1.574
123	67.5	0.0229	1.574

Discussion

In any resistance circuit—series, parallel, or both—the voltage, current, and resistance are related by Ohm's Law:

V = IR

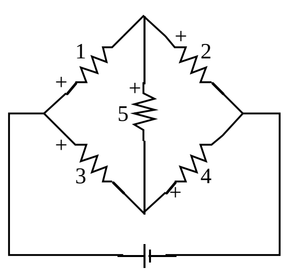
This pattern, and conclusion, should be apparent in student data.

➤**NOTE**: The product of the resistances and currents obtained experimentally will generally be lower than the measured voltage. This is due to the non-zero resistance of the ammeter. When the meter is in the circuit, its own resistance lessens the current through that circuit. With most meters, this error should be less than 5% or so.

Exp 7- Kirchoff's Rules

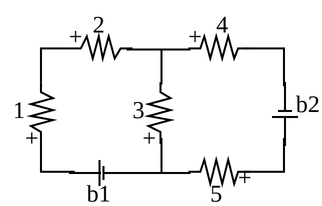
Procedure

First circuit:



	R (Ω)	V (V)	I (mA)
1	100	0.40	3.9
2	560	1.17	2.0
3	330	1.05	3.1
4	100	0.52	5.1
5	330	0.65	1.9
T	216	1.57	7.1

Second circuit:



	R (Ω)	V (V)	I (mA)
1	100	0.27	2.6
2	560	1.50	2.6
3	330	0.19	0.5
4	330	1.07	3.2
5	100	0.32	3.2
b1		1.573	2.6
b2		1.588	3.2

PASCO scientific

Analysis

First circuit:

①	node (1,3):	0.1 mA
	node (1,2,5):	0.0 mA
	node (3,4,5):	-0.1 mA
	node (2,4):	0.0 mA
②	loop (1,5,3):	0.001 V
	loop (1,2,4,3):	0.001 V
	loop (5,2,4):	0.000 V
	loop (batt,1,2):	0.001 V
	loop (batt,3,4):	0.000 V
	loop (batt,1,5,4):	0.001 V
	loop (batt,3,5,2):	0.000 V

Second circuit:

①	node (2,3,4):	-0.1 mA
	node (b1,3,5):	0.1 mA
②	loop (b1,1,2,3)	0.001 V
	loop (b2,5,3,4)	0.001 V
	loop (b1,1,2,4,b2,5)	0.002 V

Discussion

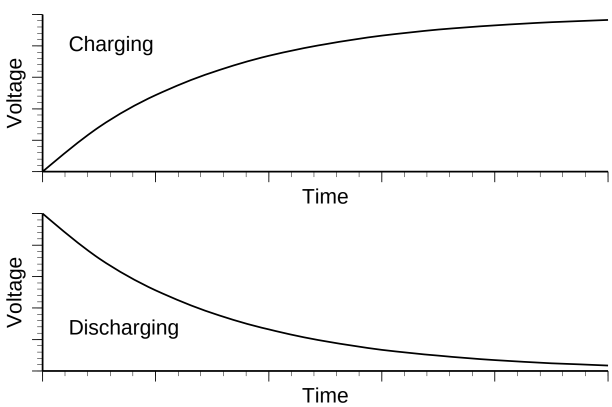
Within the experimental uncertainty of the measuring device used (a DMM) Kirchoff's Rules are verified. The net current flowing into or out of any junction is approximately zero, and the sum of the voltages around any loop is approximately zero.

Exp 8- Capacitors in Circuits

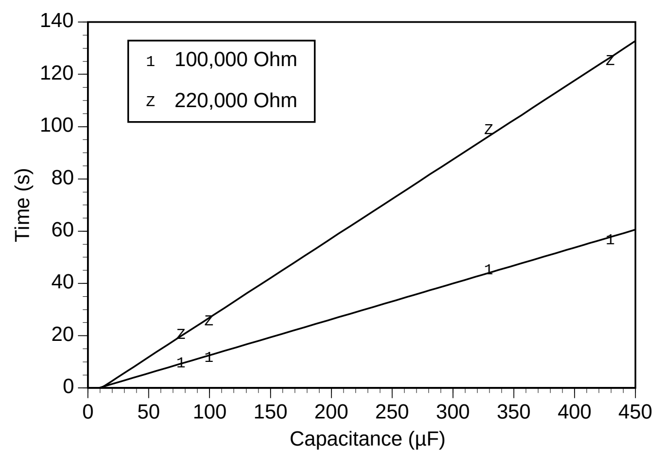
Procedure

④ The rate at which the capacitor loses its charge depends on the impedance of the meter used to measure the voltage, as well as on the size of the capacitor. For this reason, most analog meters are not sufficient for this lab.

⑤



⑦-⑪



➤**NOTES**:

①② Charging: $t = -RC\ln(1-V/V_o)$

Discharging: $t = -RC\ln(V/V_o)$

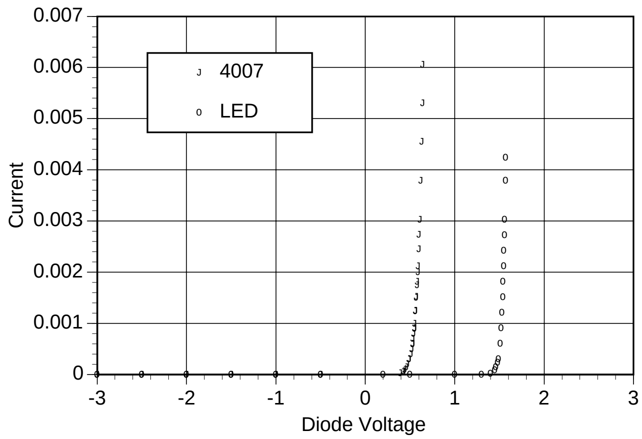
In either case, the time is linearly dependent on both resistance and capacitance.

③ Parallel: $C_p = C_1 + C_2$

Series: $1/C_s = 1/C_1 + 1/C_2$

Exp 9- Diodes

Analysis



The diode acts as a one-way valve for electricity. Current can flow in one direction, but not in the other.

Extensions

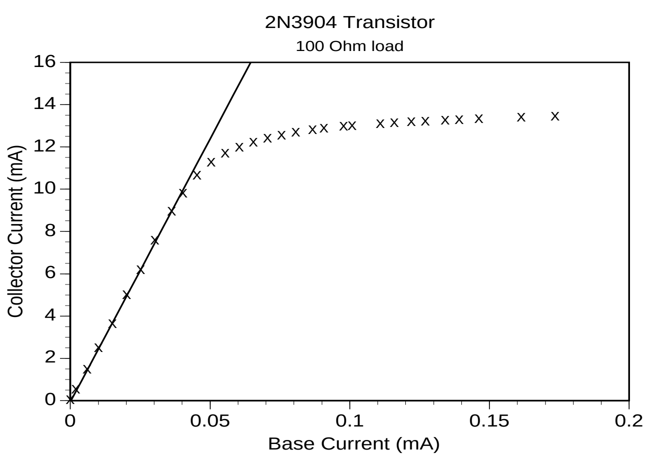
① A zener diode would be similar to the 4007, except that there would be a breakdown point on the reverse biasing, beyond which the current would flow. This makes them useful for power regulation.

②) The LED opens up at a higher voltage than the 4007 (and it lights up).

Exp 10- Transistors

Analysis

②



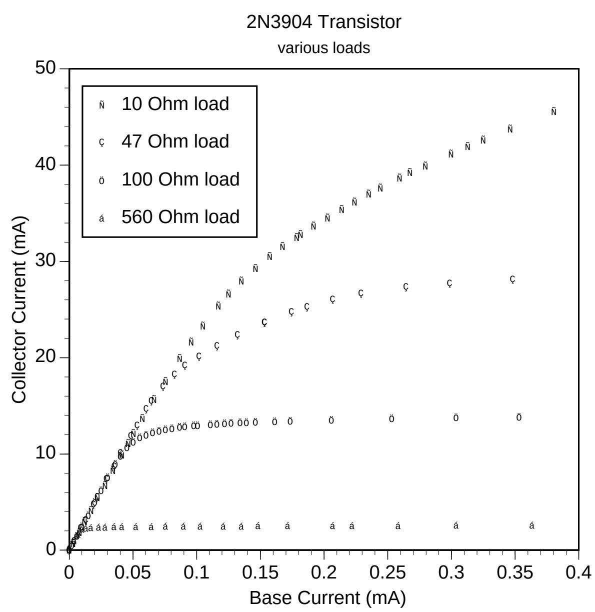
③ The linear region does not include the origin, due to the non-zero voltage that the junctions within the transistor require to turn on. (Similar to the effect in lab 9)

④ Beyond the “saturation point”, the transistor is acting like a short circuit. It offers no resistance to the current; so beyond that point, there is no amplification. The current is limited only by the battery and resistor.

⑤ The current amplification of the transistor tested was 249. This value will vary from transistor to transistor; it’s usually between 150 and 250 for the 2N3904 transistors supplied with the lab.

Discussion

① This graph shows the results of applying different values for R2. The amplification remains the same in each linear region, but the size of that linear region changes.



② The gain and/or saturation characteristics of the transistor will vary, although the basic shape of the graph will remain the same.

Technical Support

Feed-Back

If you have any comments about this product or this manual please let us know. If you have any suggestions on alternate experiments or find a problem in the manual please tell us. PASCO appreciates any customer feed-back. Your input helps us evaluate and improve our product.

To Reach PASCO

For Technical Support call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

email: techsupp@PASCO.com

Tech support fax: (916) 786-3292

Web: http://www.pasco.com

Contacting Technical Support

Before you call the PASCO Technical Support staff it would be helpful to prepare the following information:

- If your problem is computer/software related, note:

  Title and Revision Date of software.

  Type of Computer (Make, Model, Speed).

  Type of external Cables/Peripherals.

- If your problem is with the PASCO apparatus, note:

  Title and Model number (usually listed on the label).

  Approximate age of apparatus.

  A detailed description of the problem/sequence of events. (In case you can't call PASCO right away, you won't lose valuable data.)

  If possible, have the apparatus within reach when calling. This makes descriptions of individual parts much easier.

- If your problem relates to the instruction manual, note:

  Part number and Revision (listed by month and year on the front cover).

  Have the manual at hand to discuss your questions.