Instruction Manual and Experiment Guide for the PASCO scientific Model EM-8656

012-05892A
1/96

AC/DC ELECTRONICS LABORATORY
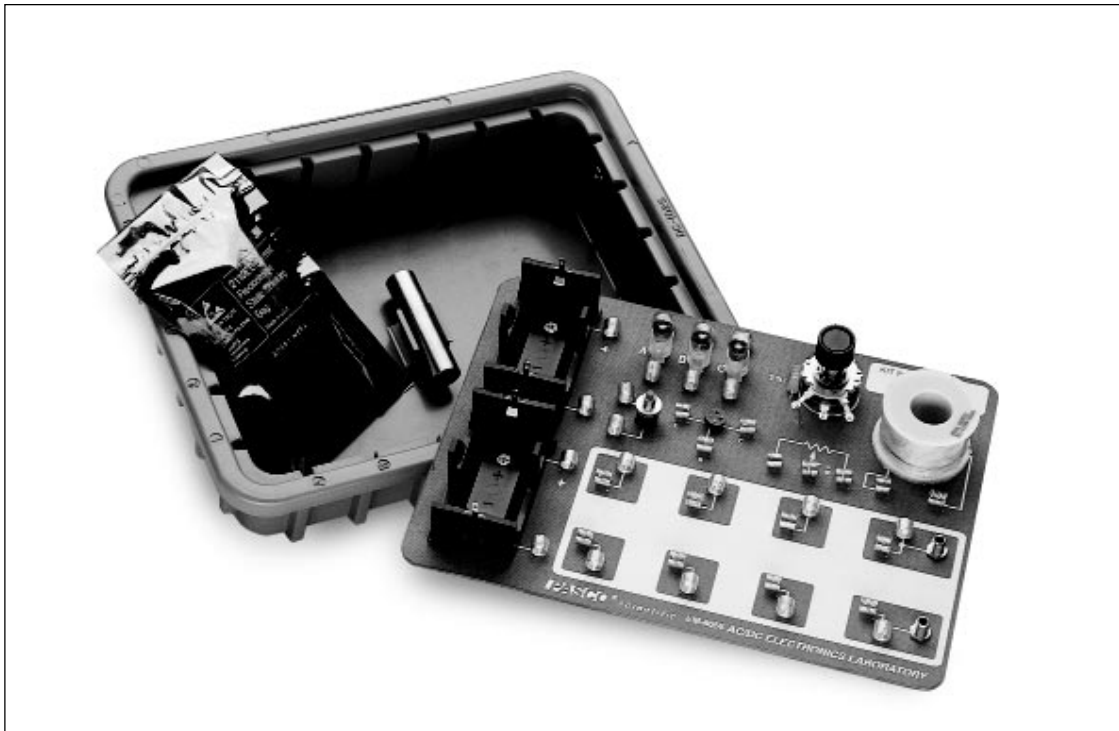
$15.00

PASCO®
scientific

10101 Foothills Blvd. • Roseville, CA 95747-7100
Phone (916) 786-3800 • FAX (916) 786-8905 • www.pasco.com

better ways to teach science

Experiment 4: Resistances in Circuits

EQUIPMENT NEEDED:

– AC/DC Electronics Lab Board: Resistors
– Multimeter

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 three resistors of 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.

$$\text{Experimental Error} = [(|\text{Measured - Coded}|) / \text{Coded}] \times 100\%.$$

Table 4.1

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

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.

PASCO ® scientific

Series

R_{12}= _____
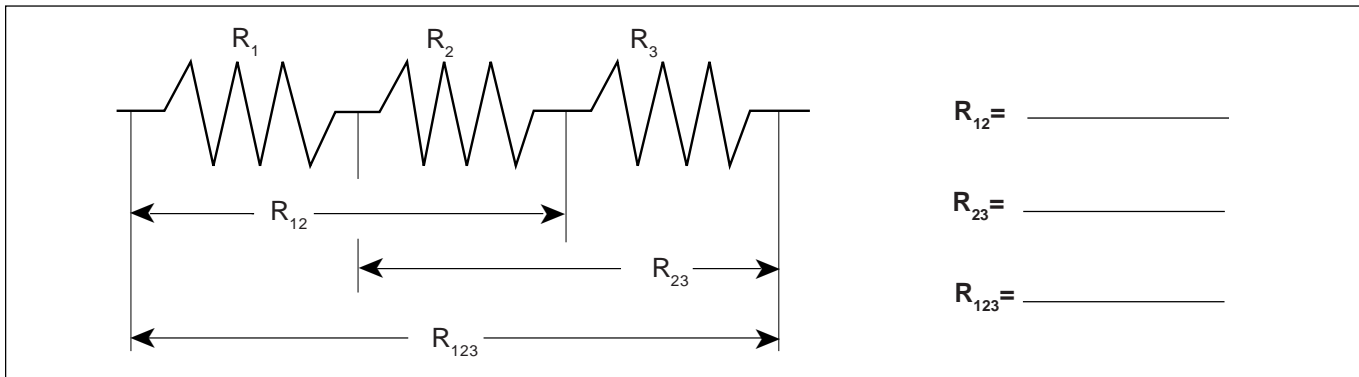
R_{23}= _____

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 R_{13} by replacing R_2 with R_3.

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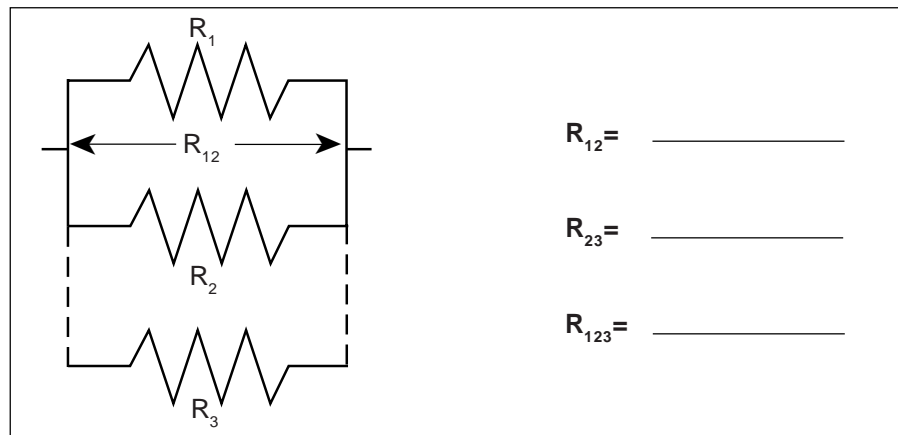

R_{12}= _____

R_{23}= _____

R_{123}= _____

Figure 4.2

Combination

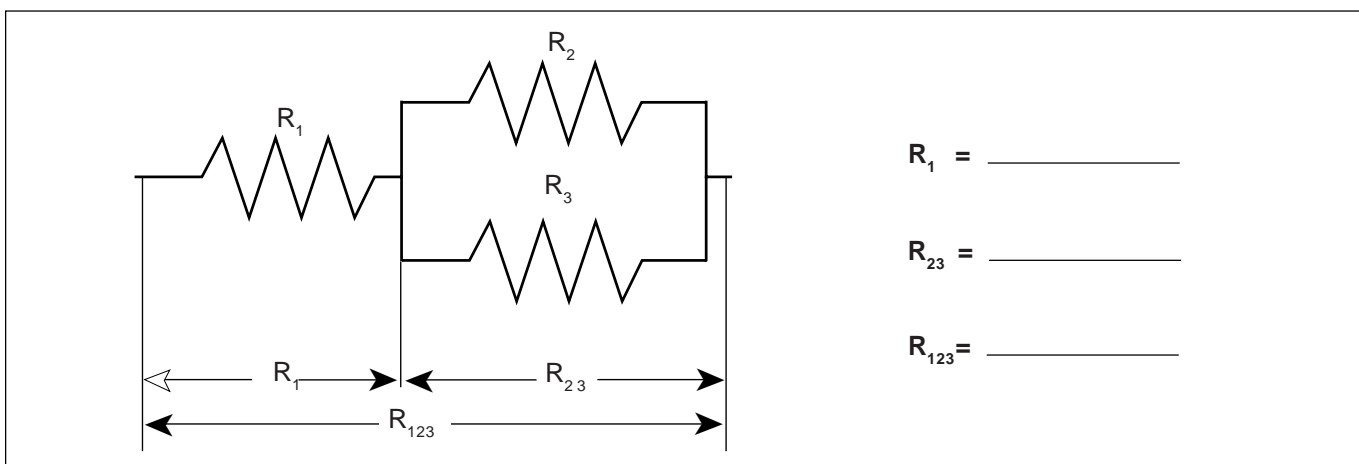R_1 = _____

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.

Table 4.2

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

Series

$R_{AB} =$ _____

$R_{BC} =$ _____

$R_{ABC} =$ _____

Figure 4.4

Parallel

$R_{AB} =$ _____

$R_{BC} =$ _____

$R_{ABC} =$ _____
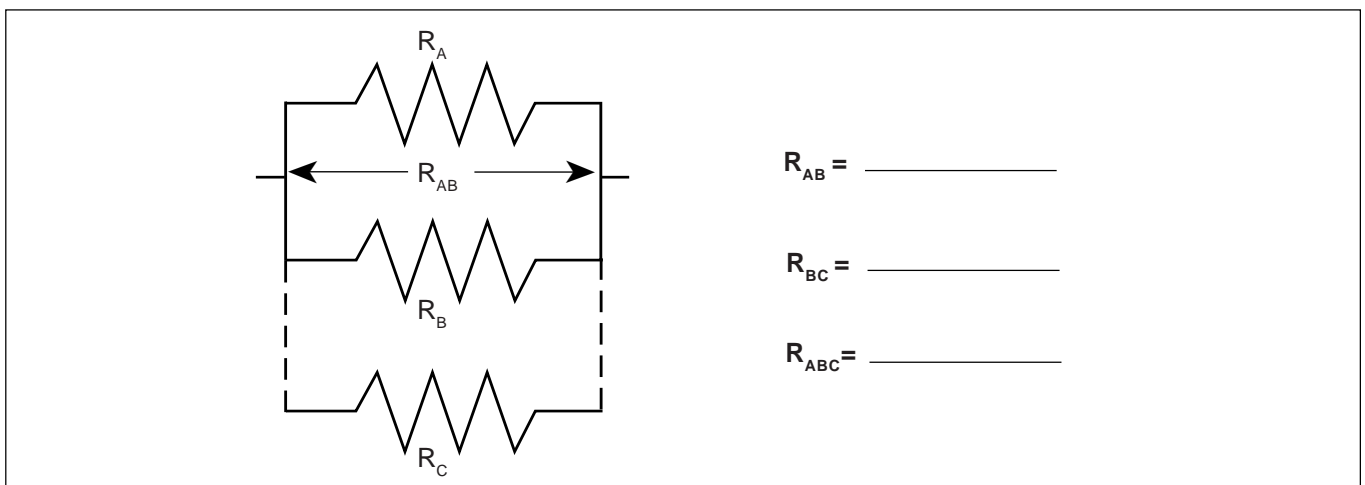
Figure 4.5

➤ **NOTE:** Include also R_{AC} by replacing $\mathbf{R_B}$ with $\mathbf{R_C}$.

Combination

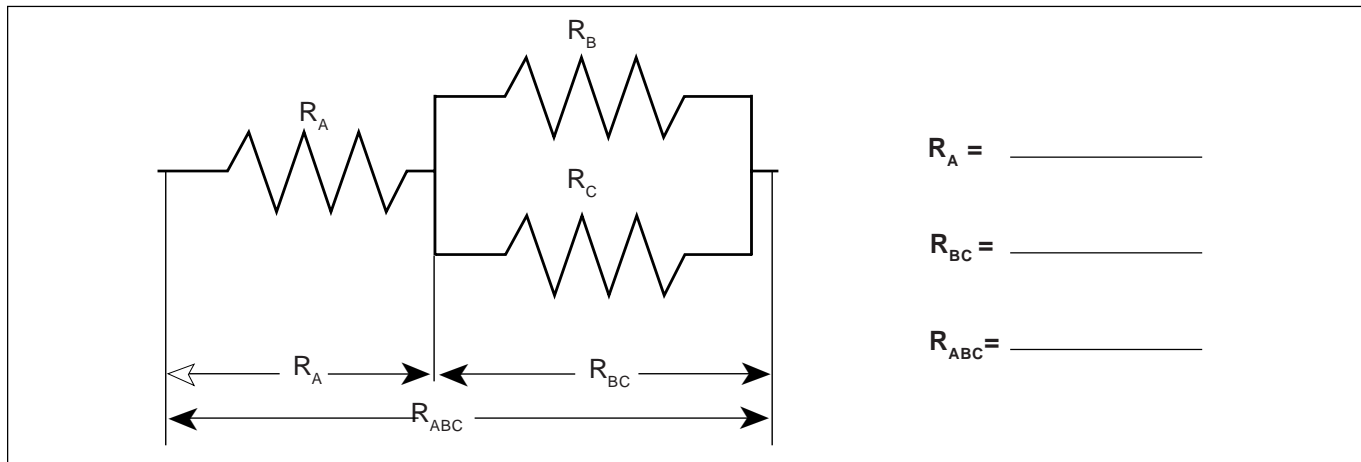$R_A =$ _____

$R_{BC} =$ _____

$R_{ABC} =$ _____

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.
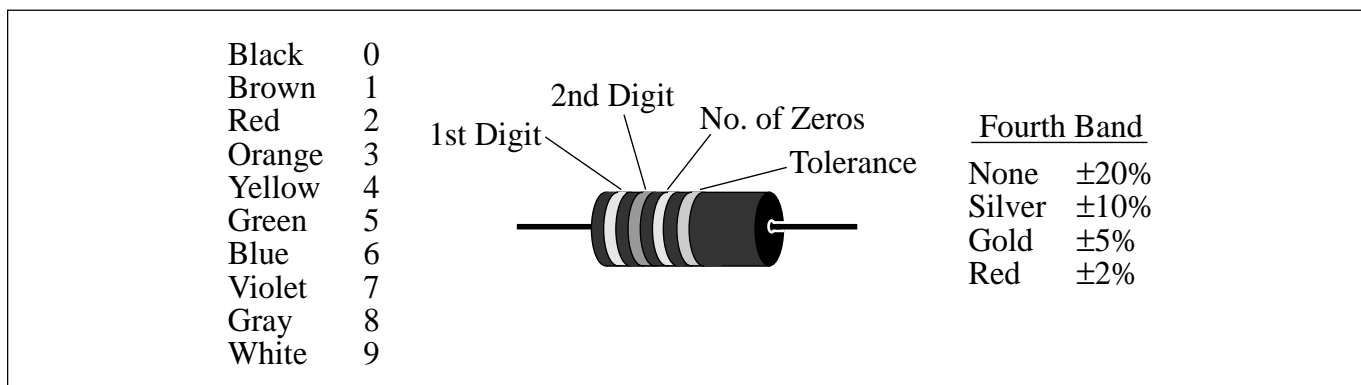
Reference

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

2nd Digit
1st Digit
No. of Zeros
Tolerance

Fourth Band

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

Figure 4.7

Experiment 5: Voltages in Circuits

EQUIPMENT NEEDED:

– AC/DC Electronics Lab Board: Wire Leads, Resistors
– D-cell Battery
– Multimeter

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.
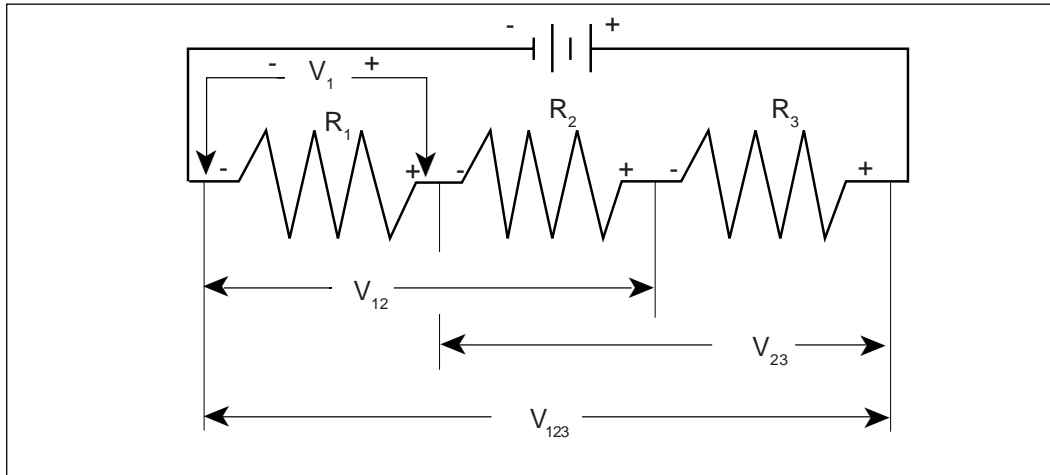
Series

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.
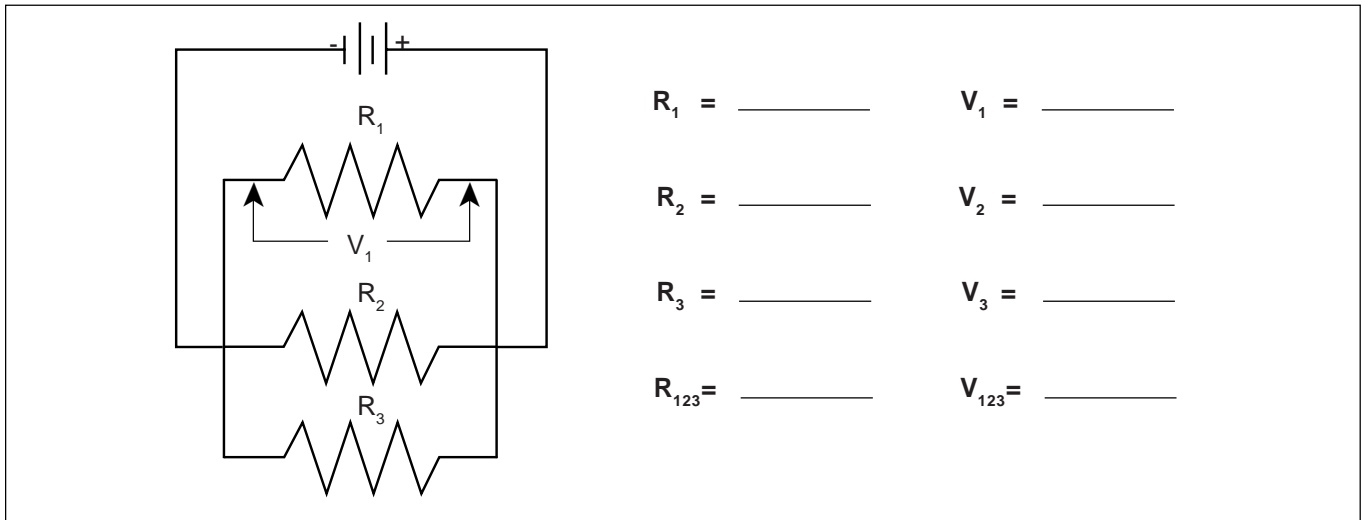
Parallel

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} = ————

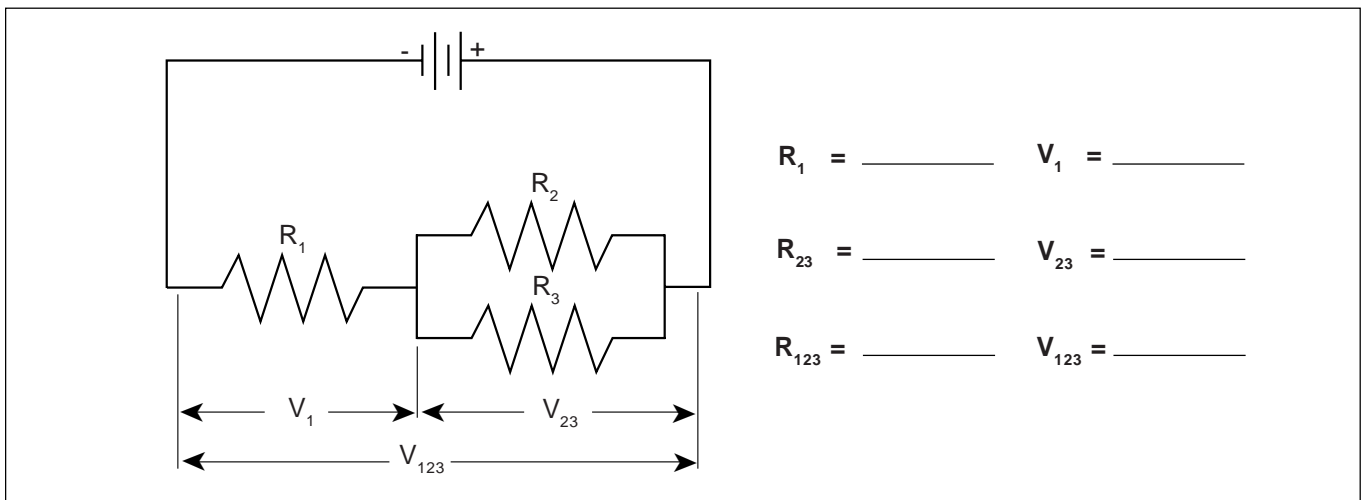R_{123} = ———— V_{123} = ————

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.
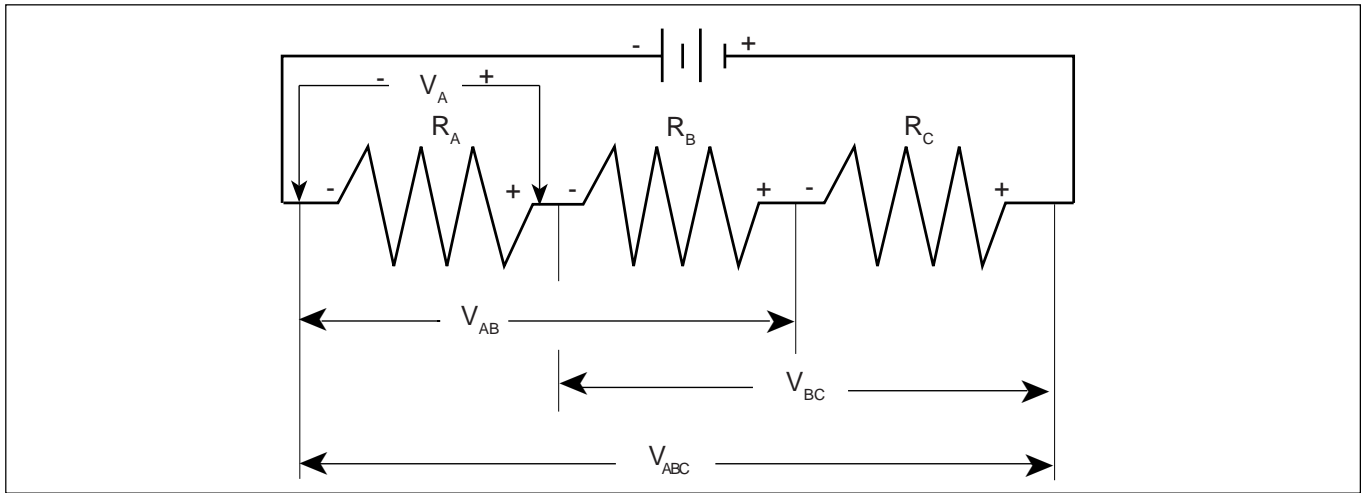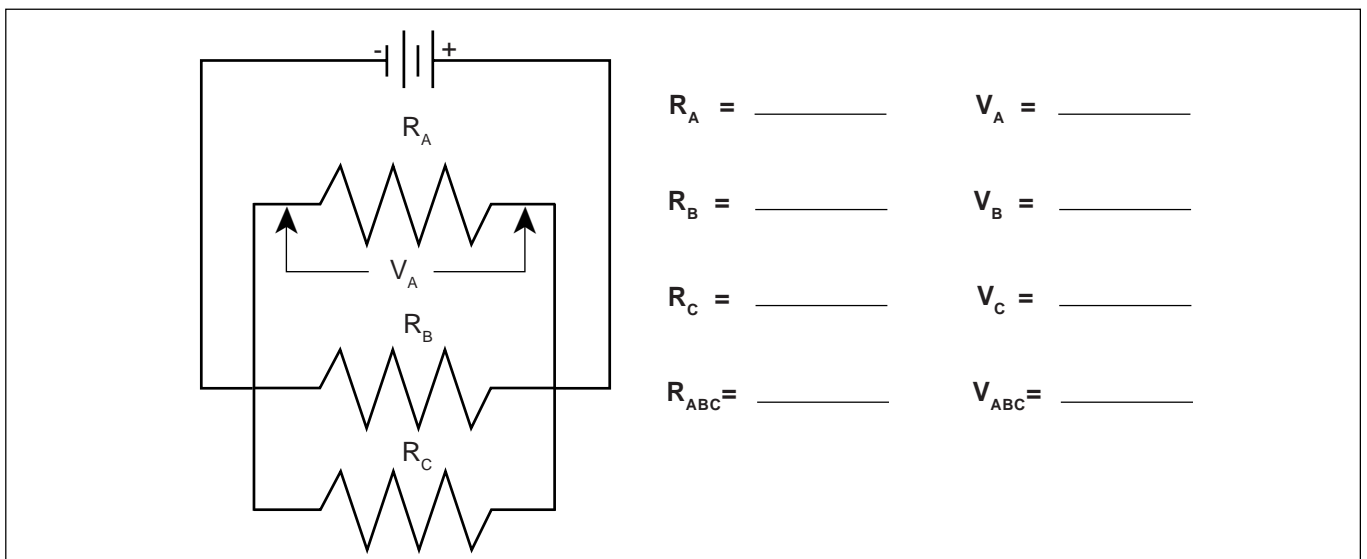
PASCO ®
scientific

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}= _____
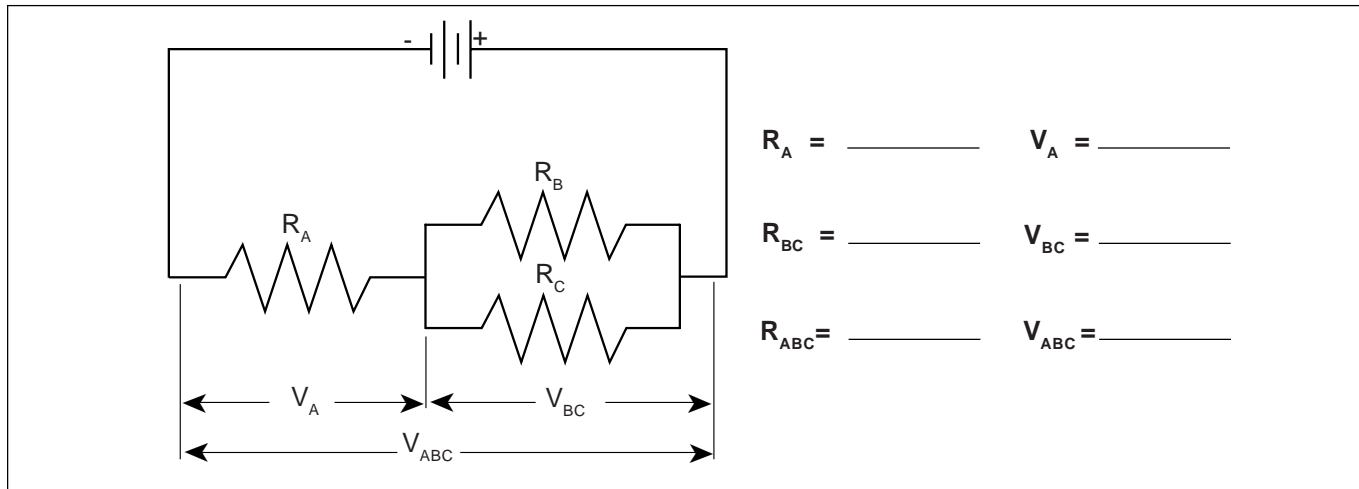
Figure 5.5

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:

– AC/DC Electronics Lab Board: Resistors and Wire Leads
– D-cell Battery
– Digital Multimeter

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 R_1, where the wire originally was connected. Record your reading in the table as 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.
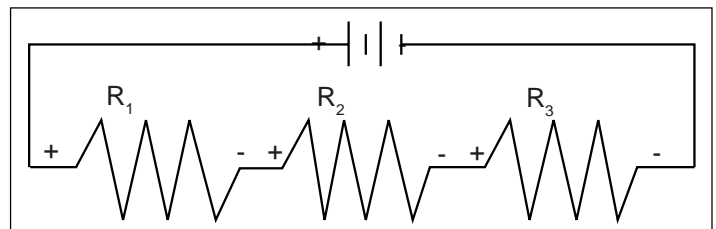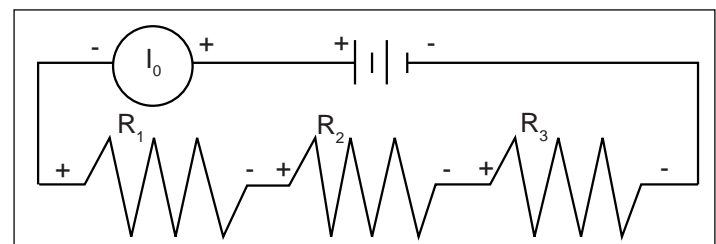

Figure 6.1

Figure 6.2

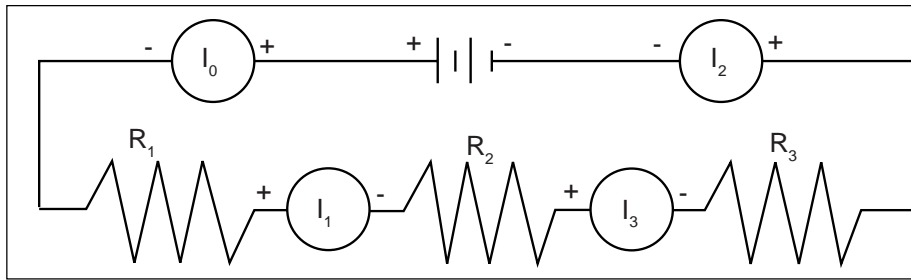➤ **NOTE:** You will be carrying values from Experiments 3 and 4 into the table on the back.

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 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

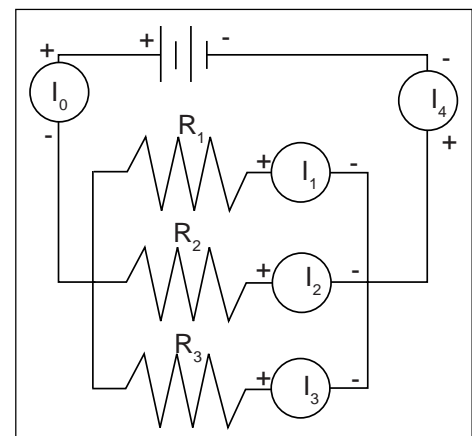|		
R_1 = _____	I_0 = _____	V_1 = _____
R_2 = _____	I_1 = _____	V_2 = _____
R_3 = _____	I_2 = _____	V_3 = _____
R_{123} = _____	I_3 = _____	V_{123} = _____
	I_4 = _____	

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.
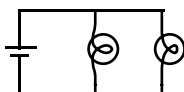
20

Teacher's Guide (Experiments 1-10)

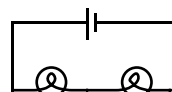## *Exp 1 - Circuits Experiment Board*

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.
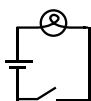
Serial:

Using this circuit, the lights will be dimmer than in part 1.
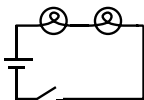
Exp 2 - Lights in Circuits

➤**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.
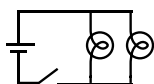
Procedure

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.)
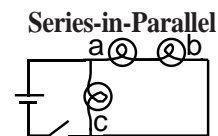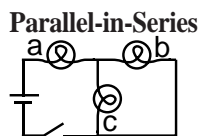
Parallel

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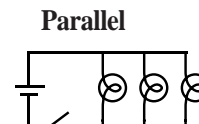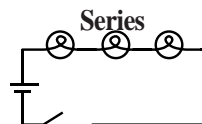
These circuits have the same characteristics as the ones in part 2-3

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.)

PASCO®
scientific

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 = $1.36 \times \text{Resistance}^{-0.98}$, which is quite close to the theoretical equation.
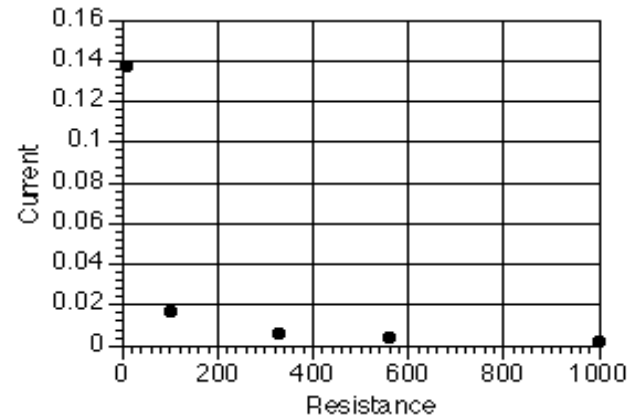
③) The greatest source of error is caused by the meter itself. Because the ammeter has some internal resistance, the measured current is less than the current when the meter is not there.

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

PASCO ®
scientific

	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

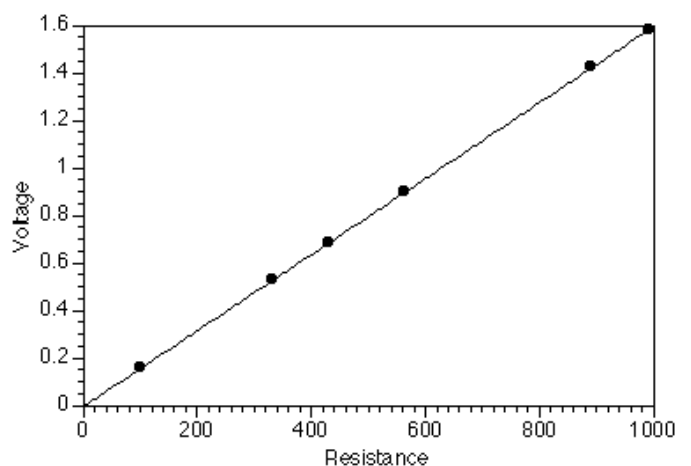| measurement	Resistance	Voltage
A	100	0.157
B	330	0.526
C	560	0.897
AB	430	0.685
BC	890	1.423
ABC	990	1.581

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.

PASCO ® scientific

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 nonzero 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

The current leaving the node is equal to the current entering the node. The sum of the voltage drops around a closed loop equals zero.
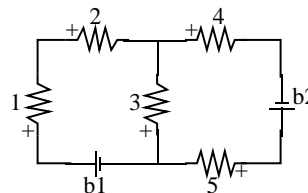
Procedure
First circuit:
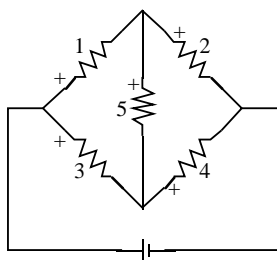
	R (Ω)	V (V)	I (mA)
1	100	0.40	3.9
2	560	1.17	2.0
3	330	1.05	3.1
4	100	0.52	5.1
5	330	0.65	1.9
T	216	1.57	7.1

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