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

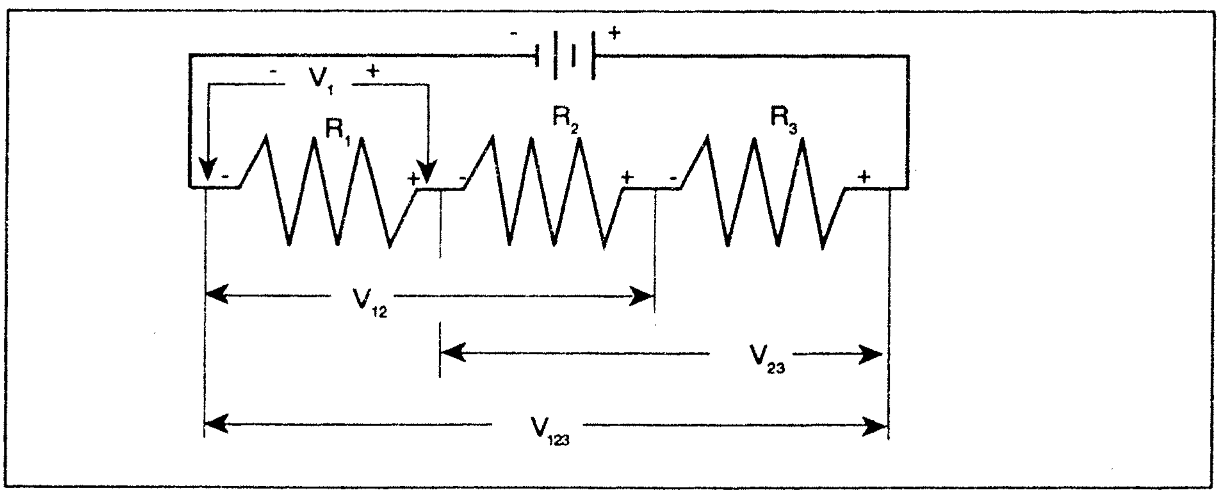


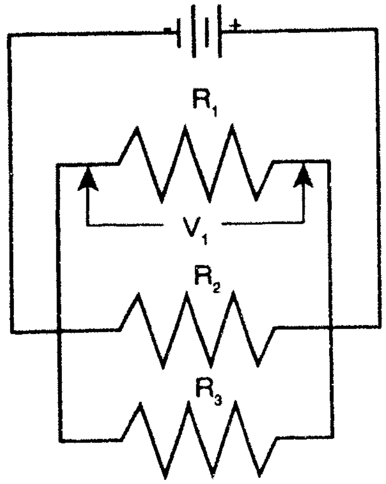
Figure 5.1

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 = ________

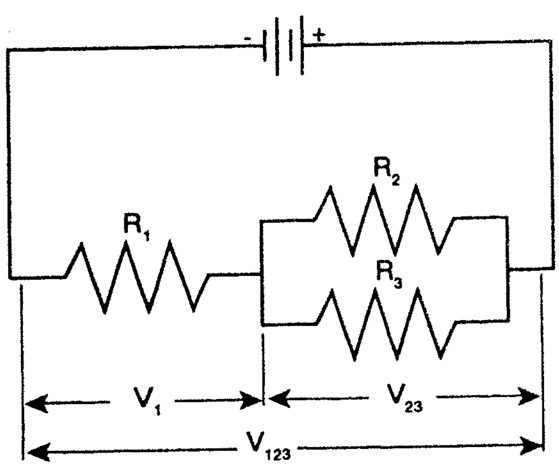
R_3 = ________ V_3 = ________

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

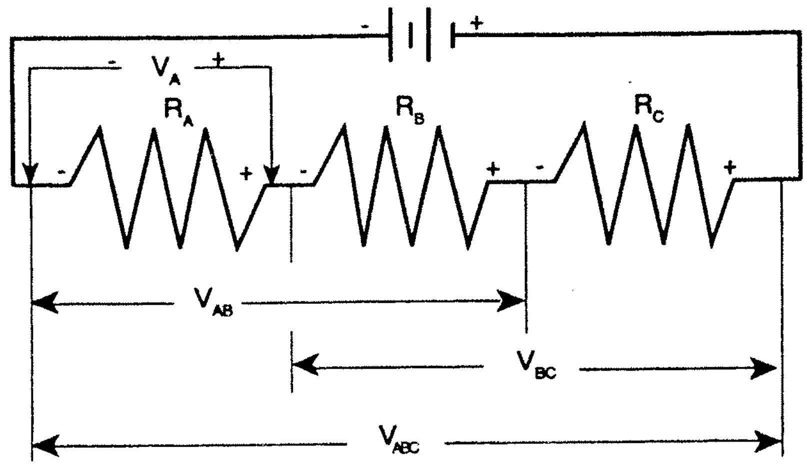
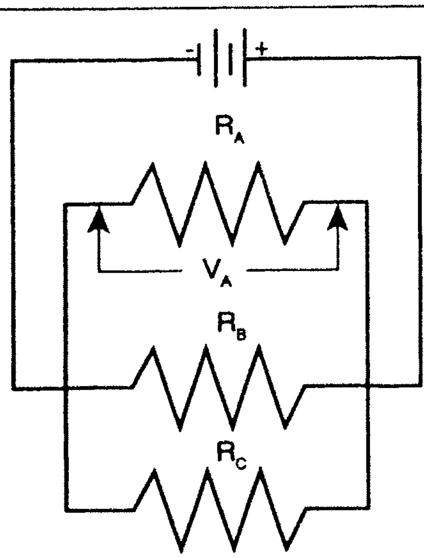


Figure 5.4

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

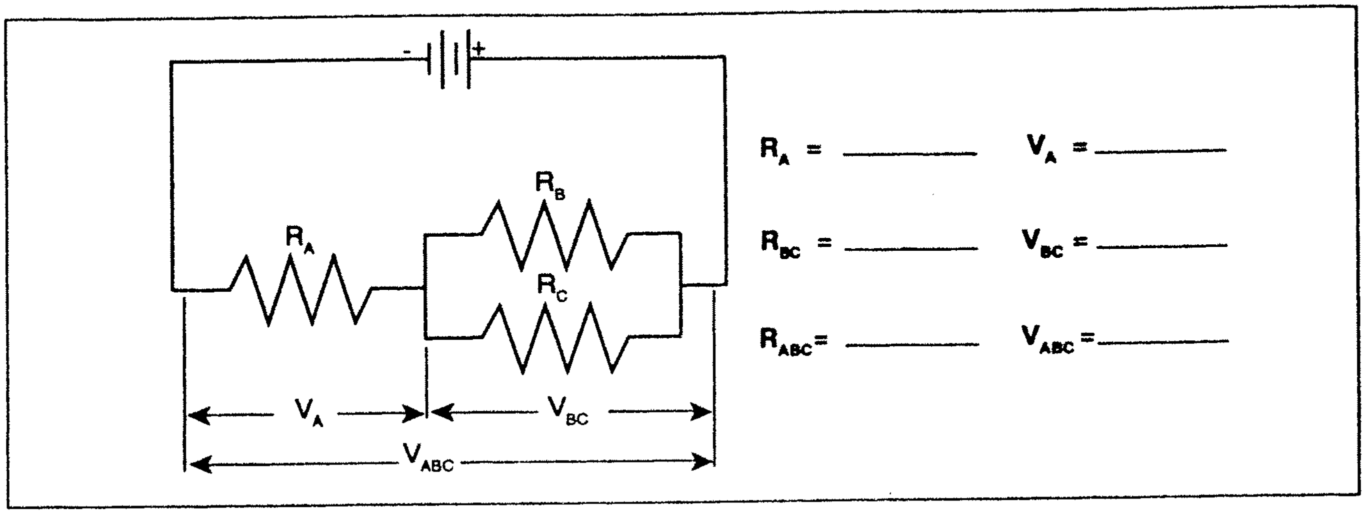


Figure 5.6

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 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**.

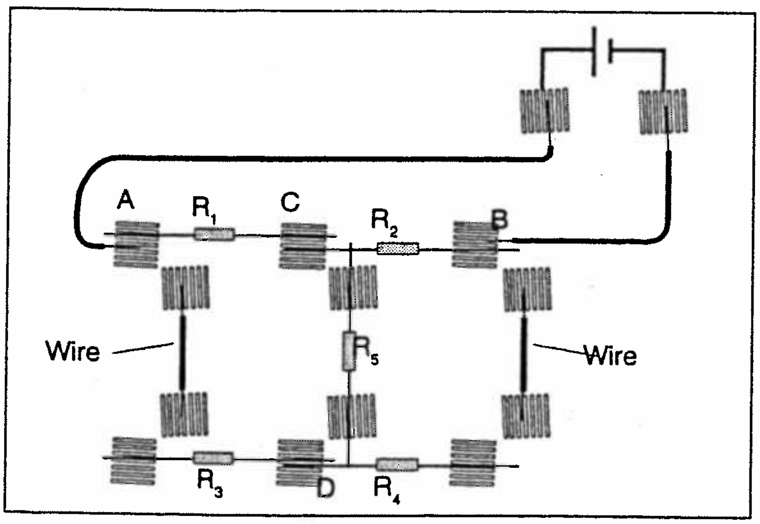


Figure 7.1a

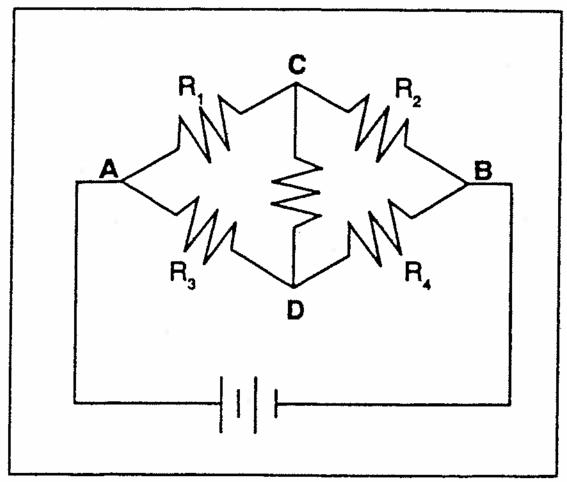


Figure 7.1b

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, 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.

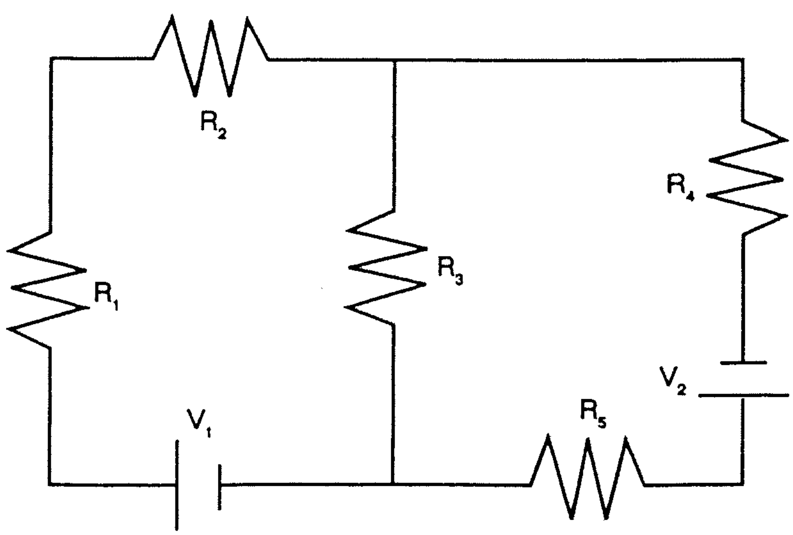


Figure 7.2

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.)

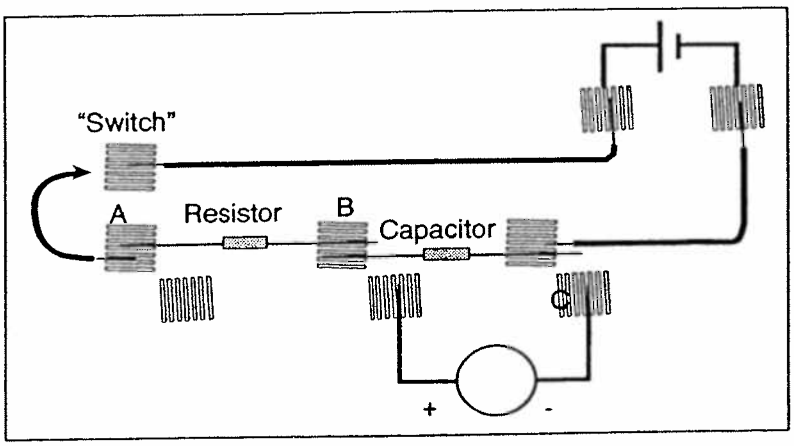


Figure 8.1

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).

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

Table 4.2

Series

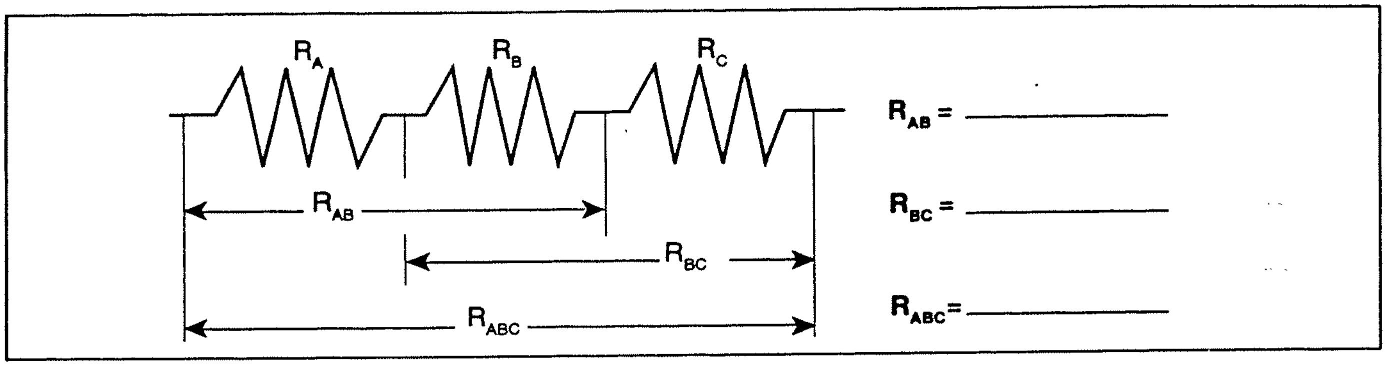


Figure 4.4

Parallel

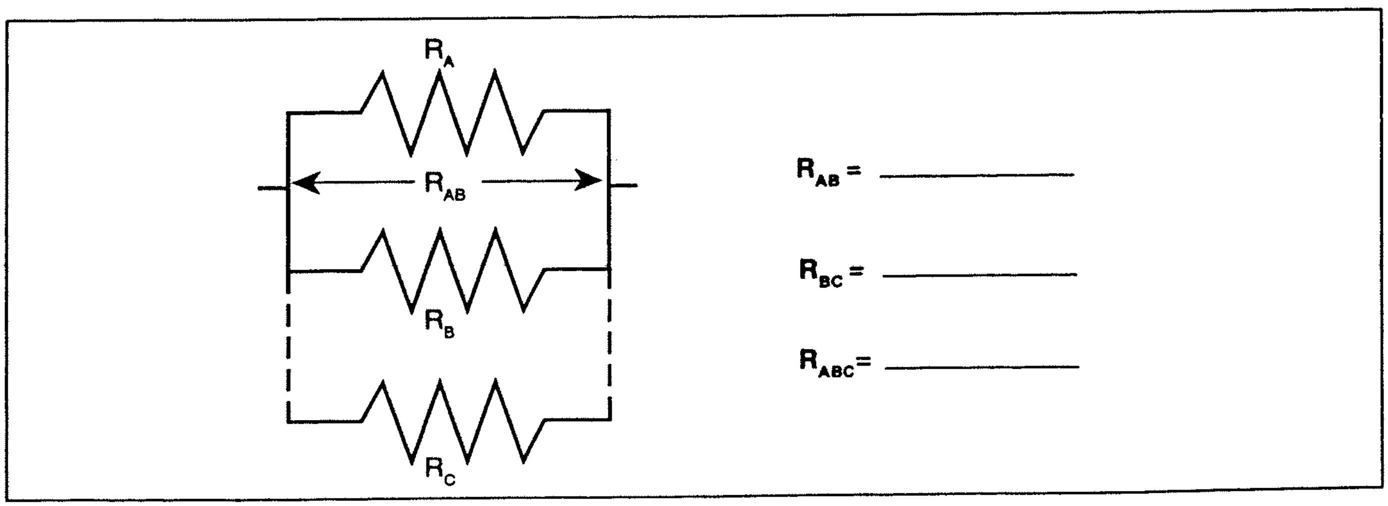


Figure 4.5

> ➤ **NOTE:** Include also R_{AC}

Combination

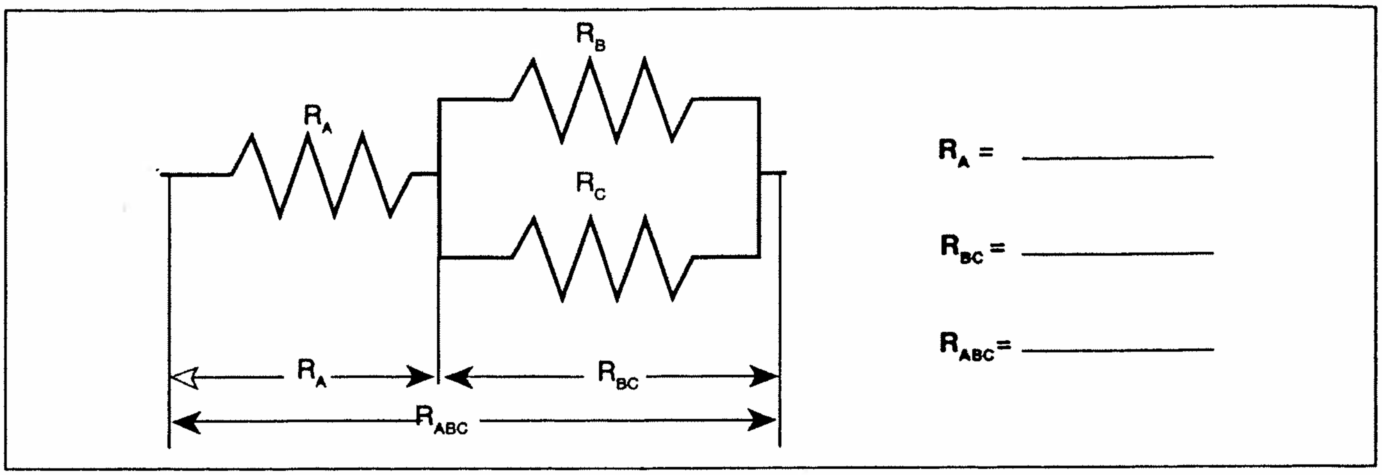


Figure 4.6

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

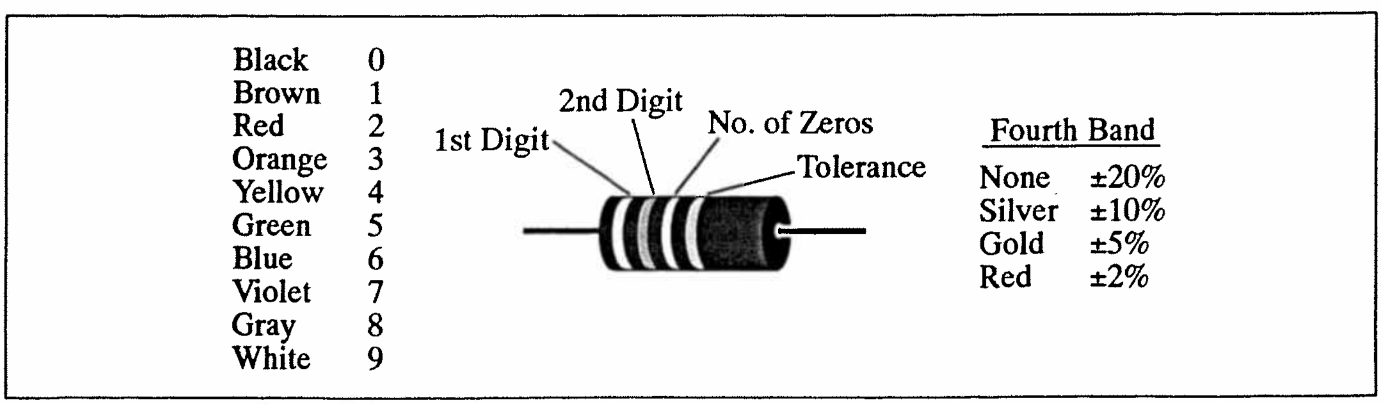


Figure 4.7

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**.

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** (V_{BC}). Measure the voltage across the diode (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 V_{BC}: 0.1, 0.2, 0.3,.....2.0 volts. Record the two voltages for each case.

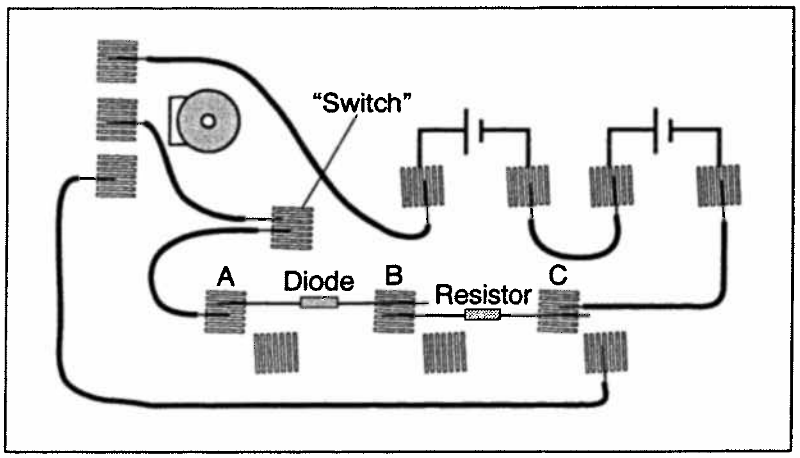


Figure 9.1a

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 (V_{AB}) to the values 0.5, 1.0,....3.0 volts. Measure the resistor voltage (V_{BC}) in each case. Record these values in the columns labeled "Reverse Bias".

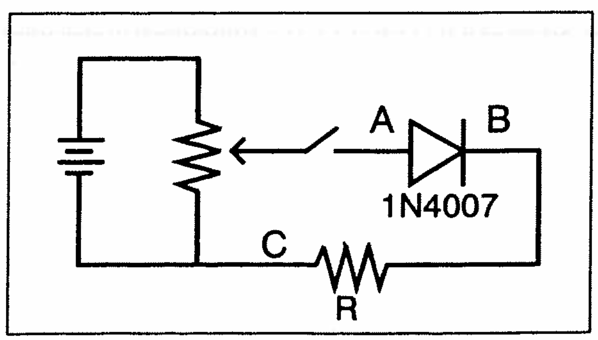


Figure 9.1b

Analysis

① Determine the current flow (I) in each setting by dividing the voltage across the resistor (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.

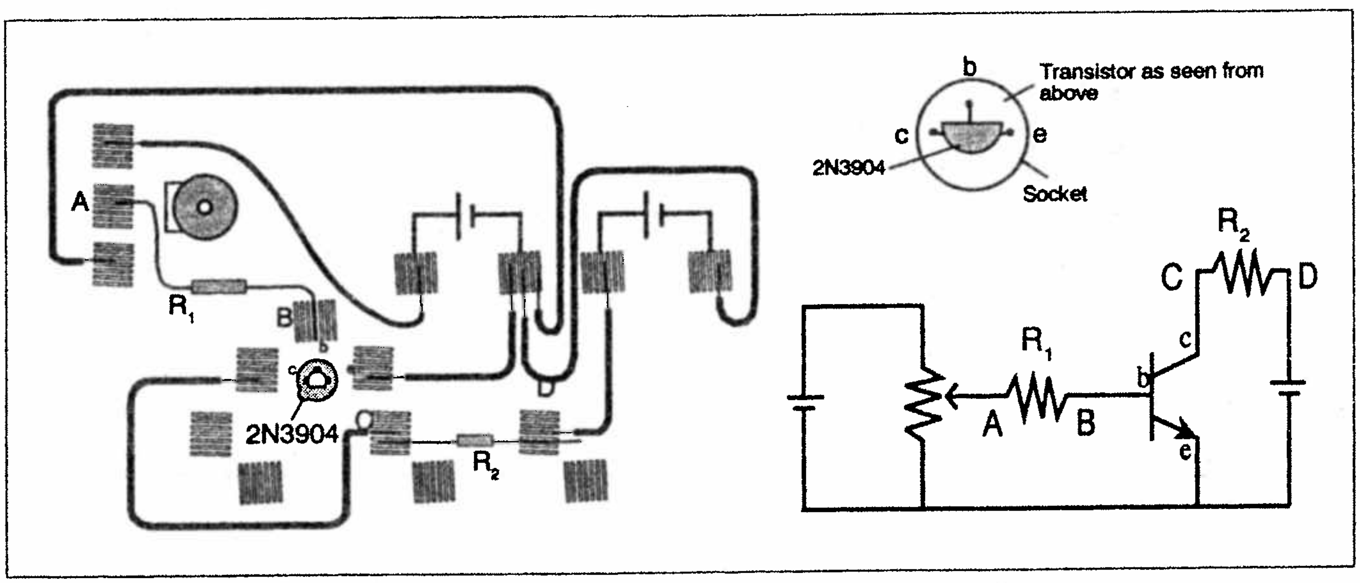


Figure 10.1a

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:

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

Record all of your current readings in mA.

② Plot a graph of I_C (vertical axis) vs 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 - 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 (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 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.