



Universiti Teknologi MARA
Fakulti Sains Gunaan

Resistance, Ohm's Law and Kirchoff's Laws

PHY407: A Physical Science Activity

Name: _____ HP: _____ Lab # 6:

Objectives

The goal of today's activity is to physically investigate the properties of conducting wires in terms of its resistance to the flow of electrons, the factors determining resistance of a wire and the laws involved in determining current and potential difference in a single-loop and a multiple-loop circuit.

At the end of this activity, students will be able to:

1. Measure resistance of resistors using an ohmmeter.
2. Read the colour coding on carbon resistors and determine its resistance.
3. Determine the relationship between resistance of a wire and its length, its material (resistivity) and its area.
4. Measure, using an ohmmeter, effective resistances for resistors connected in series or in parallel or its combination.
5. Obtain a simple relationship to determine effective resistance in a series or parallel circuit.
6. Explore, explain and describe the current-voltage characteristics for ohmic devices.
7. Measure current and potential differences for devices connected in a single loop and two loops circuit respectively.
8. Obtain Ohm's Law and also Kirchoff's Laws of current and voltage.

Background Information

Background:

Current in a circuit obeys the natural law and flows from a high potential point to a low potential point (electrons move in the opposite direction). It changes with changes in the magnitude of the electromotive force of a source (unlimited source of electrons) and the changes in obstacles (resistance). While resistive devices such as a bulb may have a linear relationship between the current through that device and the potential difference across it, other devices such as a diode or semiconductor may have a nonlinear relationship. In fact, for some conductors, the linearity relationship is temperature dependent. Device that obeyed the linear relationship was first found by Ohm and Ohm's Law is now used when describing the characteristic of current-voltage relationship for good conductors. Hence, when many conductors or resistors are connected together in a circuit, it is convenient to use Ohm's Law to determine the current flow in a circuit. Resistance of a resistor is a measure of how difficult for current to flow through a circuit element and Ohm's Law provides us with a way of determining the resistance in a circuit or the amount of current flowing in a circuit if the resistance is known. In addition, when devices are connected in more than a single loop, the current at a node or junction and the sum of the potential drops or potential rise in the loop have been found to obey Kirchoff's Laws. Your investigation today will involve obtaining both Ohm's Law and Kirchoff's Laws by using a combination of laboratory measurements and the PhET simulation.

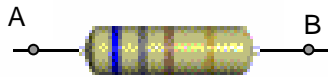
Student Activity

Investigation 1-Resistors & Resistances

Prediction 1.1: (Make your intelligent guess)

Given a carbon resistor:

- i) Will an ohm-meter read the resistance differently if the probe of the meter is reversed?
- ii) Will the ohm-meter give the same reading as those obtained by reading the color coding?



Activity 1.1:

Read the color coding of a few of the resistors provided and find the resistors 100 Ω , 1 k Ω , 10 k Ω and 470 k Ω . For each of the resistors, use a multimeter in the ohm-meter mode to measure the resistances by placing the probes of the meter across the resistors. Then change the polarity of the probe and observe the reading again. Record the reading and compare with the reading from the color coding. Tabulate the data in Table 1.

Table 1

Color on resistors Bands 1-3: Black=0, brown=1, red=2, orange=3, yellow=4, green=5, blue=6, violet=7, gray=8, white=9 Band 4: none= $\pm 20\%$, silver= $\pm 10\%$, gold= $\pm 5\%$	Resistance read from coding, Ω	Resistance from ohm-meter, Ω	Resistance from ohm-meter, (reversed polarity) Ω

Questions

1. Does changing polarity of the meter probes affect the meter reading? Why or why not?
2. Which reading, the color coding or the ohm-meter is more reliable? Explain.

Prediction 1.2: (Factors affecting resistance of resistors- Make your intelligent guess)

- i) What happens to the resistance when the length of a conducting wire is increased or decreased?
- ii) What happens to the resistance when the material of the conducting wire is changed?
- iii) What happens to the resistance when the thickness of a conducting wire is increased or decreased?

Activity 1.2:

- i) Cut about 110 cm of the copper wire. Using a micrometer, measure the thickness (diameter) of the copper wire. Then using a multimeter set to the ohm-meter mode, measure the resistance of the copper wire in increments of 10 cm beginning with the length of the wire at 10 cm and ending with the length of the wire at 100 cm. Record your readings in Table 2.
- ii) Repeat part (i) above with a nichrome wire and with a tungsten wire respectively, making sure you use wires of the same thickness as in part (i). Record your readings in Table 2.
- iii) You are provided with five different gauges of constantan wire. Using a micrometer, measure the thickness (diameter) of each of the constantan wires (there are 5 different gauges; swg22, swg24, swg26, swg28 and swg30). You may cut about 60 cm of each of the wires but make sure you devise a clever way to distinguish them. Record your readings. Then using a multimeter set to the ohm-meter mode, measure the resistance of each of the constantan wire. Record your readings in Table 2.

Table 2

Parts (i) & (ii)	R, Ω	R, Ω	R, Ω	Part (iii)			R, Ω
Length of wire, cm	Copper D=__ cm	Nichrome D=__ cm	Tungsten D=__ cm	SWG	Thickness, D cm	Surface area $A = \pi r^2$ $= \pi d^2/4$	Constantan
0				22			
10				24			
20				26			
30				28			
40				30			
50							
60							
70							
80							
90							
100							

Questions

1. How does the length of the wire affect the resistance? [Draw a graph of the resistance, R (on the y-axis) and the length, L (on the x-axis) for the copper wire]. What is the relationship you obtained?
2. Repeat drawing the graphs for the nichrome and the tungsten wire (all on the same graph as for the copper wire). Do you observe the same or different relationship as for the copper wire? What can you conclude when you compare your prediction to your observation?
3. Are the slopes the same or different for all three graphs? How does different type of conducting wires affect the slope of the graph? [Determine the slope for each graph and suggest what the slopes represent.] Can you determine which wire will have higher resistance if the length and thickness of all the wires are the same? What is the resistivity for each of the wire? (Use the slope to determine the resistivity). What can you conclude when you compare your prediction to your observation?
4. How does the thickness of the constantan wire affects its resistance? [Draw a graph of the resistance, R (on the y-axis) and the inverse of thickness (diameter), $1/d$ (on the x-axis) for the constantan wire.]. What is the relationship you obtained?

5. What happens if you draw a graph of R versus $1/d^2$? [Determine the slope and suggest what the slopes represent.] Use the slope to determine the resistivity of constantan wire. Can you determine which wire will have higher resistance if the length and thickness of all the wires are the same? What can you conclude when you compare your prediction to your observation?
7. What conclusion can you make when you compare the resistance to the length, to the material of the wire and to the surface area of the wire?

Investigation 2-Resistors & Resistances

Prediction 2: (Series & Parallel Circuit-Make your intelligent guess)

Using the brightness of the bulbs (the total power) in the previous investigation (lab #5) as a guide, what happens to the effective or total resistance when bulbs are added in series and in parallel respectively?

Activity 2:

- i) Connect the resistors in activity 1.1 as shown in the configuration below and use the ohmmeter to measure the effective resistances. Record your reading in Table 3.

Table 3

$R_{AB} = \underline{\hspace{2cm}} \Omega$	$R_{AB} = \underline{\hspace{2cm}} \Omega$	$R_{AB} = \underline{\hspace{2cm}} \Omega$	$R_{AB} = \underline{\hspace{2cm}} \Omega$	$R_{AB} = \underline{\hspace{2cm}} \Omega$
$R_{BC} = \underline{\hspace{2cm}} \Omega$	$R_{BC} = \underline{\hspace{2cm}} \Omega$			$R_{BC} = \underline{\hspace{2cm}} \Omega$
$R_{AC} = \underline{\hspace{2cm}} \Omega$	$R_{AC} = \underline{\hspace{2cm}} \Omega$			$R_{AC} = \underline{\hspace{2cm}} \Omega$

Questions

1. What happens to the total resistance when resistances are connected in series? Does it increase or decrease? Can you write down a possible mathematical relation to determine the effective resistance?
2. What happens to the total resistance when resistances are connected in parallel? Does it increase or decrease? Can you write down a possible mathematical relation to determine the effective resistance?

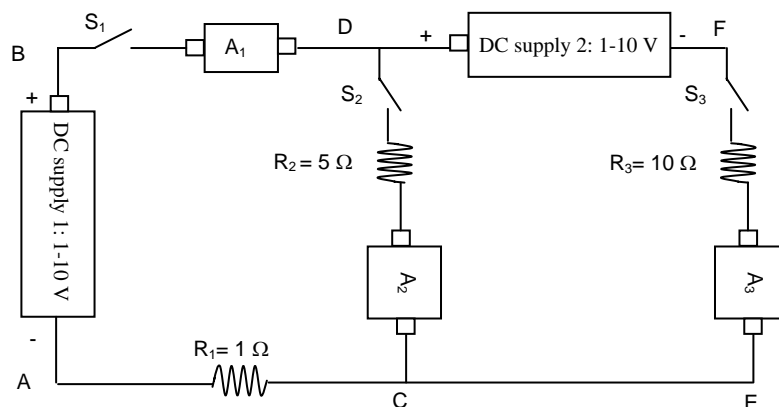
Investigation 3 – Ohm’s Law and Kirchoff’s Laws

Prediction 3 (Make your intelligent guess)

- i) What happens to the current read by ammeters A_1 , A_2 and A_3 and the voltage across the resistors R_1 and R_2 , in the circuit shown below, when only switches S_1 and S_2 is thrown down? Will all ammeters read the same values or different values? Will the current flow from point A to B to C to D and back to A or will it go in the opposite direction? Will the sum of the potential drops ($V=IR$) across resistors be equal to the emf of the power supply?
- ii) What happens to the current read by ammeters A_1 , A_2 and A_3 and the voltage across the resistors R_1 and R_2 , in the circuit shown below, when only switches S_1 and S_2 is

thrown down and the emf from the DC power supply 1 is increased or decreased? Will all ammeters read the same values or different values? Will the sum of the potential drops ($V=IR$) across resistors be the same as the emf of power supply 1 every time a new emf is chosen?

- iii) What happens to the current read by ammeters A_1 , A_2 and A_3 and the voltage across the resistors R_1 and R_2 and R_3 , in the circuit shown below, when only switches S_2 and S_3 is thrown down?



- iv) What happens to the current read by ammeters A_1 , A_2 and A_3 and the voltage across the resistors R_1 , R_2 and R_3 , in the circuit shown below, when only switches S_1 , S_2 and S_3 is thrown down. Will all ammeters read the same values or different values? Will the sum of the potential drops ($V=IR$) across resistors in loop BACDB be the same as the emf of power supply 1? Will the sum of the potential drops ($V=IR$) across resistors in loop DFECDF be the same as the emf of power supply 2? Will all the current flow into or out of junction C?

Activity 3:

(You MUST run the PhET (Circuit construction –DC only) simulation before you come to the laboratory. Set the initial voltages and the resistances as shown in the figure and record your readings in Table 4 and Table 5.)

- Connect the circuit as shown in the figure above. Throw down switches S_1 and S_2 and record the current on ammeters A_1 , A_2 and A_3 . Using the voltmeter (multimeter), measure the emf (note the polarity of the probes, a positive value indicate your probes are connected with the red probe on the high potential end and the black probe on the low potential end) of power supply 1 (V_{DA} or V_{BA}). Then measure the potential across resistors R_1 (V_{AC}), R_2 (V_{CD}) and resistors R_{12} (V_{AD}). [Based on the current flow or the polarity of the potential difference, label the high (+) and low potential (-) points in the circuit or across each resistors.] Then increase the emf on the dc power supply from 1 V to 10 V in increments of 1 V. Observe and record your readings in Table 5. Record also the directions of current flow at junctions C and D respectively.
- Set the voltage of power supply 1 to 5 V and power supply 2 to 5 V and throw down all switches S_1 , S_2 and S_3 . Record the current on ammeters A_1 , A_2 and A_3 . Then measure the potential across resistors R_1 (V_{AC}), R_2 (V_{CD}) R_3 (V_{FE} or V_{FC}), R_{12} (V_{AD}) and resistors R_{32} (V_{FD}) Record your readings in Table 6. Record also the directions of current flow at junctions C and D respectively. Repeat the above when the emf on power supply 2 is changed to 10 V.

Table 4

PhET: S ₁ & S ₂ down								Laboratory: S ₁ & S ₂ down					
V _{DA} V	I ₁ A	I ₂ A	I ₃ A	V _{AC} V	V _{CD} V	V _{AD} V	V _{DA} V	I ₁ A	I ₂ A	I ₃ A	V _{AC} V	V _{CD} V	V _{AD} V
0							0						
1							1						
2							2						
3							3						
4							4						
5							5						
6							6						
7							7						
8							8						
9							9						
10							10						
V _{AC} + V _{CD} + V _{DA} = ____ V								V _{AC} + V _{CD} + V _{DA} = ____ V					
Current directions at C: I ₁ ____, I ₂ ____								Current directions at C: I ₁ ____, I ₂ ____					
Current directions at D: I ₁ ____, I ₂ ____								Current directions at D: I ₁ ____, I ₂ ____					

Table 5

PhET: All switches down											
V _{DA} V	I ₁ A	I ₂ A	I ₃ A	V _{AC} V	V _{CD} V	V _{AD} V	V _{DF} V	V _{FE} V	V _{ED} V	V _{FD} V	
5							5				
5							10				
V _{AC} + V _{CD} + V _{DA} = ____ V							V _{FE} + V _{ED} + V _{DF} = ____ V				
Current directions at C: I ₁ ____, I ₂ ____, I ₃ ____ Current directions at D: I ₁ ____, I ₂ ____, I ₃ ____											

Table 6

Laboratory: All switches down											
V _{DA} V	I ₁ A	I ₂ A	I ₃ A	V _{AC} V	V _{CD} V	V _{AD} V	V _{DF} V	V _{FE} V	V _{ED} V	V _{FD} V	
5							5				
5							10				
V _{AC} + V _{CD} + V _{DA} = ____ V							V _{FE} + V _{ED} + V _{DF} = ____ V				
Current directions at C: I ₁ ____, I ₂ ____, I ₃ ____ Current directions at D: I ₁ ____, I ₂ ____, I ₃ ____											

Questions

1. What happens to the current in the circuit as the emf is increased? [Draw a current-voltage graph and determine the relationship between current in a wire and the potential drop across it].
2. What can you conclude about the current-voltage relationship from the graph that you plotted?
3. How is the slope of the line useful to you?
4. Is the slope or its inverse comparable to the resistance in the circuit? Explain.

5. What is the sum of the current at junction C or D when all the switches are down?
6. If you were to take the loop BACDB, can you identify and label which device suffers a potential drop or potential rise? What is the sum of the potential drop and the potential rise in the loop BACDB and the loop DFECDB respectively?
7. How would you determine the currents I_1 , I_2 and I_3 , if all the ammeters in the configuration were removed? State Kirchoff's current and voltage law.