Do Pencils Obey Ohm's Law?

Science Fair Project Report

Level : Primary Level

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Submitted by

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ARRAHMAAN
INTERNATIONAL SCHOOL

(Creating the community of Excellence)

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CONTENTS

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ABSTRACT

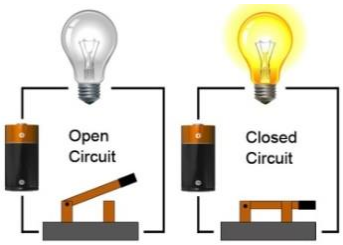
The pencil that we use in our day-to-day activities related to marking and drawings can also be used as a resistor in the electricity networks. As compared to other types of resistors this resistor also offers resistance to the flow of electricity through it. In fact the lead inside the pencil consists of properties of an electrical resistor and thus it acts as a resistor.

In this experiment I prepared different length pencils to build simple circuit and used them to investigate resistors. What do resistors do and why are they useful? How will changing the size of the resistor affect the circuit? By varying the size of the pencil resistor, I measured the resistance of each pencil resistor in ohms, and the amount of current (in amperes) flowing through the circuit for each resistor using multimeter. Then I tested whether pencils obey Ohm's law, which relates the current, resistance, and voltage in a circuit.

Through my experiment I found that the different length of pencils have different amount of resistance, the resistance value increases as the length increases and pencils obey ohm's law.

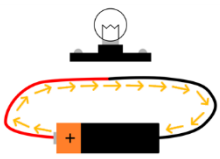
INTRODUCTION

An **electronic circuit** is a circular path of conductors by which electric current can flow. A **closed circuit** is like a circle because it starts and ends at the same point forming a complete loop. Furthermore, a closed circuit allows electricity to flow from the (+) power to the (-) ground uninterrupted. In contrast, if there is any break in the flow of electricity, this is known as an **open circuit.** As shown below, a switch in a circuit can cause it to be open or closed depending on its position.



All circuits need to have three basic elements. These elements are a voltage source, conductive path and a load. The voltage source, such as a battery, is needed in order to cause the current to flow through the circuit. In addition, there needs to be a conductive path that provides a route for the electricity to flow. Finally, a proper circuit needs a load that consumes the power. The load in the above circuit is the light bulb.

If the positive and negative ends of a battery are connected directly to each other, without anything like a lightbulb or motor in between them, this creates a **short circuit**. Short circuits are dangerous because they allow a lot of electrical current to flow, and can cause the battery to get very hot, or even explode. You should never connect the two ends of a battery directly to each other.



Short circuit

Circuits have to let electrical current flow through them easily. Materials that let electricity flow through them easily are called **conductors**. Most metals are conductors. However, materials that prevent electricity from flowing are also important for circuits. These materials are called **insulators**. Most rubbers and plastics are insulators. Insulators are important because they can help protect you from an electric shock when you touch a wire, or help protect a sensitive circuit from damage. For example, the power cord for a lamp consists of metal wires inside a rubber insulator; and an electronic toy might have a plastic case that protects the circuit inside from damage.

However, not all conductors are the same. An important property of conductors is their resistance, or how much they resist the flow of electrical current. It is easier for current to flow through something with low resistance than through something with high resistance. The resistance of a conductor depends on both the material it is made out of, and its size and shape.

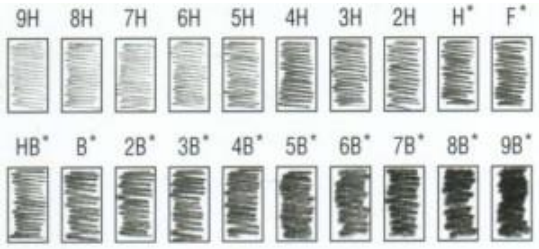
Resistors are used to resist the flow of current or to control the voltage in a circuit. The amount of resistance that a resistor offers is measured in Ohms (Ω). Most resistors have colored stripes on the outside and this code will tell us its value of resistance. You can use a multimeter to determine the value of a resistor.

Resistance is an electrical quantity that measures how the device or material reduces the electric current flow through it. The resistance is measured in units of ohms (Ω). If we make an analogy to water flow in pipes, the resistance is bigger when the pipe is thinner, so the water flow is decreased. A term called resistance is used to unravel these complications. Resistance is a measure of the difficulty of the flow of electrons in a material. Hence insulators have a very high resistance. Conductors have a very low resistance.

The **Pencils** are made of wood, glue, metal, rubber and pure graphite. Every pencil has a lead in it, which is the main part of the pencil used for writing/marking purpose. The lead used inside the pencil is made up of a material, namely graphite – an allotrope of the carbon.

Graphite has some very useful features like the following:

- ✓ Graphite is a semi metal and it is an electrical conductor.
- ✓ It is non-inductive, and has a negative temperature coefficient.
- ✓ Graphite is easily obtainable and can be recycled for reuse.
- ✓ Under standard conditions, the graphite is in the most stable form of the carbon.
- ✓ Resistance of graphite varies with its grades used in lead manufacturing, and the grades of pencil or lead are shown in the figure below.

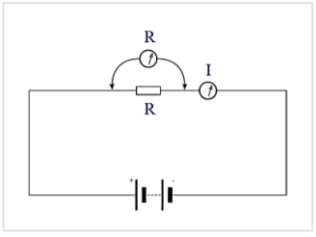


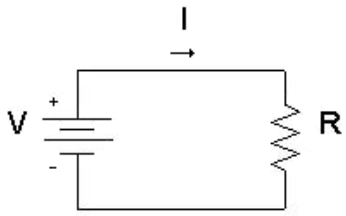
Ohm's Law:

Ohm's Law states that the current flowing in a circuit is directly proportional to the applied potential difference and inversely proportional to the resistance in the circuit.

In other words by doubling the voltage across a circuit the current will also double. However if the resistance is doubled the current will fall by half.

In this mathematical relationship the unit of resistance is measured in Ohms.





Simple illustration of Ohm's Law in a circuit-Ohm's Law formula

The Ohm's Law formula or equation is very straightforward.

Ohm's law can be expressed in a mathematical form:

$$V=IR$$

Where:

V = voltage expressed in Volts

I = current expressed in Amps

R = resistance expressed in Ohms

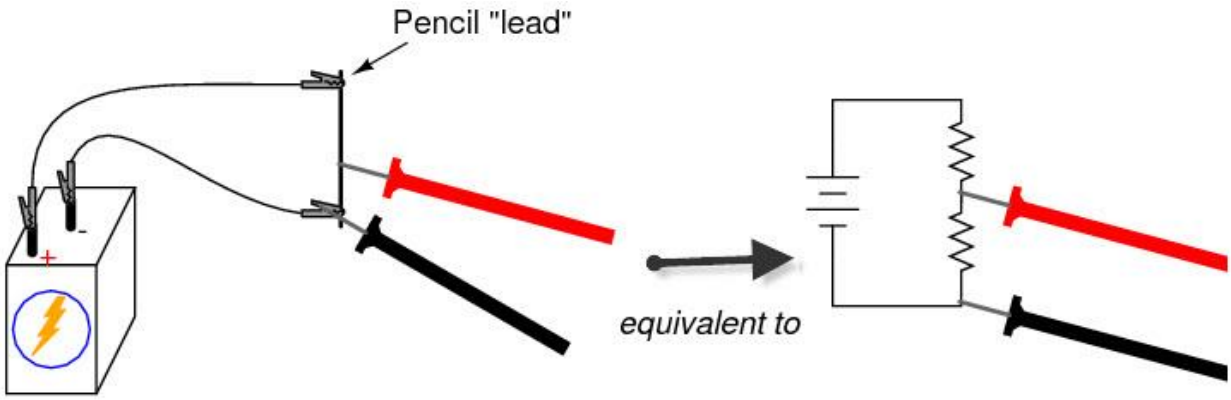
The formula can be manipulated so that if any two quantities are known the third can be calculated.

$$I = \frac{V}{R}$$

$$R = \frac{V}{I}$$

STATEMENT OF THE PROBLEM

What do you do with your old wooden pencils when they get too short to hold? Don't throw them away. We can use them to make circuits! This project shows that how to use pencils to make resistors, an important part of many electrical circuits, and test how they obey Ohm's law in a simple circuit.



HYPOTHESIS

Pencils obey Ohm's law.

DESIGN OF STUDY

Step1: ***Test how Variable length Pencils affect the current flow in a simple circuit.***	**Step 2**: ***To Verify whether Pencils obey Ohm's Law***
INDEPENDENT VARIABLE: • Length of the Pencil resistors DEPENDENT VARIALBE: • Current • Resistance CONTROLLED VARIABLES: • Voltage • Bulb	INDEPENDENT VARIABLE: • Voltage DEPENDENT VARIALBE: • Current • Resistance CONTROLLED VARIABLES: • Length of pencil

MATERIALS:

- Digital multimeter
- 9V Battery (4)
- AA Battery (4)
- Battery Holder
- Alligator clip leads (3 sets-red set, black set, red-black set))
- Connecting Wires
- Wire cutter
- Mini lightbulb
- Mini bulb screw base
- 8 pencils of different length
- Metric ruler
- Pencil sharpener
- Scissors
- Lab notebook

PROCEDURE:

Prepare variable length of pencils.

- Prepare 9 pencils of different length (range from very short to almost the full length of the pencil)
- Use the pencil sharpener to sharpen both ends of the pencils.
- User a ruler to measure the tip-to-tip lengths of the sharpened pencils and record these lengths in a data table.

Step 1: Test how Variable length Pencils affect the current flow in a simple circuit.

A. Set up the test circuit using the following steps.

- Connect a red alligator clip to the exposed metal part of the red wire from the 9V battery.
- Connect a black alligator clip to the exposed metal part of the black wire from the 9V battery.
- Attach the other end of the black alligator clip to one of the screws on the lightbulb holder.
- Screw the lightbulb into the bulb holder.
- Attach the red end of the red-black alligator clip to the other screw on the bulb holder.
- Connect the pencil resistors to the free ends of the red and red-black alligator clips.
- Test the circuit by touching the exposed metal ends of the red and red-black alligator clips together. This creates a closed circuit and lightbulb should light up.
- If it does not light up, then check the following:
    - Make sure the lightbulb is screwed tightly into the base.
    - Make sure none of the alligator clip connections are loose.
    - Make sure none of the batteries are backwards.

- Important: throughout the project, only connect the lightbulb for long enough to assess its brightness, then disconnect it when not in use. Leaving the lightbulb connected for a long time can cause it to burn out prematurely.

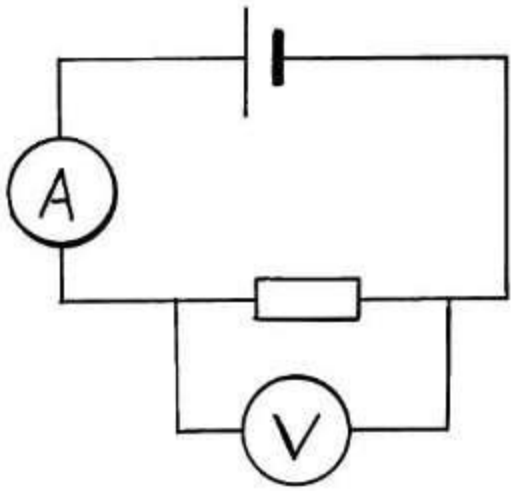
B. <u>Experiment:</u>

- Join the exposed metal ends of the red and red-black alligator clips together. Measure the resistance in ohms, and the amount of current (in amperes) flowing through the circuit using a multimeter. This is the "control" trial.
- Disconnect the alligator clips as soon as you are done.
- Next start to test each one of the pencil resistors by connecting the free end of red and red-black alligator clips to the graphite point at each end of a sharpened pencil.
- Measure the resistance of each pencil resistor in ohms, and the amount of current (in amperes) flowing through the circuit for each resistor and record the data.
- ***Precautions:*** Remember not to leave the bulb connected when not in use, as this will cause it to burn out sooner.
- Take three trails to increase the accuracy rate.

- ***Analyze the results.***
  - How the current varies change as the length of the pencil resistors increases?
  - Make a graph of the results with resistor length on the horizontal (x) axis and corresponding resistances on the vertical (y) axis.
  - How does resistance affect the amount of current flowing through the circuit?

Step 2: Test Ohm's law for the pencil resistors

- Ohm's Law states that the current flowing in a circuit is directly proportional to the applied potential difference and inversely proportional to the resistance in the circuit.
- To test ohm's law, take three pencils resistors with high resistance, low resistance and medium resistance.
- Change the battery of different voltage (9V, 6 V) and measure the resistance of three pencil resistors in ohms and the amount of current (in amperes) flowing through the circuit and record the data.
- Now ***analyze*** the results to verify that the current increases as the voltage increases and resistance decreases as the voltage increases.



COLLECTION OF DATA

PHOTOGRAPHS

TABULATION-Qualitative Data

Table 1: Length of pencils

S. No	*Pencil*	*Length of pencil(cm)*	*S. No*	*Pencil*	*Length of pencil(cm)*
1.	Pencil 1	17.9	5.	Pencil 5	9.1
2.	Pencil 2	14.2	6.	Pencil 6	7.4
3.	Pencil 3	13	7.	Pencil 7	5.4
4.	Pencil 4	10.7	8.	Pencil 8	3.7

Table 2: Measuring resistance and current through the circuit using multimeter (Battery voltage =9V):

S. No	*Pencil Length(cm)*	*Trial 1*			*Trial 2*			*Trial 3*			*Result (Average)*		
		Resistance (Ω)	*Voltage (V)*	*Current (A)*	*Resistance (Ω)*	*Voltage (V)*	*Current (A)*	*Resistance (Ω)*	*Voltage (V)*	*Current (A)*	*Resistance (Ω)*	*Voltage (V)*	*Current (A)*
1.	17.9	26.7	8.38	0.43	25.1	8.33	0.43	26.1	8.29	0.43	25.97	8.33	0.43
2.	14.2	23.5	8.21	0.43	23.2	8.29	0.43	23.2	8.24	0.43	23.3	8.24	0.43
3.	13	22	8.20	0.42	21.6	8.09	0.42	21.6	8.18	0.42	21.73	8.16	0.42
4.	10.7	21.5	8.11	0.42	21.2	8.01	0.42	21.2	8.14	0.42	21.3	8.09	0.42
5.	9.1	19.3	8.06	0.42	18.9	7.94	0.42	18.9	8.02	0.42	19.03	8.01	0.42
6.	7.4	18.8	7.86	0.42	18.3	7.61	0.42	18.5	7.46	0.42	18.5	7.64	0.42
7.	5.4	18.0	7.43	0.41	17.4	7.39	0.41	17.9	7.32	0.41	17.76	7.38	0.41
8.	3.7	17.7	7.38	0.41	17.1	7.23	0.41	16.8	7.22	0.41	17.2	7.27	0.41

Table 3: To Verify Ohm's Law

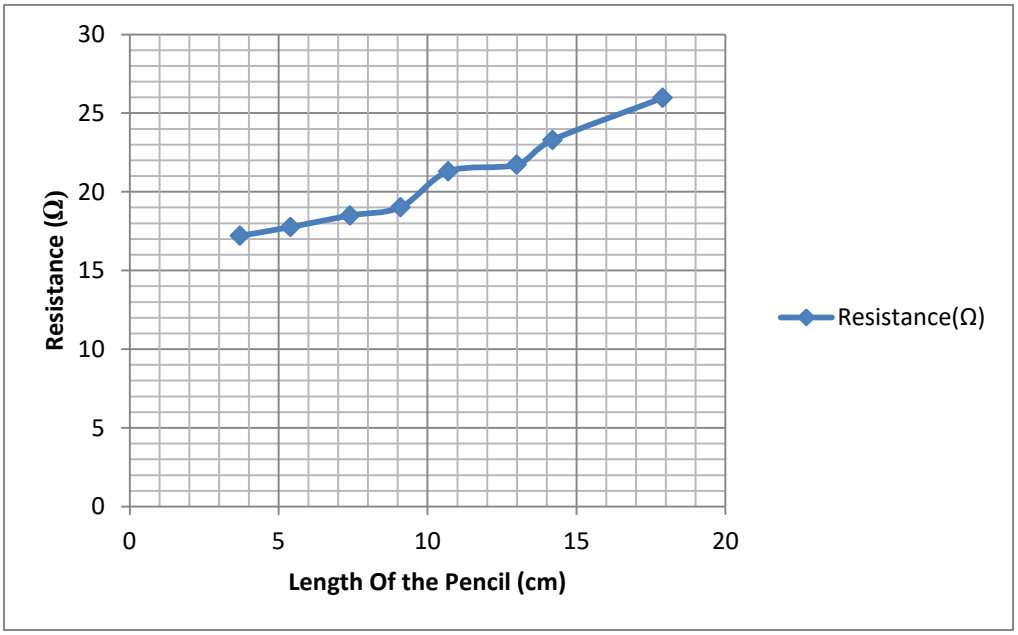
S. No	Pencil Length(cm)	Battery Voltage	Trial 1			Trial 2			Average		
			Voltage (V)	Current (A)	Resistance (Ω)	Voltage (V)	Current (A)	Resistance (Ω)	Voltage (V)	Current (A)	Resistance (Ω)
1.	17.9	9V	8.27	0.37	26.17	8.24	0.4	26.05	8.255	0.385	26.11
		6 V	5.5	0.27	21.87	5.25	0.27	20.97	5.375	0.27	21.42
		3V	2.8	0.11	25.81	2.73	0.14	21.51	2.765	0.125	23.66
2.	10.7	9V	8.12	0.36	21.2	8.09	0.32	20.5	8.105	0.34	20.85
		6 V	5.20	0.24	21.9	5.12	0.22	21.2	5.16	0.23	21.55
		3V	2.6	0.19	18.43	2.23	0.15	18.31	2.415	0.17	18.37
3.	5.4	9V	8.1	0.3	19.9	8.01	0.3	18.4	8.055	0.3	19.15
		6 V	4.64	0.21	20.98	4.14	0.23	20.73	4.39	0.22	20.86
		3V	2.3	0.2	15.2	2.09	0.2	15.09	2.195	0.2	15.15

GRAPHICAL REPRESENTATION

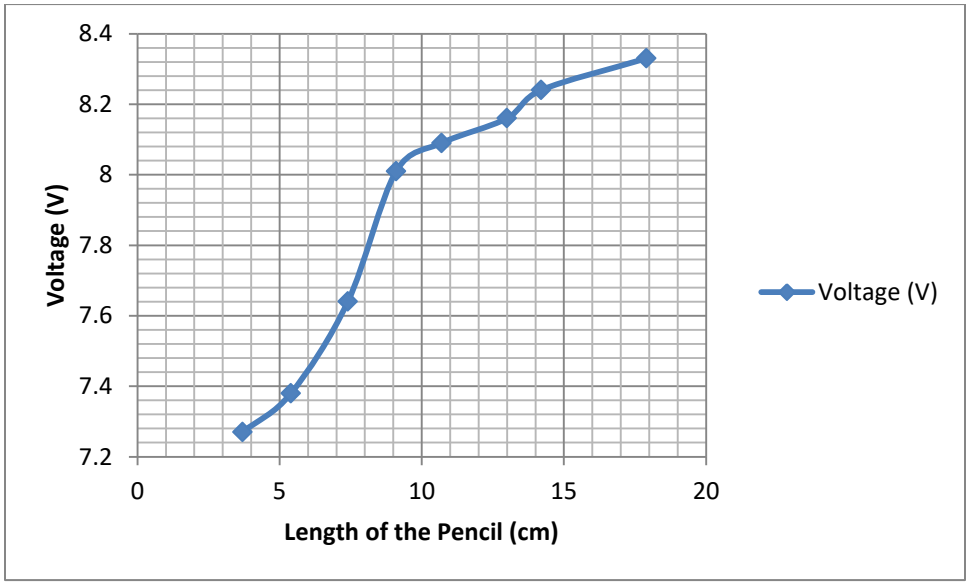
A. Using Data of Table 2:

Graph 1: Length Vs Resistance

Resistance is directly proportional to length

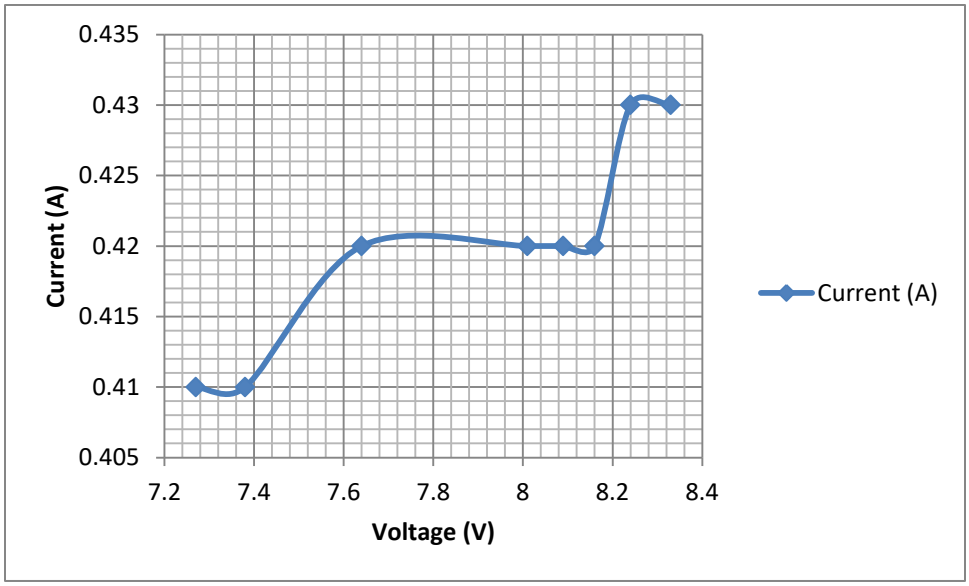


Graph 2: Length of the pencil Vs Voltage



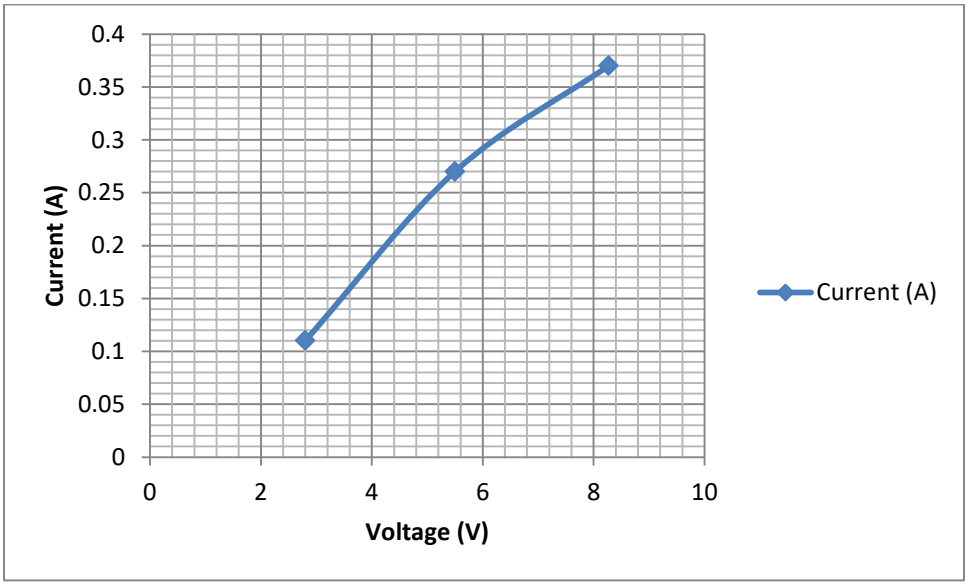
Graph 3: Voltage Vs Current

As the Voltage increases Current also increases.

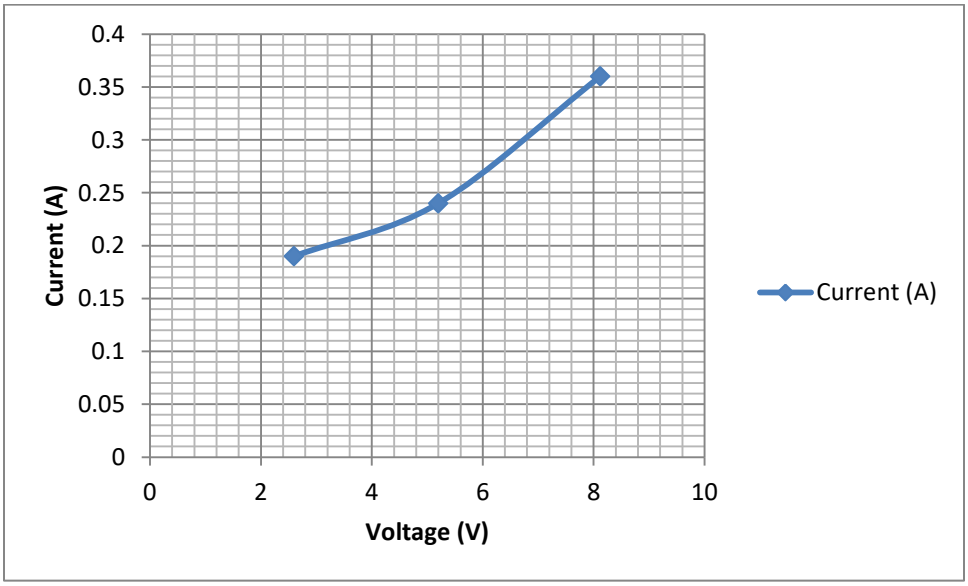


B. <u>Using data of Table 3(Ohm's Law verification for different length- Voltage Vs Current)</u>

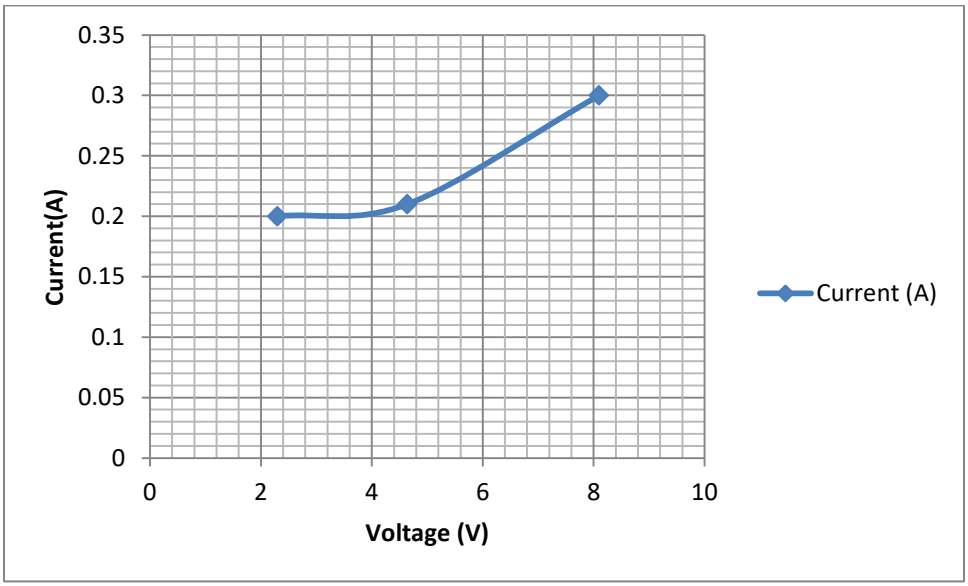
i. 17.9 cm



ii. 10.7 cm



iii. 5.4 cm



RESULTS AND DISCUSSION

- I start my experiment with HB Nataraja pencils of different length but it shows different results and in many readings I realized something different from ohm's law.
- Again I changed the experiment with some other quality pencils and check for ohm's law verification. That shows good results.
- I found that the resistance of this type of resistors can be varied by varying the grade of the graphite lead of the pencil.

Hardness	9H	8H	7H	6H	5H	4H	3H	2H	H	F	HB	B	2B	3B	4B	5B	6B	7B	8B	9B
Carbon (%)	41	44	47	50	52	55	58	60	63	66	68	71	74	76	79	82	84	87	90	93
Clay (%)	53	50	47	45	42	39	36	34	31	28	26	23	20	18	15	12	10	7	5	2

- The "lead" in pencil is made up of a combination of graphite and clay, with wax and other additives in small quantities. Clay, unlike graphite, is an insulator as it does not conduct electricity well
- As the length of the pencil increases, the resistance also increased.
- Increasing the length of the graphite in the pencil will increase the resistance of the whole circuit as the flow of electrons would have to travel longer than a short pencil resistor. As the resistance through the pencil increased, more voltage is used there and the potential energy across the circuit decreased.
- The current increases as the voltage increases and resistance decreases as the voltage increases.
- From the experiment it is proven that the pencil can be used as resistors and pencils obey Ohm's Law.

CONCLUSION

- My hypothesis, “Pencils obey Ohm’s law” has been proved.
- As the length increases the resistance increases.
- But we need a good graphite lead pencil.
- I think this happens because wood is an insulator of electricity so the electric current can run through it without interruption.
- Also lead is graphite which is a form of metal carbon so it can send current through it from the stored energy released from the 9 volt battery.

APPLICATION

Electricity is a very important part of our modern world and none of the modern technology we use today could exist without it. All of our modern day gadgets, appliances and electronics use the power of electricity to work. It is the careful balance of parts of a circuit, batteries, wires and resistors; and the completeness of a circuit, which allow electricity to be useful, and not harmful.

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.

Ohm's Law is a fundamental law of Electrical Engineering. It has a large number of practical applications in almost all electrical circuits and electronic components. The electronic devices such as laptop and mobile phones require a dc power supply with the specific current rating. Typical mobile phone batteries require 0.7 – 1 A. A resistor is used to control the rate of current flowing through these components. The Ohm's law is used to calculate the rating of current which should be used in the typical circuit. Fuses and circuit breakers are the protection components which connect in series with the electronic devices. Fuses are rated in Amperes. The current rating of the fuse is calculated by using the Ohm's Law.

The electronic components such as normal power supplies, uninterruptable supplies, iron, kettle, televisions and similar components use a lot of resistors for their control purposes. The wattage sizing of any resistor should be carefully selected for this purpose. The Ohm's law is used to size the resistors.

The speed control of conventional fans is achieved by using a potentiometer. A potentiometer is a variable resistance. A circular knob on the component can be rotated to achieve a variable resistance on the output terminals. For any specific value of the input, we can calculate the resistance, current and thus power flowing through Ohm's Law.

FUTURE ENHANCEMENT

- I want to build more innovative pencil drawn circuits in future in which the drawing of pencils will act as resistors.
- The application of Ohm's law is very wide in all the day to day electronic appliances. I wish to study that in detail and design electronic devices.

ACKNOWLEDGEMENT

"There are times when silence speaks so much more loudly than words of praise to only as good as belittle a person, whose words do not express, but only put a veneer over true feelings, which are of gratitude at this point of time."

First of all, I praise the almighty, merciful and passionate, for providing me this opportunity and strength to do my project.

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