How does the length of a conductor affect the current flowing through it?

An investigation to show how the length of a conductor effects the current flowing through it

PLANNING

During my science lessons I have learnt the following information that has enabled me to plan my investigation. With further research I have been able to extend the information to a higher level.

Atomic structure

Atoms are everywhere; in our house in our neighbourhood in fact the whole universe consists of atoms. Anything and everything is made up of atoms.
The structure of an atom contains various different parts, they all have different properties. An atom is the smallest unit into which matter can be divided without charged particles released. All elements contain one single type of atom.
An atom has three main parts, which define its state (positive, negative or neutral).

Protons

Protons are the positive part of the atom they are in the nucleus of an atom and together with neutrons make most of the mass of the atom. A proton is a stable subatomic particle. Protons have the property of which they cannot be taken away or added to other protons in any other atoms and therefore the number of protons in an atom will always stay the same within an atom.

Neutron

One of the ingredient particles of every atomic nucleus, Protons and neutrons constitute more than 99.9 percent of an atom's mass. These two types of nuclear particles, commonly called nucleons, interact through the so-called strong force and bond in various proportions to form the different atomic kind of the chemical elements. A neutron has no charge and attracts protons.

Electron

The electron is principally the lightest part of the atom, it carries a negative charge which is considered to be the basic charge of electricity; electrons are carried in the shell of an atom (around the nucleus of an atom). Electrons have an orbital path around the nucleus, within any given atom the electrons move in an orbital pattern these orbits are arranged into concentric shells proceeding outward from the nucleus with an increasing number of sub-shells.

Conductors

A neutral atom has equal protons and neutrons but if you take away or add electrons it becomes what is known as an ion - a charged atom. Positively charged ions are called cations and negatively charged ions are called anions, the number of electrons in a neutral atom is identical to the number positive charges on the nucleus and as a positive ion would attract a negative ion and a negative would attract a positive ion neutral atom attracts both positive and negatively charged particles. In a conductor the atoms are tightly packed together but the outer most electrons in the atom shell don't know which atom nucleus they belong to. A conductor cloud of electrons floating through the structure therefore a conductor is able to carry electrical energy when connected to a circuit.

Insulators

In an insulator the atoms are arranged much further apart so the outer most electrons know the nucleus they are attracted to and therefore are not available for carrying electrical energy. The static charges that exist when two objects rub against each other cause the transfer of electrons. The object that gains electrons becomes charged negatively while the object that loses electrons becomes positively charged. Insulators keep this charge but conductors quickly loose them as is passes through them and to earth.

When two insulators are rubbed together, electrons from one of the insulators are stripped off; causing both objects to get charged this can then attract or repel objects. For example when you get some wool and rub it on a polythene rod, you will get some charges to come off from the rod on to the wool, making it charged. The rod can then attract little bits of paper due to it being charged.

Static charge

A non-moving charge is said to be static. High voltage can sometimes be due to a build of static. This can cause lightning or high power sparks, creating high hazards. One way of stopping or reducing these sparks is to earth them. This is essentially a way of stopping the build up of charges so there is no longer a risk.

One very common example can be found in the aviation industry. When an aircraft is being refuelled, sparking is avoided by connecting the aircraft to the ground using a good electrical conductor. When the aircraft is connected to the ground the build up of charges gets carried safely to the ground, otherwise while the fuel is flowing through the pipes, electrons will be striped off ionising the atoms and therefore the charge would build up and cause a spark, big enough to cause disaster.

Current

A flowing charge is called an electric current; it is measured in amps using an ammeter. Charge is difficult to measure directly. The unit of charge is the coulomb. The amount of charge that flows when a current passes can be calculated using the equation:

charge = current x time. Current in a metal is due to a flow of electrons that move away from the negative terminal of the power supply towards the positive terminal. Current in conducting gases and electrolytes is due to the movement of both positive and negative ions.

A circuit that has only one path for the current is a series circuit. Where there are two or more possible current paths the circuit the circuit is a parallel circuit. The current is the same at all points in a series circuit; no longer charge is gained or lost. In a parallel circuit the current can have different values in each of the branches. Where there is a junction in a parallel circuit, the current passing into the junction is equal to the current passing out of the junction.

Ammeter

An ammeter is an instrument to measure either direct current or alternating current. An amp is number of electrons that flow past a point each second in a circuit. Ammeters measure a unit called amp (ampere). Ammeters are always connected in parallel around components.

1 Amp = 1×10^{14}

A coulomb is the quantity of electricity transported in one second by the current of one ampere. A coulomb is a measure of charge. One coulomb is 1.6×10^{-19} (c).

Voltage

The job of the current in a circuit is to transfer electrons from the power supply to the circuit components. Energy is heat, light and movement in the circuit components. The voltage between two points in a circuit is the energy transfer for each coulomb of electrons that passes. An energy transfer of 1 joule per coulomb is a voltage of 1 volt. Voltage is measured using a voltmeter which is placed in parallel with the power supply or electrical device. The amount of current passing in a circuit depends on the voltage and the resistance of the circuit. Increasing the voltage causes the current to increase, while increasing the resistance causes the current to decrease.

Resistance

The voltage across a circuit component is equal to the current times its resistance, $V = I \times R$. This equation is also used to calculate resistance from ammeter and voltmeter readings. Resistance is measured in Ohms.

Provided that the temperature does not change, the resistance of a metal wire does not alter when the current changes. A graph of a current against voltage is a line passing through the origin. The wire in a filament lamp gets hotter as the current increases and this causes the resistance to decrease.

Ohms Law

Ohms law is primarily a generalisation of voltage, current, and resistance. It interprets that the relationship that the amount of steady current through a conductor is directly proportional to the potential difference, or voltage across the conductor. The abbreviation of ohm is Ω. The formula for ohms law is $V=I/R$

Prediction

On the basis of my research, I predict that the length of the conductor will proportionally effect the current flowing through it. With the temperature consistent, shortening the length of the conductor will make the current increase, the current will fall if the length of the conductor is increased. This is because the current has to pass through more obstacles and there are more collisions with the atoms in the structure of the conductor, the current in the longer piece of wire will have great difficulty getting through due to there being more obstacles in the way. The resistance will increase with a longer conductor because the friction between the particles in the metal will be a lot; this is because a consistent current has to pass through less of a volume causing a higher amount of resistance against the current in the circuit. The current will decrease if the resistance is increased. The voltage increases with more resistance because it takes more energy to push the current around.

Apparatus

100 cm ruler, Nichrome (100 cm), ammeter, voltmeter, battery pack, stop watch, thermometer.

Method

1. Set up the apparatus as shown in the diagram, making sure to set the ammeter in series and the voltmeter in parallel.
2. Measure air temperature using a thermometer
3. Start off at 100 cm and measure both voltage and ampere with the ammeter and voltmeter attached to the , do this for every 5cm intervals (each interval lasting 10 seconds) until you get to zero, make sure to turn off the power once each interval is completed.
4. Calculate the resistance along the Nichrome wire by using the $I = V \div R$ law.

Fair test

In order to ensure that my investigation was a fair test, the following things were kept the same.

I kept the change in the length of the wire the same (at 5cm each interval), the temperature was kept the same, the output voltage was kept the same, the time it was on was kept the same(10seconds), the cross sectional area of wire was the same and the same material of wire was used(Nichrome) a composite of nickel and chromium. I had to wait for the wire to cool back to room temperature before I could measure again.

One other thing was that I took two readings so that I could be as accurate as possible.

The room temperature had to be constant.

Safety points

During the investigation the following safety procedures were used.

Whilst the wire is hooked up to the power pack it could get unexpectedly hot, be careful when handling the wire especially when on for a long period of time.

OBSERVATION

CHART SHOWING RESULTS OF EXPERIMENT

	Length (cm)	Material	Temperature (°c)	Diameter (mm)	Time (s)	Current (amps)			Voltage (volts)			R= V/I (Ohms)
						1.	2.	Average	1.	2.	Average	
1.	100	Nichrome	22	0.7	10	0.43	0.43	0.43	1.22	1.22	1.22	2.84
2.	95	Nichrome	22	0.7	10	0.44	0.44	0.44	1.19	1.19	1.19	2.70
3.	90	Nichrome	22	0.7	10	0.46	0.46	0.46	1.18	1.18	1.18	2.56
4.	85	Nichrome	22	0.7	10	0.48	0.48	0.48	1.16	1.16	1.16	2.41
5.	80	Nichrome	22	0.7	10	0.51	0.50	0.51	1.17	1.17	1.17	2.27
6.	75	Nichrome	22	0.7	10	0.54	0.54	0.54	1.14	1.15	1.14	2.11
7.	70	Nichrome	22	0.7	10	0.57	0.57	0.57	1.13	1.13	1.13	1.98
8.	65	Nichrome	22	0.7	10	0.60	0.61	0.60	1.13	1.12	1.12	1.85
9.	60	Nichrome	22	0.7	10	0.64	0.65	0.64	1.14	1.11	1.12	1.75
10.	55	Nichrome	22	0.7	10	0.69	0.70	0.69	1.07	1.09	1.08	1.56
11.	50	Nichrome	22	0.7	10	0.74	0.72	0.73	1.07	1.05	1.06	1.45
12.	45	Nichrome	22	0.7	10	0.78	0.78	0.78	0.99	1.01	1.00	1.28
13.	40	Nichrome	22	0.7	10	0.85	0.85	0.85	0.99	0.97	0.98	1.15
14.	35	Nichrome	22	0.7	10	0.94	0.95	0.94	0.95	0.94	0.94	1.00
15.	30	Nichrome	22	0.7	10	1.00	1.01	1.00	0.94	0.93	0.93	0.93
16.	25	Nichrome	22	0.7	10	1.16	1.17	1.16	0.83	0.86	0.84	0.72
17.	20	Nichrome	22	0.7	10	1.26	1.27	1.26	0.79	0.80	0.79	0.62
18.	15	Nichrome	22	0.7	10	1.51	1.56	1.53	0.63	0.65	0.64	0.41
19.	10	Nichrome	22	0.7	10	1.81	1.84	1.82	0.54	0.55	0.54	0.29
20.	05	Nichrome	22	0.7	10	2.23	2.31	2.27	0.36	0.34	0.35	0.15

*all figures have been rounded down.

ANALYSIS

My results show that there is more resistance in the wire when it is a longer length, and less when the wire is shorter. All three graphs have different line contours. My results confirm that as the length of the conductor is decreased the voltage is increased. The shorter the length gets the more dramatically the voltage decreases. The same thing happens to both the current and resistance at different proportional rates.

My results confirm my original prediction that a longer wire conductor has lower current along with higher resistance and voltage. Shortening the length of the conductor will make the current increase; the current will fall if the length of the conductor is increased. This is because the current has to pass through more obstacles and there are more collisions with the atoms in the structure of the conductor, the current in the longer piece of wire will have great difficulty getting through due to there being more obstacles in the way. The resistance will increase with a longer conductor because the friction between the particles in the metal will be a lot; this is because a consistent current has to pass through less of a volume causing a higher amount of resistance against the current in the circuit. The current will decrease if the resistance is increased. The voltage increases with more resistance because it takes more energy to drive the current around.

EVALUATION

I think the method used was good because the results followed the pattern suggested in my prediction but a few adjustments could have been made to improve accuracy.

Although my method was quite good I think I should have completed more repeats of the experiment at closer intervals making sure that I have a reliable set of results for great accuracy. For immense accuracy a much more accurate voltmeter and ammeter could have been engaged into the experiment (for example a computer controlled voltmeter and ammeter).

One of my results at the 80cm mark on the voltage field gave a higher reading than the 85cm mark, which shouldn't have happened. I think this happened because there was a point in the circuit which was resisting the current flow and therefore gave a higher reading. Overall I think my result were to a good standard because the points on the graphs gave a smooth line contour.

There were few points that could have been changed to show a variation of results for further examination , starting off with the wire material- different materials could have been used to show what effect they have on the circuit and to give a good idea of how different materials act in the experiment. Secondly the diameter of the wire could have been altered to see what effect the change has on the circuit. Thirdly more tests should have been carried out over a different length span. One more thing, a brand new battery could have been used for every repeat to make it even more accurate.

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Mohsan Mahmood 10s