

## Physics coursework: Resistance on a wire.

### Aim:

Investigate how the length of a wire affects the current and resistance of a wire

### Research:

All materials, solid, liquid or gases are made up of **atoms**. The atoms themselves consist of a central bit, called the nucleus, made up of particles called **protons** (which have a +ve electrical charge) and **neutrons** (which have no charge) Orbiting around the nucleus are **electrons** which are very tiny and have a -ve electrical charge. One can think of the electrons orbiting in layers like the rings of an onion, and it's the ones in the very outside layer, the outer shell, that are the most important when thinking about conduction.

In metals, the outermost electrons are held only very weakly to the atom and often wander away from it and go to the nearby atom or one a bit further away. These wandering electrons are called conduction electrons and the more of these there are, for a given volume of metal, the better the metal will be as a conductor of electricity will.

When you connect a battery across a wire, one end becomes +ve and attracts the conduction electrons, which drift towards that end of the wire. But the electrons have obstacles to face because the metal atoms are jiggling about because of their thermal energy and so the electrons collide with them and are knocked all over. It's this difficulty that the electrons have in moving along the wire that we call resistance.

Resistance involves collisions of the current -carrying charged particles with fixed particles that make up the structure of the conductors. A resistor is a material that makes it hard for electrons to go through a circuit. Without resistance, the amount from even one-volt would be infinite. Resistance occurs when electrons travelling along the wire collide with the atoms of the wire.

The higher the resistance, the lower the current. If there is high resistance, to get the same current a higher voltage will be needed to provide an extra push for the electricity. Some metals have less resistance than others. Wires are always made out of copper because copper has a low resistance and therefore it is a good conductor. The length and width of a wire also has an effect. In this investigation I will investigate how the diameter of a wire will affect the resistance in the circuit.

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The unit of resistance is Ohms and the symbol is:

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**Resistance opposes the flow of an electric current around a circuit so that energy is required to push the charged particles around the circuit. The circuit itself can**

resist the flow of particles if the wires are either very thin or very long.

E.g. The filament in an electric light bulb

### Ohm's law

He discovered a relationship that the amount of steady current through a large number of materials is directly proportional to the potential difference, or [voltage](#), across the materials. Thus, if the voltage  $V$  (in units of

Volts) between two ends of a wire made from one of these materials is tripled, the [current](#)  $I$  (amperes) also triples; and the quotient  $V/I$  remains constant. The quotient  $V/I$  for a given piece of material is called its resistance,  $R$ , measured in units named ohms. The resistance of materials for which Ohm's law is valid does not change over enormous ranges of voltage and current. Ohm's law may be expressed mathematically as  $V/I = R$ . That the resistance, or the ratio of voltage to current, for all or part of an electric circuit at a fixed temperature is generally constant had been established by 1827 as a result of the investigations of the German physicist George Simon Ohm. Alternate statements of Ohm's law are that the current  $I$  in a conductor equals the potential difference  $V$  across the conductor divided by the [resistance](#) of the conductor, or simply  $I = V/R$ , and that the potential difference across a conductor equals the product of the current in the conductor and its resistance,  $V = IR$ . In a circuit in which the potential difference, or voltage, is constant, the current may be decreased by adding more resistance or increased by removing some resistance. Ohm's law may also be expressed in terms of the [electromotive force](#), or voltage,  $E$ , of the source of electric energy, such as a battery. For example,  $I = E/R$ .

With modifications, Ohm's law also applies to alternating-current circuits, in which the relation between the voltage and the current is more complicated than for direct currents. Precisely because the current is varying, besides resistance, other forms of opposition to the current arise, called reactance. The combination of resistance and reactance is called [impedance](#);  $Z$ . When the impedance, equivalent to the ratio of voltage to current, in an alternating current circuit is constant, a common occurrence, and Ohm's law is applicable. For example,  $V/I = Z$ .

With further modifications Ohm's law has been extended to the constant ratio of the electromotive force to the magnetic flux in a [magnetic circuit](#).

Resistance values in electronic circuits vary from a few ohms,  $\Omega$ , to values in **kilohms**,  $\text{k}\Omega$ , (thousands of ohms) and **megohms**,  $\text{M}\Omega$ , (millions of ohms). Electronic components designed to have particular resistance values are called **resistors**.

Resistance occurs when the electrons travelling along the wire collide with the atoms of the wire.

These collisions slow down the flow of electrons causing resistance. Resistance is a measure of how hard it is to move the electrons through the wire.

### Factors

1. Temperature: If the wire is heated up the atoms in the wire will start to vibrate because of their increase in energy. This causes more collisions between the electrons and the atoms as the atoms are moving into the path of the electrons. This increase in collisions means

causes an increase in resistance.

2.Material: The type of material will affect the amount of free electrons, which are able to flow through

the wire. The number of electrons depends on the amount of electrons in the outer energy

shell of the atoms, so if there are more or larger atoms then there must be more electrons

available. If the material has a high number of atoms there will be high numbers of electrons

causing a lower resistance because of the increase in the number of electrons. Also if the

atoms in the material are closely packed then the electrons will have more frequent collisions

and the resistance will increase.

3.Wire length: If the length of the wire is increased then the resistance will also increase as the

electrons will have a longer distance to travel and so more collisions will occur. Due to this

the length increase should be proportional to the resistance increase.

4.Wire width: If the wire width is increased the resistance will decrease. This is because of the

increase in the space for the electrons to travel through. Due to this increased space between

the atoms there should be less collisions.

#### Density

Density has a large affect on the amount of resistance. The resistance depends upon the amount of denseness e.g. a large surface area has less resistance because a small area has tightly packed atoms which in turn rebound many of these electrons

#### Prediction

I predict that if the length increases then the resistance will also increase in proportion to the length. I believe this is because the longer the wire the more atoms and so the more likely the electrons are going to collide with the atoms. So if the length is doubled the resistance should also double. This is due to the fact that if length is doubled the number of atoms will also double resulting in twice the number of collisions slowing the electrons down and increasing the resistance. My results should show that the length is proportional to the resistance. Heat in metals causes an increase of resistance or a reduction of conductivity. An increase of active vibration makes atoms get in the way of electrons. The electrons therefore spend more time on deflected courses. This in turn cuts down current slightly.

At higher temperatures, the vibrating ions frequently obstruct the flow of electrons.

At low temperatures the electrons flow relatively freely.

#### Fair Test:

To ensure that the investigation is carried out in a fair way and that the results will be accurate and reliable a number of things must be followed. The only variable in the test will be the length of the wire. The wire must be pulled tight against the ruler and taped in place to ensure the length is accurately measured. The same circuit and battery must be used throughout as different batteries may have different voltages if they are old. The experiment should be repeated 3 times and an average taken to make sure that the results are reliable.

#### Safe test:

I must do everything in my ability to ensure this is a safe and organised investigation. I must make sure that the wire never gets too hot, as not to cause any accidents. I will always ensure that the wire is visible to passers by, as a thin wire stretched across the floor would be easy to trip over.

#### Apparatus

##### **2x crocodile clips**

I shall use these to connect to the each end of the wire at appropriate points, e.g.; at 0cm and 20cm for the first measurement.

##### **3 metre wire**

This is the wire I shall be using throughout my experiment it is important to use the same wire throughout the whole experiment to keep reliable set of data.

##### **power pack**

To produce a current through my wire completing my circuit.

##### **voltmeter**

To make sure the power pack is producing a constant voltage of 4 volts, the voltmeter will allow me to check this and make a record of it.

##### **ammeter**

To allow me to record the current, this and the voltage will allow me to calculate the resistance of the wire. It is important that the ammeter is accurate to produce a reliable set of results.

##### **meter ruler**

To make measure the length of wire for each "testing" of the wire.

#### Preliminary Method

In this preliminary experiment I will select a wire that will be used in my main experiment when Investigating the connection between the length of the wire and the resistance of the wire.

To ensure a fair test whilst carrying out my preliminary experiments I am going to be very careful

When selecting my independent variables which are the length of wire and the wire material. I am

Going to use a constant voltage of 4 volts and a constant length of 50 cm. This preliminary investigation allow me to do a plan for my final experiments as it has allowed me to review any mistakes or loop holes in my investigation.

Results From Preliminary Investigation:

Voltage On wire Current (V) (amps) 4	Length of wire (cm) 50	Current Through Wire (amps) 0.62	2 0.61	3 0.62	Average 0.61
Voltage on wire Resistance (V) (ohms) 4	Length of wire (cm) 50	Resistance on wire (ohms) 6.4	2 6.5	3	Average 6.4

After observing factors during this short preliminary investigation I have decided to use the following measurements: the length of wire will range from 20cm – 300cm (3m) with intervals of 20cm. The length of wire will be changed by moving the crocodile clip across the wire on a metre ruler. We decided that the best thickness of the wire to use would 30swg. This is because a thicker wire would cause too much heat, and the resistance of a thinner wire would be too high and difficult to measure. The reason for this is that a thicker wire allows more room for the electron to travel through it.

#### Method:

Experiment One - First a length of wire over a metre long is sellotaped to a metre rule. The positive crocodile clip is attached at 0cm. And the negative is moved up and down the wire, stopping at 20, 40, 60, 80 and 100cm etc until we reach 3m. Each time reading the ammeter and voltmeter to work out resistance  $R = V/I$ . This is using 30 SWG wire. Other variables, voltage, thickness, and temperature will be kept constant, although the temperature will rise once current is passing through it, which will cause the atoms in the wire to vibrate, and so obstruct the flow of electrons, so the resistance will increase, creating an error.

After switching the power pack, when a full circuit was produced, we shall leave the power pack on until I get a reading. The readings shall be recorded in a table of results and used it to get a recorded resistance of the wire. I shall repeat this experiment three times to allow and more accurate and varied set of data.

#### Diagram of circuit:

Table of results:

Voltage (V)	Length of wire (cm)	Current through wire (amps) Test 1	Test 2	Test 3	Average current (amps)
4	20	0.95	0.95	0.62	0.84
4	40	0.48	0.51	0.38	0.45
4	60	0.33	0.34	0.27	0.31
4	80	0.26	0.24	0.21	0.23
4	100	0.20	0.25	0.15	0.20
4	120	0.17	0.20	0.13	0.16
4	140	0.15	0.14	0.12	0.13
4	160	0.14	0.13	0.13	0.13
4	180	0.13	0.12	0.10	0.11
4	200	0.11	0.11	0.09	0.10
4	220	0.10	0.10	0.08	0.09
4	240	0.09	0.09	0.08	0.08
4	260	0.08	0.08	0.07	0.07

4	280	0.07	0.08	0.07	0.07
4	300	0.06	0.07	0.06	0.06

Length of wire (cm)	Average Resistance on the wire (ohms)
20	4
40	8
60	12
80	17
100	20
120	25
140	30
160	30
180	36
200	40
220	44
240	50
260	57
280	58
300	66

#### Analysis of graphs:

I have produced two graphs on resistance, one portraying experiment 1, 2 and 3. The other being an overall average current. Both these graphs back up the prediction I made that as the length of wire gets longer the current will reduce. I do have a couple of anomalous results on both the first graph and the graph of averages. This could be down to a number of factors such as the fact that with a constantly changing reading I may not have taken the correct figure shown. Ammeters will only read to a certain point as the numbers would be getting so small so this can account for the "tailing off" that is depicted in my graph. Apart from the fairly minor errors which caused this anomalous results I believe these two graphs are both fairly accurate and clearly show that when the length increases the current decreases. The two main anomalous results were (100,0.25) and (120,0.20) these were on experiment 1.

My third graph showing average resistance does back up my prediction proving that if the length increases then the resistance will also increase in proportion to the length. I believe this is because the longer the wire the more atoms and so the more likely the electrons are going to collide with the atoms. So if the length is doubled the resistance should also double. This is due to the fact that if length is doubled the number of atoms will also double resulting in twice the number of collisions slowing the electrons down and increasing the resistance. My results should show that the length is proportional to the resistance. My line of best fit obviously does not connect through every point (this would have shown perfect results) which is due to minor errors. A lot of these anomalies

would be due too poor working out of the resistance, a rounding numbers to 1dp may have lost some accuracy.

Heat in metals causes an increase of resistance or a reduction of conductivity. An increase of active vibration makes atoms get in the way of electrons. The electrons therefore spend more time on deflected courses. This in turn cuts down current slightly. My graphs do seem to reflect these points which are possible reasons for some of my inaccuracies. Overall I am pleased with the graphs I have produced as they both have clear scales with are appropriate to the results shown and clearly display the results I obtained from this investigation.

### Evaluation:

In the Analysis and the graph I have shown two main anomalous points, this means that there must have been a slight error in my experiment. As the wire, length is bigger than our metre ruler at these points I found it harder to stretch it out and consequently, measure it accurately. Although the graph is overall accurate and the results precise it is easy to see, the anomalous points plotted because they do not all lie along the same best-fit line. The graph shows that my results are reliable as there are only two main anomalous points, (which are easily accounted for) to improve the reliability of my results, I could do more repeats in doing this my average would be more reliable.

As I increased the wire length, the wire became hotter and gave off heat. This could explain why the anomalous results were about half way through my graph of my graph, 100cm and 120cm. I think one of the reasons why my experiment is quite accurate is because I tried to measure the wire as accurately as possible. The metre rule was selotaped onto the workbench. The wire was stretched until it was nearly in a straight line so a bit was overlapping at each end. As the metre rule was curved and worn down at the corners it was slightly hard to see where 0cm was. Finally, the inside edge of the crocodile clips was placed at the appropriate point. I still however would like to make the measuring more accurate during my experiment; I have noticed several modifications I could make to improve on the Investigation if I was to repeat it.

The first of these modifications would be the circuit that I would use. To be more accurate with my results I would place the Metre rule directly under the wire, so therefore it would be measured easier and therefore making the lengths more precise. Instead of connecting the voltmeter to the main circuit, I would connect it to the wire that is being tested. I would do this so that the voltmeter is measuring the voltage of just the wire being tested and not the wires of the main circuit as well.

To also improve on my results I could use a new or higher quality digital voltmeter. The next modification I would make would be to use pointers instead of crocodile clips to attach to the wire; I would do this because pointers would be more accurate. The pointers would be more accurate because the tips have a much smaller area than the crocodile clips giving a more accurate measurement of the length of wire. I would also use a newer metre rule. The graph shows that my results are reliable, as there are only two main anomalous points, to improve the reliability of my results, I could also have repeated the same lengths of wire more times. The thickness of the wire may vary by a small amount and maybe helping to cause the anomalous results. Sometimes the ammeters flicked between a decimal point, I maybe could have thought it was the wrong number and therefore would have ended up with the wrong average resistance. In the experiment, I did not control the room temperature but instead just assumed it was keep constant throughout my experiment; this could have made the wire get hotter and therefore making my experiment not as accurate. In future experiments I would control

this variable factor and make it a constant factor. I would do this, as it would be an unfair test if there were two known variables.

As well as making these modifications, I could also expand on my investigation by testing the same wire but different widths of that wire. I would do this if I had more time to complete it. I think the circuit and method used was quite suitable although I would make the modifications above to improve my results. If I did this experiment again I would defiantly use top quality equipment, I would probably control the temperature and use pointers instead of crocodile clips. After changing those few things, there is not really much difference to how I would do the experiment again. I could therefore extend my enquiry by producing a further investigation into the effect heat has on the accuracy of my results on resistance. I could do this by attaching a thermometer to the wire or using a digital thermometer attached. Also next time I would use both digital ammeter and voltmeter to allow a more accurate set of results.

Although I have justified the points I have brought up I was still pleased with the overall investigation I produced.

#### Conclusion:

To conclude this investigation; I have found that my prediction was correct. I expressed that the resistance will increase approximately proportionally to the length, and as you can see from my resistance graph, this was correct. This is emphasised because the line of best fit is a straight line, which means the resistance is proportional to the length. This proves the fact that the longer the wire is, the more collisions there are between atoms and electrons. So if the wire increases in length, so does the resistance.

I am confident in saying that I have produced an investigation that have achieved its goal and portrayed accurate results.

#### Bibliography:

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- Encyclopedia britannica

