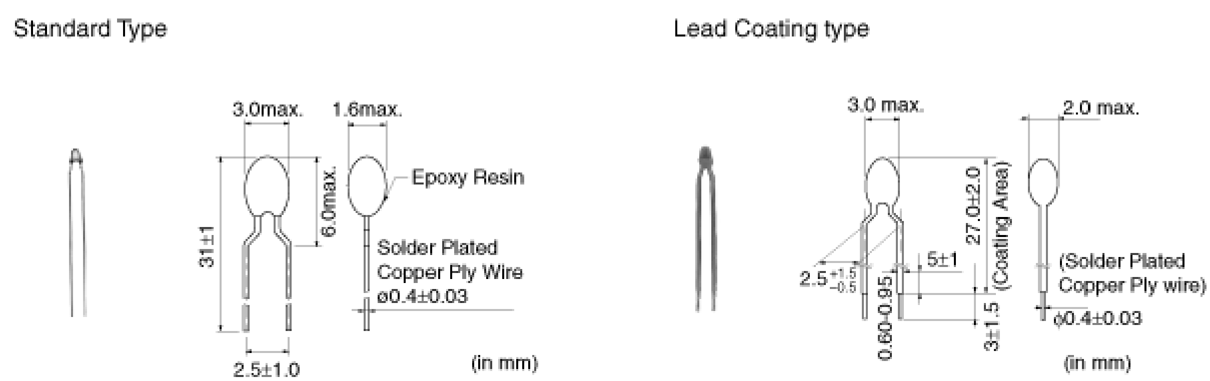
The aim of my investigation is to see whether the resistance of a thermistor (a type of temperature sensitive resistor) is directly proportional to the temperature. Also I aim to see whether the length of the wires in the circuit affects the resistance. I'm anticipating that this experiment will be interesting and relatively challenging because a thermistor is a type of resistors whose resistance changes significantly when its temperature changes, consequently a slight variation in temperature can lead to a vast change in the resistance, therefore I have to be extremely accurate when calculating the temperature as a mistake or inaccurate reading on the thermometer will affect my results considerably.

I will be using a bead thermistor with a negative temperature coefficient, which means the resistance decreases with an increase in temperature. The apparatus I will require will be a thermistor, a multimeter, two wires and crocodile clips. I will also need a beaker, a kettle and a thermometer.



As thermistors are thermally sensitive resistors known for exhibiting a large change in resistance with only a small change in temperature, they are considerably interesting and significant in industry. If a chip in a circuit overheats, its resistance falls, so more current passes through it. This could very easily cause it to overheat even more in a thermal runaway process which might end in self-destruction of the circuits in the chip.

I plan to expose the thermistor to different temperatures, therefore I feel it will be extremely beneficial for me to heat some water and then as the temperature of the water will inevitable decrease as it cools, I could therefore take the resistance of the thermistor at a range of different temperatures as the water cools.

Obviously I expect the resistance to decrease with temperature increase; this is because the resistance of a semiconductor generally decreases with increase of temperature. Subsequently semi-conductors are used to manufacture thermistors with negative temperature coefficients i.e. the type of thermistor I am using. As the temperature of a semiconductor is increased, the number of charge carriers increase as more valence electrons gain sufficient energy to break free from atoms to become conduction electrons. The number of charge carriers increases as the temperature increases, and that is why I feel the resistance of the semiconductor will fall.

For the second part of the investigation, I will vary the length of the wire to see if this has any effect on the resistance. The apparatus required will be a number of wires, a power supply, a thermistor, crocodile clips, a voltmeter and an ammeter.

I believe that as the length of the wire increases so to will the resistance of it. With electricity, the property that transforms electrical energy into heat energy, in opposing electrical current, is resistance. A property of the atoms of all conductors is that they have free electrons in the outer shell of their structure.

As a result of the structure of all conductive atoms, the outer electrons are able to move about freely even in a solid. When there is a potential difference across a conductive material all of the free electrons arrange themselves in lines moving in the same direction. This forms an electrical current. Resistance is encountered when the charged particles that make up the current collide with other fixed particles in the material. As the resistance of a material increases so to must the force required to drive the same amount of current. In fact resistance, in ohms is equal to the electromotive force or potential difference, in volts divided by the current, in amperes.

The material and cross sectional area of the wire is constant throughout the experiment. In this experiment I will only change one factor, the length of the wire. This should affect the resistance of the wire in the ways stated above.

I must keep the surrounding room temperature the same or the particles in the wire will move faster (if the temperature is increased) and this will therefore have an effect on the resistance. The cross sectional area of the wire must be kept constant throughout as well.

The material of the wire must also be kept the same as different materials have different conductivity.

Also for the thermistor experiment, I must also keep the surrounding room temperature constant, the cross sectional area and the wire material constant for the same reasons as above.

To get an accurate reading on the thermometer which is going to be used, the depth of water must be at least 7cm, therefore I will need at least 7cm of water in my beaker to avoid inaccurate thermometer readings.

For the first experiment, the apparatus will be set up as above and the multimeter will be set on resistance. The water will then be heated using a kettle (a Bunsen burner etc. could also be used) but I felt a kettle would be safer. A thermometer will record the temperature of the water which is to be poured into the beaker. The thermistor will then be complete submerged in the water. The results will be recorded. As the water cools be one degree, the resistance will be read ad recorded again. The cycle will repeat until the water has reached approximate room temperature. To acquire results of a temperature below room temperature, ice will be used to cool the water further so more results can be attained; therefore more valid conclusions can be reached.

To get an accurate reading on the thermometer which is going to be used, the depth of water must be at least 7cm, therefore I will need at least 7cm of water in my beaker to avoid inaccurate thermometer readings.

When submerging the thermistor in water, I will try to get the thermistor half way down the beaker each time as the temperature at the bottom of the water in the beaker may be different to the temperature at the top of the beaker due to convection currents etc. I consider three significant figures to be a reasonably degree of accuracy for the investigation.

For the length investigation, the circuit will be connected as in the diagram, the current will be set on 3A and the voltage will be taken from the voltmeter. The process will be repeated for the different lengths of wire. Ohms law will be used to calculate the resistance.

My experiments aren't particularly dangerous, yet I must ensure that I don't handle electricity with wet hands. Also I can keep the current low to minimize risks.

I must also be care full not to burn my self with the hot water, or not to spill it as it may cause someone to slip on it. I will try to keep the temperature of the water below 60 degrees to minimize risk of scolding.

If I use a mercury thermometer, I must ensure that I don't smash it as the mercury could seriously harm someone if it is inadvertently consumed.

By looking at FIG 1 it is clear to see that as the water temperature increase, the average resistance decreased as I anticipated as the thermistor has a negative temperature coefficient. Also it is clear to see that the relationship is non-linear, consequently the resistance is not directly proportional to the temperature. When plotted as a graph, you attain a relatively smooth curve (FIG5). FIG 6 is vastly more accurate than FIG 5, therefore you can see that the curve is not quite as smooth as it is on FIG 5.

I noticed that as the temperature increased, the difference between the resistances's decreased as you can see from the difference column of FIG 1. I repeated the experiment and took the average resistance as it would be more accurate and would therefore benefit my investigation a lot.

As you can see from FIG 1.5, I used the formula *temperature coefficient of resistance = increase of resistance / (resistance x temperature rise)* to calculate the temperature coefficient of the average resistance. The temperature coefficient of the resistance was clearly not the same for each reading, but in a perfect world, they all would have been identical. I calculated the average temperature coefficient of the resistance to be 0.035092749. Most results were rather near to the average. By looking at the temperature coefficients, I can see which results were most inaccurate or anomalous. Generally the lower temperatures and the higher temperatures gave me the most inaccurate results, i.e. at 5 oC the temperature coefficient of the resistance was 0.050999105, and at 62 oC the temperature coefficient was 0.014571949. I used standard deviation to calculate how much the resistance deviates from the mean. I discovered that the deviation was 0.4286636313 and the mean resistance was 0.8031111. this is a good process to use, but it is extremely slow and time consuming, especially if you had vast quantities of data as I did.

To avoid anomalous results, I could have repeated the experiment plenty of results. Anomalous results could have been caused by an inaccurate thermometer in the water. To counter this problem I could have used more than one thermometer. Also human error could have been to blame. A digital thermometer would have reduced error in taking the temperature of the water. Maybe convection currents in the water could have caused slight inaccuracies with the themistor and thermometer.

I believe that as the temperature increased, the resistance fell because when the temperature of a semiconductor is increased, the number of charge carriers increase as more valence electrons gain sufficient energy to break free from atoms to become conduction electrons. The number of charge carriers increases as the temperature increases, and that is why the resistance fell.

I believe my strategy used clear and easy to comprehend and I also feel I used good methods and techniques.

To make my investigation even better, I could have continued this experiment for temperatures between 62 and 100 oC. Also I could have used more thermistors with different temperature coefficients i.e. thermistors of the non-semiconductor variety.

Due to this investigation, my understanding of a thermistor has increase vastly and this investigation has been generally successful.

With the second part, as anticipated, as the voltage increased, as did the current and therefore the resistance fell. Obviously I used ohms law to calculate the resistance (Resistance (ohms) = P.D (Volts) divided by Current (Amps)), as you can see from FIG 2, FIG 3 and FIG 4.

Also as I anticipated, as I added more wires to the circuit, the resistance increased, yet the voltage remained fairly constant and the amps decreased. This is clearly summed up in FIGS 7 and 8. The mean resistance for the circuits has been calculated, and my results for this tell me that each time 2 wires are added, the mean resistance gets greater and greater than the previous each time. Not only does the mean resistance increase each time wires are added, but also the standard deviation increases each time. It increased from 0.45643024 to 0.4723113824 to 0.665314431, this clear proves that the resistance of a circuit increases when the length of wire in that circuit increases.

Anomalies: there was only one real anomaly in this experiment and it has been highlighted with a * on FIG 8

From the graph we can see one very clear trend, which is, as the length of the wire increases so does the resistance of it. Another, more significant thing is that it the increase is constant. This is indicating by the fact that the line drawn is relatively straight.

I think that from my results I can safely say that my prediction was right. The resistance did change in proportion to the length. This is because as the length of the wire increased the electrons that made up the current had to travel through more of the fixed particles in the wire causing more collisions and therefore a higher resistance.

As stated earlier, as a result of the structure of all conductive atoms, the outer electrons are able to move about freely even in a solid. When there is a potential difference across a conductive material all of the free electrons arrange themselves in lines moving in the same direction. This forms an electrical current. Resistance is encountered when the charged particles that make up the current collide with other fixed particles in the material. As the resistance of a material increases so to must the force required to drive the same amount of current. In fact resistance, in ohms is equal to the electromotive force or potential difference, in volts divided by the current, in amperes.

I feel that overall the results were quite accurate. This can be seen when we look at the graphs, which shows a relatively straight line with all of the points apart from one being very close to or on that line.

Wire temperature and may have affected some results, also the material of the wires may not be as pure as it should have been. The main reason for this was probably due to the equipment that we used being inaccurate. To extend the investigation, I could have used a different resistor, or changed the cross sectional area of the wire.