Module 1, Lesson 3 – Temperature vs. resistance characteristics of a thermistor

Teacher

45 minutes

Purpose of this lesson

- How thermistors are used to measure temperature.
- Using a multimeter to measure the resistance of a thermistor.
- Investigating the variation of thermistor resistance with temperature.
- Graph data and reason about curves and linear relationships.

Materials

Copy of the lesson

1 Multimeter

2 Alligator clips

1 Thermistor

1 Beaker

Hot water

Ice

1 Thermometer

Graph paper (or Excel)

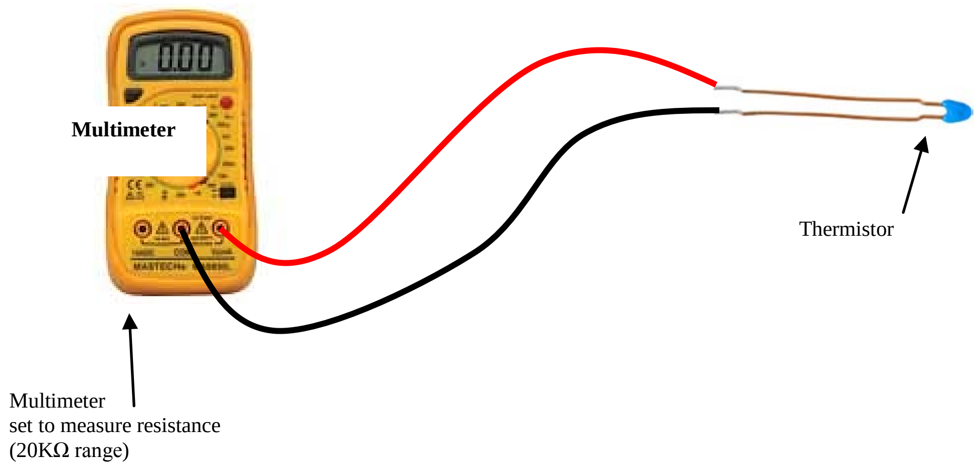
Background and Discussion

Conductors, like metals, are materials in which many of the electrons are free to move easily between atoms. Because of this, they have low resistance, and can conduct electricity easily. Insulators, such as rubber, are materials in which none of the electrons can move freely between atoms, have very high resistance and do not conduct electricity. Semiconductors (or semi-metals), such as silicon, can sometimes act like conductors and sometimes like insulators, depending on how they are used.

The thermistors used in this module are made of semiconductor material. The ability of a thermistor's electrons to move between atoms depends strongly on temperature which makes them a useful device for using electricity to measure changes in temperature.

Procedure

1) Use alligator clips to connect the ends of the thermistor to the multimeter probes.



2) Set the multimeter to measure resistance in kOhms by turning the dial to the “20 KΩ” setting. This means that the number on the screen represents kOhms (i.e. “1.5” means 1.5kOhms which equals 1500Ohms) and will go up to a maximum of 20kOhms.

(NOTE: If the multimeter displays “OL” (overload), the resistance is too high to be measured, and you will have to use a higher setting on the multimeter.)

3) Place the thermistor in a cup of hot water. (**NOTE: Make sure the clips stay out of the water, water will conduct electricity and result in an inaccurate measurement.**)

4) Measure the temperature with a thermometer and at the same time read the thermistor resistance from the multimeter. (**NOTE: When connecting the alligator clips to the thermistor, make sure you connect to the silver-colored segments at the ends. The brown coloring along most of the leads is an insulating layer**.)

5) Record the data in the table on the following page. Now reduce the temperature by adding a little cold water and stirring/mixing well, and then measure temperature and resistance again. Repeat over a range of temperatures, eventually adding ice to get down to 0°C, recording data for each temperature.

Assessment

1) Record the data you have measured, listing temperatures and thermistor resistances.

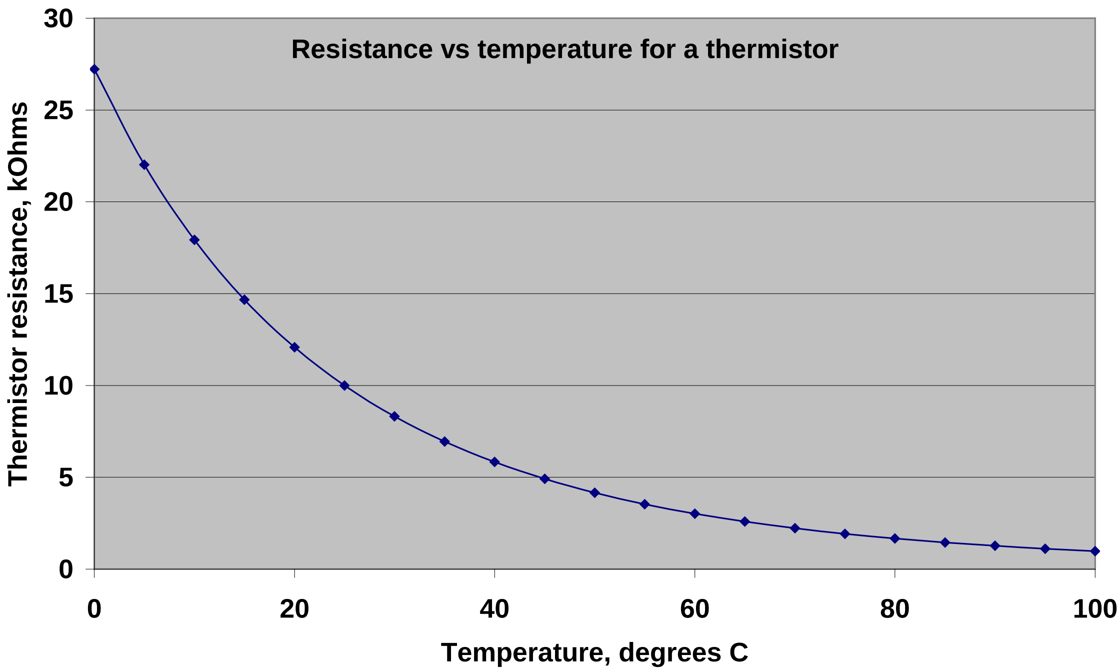
Answer – table should look something like this:

Temperature °C	0	10	20	30	40	50	60	70	80
Resistance kΩ	27.2	17.9	12.1	8.3	5.8	4.2	3.0	2.2	1.7

It is not necessary for readings to be taken exactly every ten degrees or even at exactly equally spaced intervals, as long as readings adequately cover the temperature range (from 0 up to whatever hottest max temp is deemed safe in your classroom).

2) Plot a graph of thermistor resistance versus temperature. Use the vertical (y) axis for resistance, and the horizontal (x) axis for temperature.

Answer – graph should look something like this:



3) Describe the relationship between resistance and temperature for a thermistor.

Answer:

- *Resistance decreases with temperature*
- *The relationship is non-linear*
- *(depending on student knowledge) relationship is exponential decay*

- *Some students assume this curve is some kind of quadratic, cubic or other polynomial curve (especially when they find a polynomial fitting function in excel, or if they have previously studied such curves in class). If so, the teacher may wish to discuss the nature of exponential decay and point out how it is a different beast from a polynomial curve. However, approximating an "unknown" curve by a polynomial is often a sensible engineering solution to real world problems, and so this should not necessarily be viewed as "wrong" or "bad" – the students may well be able to make useful predictions and approximations by best fitting such an "incorrect" polynomial to the exponential decay curve.*
- *If your students do know about exponential decay (or cooling curves), you may want to have them figure out an exponential decay equation for the curve that they have plotted.*

<u>Further questions for group discussion with your teacher</u>

i) One way to measure temperatures in the environment would be to use the graph you have just plotted. You could place your thermistor in the environment, measure its resistance, and then look the resistance up on your graph to read off the corresponding temperature. Is this procedure a useful system for measuring temperature? What might be difficulties with using this method as a temperature measuring system?

Answer:

- *Yes, system could be used to measure temperature – read off the resistance of the thermistor and then look up corresponding temperature on your graph.*
- *However, accuracy would decrease as temperature increases. This is because, at low temperatures a small change in temperature shows as a big change in resistance (i.e. high sensitivity, high resolution) whereas at high temperature even a big change in temperature shows as only a small change in resistance (i.e. low sensitivity, low resolution sensor). So now your temperature sensor would have different accuracies in different temperature ranges.*

***Note next question (ii) is fundamental to properly understanding this project and it is important that teachers cover it with their students:**

ii) What kind of mathematical relationship between temperature and sensor output signal would be most desirable for a simple temperature measuring sensor?

Answer:

- *It would be convenient if we could build a sensor whose outputs varied linearly with temperature.*
- *That way, we can find a very simple mathematical formula to convert sensor output values into temperatures, i.e. y=mx+b, or "temperature = something times sensor signal, plus something".*
- *We could use this formula ourselves, or program a computer to do it for us.*
- *The linear sensor would have consistent precision over the whole temperature range.*
- *It is also convenient if this is a* ***positive*** *linear relationship – that way the sensor output will increase as temperature increases, in an intuitive manner that is easy to look at on a graph (in contrast, graphing a sensor output that goes down when temperature goes up maybe counterintuitive and confusing for some students).*

In the next lesson we will build an electric circuit around the thermistor so that the output of the circuit (what we measure) varies positively and linearly with temperature over the range of temperatures we are interested in.

Imagine that you would like to connect your temperature sensor to a computer. You could then leave the computer to do all the hard work of recording temperature over a long period of time (i.e. automate your data gathering). The computer could also calculate the temperature, instead of you having to look up the temperature values on your temperature-resistance graph.

iii) How do computers measure the outputs of sensors? How might the computer convert measurements of the transducer (resistances or voltages) into figures for temperature?

Answer:

- *Inside the computer there is a device for measuring voltage. So the sensor's electrical circuit must produce a voltage that varies in some way with temperature.*
- *Also inside the computer, is a device called an Analogue-to-Digital, or A-to-D converter. This takes the analogue voltage signal and converts it into a number*

which is then stored in the computer's memory where it can be accessed by a computer program running on the computer.

- *The computer program can contain a formula or equation that relates this "sensor number" to temperature. For example, if the sensor outputs a signal that varies linearly with temperature, then we can program the computer to convert this signal into temperature by using a formula such as* $y = mx + b$ *(where* y *is temperature in °C and* x *is the number read from the sensor).*
- *In module 2, students will connect their sensor to a computer and explore these ideas in practice.*