Teacher's Preparatory Guide

Lesson 3: Thermistor Circuit

Purpose:
The purpose of this activity is to show a thermistor's usefulness within a circuit. This activity will introduce thermistors in a circuit so that future activities may build upon this idea to conclude with micro/nano-circuits. In Lesson1, students learned that a thermistor is a component that has a resistance that changes with temperature. They were introduced to two types of thermistor - those with a resistance that increase with temperature (Positive Temperature Coefficient – PTC) and those with a resistance that decreases with temperature (Negative Temperature Coefficient – NTC). In this lesson, they will learn the importance of thermistors in circuit protection by limiting the amount of current that can flow into it.

Time required: 45 – 55 minutes

Level: High School Physics

Teacher Background:
Ohm's Law:

Georg Simon Ohm discovered that materials have an ohmic, or linear, region. His equation (Eqn 1) explains that as the potential difference (ΔV) increases, so does the current (I), and the relationship is linear to a point. The slope of a voltage vs. current plot yields the resistance (R). Temperature affects the resistance. If a resistor heats up, the value of its resistance increases, and the resistor is now considered non-ohmmic. Non-ohmmic materials have a non-linear relationship between voltage and current.

$$\Delta V = IR \qquad \text{Eqn 1}$$

Thermistors:

Thermistors are sometimes used as temperature devices in the electronics industry. They have unique properties. In this lab it will be shown that thermistors have a negative coefficient of temperature (NTC), which is counter intuitive. Positive coefficient of temperature (PTC) thermistors also exist.

See resource section for additional information on thermistors and circuits.

Materials: (For each lab set-up)

- Breadboard
- Power Supply
- 10 K NTC Thermistor
- Jumper wires

Developed by Jaclyn Murray
Development and distribution partially funded by the National Science Foundation

- Christmas Light bulbs or LED
- Multimeter

Advance Preparation:
Holiday light bulbs can be purchased at Home Depot, Walmart, or other box/hardware stores during the holidays. If holiday lights are chosen, the lights will need to be cut. A wire cutter can cut and strip the ends to create leads. Twist the exposed copper so that it is easier to place in the breadboard. Thermistors are sold by Frys, Digi-Key, and Mouser.

Safety Information:
Make sure students connect the power supply correctly. Also, students should not increase the voltage to a level that will melt the wires.

Directions for the Activity
1. Discuss how to assemble a series circuit with three components (a battery, thermistor, and light bulb).
2. Discuss the role of a thermistor (You may want to include the Lesson 1 first: *The Effect of Temperature on the Electrical Resistance Properties of a Thermistor* Activity)
3. Distribute the activity for the students to complete.

Procedure is in the Student Guide

Student Worksheet (with answers in red)

Lesson 3 Thermistor Circuit

Objective:
The purpose of this experiment is to determine the function of an NTC thermistor in a circuit. In a prior lesson, you were introduced to two types of thermistor - those with a resistance that increase with temperature (Positive Temperature Coefficient – PTC) and those with a resistance that decreases with temperature (Negative Temperature Coefficient – NTC). In this lesson, you will learn the importance of thermistors in circuit protection by limiting the amount of current that can flow into it.

Materials:

- Breadboard
- Power Supply
- 10 K NTC Thermistor
- Jumper wires
- Holiday Light bulb or LED
- Multimeter

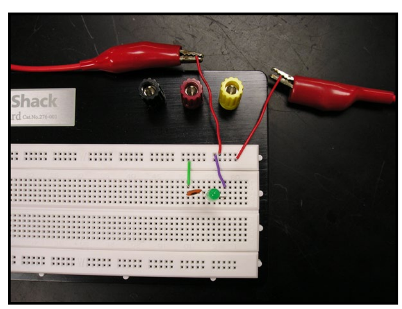

Figure 1. Breadboard setup.

Developed by Jaclyn Murray
*Development and distribution partially funded by the **National Science Foundation***

Procedure:

Part A: Thermistors and Changing Potential Difference

1. Create a series circuit on the breadboard without attaching the power supply. Place the thermistor before the Holiday light bulb or LED. Figure 1 is the breadboard setup. Figure 2, below is the schematic.

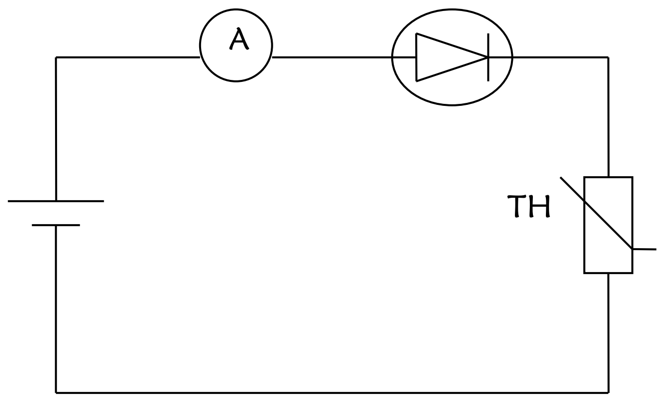

Figure 2. Series circuit of a thermistor and LED or light bulb.

2. Attach a jumper wire to the thermistor to connect to the negative side of the battery. Do NOT turn on the power supply yet.

3. Attach a jumper wire to the light bulb or LED to connect to the positive side of the battery.

4. Now turn the voltage dial on the power supply to zero.

5. Turn on the power supply. Turn the dial to create a voltage of 1 V.

6. Measure the current in the circuit with the multimeter. Record the value for current in Table 1. Remember that the current is measured in series.

7. Measure the voltage across the thermistor. Record the value for voltage in the data table. The voltage is measured in parallel.

8. Increase the voltage by 0.2 V.

9. Repeat steps 6 through 8 until the LED or Holiday light turns on.

10. Do not increase the voltage after the LED or Holiday light turns on because the LED will burn out.

Developed by Jaclyn Murray
Development and distribution partially funded by the ***National Science Foundation***

Part B: Thermistor Response to Heating while in a Circuit

1. Turn the voltage to a value between 2.5 V and 3.0 V. A voltage any higher will cause the LED to burn out.

2. Record the current with an ammeter in Table 2.

3. Heat the thermistor with a hair dryer.

4. What happens to the LED or light bulb?

5. Record the current as the thermistor becomes warmer in Table 2.

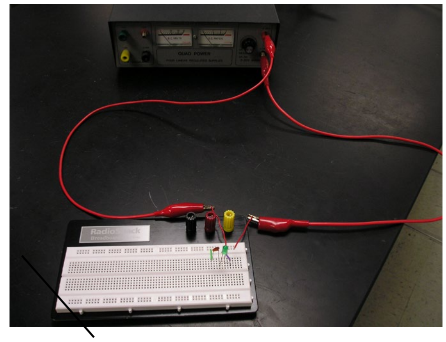

Figure 3. Lab setup.

Data:

Table 1. Current, voltage, and resistance data for the thermistor circuit.

Power Supply Voltage (V)	**Thermistor Voltage (V)**	**Current**	**Thermistor Resistance (?)**	**LED (On/Off)**
1.0				
1.2				
1.4				
1.6				
1.8				
2.0				
2.2				
2.4				
2.6				
2.8				
3.0				
3.2				
3.4				
3.6				

Table 2. Current data.

	Current (A)
Room Temperature	
Hair Dryer	

Analysis and Conclusion:

1. At what temperature did the LED light up? Look at the lab data found from *Lesson 1: The Effect of Temperature on the Electrical Resistance Properties of a Thermistor.*
   Look at the resistance value when the LED turns on. Compare it to the data already found in previous experiment.
2. Why does the LED eventually turn on?
   The resistance is low enough that it allows the current to flow through and reach the light bulb to light it.
3. If the light bulb were placed in parallel with the thermistor, what would happen to the lightbulb?
   The lightbulb should decrease in brightness because current takes the path of least resistance (towards the thermistor).

Cleanup: Have the students turn off the power supply. Then they should remove all of the components

Assessment: Answer the analysis and conclusion section correctly. You may also want to examine their circuits for accuracy.

Resources:
To learn more about nanotechnology, circuits, and thermistors, here are some additional educational resources:

Nanotechnology 101 https://www.nano.gov/nanotech-101
Temperature sensor - the thermistor:
http://www.facstaff.bucknell.edu/mastascu/elessonsHTML/Sensors/TempR.html
Resistance of a lamp: http://www.gcsescience.com/pe9.htm
Thermistors: https://www.omega.com/en-us/resources/thermistor
What is a thermistor? https://www.teamwavelength.com/video-what-is-a-thermistor/

Developed by Jaclyn Murray
*Development and distribution partially funded by the **National Science Foundation***

How Thermistors Work: https://www.kitronik.co.uk/blog/how-a-thermistor-works/
Electric Circuits: https://www.allaboutcircuits.com/textbook/direct-current/chpt-1/electric-circuits/; https://eschooltoday.com/science/electricity/what-is-an-electrical-circuit.html; http://www.schoolphysics.co.uk/age16-19/Electricity%20and%20magnetism/Current%20electricity/text/Potential_divider/index.html
Circuits PowerPoint: https://slideplayer.com/slide/10084434/

National Science Education Standards

Physical Science Standards

- Structures and properties of matter
- Interactions of energy and matter

Science and Technology

- Understandings about science and technology

Next Generation Science Standards

PS1.A: Structure and Properties of Matter

HS-PS1-1: Each atom has a charged substructure consisting of a nucleus, which is made HS-PS1-3: The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

HS-PS3: Energy

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).

Developed by Jaclyn Murray
*Development and distribution partially funded by the **National Science Foundation***