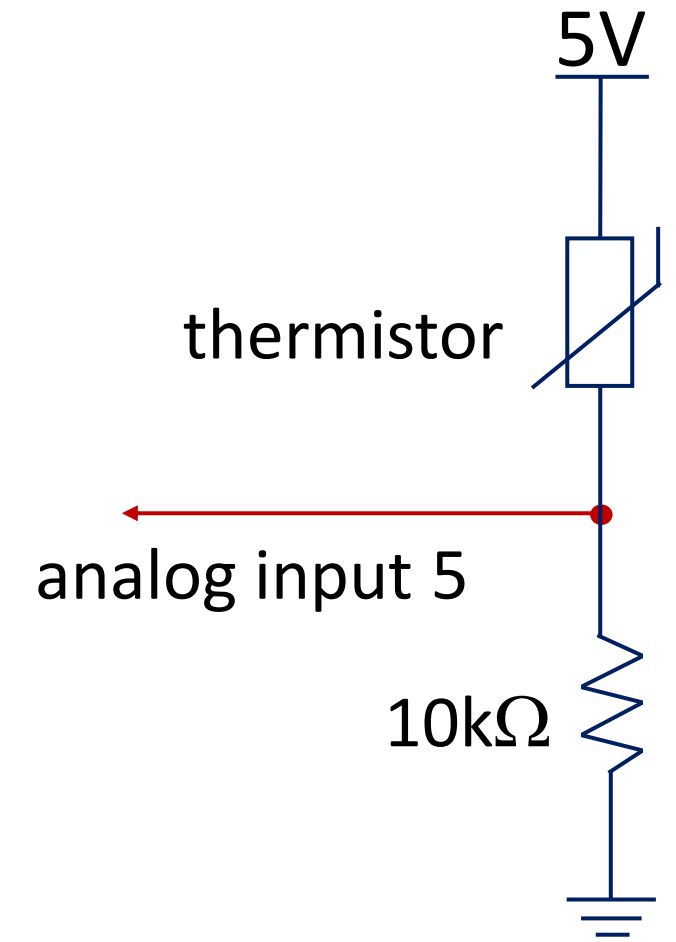
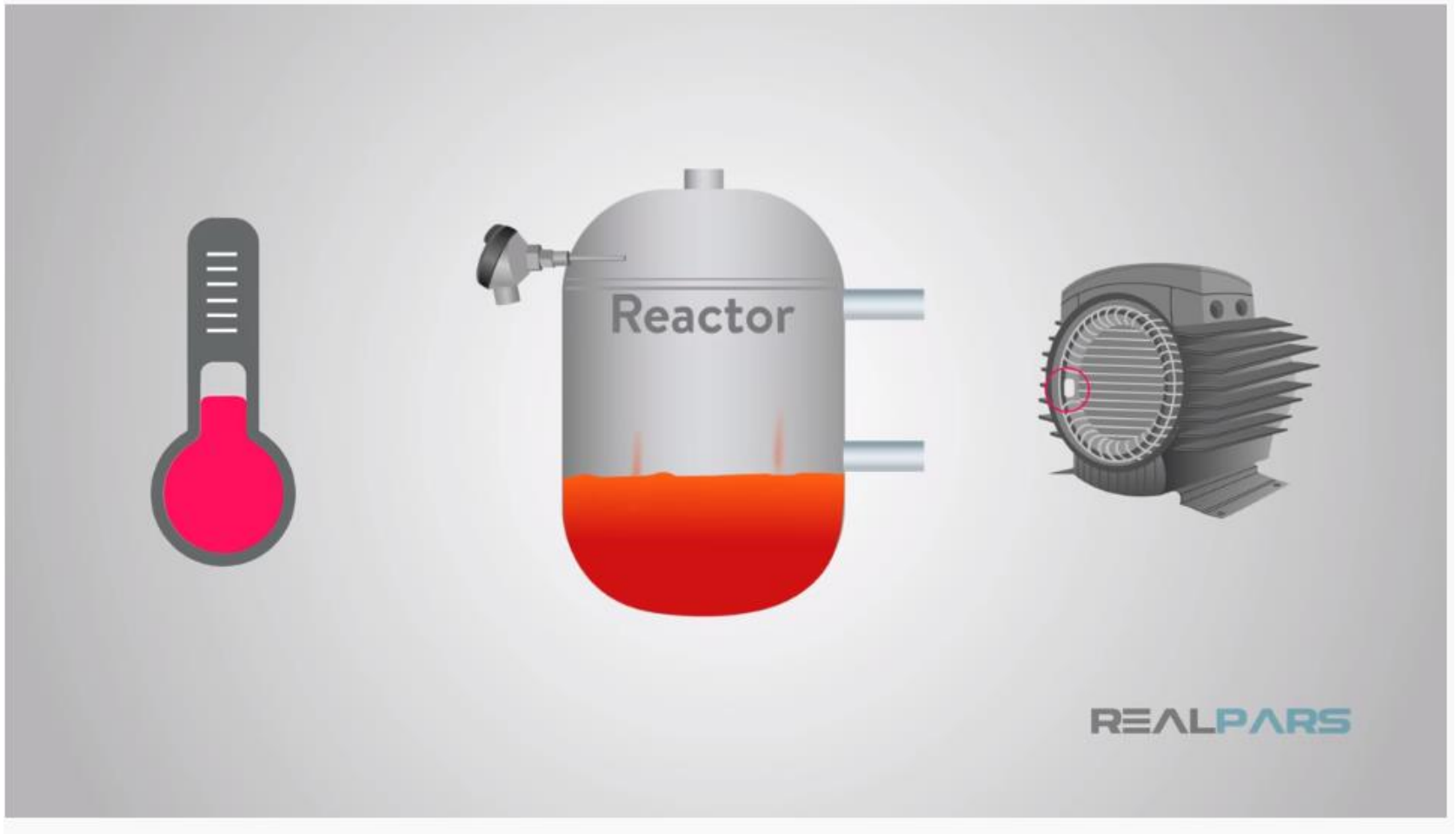
Class Problem 09b-1

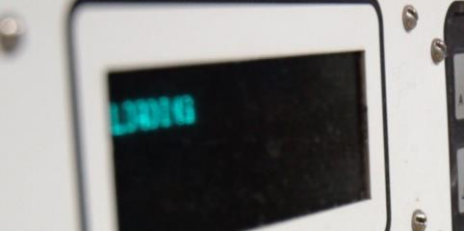
This circuit returns an analogRead value of 419 at room temperature (73°). What is the resistance of the thermistor?



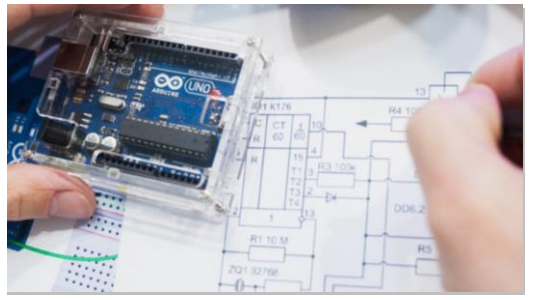
Temperature Sensors



Temperature Sensors(11:19) https://www.youtube.com/watch?v=4mQ3o1t4Ssg&list=PLln3BHg93SQ812ihcqWb9OOWbZ-09DLW6&index=8







pathways to engineering technology employment

Thermistors and Calibration

LOUISIANA DELTA COMMUNITY COLLEGE

Thermistors and Calibration

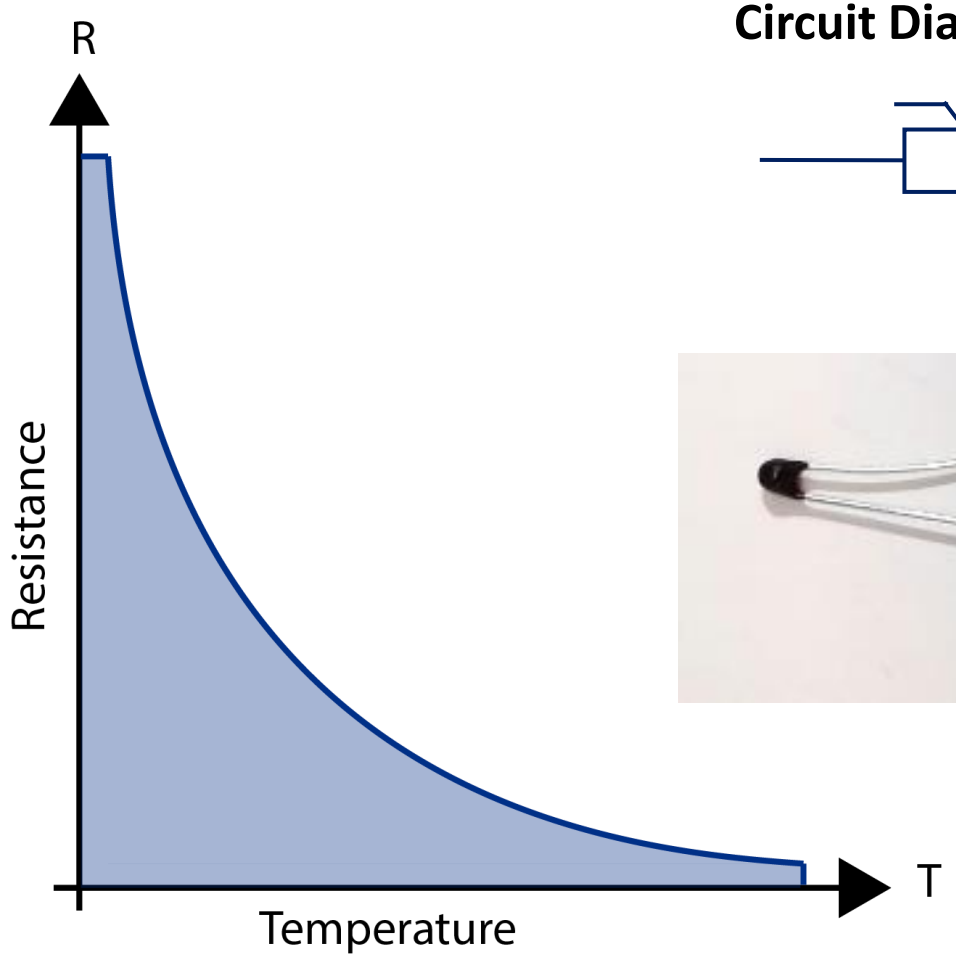
- Describe how to measure temperature with a thermistor.
- Measure a thermistor resistance over temperature with a multimeter. (Waterproof thermistor for taking data.)
- Collect data (from a thermistor) using a multimeter.
- Develop a calibration equation that correlates analog values to temperature values.
- Use a calibration equation to monitor temperature using the Arduino.

What is a temperature?

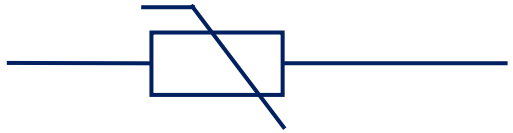
- Sense of warmness of coldness of a material
- Measure of the average thermal energy of particles in a material
- Thermodynamic property of a substance that is related to the average energy of microscopic motions in a substance.

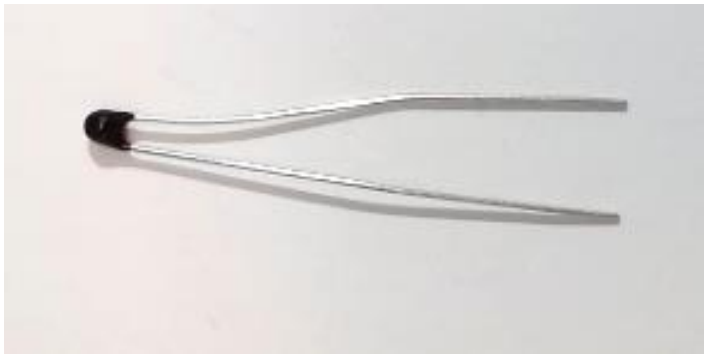
Measuring Temperature with a Thermistor

- Measures electrical resistance changes with temperature
  - As resistance decreases, temperature increases
- Advantages
  - High Output
  - Fast
  - Two-wire Ohm Measurement
- Disadvantages
  - Non-linear
  - Limited Temperature Range
  - Fragile
  - Current Source Required
  - Self-heating



Circuit Diagram Symbol:

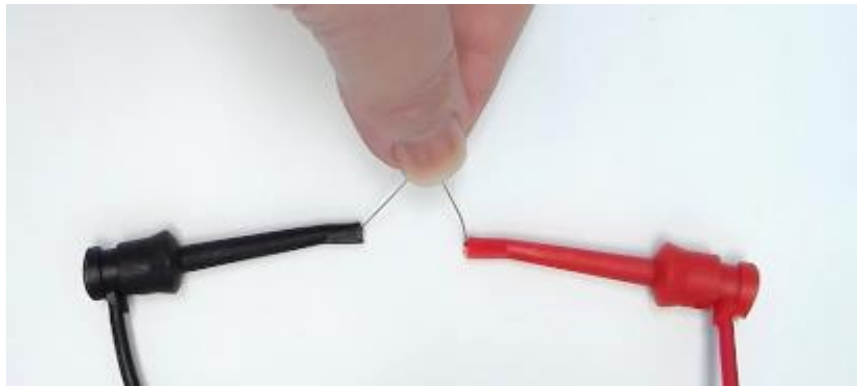




Measure Thermistor Resistance

- Connect a thermistor to your multimeter
- Measure its resistance
- Hold the thermistor to change the temperature
- Measure its resistance
- What do you observe?

Resistance _____ as Temperature _____



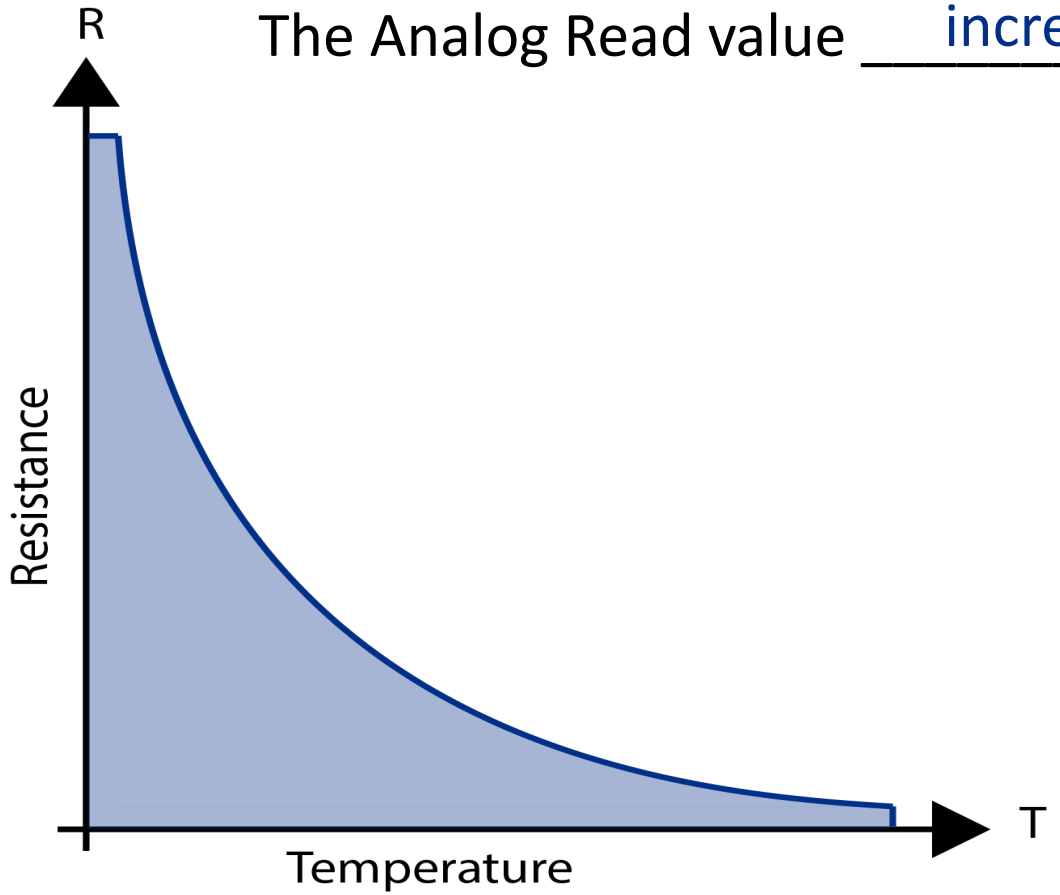
Voltage Divider (Thermistor)

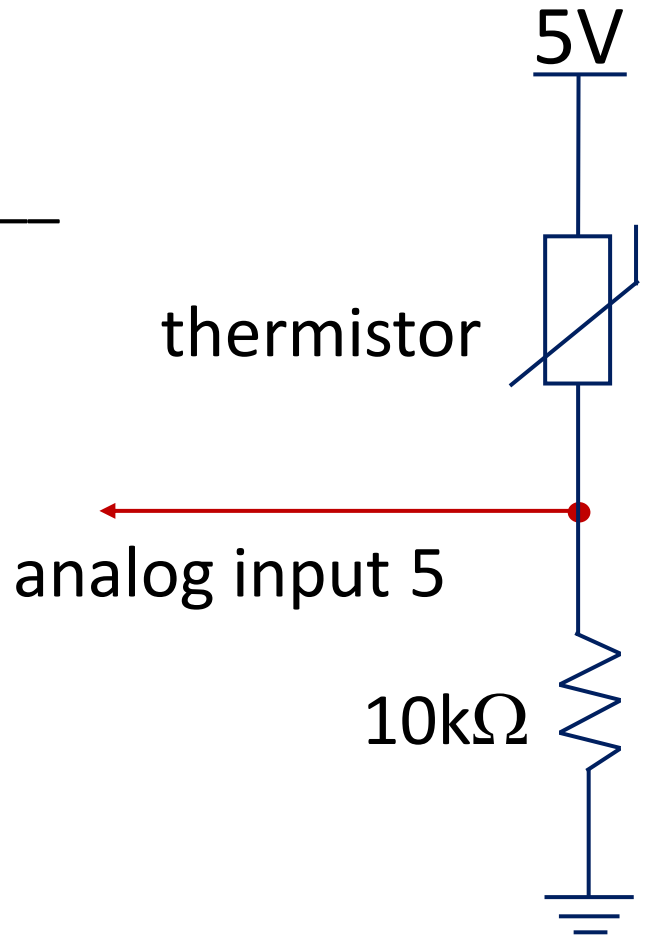
As the temperature increases:

The resistance of the thermistor ___decreases___

The voltage drop across the 10K resistor ___increases___

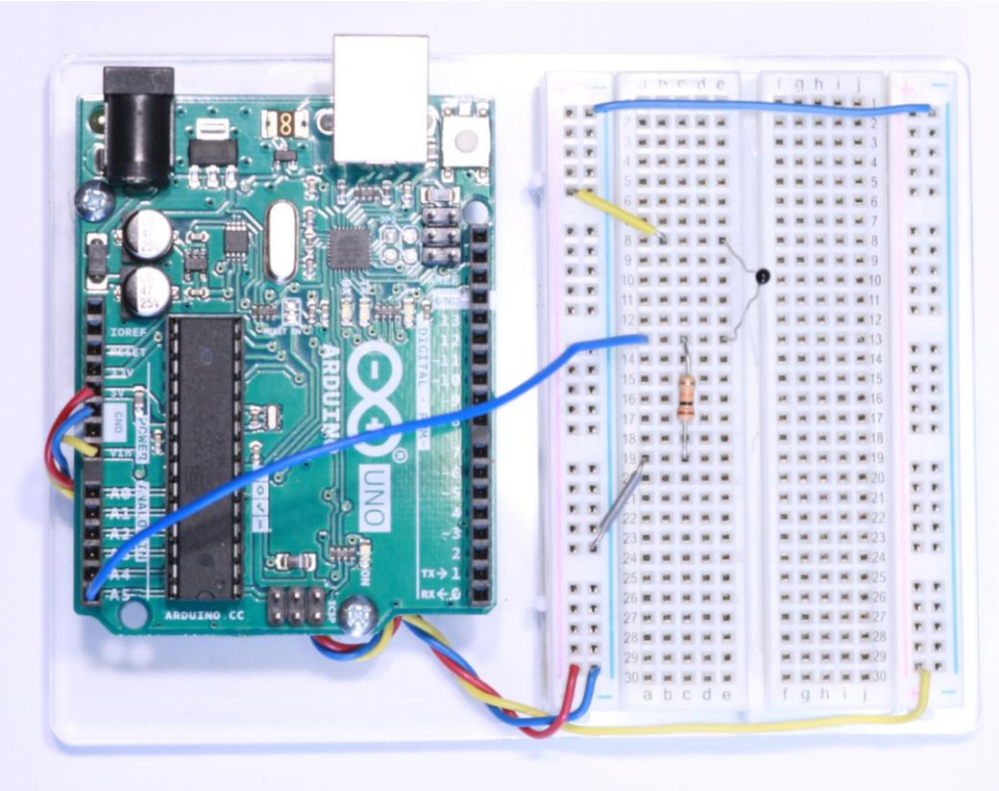
The Analog Read value ___increases___

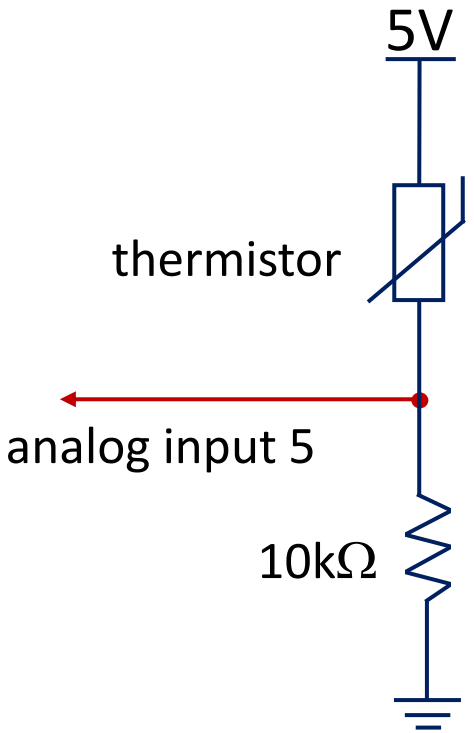




Collect Data Using Arduino

- Connect the thermistor to your breadboard and Arduino
- Use the given sketch to print analog values read by the voltage divider circuit





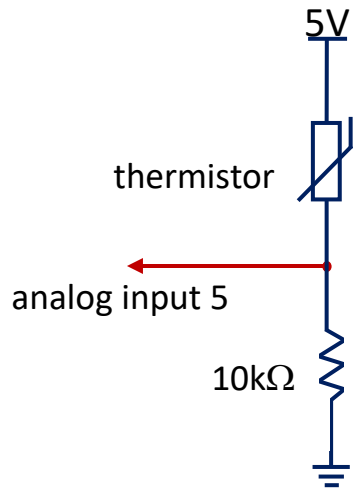

```
int val;

void setup() {
    Serial.begin(9600);
}

void loop() {
     val = analogRead(5);
     Serial.println(val);
}
```

- Press your fingers over the thermistor (Increase temperature).
- What do you observe? Analog Value _____ as Temperature _____

Collect Data Using Arduino

- Analog values can be converted to voltage drop across the 10kΩ resistor

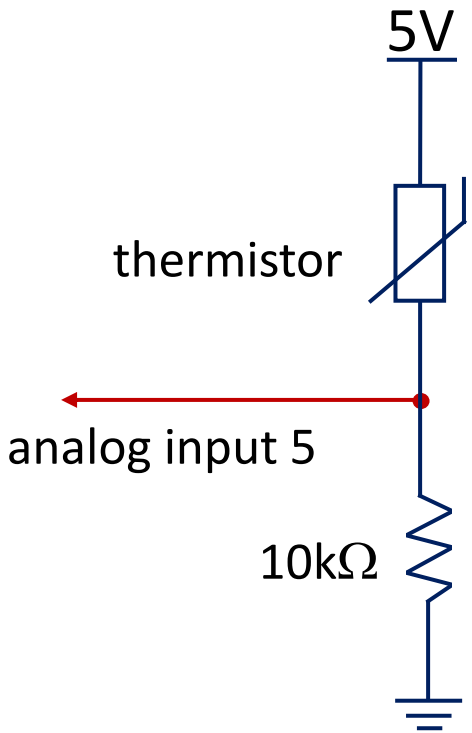
$$voltage = \texttt{analogRead}\ value \cdot \frac{5\ volts}{1023}$$



- Recall Resistors in series and Ohm's Law: $V = I \cdot R$
  - If the voltage drop across the 10kΩ resistor increases, then the voltage drop across the thermistor _____.
  - If the voltage drop across the thermistor decreases, then the resistance of the thermistor _____.
- **Summary:** An ***increase in analog values*** read by the Arduino means the resistance of the thermistor is _____ which means ***temperature is increasing***.
- Is this consistent with the values read by your multimeter at the beginning of class?

Data Collection

Collect data and complete data collection sheet.



Name(s): _____

09b Thermistor Data Collection

Remove waterproofed thermistor from circuit and measure the following:

Room temperature measurement (~73°) in Ohms with DVM: _____

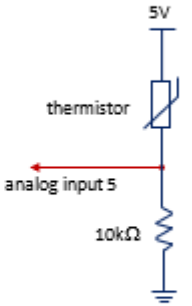
Body temperature measurement (~98.6) in Ohms with DVM: _____

Place thermistor in the circuit and measure the following:

analogRead at room temperature (in air): _____

analogRead at Body temperature (between fingers): _____

analogRead in cold fluid:	Thermometer: _____	analogRead: _____
analogRead in room temp fluid:	Thermometer: _____	analogRead: _____
analogRead in hot fluid:	Thermometer: _____	analogRead: _____



M. Nelson, 2020

Calibration Equation

- Develop an equation (called a **calibration equation**) that correlates analog values to temperature values.
  - Use known temperature values that are mapped to analog values read by the Arduino.

Setup per group:

- 3 Cups
  - Cup 1: Cool water
  - Cup 2: Warm water
  - Cup 3: Hot water
- 1 digital thermometer
- Waterproofed thermistor connected in voltage divider circuit
- Arduino, laptop, Excel

Procedure:

- **Step 1:** Fill cups with respective water temperatures
- **Step 2:** Collect analog values for each cup of water (three data points)
- **Step 3:** Record data points in Excel
- **Step 4:** Plot data points on a scatter plot
- **Step 5:** Add appropriate trendline and obtain corresponding equation

Details on subsequent slides

Step 1: Fill cups about 2/3 full with cool, warm, and hot water

- Cool water – water fountain (~54°F)
- Warm water – faucet in classroom (~72°F)
- Hot water – Hot water pot (~122°F)

Step 2: Collect analog values for each cup of water

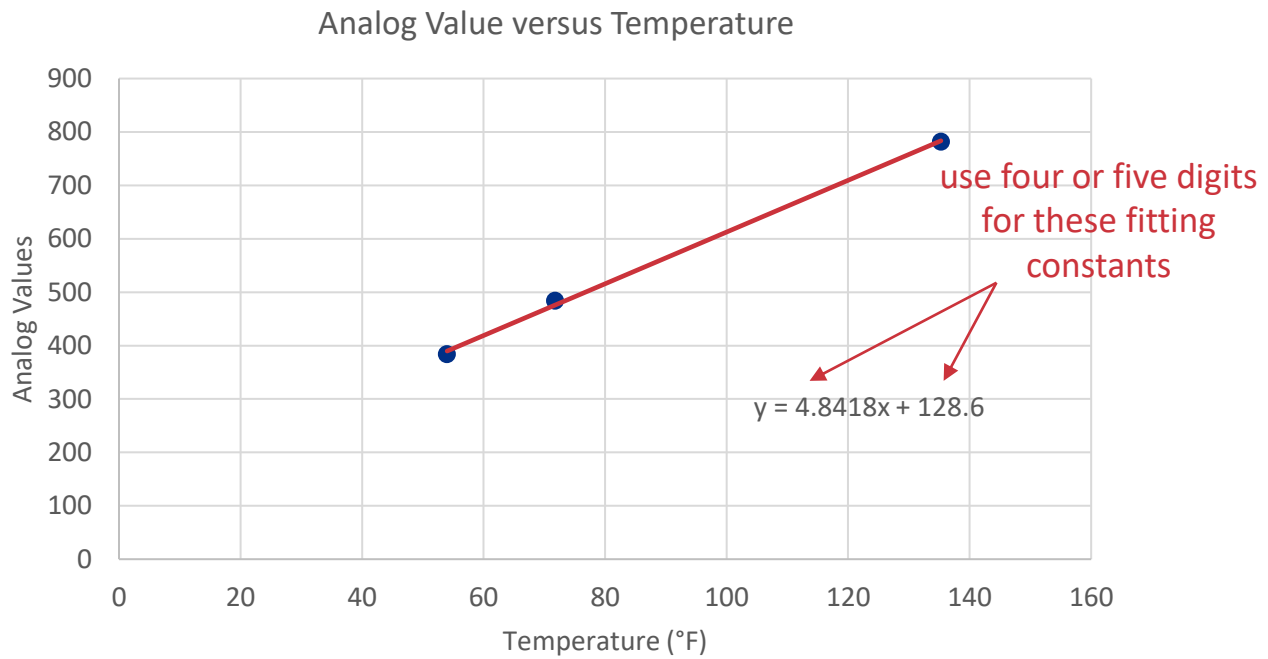
- Insert thermistor and thermometer into water while running the sketch that prints analogRead values (Sketch can be found on slide 6).
- Wait until values from thermistor circuit reach a steady value.
- Record the temperature from the thermometer and the analog value on the Serial Monitor.
- Repeat for each cup of water (three data points).

Cup	Thermometer Temperature (°F)	Analog Value (0 to 1023)
1 (Hot)		
2 (Warm)		
3 (Cold)		

Do not move the thermistor (stir it in the water) while collecting data points. This could give erroneous values

Step 3: Record data points in Excel
Step 4: Plot data points
Step 5: Add linear trendline and equation on chart

Cup	Thermometer Temperature (°C)	Analog Value (0 to 1023)
1 (Hot)	54.0	384
2 (Warm)	71.8	484
3 (Cold)	135.3	782



Calibration Equation:

$$AnalogValue = 4.8418 \cdot Temperature + 128.6$$

Using the Calibration Equation

- When temperature is known, input temperature and get corresponding analog value

$$AnalogValue = 4.8418 \cdot Temperature + 128.6$$

- What is the ***analog*** value when ***temperature*** is 62.7°F?

$$AnalogValue = 4.8418 \cdot 62.7°\text{F} + 128.6$$

$$AnalogValue = 432.1$$

$$AnalogValue = 432$$

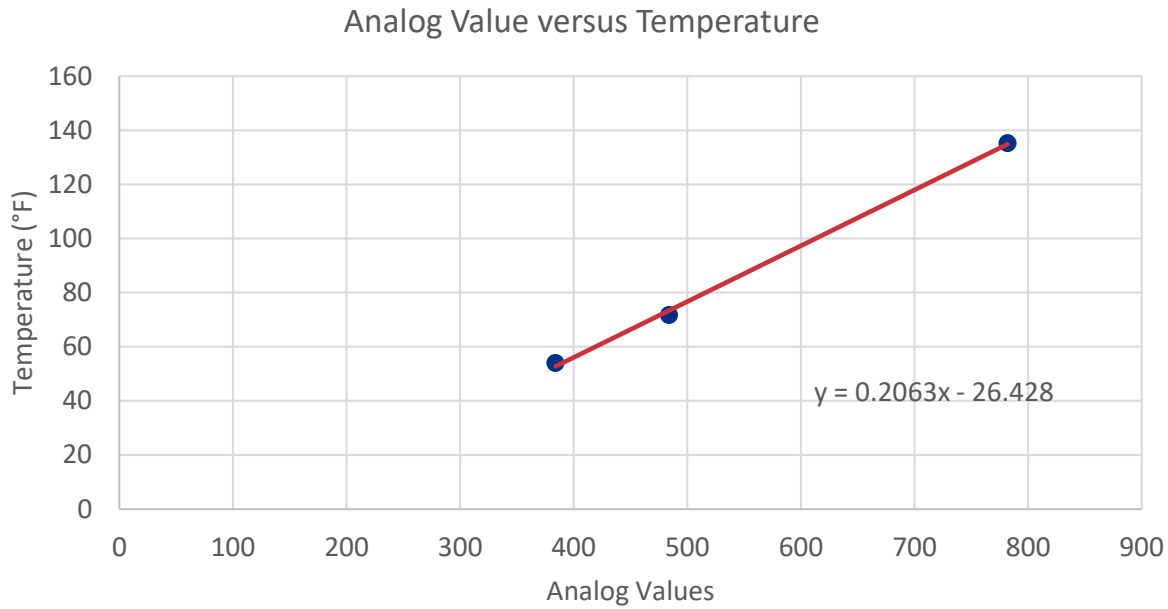
Remember analog values are whole numbers and the Arduino truncates values after the decimal.

Using the Calibration Equation

- Calibration Equation:

$$AnalogValue = 4.8418 \cdot Temperature + 128.6$$

- What if temperature is not known? Invert the Equation
- Replot the data but <u>swap the x and y axis values</u>.



$$Temperature = 0.2063 \cdot AnalogValue - 26.428$$

Inverting the Calibration Equation

$$AnalogValue = 4.8418 \cdot Temperature + 128.6$$

- Rewrite the Calibration Equation as Follows:

$$A = 4.8418T + 128.6$$

- Solve this equation for T

Class Problem 09b-2 (2022 Data)

$$y = 5.2468x + 111.28$$

$$A = 5.2468T + 111.28$$

$$T = 5.2468A + 111.28$$

Swap A and T
Solve for A

2022 Data: T = 0.19A - 20.943

Using the Calibration Equation

Calibration Equation:

$$AnalogValue = 4.8418 \cdot Temperature + 128.6$$

Inverted Calibration Equation:

$$Temperature = 0.2063 \cdot AnalogValue - 26.428$$

- Now you have equations that can take you from Analog to Temperature OR from Temperature to Analog.
- What is the ***temperature*** value when the ***analog*** value is 578?

$$Temperature = 0.2063 \cdot AnalogValue - 26.428$$

$$Temperature = 0.2063 \cdot 578 - 26.428$$

$$Temperature = 92.81°\mathrm{F}$$

Using the Calibration Equation

- Adapt the Arduino sketch to print both the analog value and its corresponding temperature value in degrees Fahrenheit.
  - Move the thermistor around in the air (or water) to change the temperature readings.

```
1  int val;
2  int temp;
3
4  void setup() {
5  Serial.begin(9600);
6  }
7
8  void loop() {
9    val = analogRead(5);
10   Serial.print("Analog = "); Serial.print(val);
11   temp = 0.2063*val-26.428;
12   Serial.print("  Temperature = "); Serial.print(temp); Serial.println(" degF");
13   }
```

A new variable is needed.

Use inverted calibration equation.

```
Analog = 547  Temperature = 86 degF
Analog = 548  Temperature = 86 degF
Analog = 547  Temperature = 86 degF
Analog = 547  Temperature = 86 degF
Analog = 548  Temperature = 86 degF
Analog = 548  Temperature = 86 degF
Analog = 548  Temperature = 86 degF
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Analog = 548  Temperature = 86 degF
Analog = 548  Temperature = 86 degF
Analog = 548  Temperature = 86 degF
Analog = 548  Temperature = 86 degF
Analog = 549  Temperature = 86 degF
Analog = 548  Temperature = 86 degF
```

Autoscroll Show timestamp

Using the Calibration Equation

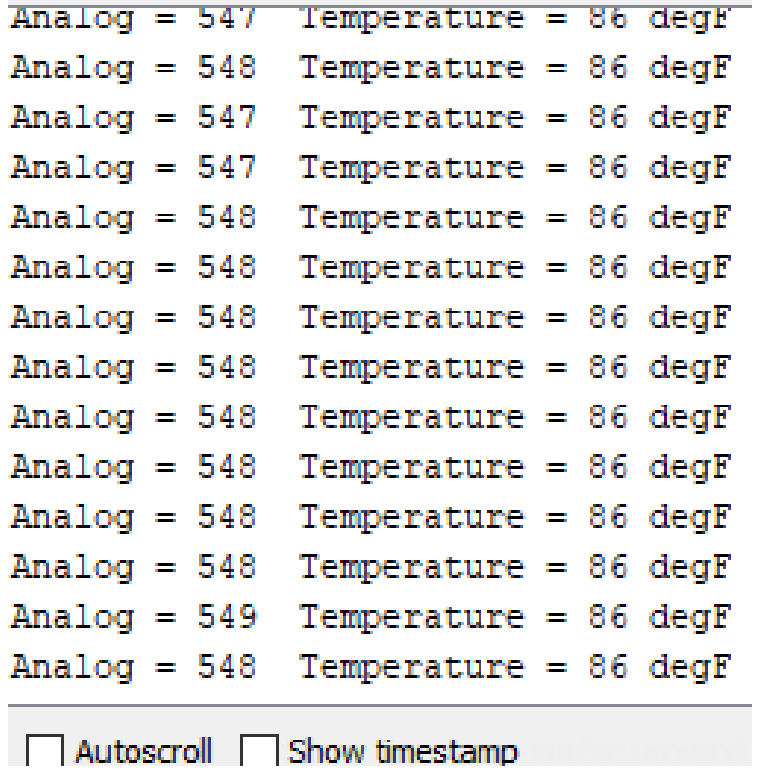
- What do you notice about the values? 547, 548, and 549 are all 86°F
- Check the equation.

$$Temperature = 0.2063 \cdot 547 - 26.428 = 86.4181°\text{F}$$

$$Temperature = 0.2063 \cdot 548 - 26.428 = 86.6244°\text{F}$$

$$Temperature = 0.2063 \cdot 549 - 26.428 = 86.8307°\text{F}$$

The decimals are not printed on the serial monitor. It is like values after the decimal are chopped off. This is called ***truncation****.*



Never trust that you program everything correctly or that the computer is giving you exactly what you want. Always check your work! If you have a calculation, you should check it!

Using the Calibration Equation

- What happens if you change the temperature variable to be a `float` instead of an `int`?

  You get decimals to appear. *You will learn more about data types in another lesson.*

- A `float` is a data type that allows for decimal values to be included in the sketch.

```
1  int val;
2  float temp;
3
4  void setup() {
5  Serial.begin(9600);
6  }
7
8  void loop() {
9    val = analogRead(5);
10   Serial.print("Analog = "); Serial.print(val);
11   temp = 0.2063*val-26.428;
12   Serial.print("  Temperature = "); Serial.print(temp); Serial.println(" degF");
13   }
```

```
Analog = 546  Temperature = 86.21 degF
Analog = 546  Temperature = 86.21 degF
Analog = 546  Temperature = 86.21 degF
Analog = 546  Temperature = 86.21 degF
Analog = 546  Temperature = 86.21 degF
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Analog = 548  Temperature = 86.62 degF
Analog = 548  Temperature = 86.62 degF
Analog = 548  Temperature = 86.62 degF
Analog = 548  Temperature = 86.62 degF
☐ Autoscroll ☐ Show timestamp
```
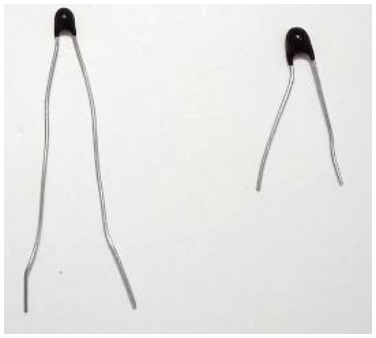
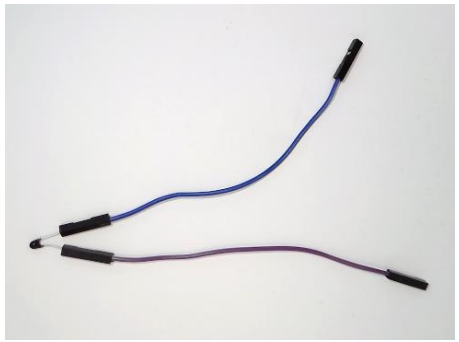

Tip: By default the sketch will print 2 decimal values. To have it print more, go to the line of code that is printing the variable put a comma followed by the number of decimal values you would like it to print.


```
Serial.print("  Temperature = "); Serial.print(temp,4); Serial.println(" degF");
```

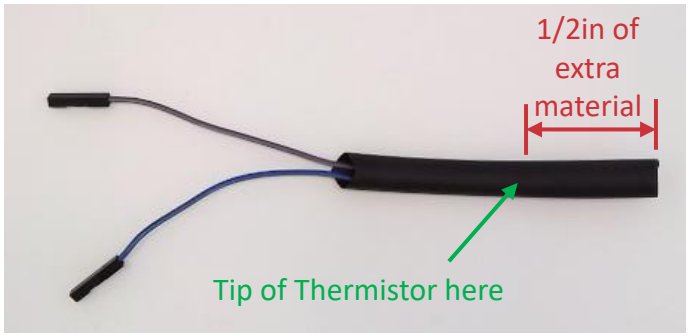
Behind the Scenes: Waterproofing the Thermistor



Clip approx. 1/2in off of thermistor legs

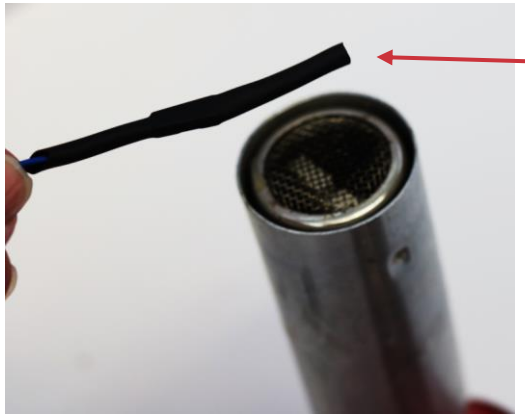


Attach wire extensions to each leg



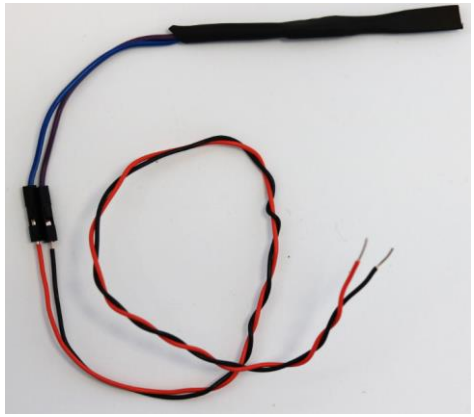
Cut heat shrink material to approx. 3in and slide it over the thermistor

Note: Leave approx. 1/2in of material passed the thermistor to be used as for a seal



Shrink material using heat gun

Clamp end of heated material to seal in the thermistor
Be sure to not crush the thermistor when clamping material



Strip jumper wires and connect them to wire extensions