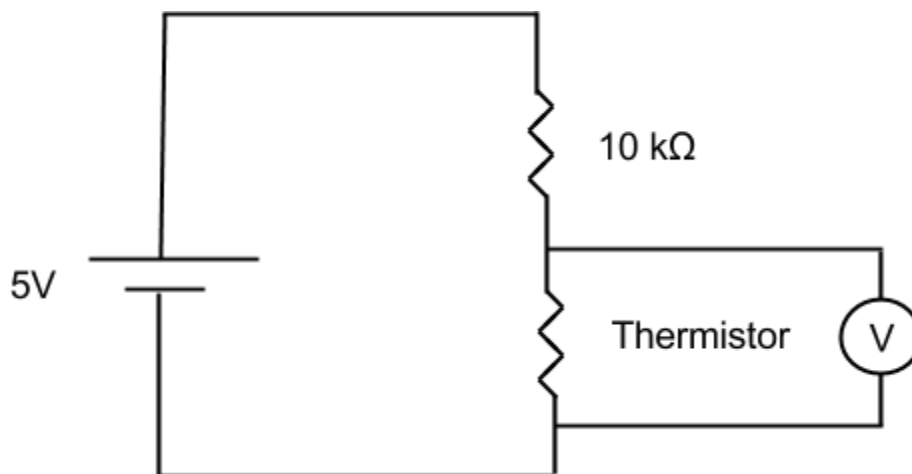


Linear Temperature Sensor

Goal: To find a linear equation that fits our temperature and voltage data so we can program our NXT computer to display temperature based on resistance

Background:

Remember that the circuit in the NXT computer is as follows.



This means that the numbers that you are seeing on the screen are related to the **voltage across the thermistor**. We would expect a voltage of 0 - 5 V depending on the resistance, however because the NXT cannot use decimals it gives us a range of 0-1023. With this information we have the following relationship.

1. $1 \text{ V} \approx 205 \text{ Raw numbers}$

We also know that it is more useful for us to calculate the voltage across the resistor by using the equation:

2. $V_{Resistor} = 5V - V_{Thermistor}$

So using our excel sheet from the previous assignment we will first calculate the voltage of the resistor, then convert to raw numbers and make a graph using this information. I will show you the best way to do this on the following pages.

You should currently have a chart that looks like this (your numbers will be different):

A	B
Temperature	Resistance
0	28
5	22
10	18
15	15
20	12
25	10
30	8
35	7
40	6
45	5.5
50	4

Let's add the following headers to make extra columns (you may want to delete or hide your chart so you can see your full sheet)

	A	B	C	D	E	F
1	Temperature	Resistance in kOhms	Resistance in Ohms	Voltage of Thermist	Voltage of Resis	Raw Numbers
2	0	28				
3	5	22				
4	10	18				
5	15	15				
6	20	12				
7	25	10				
8	30	8				
9	35	7				
10	40	6				
11	45	5.5				
12	50	4				

So in order to calculate the voltage of the thermistor we need to remember our equation

$$3. \quad V_2 = \frac{R_2}{R_2 + 10,000} \times 5$$

Where V_2 is the voltage across the thermistor, and R_2 is the resistance of the thermistor.

The first thing we need to do is convert our kOhms into regular Ohms. Remember there are 1000 Ohms in 1 KOhm. So we should just multiply by 1000. Sheets makes this very easy. Type the following into cell C2:

	A	B	C
1	Temperature	Resistance in kOhms	Resistance in Ohms
2	0	28	=B2*1000
3	5	22	

Whenever you type “=” into a cell, you are telling sheets to do a calculation. In this case you are telling it to take the value from cell B2 (notice that it’s highlighted) and multiply it by 1000.

Press enter. You should see the correct value appear.

Now we can easily do this same thing for the entire column. Move your cursor to the bottom left of the cell C2 until it becomes a cross. Click and drag the cursor all the way down column C. When you release you should see all the values fill in.

	A	B	C	
1	Temperature	Resistance in kOhms	Resistance in Ohms	Volt
2	0	28	28000	
3	5	22		
4	10	18		
5	15	15		
6	20	12		
7	25	10		
8	30	8		
9	35	7		
10	40	6		
11	45	5.5		
12	50	4		
13				

Now we need to calculate the voltage in a similar way.

In sheets type the following into cell D2. This is formula 3.

C	D	
Resistance in Ohms	Voltage of Thermist	Volt
28000	=(C2/(C2+10000))*5	
22000		

Notice that C2 is highlighted with orange. This means that sheets is going to be using whatever number is written in cell C2 as part of the formula. In this case it will use the number 28000 to do the calculation. **Be sure that you have your parenthesis in the right place.**

Hit enter and you should see a value appear. Now we will click and drag D2 just as we did with C2 to apply this formula to all the cells in column D.

You should now have a sheet that looks like the following.

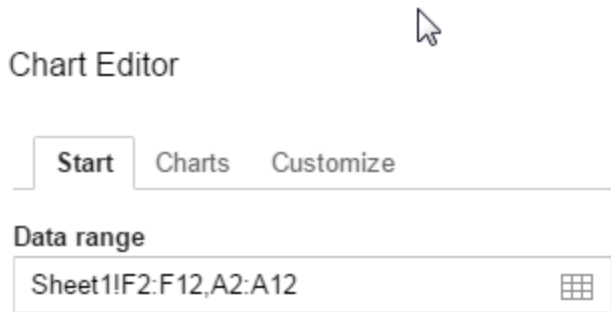
	A	B	C	D	E	F
1	Temperature	Resistance in kOhms	Resistance in Ohms	Voltage of Thermist	Voltage of Resis	Raw Numbers
2	0	28	28000	3.684210526		
3	5	22	22000	3.4375		
4	10	18	18000	3.214285714		
5	15	15	15000	3		
6	20	12	12000	2.727272727		
7	25	10	10000	2.5		
8	30	8	8000	2.222222222		
9	35	7	7000	2.058823529		
10	40	6	6000	1.875		
11	45	5.5	5500	1.774193548		
12	50	4	4000	1.428571429		
13						

Now to calculate the value column E we need to use formula 2 to do this. Go ahead and try to do this one on your own. You will know it works if columns D and E add up to 5.

Finally we need to find column F. We need to use our formula 1 for this calculation. You should multiply the value in column E by 205. Your final sheet should look like this:

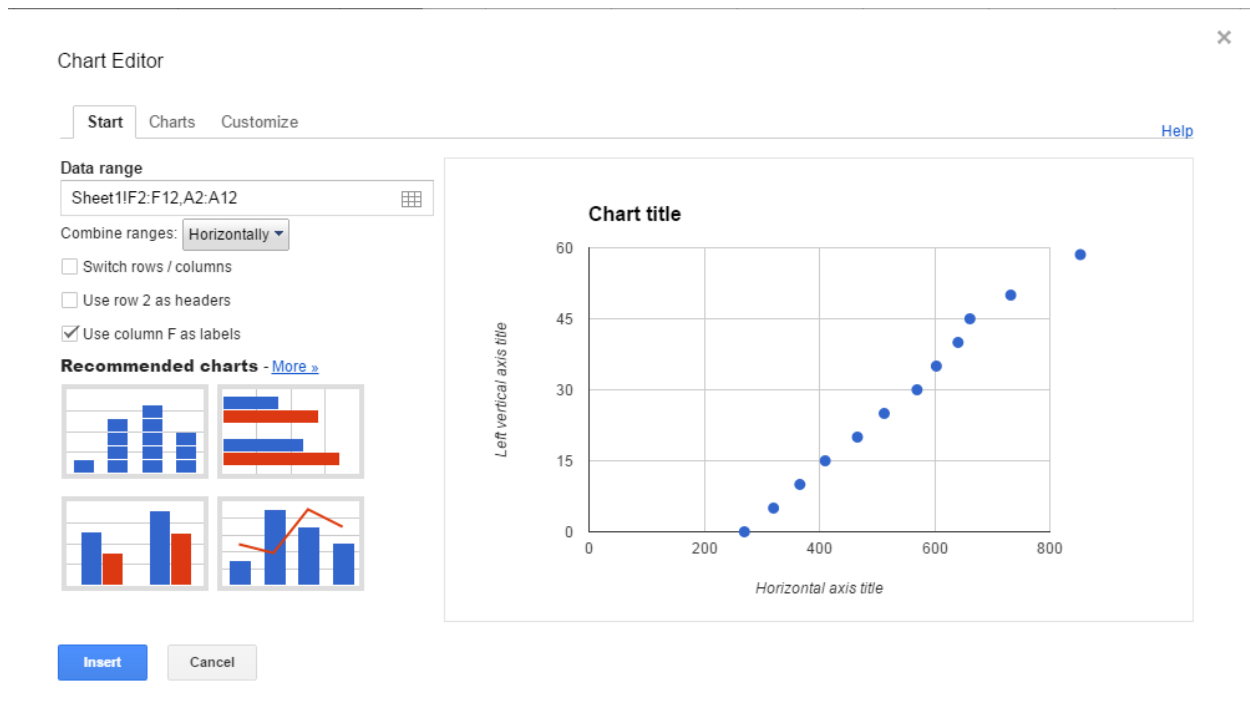
	A	B	C	D	E	F
1	Temperature	Resistance in kOhms	Resistance in Ohms	Voltage of Thermist	Voltage of Resis	Raw Numbers
2	0	28	28000	3.684210526	1.315789474	269.7368421
3	5	22	22000	3.4375	1.5625	320.3125
4	10	18	18000	3.214285714	1.785714286	366.0714286
5	15	15	15000	3	2	410
6	20	12	12000	2.727272727	2.272727273	465.9090909
7	25	10	10000	2.5	2.5	512.5
8	30	8	8000	2.222222222	2.777777778	569.4444444
9	35	7	7000	2.058823529	2.941176471	602.9411765
10	40	6	6000	1.875	3.125	640.625
11	45	5.5	5500	1.774193548	3.225806452	661.2903226
12	50	4	4000	1.428571429	3.571428571	732.1428571

Now we can make a graph! Go to insert, chart and then type the following:



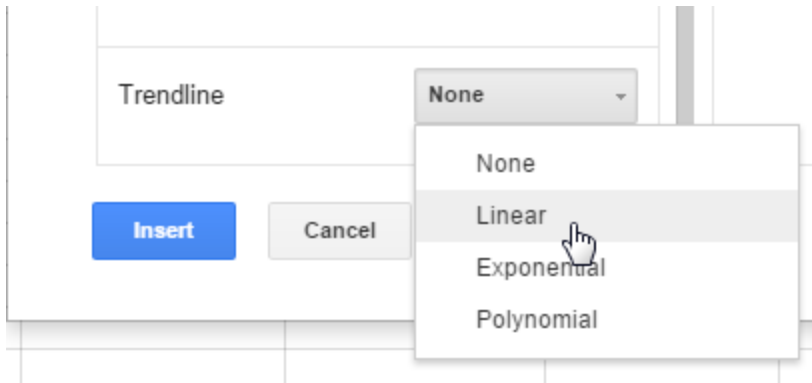
Notice that my ranges are from 2-12 because that's how many rows of data I have. If your data only goes to row 10 then you would write F2:F10,A2:A10.

Now click charts and select scatter. You should see a graph appear that looks roughly like this:

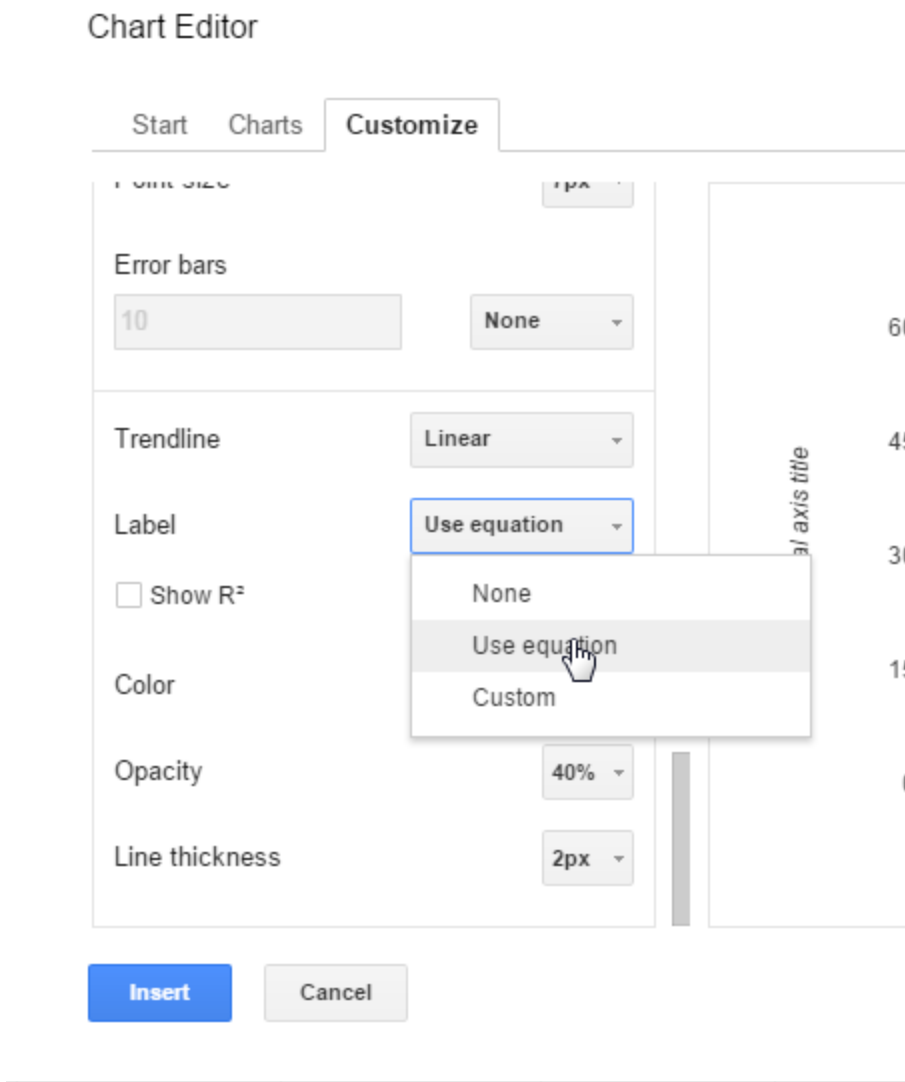


Click customize and choose appropriate labels. You x-axis is the raw numbers, your y is the temperature in Celsius.

Scroll all the way down to trendline and choose Linear



Now scroll down and click label, use equation:



Now we have a trendline that we will use to program our robot to show us the temperature! If you have not already shared your sheet with me, please do so. If you have shared it with me send me an email saying I should look at the updated version.