Lab: Temperature measurements

In this lab, you will make measurements of temperature using a device called a thermistor. A thermistor is nothing more than a resistor whose resistance changes with temperature. You will conduct an experiment that you will revisit from the modeling perspective in a few weeks in ModSim. In our class you will try out the problem experimentally, to get the real answer. The question as stated by Allen Downey in his ModSim Python book is:

> Suppose I stop on the way to work to pick up a cup of coffee, which I take with milk. Assuming that I want the coffee to be as hot as possible when I arrive at work, should I add the milk at the coffee shop, wait until I get to work, or add the milk at some point in between?

We will conduct a model experiment similar to the ModSim problem. You should save this data as you can later use it to check that your work in ModSim is actually based in reality.

The thermistor we will use has the following relationship between resistance and temperature

$$R = 1000\ \Omega \times e^{-3528\left(\frac{1}{298}-\frac{1}{T}\right)}$$

where T is the temperature in Kelvin (T in Kelvin is T in Celsius plus 273). At room temperature (defined as 25 C or 298 K) then the thermistor we are using has a resistance of 1000 ohms.

Create a circuit using the voltage divider concept that will allow you to convert measured voltage to resistance of the thermistor. We will leave it as an exercise for you to invert the above expression – i.e. compute temperature from resistance. Check that your system seems to be working by squeezing the thermistor to heat it up. You should notice a change.

Once you think it is working, make a copy of the circuit on your breadboard so that you can make two simultaneous temperature measurements. We will measure both scenarios simultaneously. Since the experiment will take about fifteen minutes you will want to make sure that you have everything working before you actually start collecting data.

Set the time axis in Waveforms to be 2 minutes per division. This will allow you to collect a long enough time series of data.

WARNING – the experiment involved boiling water sitting next to your laptop. Please be careful setting up and cleaning up the experiment.

Procedure:

- Get two coffee cups. Get two cups of boiling water from the tea kettle. Fill the cups up to equal volume and leave enough room to add the “milk” (ice water).
- Take the cups to your desk, place them carefully and out of the way, and hit run on the Analog Discovery scope – with a slow 2 min per division time scale.
- Plunge a thermistor in each cup of “coffee” (without pulling the wires from the breadboard). Place the thermistors so they are well submersed. Try to place the thermistors in approximately the same location and depth – i.e. either the center of the cup, near the wall, near the bottom. The location doesn’t matter much, but both cups should be about the same location for an equal comparison.
- You should see the measured voltage change fairly rapidly as the thermistor heats.
- Now, relatively quickly before the coffee cools much, go get 40 mL of ice water from the front of the room (this is the "milk" in this experiment). This water should be very close to 0 C. Dump this 40 mL of ice water into **one** of the cups of coffee. Mark which one got the cold water so you don’t forget.
- Set a timer for 10 minutes.
- After about 10 minutes (the exact time doesn’t matter so much), go get another 40 mL of ice water, and dump that in the other cup of coffee.
- Set a timer for 5 minutes.
- Hit stop on the scope and **export the data from Waveforms to a CSV file**. Confirm that the data was saved and open the file in Excel or some other program before closing Waveforms – just to make sure you have the data and don’t need to repeat the experiment. Don’t close waveforms until you make sure the data is saved.
- Use one of the beakers at the front of the room to measure the volume of water in both cups. The initial volume will be that value minus 40 mL of cold water. Record these numbers and make sure you keep them for your lab report and have them for your later ModSim work.

For your analysis, you will need to convert measured voltage to resistance of the thermistor to temperature. Your lab report should contain a plot of temperature vs time for the two experiments, superimposed on the same graph. You should note all the parameters used in your experiment – i.e. volumes of water, etc. Draw some conclusions about the original question.

For the data where you dump the cold water in at the beginning, try to fit the measured data just after the cold water has been added with a function,

$$T(t) = 22\ C\ +\ (T(t=0) - 22\ C)e^{-t/\tau}$$

Where here we are assuming that the room is at 22 C, T(t=0) is the temperature at time 0 (defined as just after the cold water is poured), and the parameter "tau" is the experimentally determined constant which has units of seconds. You will learn later in ModSim how this single parameter relates to the physics of the problem. In this class we will see this same functional form governs the dynamics of one of our key future circuits. In your lab report, also include a plot with the fit of your data to this function and report what the value of tau is.