UBC ATSC 303 2019W
Lab 2 – Thermometry (/40)

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Learning goals

1) Learn how to make a thermocouple
2) Be able to identify types of thermocouples based upon their output

Background

Thermometry lecture and demo
Harrison: Ch. 5 (5.3.1 for thermocouples)

Safety

- **Do not touch** the very hot exposed metal end of the soldering iron. If a burn occurs immediately run it under cold water.
- There is no electric shock danger when handling the thermocouple wires (voltage levels are very low).

Due to limited equipment, get started on the assignment questions at the end of this handout while you are waiting.

Method

Part 1 – Making a thermocouple

Equipment:

- 2 x wires (one purple and one blue)
- Wire cutters/strippers
- Soldering iron and metal rest
- Solder
- Heat mat
- Wire clips
- Safety glasses
- Pliers (not necessary but useful)

1. Taking care not to cut through the inner metal wires, strip the outer jacket off each wire up to about 1 cm length.

2. Strip each inner wire up to about 0.75 cm length so that the bare wires are exposed.

3. If you cut through the inner wire by mistake, even up the lengths with the wire cutter and try again.

4. Twist the two metal wires together so they are joined (on one side only).

5. Solder **the twisted end only** for each wire (do not worry about the quality of the soldering).

6. Cut the wire up to where the outer jacket begins again and repeat steps 1-5 until everyone in your group has had a go. When the last person is done, do not cut off the thermocouple.

7. Finally, tightly wrap electrical tape around the junction to insulate it before use in Part 2 of the lab. The bare wires must be completely sealed (from the outside air/water).

Part 2 – Measuring output from thermocouple

Equipment:

- Laptop with LoggerNet software installed
- Datalogger
- 12V battery
- Power adapter
- Serial cable
- Small screwdriver
- 2 x thermocouple wires

1. Connect the 12V battery to the datalogger, by inserting the green tab into the appropriate slot on the datalogger.

2. Connect the power adapter to the battery, and then plug it into an electrical outlet. A red light should turn on, indicating that the battery is charging.

3. Attach the thermocouples to the datalogger, with the blue thermocouple going into an odd differential channel (i.e. 1, 3, 5, etc.) and the purple thermocouple going into an even differential channel (i.e. 2, 4, 6, etc.). Taking the non-soldered end of a thermocouple, insert the inner **red** wire into the slot marked with an **L**, and the other wire into the slot marked with an H. Groups sharing the datalogger will have to take it in turns.

4. Connect the laptop to the datalogger using the serial cable.

5. Open up **LoggerNet**, then click "Main → Connect" In the window that pops up under **Stations** select "CR1000" (one group may have to select "CR3000") then finally select "Connect" on the top bar. Ensure that the datalogger power supply is connected and switched on.

6. Hit "Send New" to send a copy of the compiled script used for collecting data to the datalogger. (file found: /Desktop/ATSC303/ATSC303_data_laptop2/code/lab1_TCs.CR1)

7. Then under clocks press "Set" to synchronize the time with the PC

8. On the top bar of the screen, where it says **Num Display**, click "Display 1". If there are already filled-in cells on the screen, hit "Delete All" to start from scratch. Press "Add", select "Public", and then select all of the variables to paste them into the Numerics window.

9. Check to see that the channels in which you inserted a thermocouple read room temperature. To double check that you have connected the wires the right way around, pinch the junction with your fingers and make sure you see a temperature increase. If you see a decrease, swap the two wires in the differential channel.

10. Collect temperature data (air, hot water and cold water), taking note of the **time period** for each scenario (air/hot/cold) that you were collecting data for. This will help you filter out "junk" transition data in your report.

11. After ~40 min., press "Collect Now" to download the data file. Navigate to where it is saved, and move the data file to the Desktop. Rename it with the following format: **lab1_{starttime}_{endtime}_{last names of group members}.dat** . The data will be posted on the website immediately following the lab.

12. Using Excel, Matlab, or whatever spreadsheet/numerical program you are comfortable with, determine the type of each of your thermocouples by plotting voltage vs. temperature. **The Type E is ~60 microVolts/degC. Type T is ~40 microVolts/degC.**

<u>Assignment</u>
To hand in by next Wednesday (Jan 22nd), **each person submits an individual report:**

<u>Analysis, results and discussion of the data your group collected (/10)</u>

- At least **2** graphs (one for each thermocouple type) showing the equation that fits the **3** temperature scenarios. The slope of this equation will give the thermocouple type.
    - Be sure your graph is up to "scientific" standard. That is, make sure your axes are labeled properly and with the correct units, the plot is titled, and the equation of your regression line displayed clearly.
    - Clearly identify the thermocouple types.
- List sources of error.

- What assumptions are we making when using the data from the thermocouples?

In the report be sure to write down your group members, which DIFF channels your group is using and which datalogger/laptop pair you are using.

Questions (based on lab/lecture/demo/readings)

1. Discuss how the model on slide 14 of the Overview lecture applies to the measurements done in the lab. Label what happened in each applicable step and say what device it was associated with (wire, datalogger, computer, cables, etc). (Our lab may not have used all the blocks in the figure) /3
2. What are some advantages of using thermocouples over other temperature sensors? /2
3. What are some disadvantages? /2
4. Why does soldering the two wires not affect the temperature reading? /2
5. Why will your temperature/voltage measurement be biased if the thermocouple wire is too short? /1
6. What is the Seebeck effect? /2
7. Assume internal datalogger metals are not the same as the thermocouples. Why does the presence of a third dissimilar metal not affect our results? What do we need to make sure in regards to the terminals on the datalogger? /2
8. What does the sensitivity of a sensor mean? What are the units of sensitivity for a thermocouple? /2
9. Is what we performed a calibration? If so, explain. If not, how could we have performed one? /3
10. How much will a bimetallic strip deflect for a temperature change of $10^{o}C$, if it is 5 cm long, 1 mm thick, and has a deflection constant of $5 \text{ X } 10^{-5}\ {}^{o}C^{-1}$? /1
11. Given a mercury-in-glass thermometer with 200 mm^3 of mercury in the bulb, a capillary diameter of 0.15 mm, and a mercury cubic thermal expansivity of $1.6 \text{ X } 10^{-4}\ {}^{o}C^{-1}$, calculate the sensitivity. /2
12. Define the following terms: thermistor, Centigrade scale, metal resistance thermometer, self-heating, bimetallic strip /3
13. An ideal radiation shield has what characteristics? /2
14. What happens if you pass an excessive current through a metal resistance thermometer? /1
15. A thermocouple has a transfer equation $\Delta V = (a + b\Delta T)\Delta T$, where $a = 38.6\ \mu V K^{-1}, b = 0.0413\ \mu V K^{-2}$.

(a) When $\Delta T = 10\ K$, what is the output voltage? What are the units? /0.5 =390 13 μV
(b) When $\Delta T = -10\ K$, what is the sensitivity? Show your work. /1
(c) When $\Delta T = 40\ K$, what is the sensitivity? /0.5
(d) (Bonus /1): Show that $\frac{d(\Delta V)}{d(\Delta T)} = \frac{dV}{dT}$. *Hint:* $\Delta V = V - V_0, \Delta T = T - T_0$

(optional) To help design better labs:
What did you like/dislike about the lab? What improvements would you like to see in future labs?

Comments for the TA?
-you can submit these earlier, by email, to improve the next lab.