Principles of Temperature Measurement

Objectives

1. To become familiar with operation of various devices used to measure temperature
2. To use simple circuit analysis techniques

Apparatus

Cup for water, mercury-in-glass thermometer, a type K thermocouple (room temperature reference with no compensation), a thermistor, a wheatstone bridge circuit (shown in Figure 1), two digital multimeters, and a power supply unit. The overall schematic is shown in Figure 2.

Figure 1. Wheatstone bridge circuit diagram

Figure 2. Lab set-up schematic
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Procedure

1. Construct the wheatstone bridge circuit with the thermistor
   a. Do a quick check to see if thermistor resistance decreases with increasing temperature
   b. Measure the resistance of the thermistor in an ice bath
   c. Measure the supply voltage
   d. Pick two fixed resistors to complete the Wheatstone Bridge making sure your choices are logical for balancing the bridge (pick an R3 and R4 so that R2 can be achieved)
   e. Calculate variable resistance to balance the bridge as described in class
   f. Set the variable resistor and check the null balance the bridge ($V_{bc} \approx 0$)
2. Connect the thermocouple leads to a digital multimeter
3. Heat about 50 ml of water to boiling (too much water will increase your time!)
4. Immerse the mercury thermometer (reference) and thermocouple in the water
5. When the mercury thermometer reads about 75°C, place the thermistor in the water
   (Warning - the thermistor’s maximum rated temperature is 100 °C)
6. During the cooldown process to about 40°C, take about 12-15 simultaneous readings of the mercury thermometer, thermocouple emf, and the unbalanced bridge voltage ($V_{bc}$). It is preferred to record data corresponding to integer values of the thermometer reading.

Extra Credit
Repeat the experiment using data acquisition and compare your plots (below) in 2c. and 2d. using manually collected data to the ones generated with data acquisition (using tc temperature).

Requirements for analysis (laboratory write-up)

1. Analyze thermocouple data.
   a. Plot thermocouple emf (mV) versus mercury thermometer reading (°C) Use symbols to represent experimental data and lines to represent regression analysis.
   b. On the same graph, plot the emf values from Omega versus thermometer temperature
   c. Perform a regression analysis (and show the best fit line) on both sets of data and compare. Step c should be done on the same two graphs as (a) and then (b).
2. Analyze thermistor resistance as a function of the unbalance bridge voltage.
   a. Develop an explicit relationship for the thermistor resistance as a function of bridge voltage, supply voltage, and the three arm resistances. Show this development in the laboratory write-up appendix.
   b. Using this relationship, convert all bridge voltages into thermistor resistances
   c. Plot thermistor resistance (Ω) versus thermometer reading (°C)
   d. Plot the natural log of thermistor resistance (Ω) versus 1/T(°K), find the curve fit relation for this data, and compare the slope with the typical values of Beta for thermistors.
3. Determine the uncertainty of the calculated variable resistance needed balance the bridge.

References
Holman, Experimental Methods for Engineers.
Omega Temperature Handbook