ME 4/549 Lab Assignment 1
Spring 2006 due 18 April 2006

1 Overview

For all experiments this week, form groups of no more than two students. Each student must turn in a short lab report. If you work with someone else, be sure to identify your lab partner on your report. You can work alone if you wish.

Objectives

- Learn how to fabricate thermocouples
- Gain familiarity with thermocouple circuits
- Get exposure to thermistors
- Gain familiarity with scanning digital multimeter (Agilent 34970A)
- Learn how to measure temperature with a thermocouple having its reference junction in an isothermal zone box.

2 Thermocouple Construction

1. Fabricate two thermocouples. (Repeat the following steps twice.) For the first thermocouple start with a length of wire that is approximately 50 cm long. For the second thermocouple, start with a length of wire approximately 100 cm long

    a. Put on safety glasses

    b. Locate the thermocouple welder. Clear a work area for it. Arrange the working ends—the ground cable with the graphite block and the cable with pliers attached—so that they can be touched together. Plug in the welder.

    c. Strip one end of the thermocouple wire to expose 1 cm or less of bare wire for both positive and negative conductors.

    d. Twist the bare wires together one to two turns. If the free ends of the wire extend beyond the twist, clip the free ends so that the wires end at the twist.

    e. Make sure other people nearby are wearing safety glasses. If they are not, ask them to move away.

    f. Set the power knob on the control unit to “10”.

    g. Grasp the exposed wire with the pliers, making sure that the twisted end of the thermocouple wire protrudes slightly.

    h. Hold the twisted end of the thermocouple wire against the graphite block, and push the discharge button on the welder control unit.

    i. Inspect the weld. If necessary, adjust the power, and repeat the weld.

j. When you are satisfied with the junction, apply two or three coats of nail polish to the junction and any exposed wire near the junction.

2. Verification and Report

   a. Measure the length of the thermocouple wires.

   b. Identify and record the part number(s) from the wire spool.

   c. Measure and record the electrical resistance of the thermocouples.

3 Compensation with an Ice Point Reference

In this part of the exercise you will construct the two ice-point referenced circuits shown in Figure 3 and Figure 4. Use the thermocouples created in the preceding exercise.

3.1 Ice Point Reference Circuit A

Complete the thermocouple circuit from Figure 3.

1. Select the (approximately) 50 cm long thermocouple constructed in section 2.

2. Solder the extension wire to the thermocouple wires.

3. Label the positive and negative leads of the extension wire with pieces of masking tape.

3.2 Ice Point Reference Circuit B

Complete the thermocouple circuit from Figure 4.

1. Select the (approximately) 50 cm long thermocouple constructed in section 2.

2. Separate P and N leads along half of the thermocouple wire.

   a. Clear a work area on a piece of scrap plywood or other cutting surface.

   b. Lay the thermocouple wire on the cutting surface. Refer to Figure 1 At approximately midway between the welded junction and the open circuit end of the thermocouple, insert the point of a sharp utility knife into the seam between P and N legs of the thermocouple.

   c. Carefully, and without injuring yourself (or others), and without damaging the insulation on either leg of the thermocouple, cut towards the open circuit end of the thermocouple

3. Cut out about 30 cm of the N type wire and strip 1 cm of the open circuit end.

4. Cut another length of 30 cm of thermocouple wire (use scrap if possible), and separate the wires to obtain a length of the P type material (Copper if using type T). Refer to Figure 2. Solder the P wire from the short length of separated wire to the N wire from the thermocouple

5. Label the positive and negative leads of the extension wire with pieces of masking tape.

3.3 Simple Shakedown

For each of the circuits constructed in the preceding steps, perform the following tests.

1. Connect the extension wire leads to a voltmeter. A hand-held multimeter is sufficient.
2. Insert the reference junction into the ice bath.
3. Insert the measurement junction into the ice bath and record the output voltage.
4. Insert the measurement junction into the hot water bath and record the output voltage.

If the circuit is wired correctly, the thermocouple output should be zero when the measurement junction is in the ice bath, and positive when the measurement junction is in the hot water bath. The sign of the voltage is a sanity check only. It does not *prove* that the thermocouple is constructed correctly.

3.4 Report

1. Sketch the thermocouple circuits. Identify the positive and negative leads: indicate the polarity and the material (copper or constantan).
2. Measure the resistance of the thermocouple with the extension leads. Is it greater or less than the resistance of the thermocouple only?
3. Use the thermocouple emf vs. temperature tables or polynomials to convert the measured voltages to temperatures. Compare your temperature of the hot bath with the temperature indicated on the front panel.

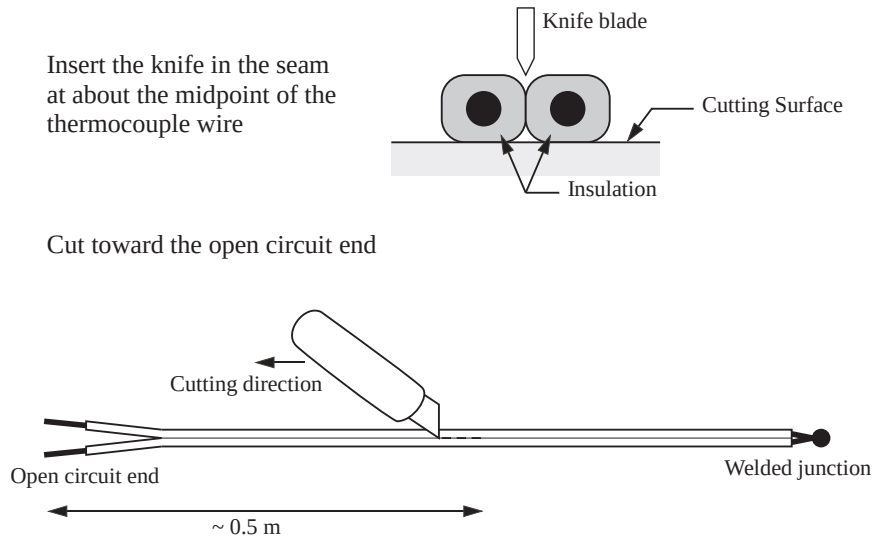

Figure 1: Splitting thermocouple wire to create the circuit in Figure 4.

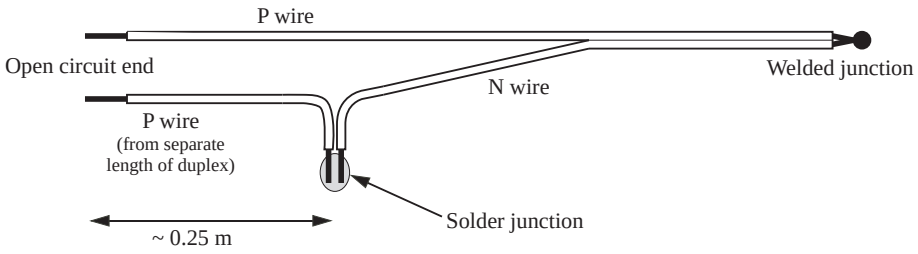

Figure 2: Configuration of the reference junction for the thermocouple circuit in Figure 4.

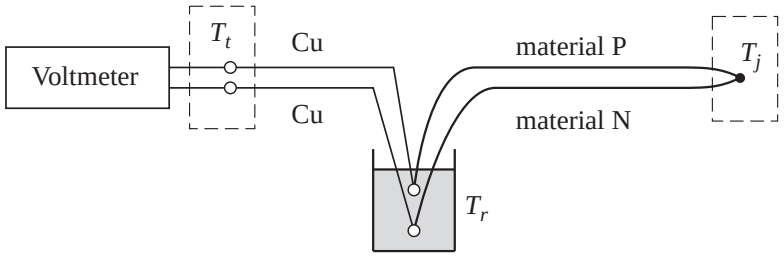

Figure 3: **Circuit A:** The ice-point reference junction includes connections to both the P and N wires. The two reference junctions must be electrically isolated from each other *and* the ice/water mixture.

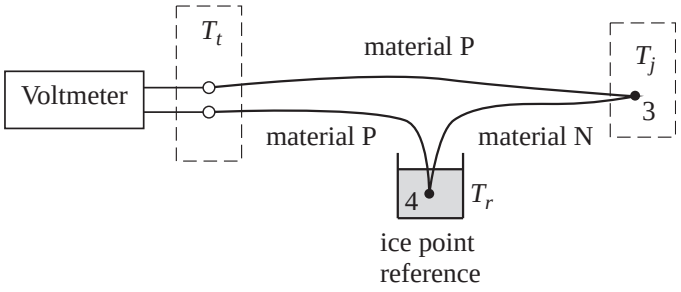

Figure 4: **Circuit B:** The ice-point reference junction has a connection for just the N lead. The reference junction must be electrically isolated from the ice/water mixture.

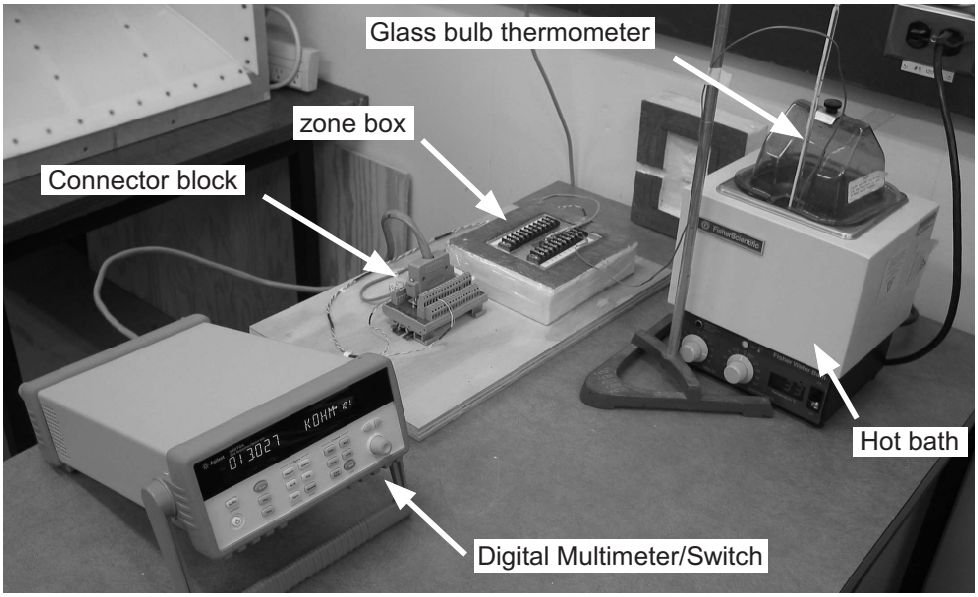

Figure 5: Apparatus for the zone box compensation experiment.

4 Compensation with a Thermistor

You will find thermocouples connected to a zone box and a digital multimeter[1] configured to measure the temperature of the hot water bath. Additional thermocouples are connected to hand held multimeters with built-in thermocouple compensation. In this part of the lab exercise, you will use these thermocouples (and the zone box thermistor) to make temperature readings. You will compare the temperature readings from the thermocouple you fabricated with the thermocouples provided in the lab.

Before taking any readings, create a block diagram sketch of the apparatus. Be sure to identify the sequence of connections between the thermocouple and the digital multimeter.

4.1 Thermocouple Comparison

1. Make sure the heater for the hot water bath is turned on. Allow the bath to achieve a reasonably steady temperature.

2. While the bath is coming into thermal equilibrium, connect your ice-point compensated thermocouple circuit to the multimeter.

3. Create a table in your notebook like Table 1.

4. Set the multimeter channel to record the resistance of the thermistor in the zone box. Record the thermistor value and the time at the beginning of the experiment.

[1] An Agilent 34907A Data Acquisition/Switch Unit.

5. Record the first row of values in the bottom half of Table 1. (Reading 1 in the table).
6. Turn off the power to the hot bath.
7. At intervals of one minute or longer, repeat the temperature measurements. (Readings 2 through 5). Note that the panel meter reading cannot be made when the bath is turned off. Only record the panel meter at the start and end of the transient.
8. Record the resistance of the thermistor in the zone box and the time at the end of the experiment.
9. Turn off the equipment.

Table 1: Raw data.

Start time: _____

Stop time: _____

Thermistor reading at start: _____

Thermistor reading at stop: _____

Panel meter reading at start: _____

Panel meter reading at stop: _____

Reading	T_{bulb} (°C)	EMF of TC circuit A (mV)	EMF of TC circuit B (mV)	EMF of TC ref. zone box (mV)
1				
2				
3				
4				
5				

4.2 Report

- Document thermocouple fabrication
  1. Report the length of wire and part number.
  2. Report the resistance of the thermocouple with and without the extension wires.
- Create a block diagram schematic of the apparatus with the zone box, hot bath, and thermocouples.
- Present the raw data in a table.
- Convert the emf of the thermocouples to temperature, and present the results in a table similar to Table 1. (All emf values replaced by temperatures.)
- For the readings in Table 1, plot the thermocouple temperatures (columns 3 through 5 in Table 1) versus the temperature reading of the glass bulb thermometer. Add to the plot a line *through the origin* with a slope of one. Comment on the agreement between the temperature measurements and the temperature indicated by the panel meter.
- For the five readings in Table 1, plot the two ice-point compensated thermocouple temperatures (columns 3 and 4 in Table 1) and the temperature of the bulb thermomoeter (column 2 in Table 1) versus the temperature of thermocouple with its reference junction in the zone box. Add to the plot a line *through the origin* with a slope of one. Comment on the agreement between the temperature measurements.