Thermocouple

In this experiment, the characteristics of a thermocouple will be investigated. Thermocouples are comprised of two different metals joined at one end to form a junction. The junction completes the circuit so that current flow can take place. A voltage is developed along each wire as the temperature changes. The voltage difference is observed at the receiving end because the two differing metals have different Seebeck coefficients and produce a voltage difference at the meter point. For certain metals this voltage is large enough to find use as a temperature sensor. Several metal pairs are in use in industry and their characteristics are well documented. A few of the common thermocouples are given in the table below.

Type	Materials	Temp Range
J	Iron-Constantan	-190°C to 760°C
T	Copper-Constantan	-200°C to 371°C
K	Chromel-Alumel	-190°C to 1260°C
S	(10% Platinum+ 10% Rhodium) – Platinum	0°C to 1482°C

Table 1. Some Common Thermocouples

The thermocouple used in this experiment is the type T, copper-constantan. A cutaway few of the thermocouple probe is shown below. The **blue-insulated lead is copper** and the **brown-insulated lead is constantan**.

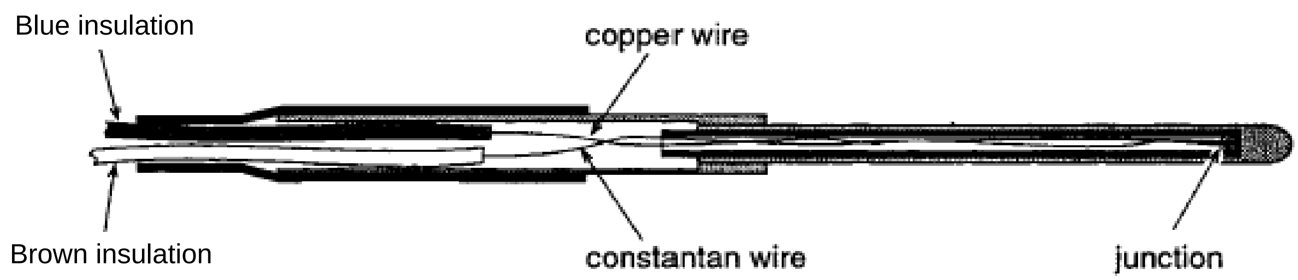

Figure 1. Cutaway View of Thermocouple Probe

The voltage produced by the thermocouple is very small ($\approx 1 - 10$ mV) so a high-resolution DVM (or amplification) is required. Also, a reference junction is required such that a calibrated temperature of the measuring junction can be found. Historically, the reference junction was placed in an ice water bath. For this reason, the reference junction of the thermocouple wires is referred to as the "Cold Junction." The measuring junction is then referred to as the "Hot Junction" even if it is measuring a temperature that is less than the ice bath junction.

When one of the thermocouple junction materials is the same as that of the connecting wires, only one additional junction is formed. This is the case for the copper-constantan thermocouple when copper connecting wires are used. Only the junction between the constantan and the copper connecting wire must be kept in the bath as shown in Figure 2. Notice that the brown lead should be connected to the positive input of the DVM for proper voltage polarity.

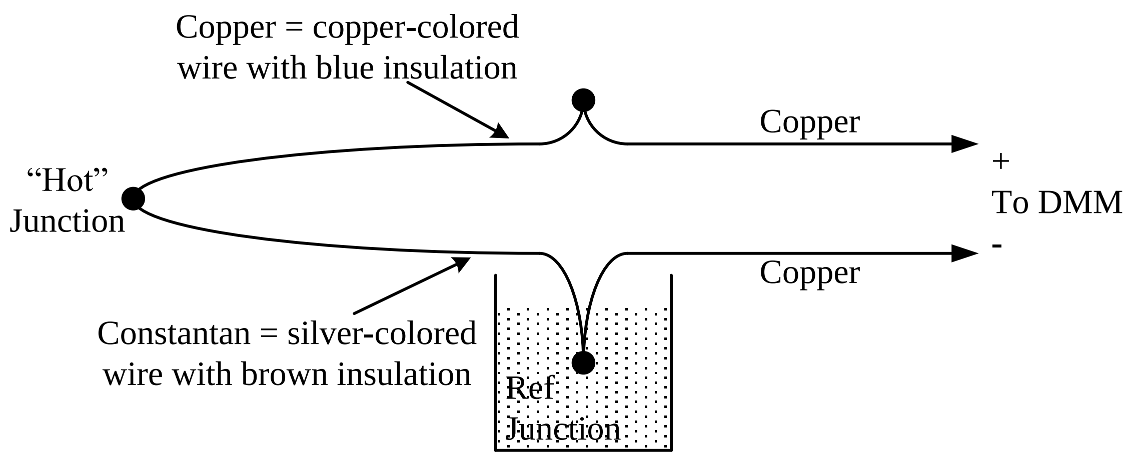

Figure 2. Thermocouple Junction Connections

Although the voltage produced is nearly linear with respect to junction temperature difference, tables are typically used to describe the voltage-temperature relationship. Tables are available for each type of thermocouple and are specific for a particular cold junction temperature (usually 0°C). Please refer to the table for type-T thermocouples located on Canvas. This table is based on a 0°C cold (reference) junction temperature. (Table temperatures are Celsius, voltages are in millivolts.)

To obtain a range of temperature measurements, a hot plate will be used to slowly heat the thermocouple hot junction while it is submerged in a bath of water that initially contains ice. The **cold junction** is held in a bath of **room temperature** water.

Experimental Setup / Instructions

Place the junction between the constantan thermocouple lead and the copper DMM lead into a beaker containing **room temperature water** (yes, submerge the tip of the DMM lead into the water). This will serve as the "cold junction." Measure and record the temperature of the cold junction bath with the reference temperature probe.

As in previous temperature sensor experiments, use a hot plate (set to about 7 on the dial) to heat water, starting with ice water, to about 50ºC. Measure the thermocouple voltage (with a higher resolution Fluke DMM connected as shown in Figure 2) and water temperature (using a reference temperature probe attached to the thermocouple probe with rubber bands) at approximately 5ºC increments. Measure and record the temperature of the cold junction bath again.

Results

Plot the measured data and compare to expected results for a type-T thermocouple. Note that the table for type-T thermocouples located on Canvas assumes a cold junction temperature of 0°C. Therefore, the measured data must be adjusted so that the two sets of data can be plotted with the same cold junction temperature. Why is it better to adjust the measured data instead of the table values?

Thermocouples are not truly linear devices. But your measured and expected data look linear, don't they? Add a best-fit linear approximation to both your measured and expected plots. Compare the slopes and y-intercepts for your measured and expected results. Discuss whether or not this comparison is valid.