TEMPERATURE MEASUREMENT LABORATORY

1. Objectives

The objectives of this lab are to familiarize you with some of the various types of temperature sensors in current use, to calibrate them (and hence to recognize the relationship between data quality and instrument calibration), and to evaluate the impact of ventilation on temperature measurement.

In this lab, you will also calibrate the Davis temperature sensor for your weather station.

2. Tasks

2.1 Calibrations

2.1.1 Calibrate the regular Hg thermometers (make sure their range covers 0-100 C) against the boiling and freezing points of water. Take at least 3 points at each of the two standard temperatures

2.1.2 Use Dewars of five different temperatures from freezing to 30°C to calibrate the following sensors:
(a) thermocouple (type E, chromel-constantan)
(b) bead thermistor
(c) Platinum resistance thermometer
(d) Davis temperature probe

The calibrations are made using the calibrated ASTM Hg thermometer as a standard. (ASTM stands for “American Society for Testing and Materials”, which is the non-profit organization that writes standards for materials and measurements.)
Get three replicate temperatures at each point.

2.2 Time Response

Determine the time constant for the following:
(1) a Davis temperature probe
(2) a regular Hg thermometer

You will do this by heating them to a temperature far above ambient and then cooling them using ventilation. A wind tunnel is used for the ventilation. Note that at the end of the wind tunnel is a needle telling you how many feet the air has traveled in a given time. Be sure to account for any initial offset in the needle, and simply divide the feet traveled by the time (e.g., 40 feet in 10 seconds would be a wind speed of 4 feet per second, which can be converted into SI units).
Record points at least every 10 seconds. Possibly, every 5 seconds may be necessary. Take three sets of measurements for each temperature sensor. Try three wind speeds. **Make sure you measure the ambient temperature.** Then determine the 1/e decay time from a non-linear regression analysis at each wind speed (i.e. the time for the difference between the thermometer reading and final (ambient) reading to reach 37% (1/e) of the initial difference between the thermometer reading and ambient). Note the estimate of the uncertainty on the time constant. For the non-linear regression, assume a form like

\[
(T - T_{\text{ambient}}) = (T_0 - T_{\text{ambient}}) e^{-t/\tau}
\]

\[
\Rightarrow (T - T_{\text{ambient}}) = ae^{-bt}
\]

where \(T_0\) is the first data point (hot), \(\tau\) is the time constant.

### 3. Questions to address in the lab report

#### 3.1 From a linear regression analysis (\(T_{\text{true}} = aT_{\text{Hg}} + b\)), evaluate the accuracy of the regular Hg thermometer from the two-point calibration (freezing and boiling points of water). Compare your two-point calibration with the ASTM calibration, i.e. calibration of the regular Hg thermometer against the ASTM thermometer using regression (\(T_{\text{ASTM}} = cT_{\text{Hg}} + d\)). Are they in agreement? If not, discuss.

#### 3.2 Using the ASTM thermometer as a transfer standard, what is the accuracy of each of the other transducers relative to the standard based on your 5-point calibration? (Be sure to take the independent variable as the observed temperature, and the dependent variable as the ASTM temperature in the regression). Evaluate the absolute accuracy of the non-standard transducers that you calibrated. You can do this using the combination of error rules and combining the uncertainty of the ASTM Hg thermometer relative to NIST (the national standard from the “National Institute for Standards and Technology”) with the uncertainty of the transducers relative to the ASTM thermometer.

#### 3.3 Assuming that the ASTM thermometer is linear, how linear are the other transducers?

#### 3.4 For the transducers tested for time response, rank them in terms of time response. Does wind speed change the ranking?

#### 3.5 Assume that the relationship between time constant (\(\tau\)) and wind speed (\(v\)) is

\[
\tau = C v^{-r}
\]

where \(C\) and \(r\) are transducer-specific constants.
Find $C$ and $r$ from your data. (Hint: use non-linear regression with initial guesses for $C$ and $r$).

**NOTE: Using non-linear regression in SPSS**

Use **Analyze > Regression > Nonlinear**

Set up the equation for time response so that you have something like

$\Delta T = A \times \exp (-B \times t)$

Create a variable for $\Delta T$ using **Transform > Compute**

Then under dependent variable (in the non-linear regression dialog box) put $\Delta T$ and for the expression put $A \times \exp (-B \times \text{time})$, where ‘time’ is your time variable.

Under “Parameters” you will need to input a guess for both ‘$A$’ and ‘$B$’ so that the algorithm has somewhere to start. You can guess these parameters by visual inspection of the curve.

Then click OK to run the regression analysis.