12-778 Fall 2023: Assignment #3

Mario Bergés

Instructions

When answering the following questions, please provide all of your calculations to arrive at the answer (in addition to the answer itself). Your calculations should be very clear and easy to understand. They should include your assumptions, and a step-by-step explanation of how you arrived at the solution. Also, make sure you type your name and AndrewID somewhere on the first page, and that you clarify who you worked with in developing the intuitions behind your answer.

Some other recommendations:

- Before finding the answer to each question or looking at the next step in the solution, take some time to think about how you can come up with this on your own.
- Again, make sure you document everything you do, and not just write down the answer to the question. This will both help during grading as well as improving your learning process.
- Do not write down any solution or process that you do not understand. If you feel that you do not understand how to do something, seek some help. The preferred method for this is to post your questions on the discussion board for the course (i.e., Piazza).

Measurement Error and Uncertainty (50%)

Uncertainty Estimation (15%):

The density of air (ρ) can be estimated by measuring the absolute air pressure (p) and the aboslute temperature (T):

$$\rho = \frac{p}{RT}$$

where $R = 287.04$ J/(kg K) is the specific gas constant for dry air, ρ is in units of kg/m^3, T is in Kelvin and p is in mm Hg.

Assuming that the accuracy of the pressure and temperature measurements are 1 mm Hg and 1 K respectively, what is the uncertainty of the air density estimation when $T = 24$ Celsius and $p = 760$ mm Hg?

Total uncertainty (15%):

The supply air pressure in a duct is going to be kept constant at a set value for a series of tests. A damper controls the air flow (and pressure) supplied by the air handling unit. The duct is equiped with a dial gauge (resoluton of 1 psi and accuracy of 0.5 psi) to monitor the air pressure. Thirty trials of maintaining a static pressure of 50 psi are attempted to estimate how precisely the pressure can be controlled via the damper. The results show that the standard deviation in the set pressure is 2 psi. Estimate the total uncertainty at 95% confidence in the set pressure that would be expected during normal operation.

Note: since we do not know the population standard deviation, you will need to use Studennt's t-distribution.

Multiple-Measurement Uncertainty Analysis (20%):

The stress on a loaded wing for an electric drone is measured using a system consisting of a strain gague, a Wheatstone bridge, an amplifier, and a data acquisition system. The bias and precision uncertainties arising from calibration, data acquisition and data reduction are listed below:

Error source	**Bias uncertainty** (N/cm^2)	**Precision uncertainty** (N/cm^2)	# of Samples
Calibration	1.0	4.6	15
Data acquisition	2.1	10.3	38
Data reduction	0.0	1.2	9

Assume 100% reliability in the values of all bias errors and that there are no correlated uncertainties.

For 95% confidence, determine the range that contains the true mean value of the stress given that the average value is 223.4 N/cm^2.