Measurement Uncertainty Analysis

- Overall goal:

    Obtain an *estimate* of U_x, where

    x can be either a single value or an average value.

- The magnitude of U_x depends upon %C, the contributing uncertainties, and how these contributing uncertainties are combined.

Measurement Uncertainty Analysis

- The overall uncertainty, U_x, is related to the combined standard uncertainty, u_c, through a coverage factor, where

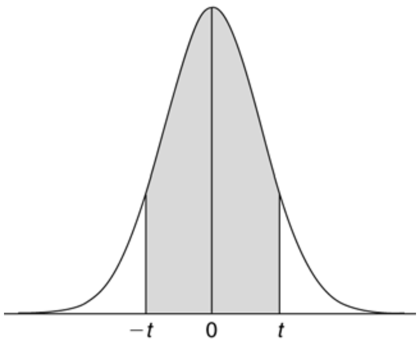
- For most experiments, $N \geq 10 >> t_{\nu,95} \approx 2$ (<10 % error). This implies $U_{x,95} \approx 2u_c =$. This is called *the large scale approximation*.

Student's *t* Table

Gives the value of *t* for a given ν and P % confidence .

TWO-SIDED STUDENT'S *t* VARIABLE VALUES

ν	$t_{\nu,P=50\%}$	$t_{\nu,P=90\%}$	$t_{\nu,P=95\%}$	$t_{\nu,P=99\%}$
1	1.000	6.341	12.706	63.657
2	0.816	2.920	4.303	9.925
3	0.765	2.353	3.192	5.841
4	0.741	2.132	2.770	4.604
5	0.727	2.015	2.571	4.032
6	0.718	1.943	2.447	3.707
7	0.711	1.895	2.365	3.499
8	0.706	1.860	2.306	3.355
9	0.703	1.833	2.262	3.250
10	0.700	1.812	2.228	3.169
11	0.697	1.796	2.201	3.106
12	0.695	1.782	2.179	3.055
13	0.694	1.771	2.160	3.012
14	0.692	1.761	2.145	2.977
15	0.691	1.753	2.131	2.947
16	0.690	1.746	2.120	2.921
17	0.689	1.740	2.110	2.898
18	0.688	1.734	2.101	2.878
19	0.688	1.729	2.093	2.861
20	0.687	1.725	2.086	2.845
21	0.686	1.721	2.080	2.831
30	0.683	1.697	2.042	2.750
40	0.681	1.684	2.021	2.704
50	0.680	1.679	2.010	2.679
60	0.679	1.671	2.000	2.660
120	0.677	1.658	1.980	2.617
∞	0.674	1.645	1.960	2.576



What is *t* for N = 12 ?

Table 8.4

Quadrature Combination of Uncertainties

- The combined standard uncertainty, u_c, comes from the combined estimated variance, u_c^2, which is expressed as:

assuming each x_i is *independent* of the other J-1 variables.

- r denotes a result (a variable that is a function of one or more measurands)

θ_i is the absolute sensitivity coefficient, which weights the uncertainty contribution of x_i to the result.

$\theta_i = 1$ for a measurand.

In-Class Example

- Determine the combined standard uncertainty in the dynamic pressure, u_p, where $p = ½ \rho V^2$. The measurement uncertainties are u_ρ = 0.03 kg/m^3 and u_V = 0.02 m/s. Assume nominal values of ρ = 1.16 kg/m^3 and V = 1 m/s.

In-Class Example (cont'd)

- What is the overall uncertainty in the dynamic pressure assuming the results were based upon a large number of measurements and 95 % confidence?

The large scale approximation gives

Tracking Down Uncertainties

- Uncertainties for an experiment can arise from

- We will focus on characterizing the first two sources of uncertainties. Some of the third (primarily related to curve fitting) will be considered later.

Temporal Precision Uncertainty

- When an experiment is conducted under ‘fixed’ operating conditions, the measurand signal still may vary somewhat in time. This results from uncontrolled ‘extraneous’ variables that change in time.