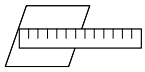
Measurement Uncertainty

Introduction

Why study uncertainty?

- What is my weight?

Experiment:

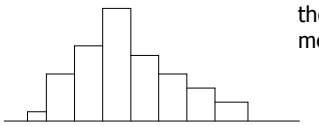


- Each person take one reading
- Do not divulge
- Pass after noting
- Make a histogram or dot plot

What is the measurement result?

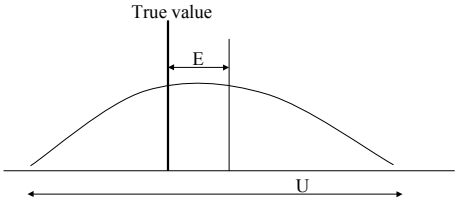
- How good is the result?
- How can we compare measurement results?
- Is the result significantly different?
- Is the procedure sufficient?
- How can we improve the procedure?

What is Measurement Uncertainty?



- the *quantification* of the *doubt* about the measurement result

Error vs Uncertainty?



ISO 9001:2000 Clause 7.6

- The organization shall determine the monitoring and measurement to be undertaken and the monitoring and measuring devices needed to provide evidence of conformity of product to determined requirements

Guide to the Expression of Uncertainty in Measurement:1993

- BIPM - Bureau International des Poids et Mesures
- IEC - International Electrotechnical Commission
- IFCC - International Federation of Clinical Chemistry
- ISO - International Organization for Standardization
- IUPAC - International Union of Pure and Applied Chemistry
- IUPAP - International Union of Pure and Applied Physics
- OIML - International Organization of Legal Metrology

What is uncertainty (of measurement)?

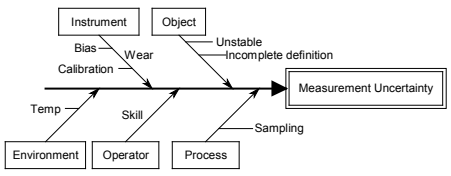
- Parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

– ISO/VIM1993: 3.9

The parameter

- Could be
  - a standard deviation
  - Half width of an interval
  - Any, which characterizes the spread of distribution

Why does uncertainty occur?



Sources of error and uncertainty in dimensional calibrations

- Reference standards and instrumentation
- Thermal effects
- Elastic compression
- Cosine errors
- Geometric errors

– UKAS M3003 Dec 1997

Sources of error and uncertainty in temperature calibrations

- Calibration of reference thermometer
- Measuring instruments
- Further influences
  - Drift since calibration
  - Resolution
  - Temp gradients
  - Self heating
- Contributions of thermometer to be calibrated
- Mathematical interpretation

– UKAS M3003 Dec 1997

Sources of error and uncertainty in mass calibrations

- Reference weight calibration
- Secular stability of reference weights
- Weighing machine / weighing process
- Air buoyancy effects
- Environment

– UKAS M3003 Dec 1997

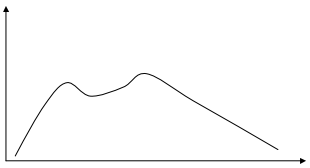
Sources of error and uncertainty in electrical calibrations

- Instrument Calibration
- Secular Stability
- Measurement Conditions
- Interpolation of calibration data
- Resolution
- Layout of apparatus
- Thermal emfs
- Loading and lead impedance
- RF mismatch errors and uncertainty
- Directivity
- Test port match
- RF Connector repeatability

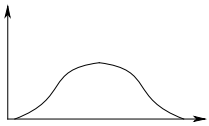
– UKAS M3003 Dec 1997

Distribution

- The shape of the different measurement results

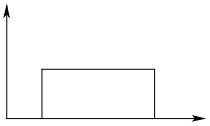


Normal distribution



- Likely to be in the middle
- Resultant of a large number of small causes, none dominant
- Very common

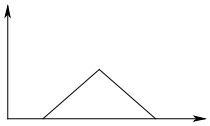
Uniform distribution



- Equally likely at any point
- Digital output

Triangular distribution

- Sum of two dominant rectangular distributions



Standard uncertainty

- Uncertainty of the result of a measurement expressed as a standard deviation

  – GUM 2.3.1

- Denoted by u

Combined standard uncertainty

- Standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the variances or covariances of these other quantities weighted according to how the measurement result varies with changes in these quantities

  –GUM 2.3.4

- Denoted by u_c

Expanded uncertainty

- Quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could be reasonably be attributed to the measurand

  – GUM 2.3.5

- Usual practice: 95%
- Denoted by U

How to evaluate uncertainty?

- Type A
  - By statistical analysis of a series of observations
  - probability density function derived from an observed frequency distribution
- Type B
  - By means other than statistical analysis
  - assumed probability density function based on the degree of belief that an event will occur

Do not mix up!

- Random and systematic components of uncertainty do not correspond to Type A and Type B.
- Type A Evaluation,
- Type A Regression
- Type B Evaluation