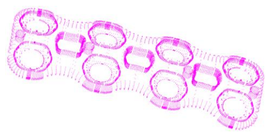
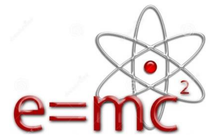
Measuring Procedure

- Conditions
- Strategy
- Clamping
- Fixturing
- Probing principle
- Probing strategy
- Probing alignment
- Number of data points
- Number of measurements
- Order of measurements
- Duration of measurements
- Choice of principal
- Choice of reference
- Choice of apparatus
- Choice of metrologist
- Alignment
- Number of operators
- system
- Drift check
- Reversal measurements
- Multiple redundancies, error separation

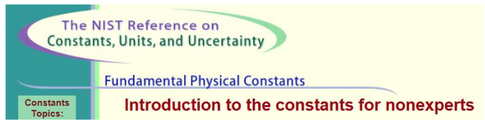


Physical Constants and Conversion Factors

- Knowledge of the correct physical values of, for example, material properties (workpiece, measuring instrument, ambient air, etc.)

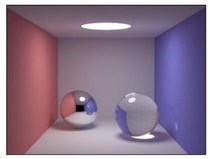


http://physics.nist.gov/cuu/Constants/introduction.html



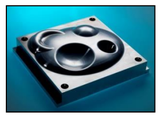
Environment

- Temperature
- Vibration / noise
- Humidity
- Contamination
- Illumination
- Gravity
- Ambient pressure
- Air composition and flow
- Electromagnetic Interference
- Transients in the power supply
- Pressured air (e.g. air bearings
- Heat Radiation
- Instrument thermal equilibrium



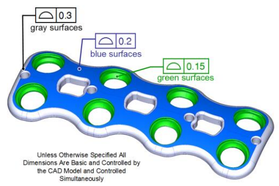
Reference Element of Measurement Equipment

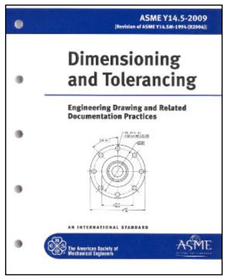
- Uncertainty of the calibration
- Time since last calibration
- Stability
- Scale mark quality
- Coefficient of thermal expansion, thermal time constant
- Physical Principle: line scale, optical digital scale, magnetic digital scale, spindle, rack and pinion, interferometer
- CCD-techniques
- Wavelength error

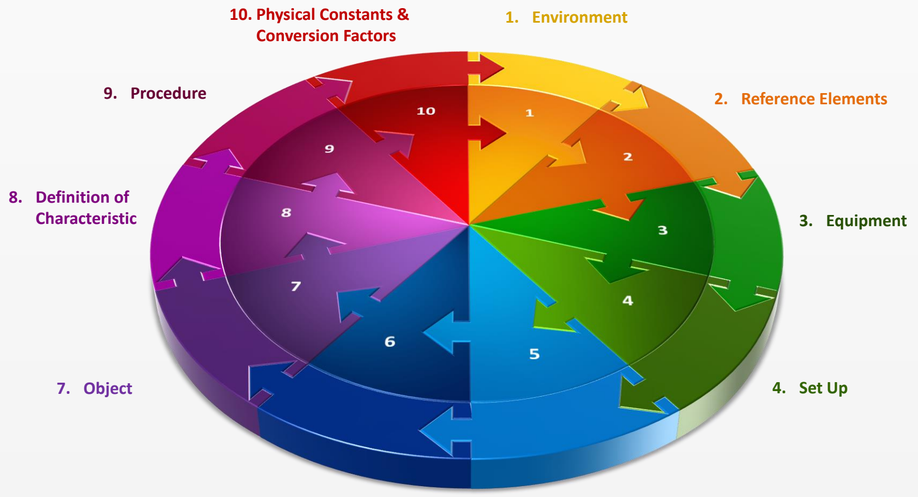


Definition of Characteristic

- Reference conditions
- Datum, reference system
- Degrees of freedom
- Toleranced feature
- Distance
- Angle

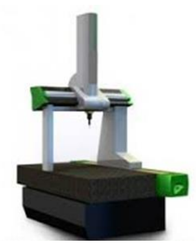






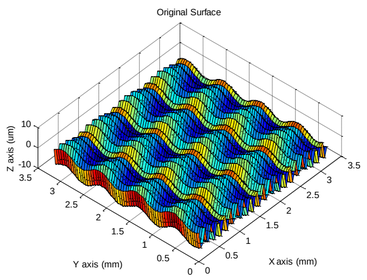
Measuring Equipment

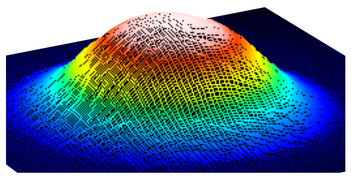
- Stylus / probe configuration and calibration
- Geometrical imperfections
- Stiffness / rigidity
- Sampling strategy
- Probe reading system
- Temperature, CTE, time constants
- Temperature stability / sensitivity
- Time since last calibration
- Magnification stability
- Wavelength error
- Zero-point stability
- Interpretation system
- Force stability/absolute force
- Hysteresis
- Guides / slideways
- Abbe, Cosine errors
- Response characteristic
- Interpolation system
- Interpolation resolution
- Digitization



Measuring Object

- Form deviations
- Surface roughness
- Stiffness
- Cleanliness
- Workpiece distortion due to clamping
- Temperature, CTE
- Weight, shape, size
- Creep Characteristics
- Internal stress, stability
- Elastic modulus (Young's modulus)
- Poisson ratio
- Thermal conductivity and diffusivity
- Magnetism
- Hydroscopic characteristics
- Aging, dimensional stability
- Orientation





Wheel of Uncertainty Contributors (Design, Manufacturing & Measurement)

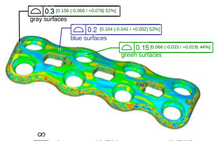
Dr. Greg Hetland, President - IIGDT

Metrologist

- Education, training, knowledge
- Experience, dedication
- Heat source
- Physical ability
- Personal diligence
- Honesty

Software and Calculations

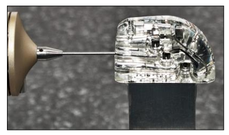
- Sampling, filtering
- Algorithms and implementation
- Validity / certification of algorithms
- Rounding / quantification
- Significant digits in the computation
- Interpolation/ extrapolations
- Outlier handling

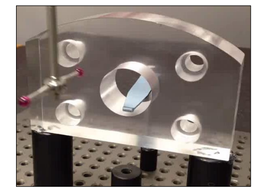


$$f(x) = a_0 + \sum_{n=1}^{\infty}\left(a_n \cos\frac{n\pi x}{L} + b_n \sin\frac{n\pi x}{L}\right)$$

Measuring Setup

- Interaction between workpiece and setup
- Temperature sensitivity, warm up
- Stiffness / rigidity / stability
- Tip radius
- Form deviation of tip
- Stiffness of the probe system
- Abbe, Cosine errors
- Optical aperture





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