

**CANADIAN CERTIFICATION OF
COORDINATE MEASURING MACHINES(CMMs)
PROFESSIONALS**

Draft 3/ May 2000

BODY OF KNOWLEDGE

A. TECHNICAL MATHEMATICS

1. Basic operations
 - Addition, subtraction, multiplication, division
 - Exponent, powers, roots
 - Fractions
2. Trigonometry
 - Trigonometric functions
 - Use of calculator for trigonometric functions of any angle
 - Trigonometric conversions
3. Algebra
 - Polynomials
 - Inequalities
 - Linear algebra for coordinate manipulation
4. Matrices
 - Addition, subtraction and multiplication
 - Matrix inversion
5. Vectors
 - Dot and cross vector product
 - Construction of a rotation matrix using orthonormal vectors
 - Reference frame transformation
 - Normalization of a vector
6. Geometry in plane and space
 - Angles
 - Triangles and relations of their main features
 - Circles
 - Solid bodies
7. Analytical geometry
 - Coordinate systems
 - Straight lines, segments
 - Circles
 - Planes and surfaces
 - Solid bodies
8. Calculus (partial derivatives for uncertainty evaluation)
 - Derivative
 - Basic differentials
9. Optimization
 - Least square minimization
10. Measuring units
 - Length (inch and metric, conversion)
 - Temperature ($^{\circ}\text{C}$, $^{\circ}\text{F}$, $^{\circ}\text{K}$, conversion)
 - Humidity
 - Vibrations

B. TECHNICAL DRAWINGS

1. General principles
 - Orthographic projections
 - Drawing conventions
 - First and third angle projection
 - Drawing conventions
 - Dashed lines, solid lines, centerlines
 - Partial and enlarged views
 - Sections
 - Scales
 - Auxiliary views
2. Dimensional tolerances
3. Limits and fits
 - International tolerance grades
 - Fundamental deviations
4. Geometric dimensioning and tolerancing

C. APPLIED STATISTICS FOR MANUFACTURING

1. Basic theory of probabilities
2. General terms
 - Histogram
 - Normal distribution
 - Binomial distribution
 - Mean and standard deviation
 - Normal probability curve
 - Central limit theorem
3. Process capability
 - C_p and C_{pk} ratios
4. Process control charts
 - Charts for variables
 - Estimated process standard deviation
 - Control limits
 - Charts for attributes
5. Statistical sampling
 - Non-conforming product and non-conformities
 - Acceptable quality level
 - Sampling plans

D. DIMENSIONAL METROLOGY, MEASURING INSTRUMENTS

1. Language of measurement
 - Abbe's principle
 - Accuracy, precision and reliability
2. Measurement with graduated scales
3. Vernier instruments
4. Micrometer instruments
5. Gage blocks

6. Dial indicators and high amplification comparators
7. Pneumatic measurement
8. Optical metrology
9. Reference planes
10. Angle measurement
11. Surface metrology
12. Measurement of roundness

E. COORDINATE MEASURING MACHINE — HARDWARE

1. CMMs types, advantages and limitations
2. Measuring scales
3. Probes types, advantages and limitations
4. Measuring environment and its influence on CMMs accuracy

F. COORDINATE MEASURING MACHINE — SOFTWARE

1. Measured geometric elements
2. Basic programming
3. Programming routines
4. Operator interface
5. Best-of-Fit mathematics
6. Software architecture
7. DMIS
8. CAD and CMMs software interface

G. CMMs PERFORMANCE EVALUATION

1. Errors and uncertainty
 - Error types
 - Machine structure dependent
 - Geometrical errors
 - Dynamic errors
 - Probe dependent error
 - Ambient conditions dependent
 - Temperature dependent
2. Probe effective type radius
3. Errors combination and propagation
4. Methods and artifacts used to discover errors
 - 1D artifact (gage blocks and length bars)
 - 2D artifacts (ball bars and ball plates)
 - 3D artifacts (spatial structure)
5. CMMs acceptance and re-verification tests
 - Interim testing and suitable artifacts
 - Software error compensation
 - Software temperature compensation
6. International standards for CMM acceptance and verification
 - Machine uncertainty in 1D, 2D and 3D
7. International standards for assessment of measurement uncertainty
8. Uncertainty rules for accepting and rejecting parts

H. USER GROUPS AND ASSOCIATIONS, CERTIFICATION BODIES, ETC

1. Association for Coordinate Metrology Canada;
www.acmc-canada.ca
2. CMM Forum —USA; www.mimet.com
3. Certification of CMM operators — Italy;
www.cmmclub.it
4. CMM group — Australia;
www.ozemail.com.au/