19.2.0   METROLOGY AND INDUSTRIAL MEASUREMENT I

19.2.1   Introduction
Metrology and industrial measurement deals with knowledge and skills on the importance and proper use of measuring and inspection instruments to facilitate interchange ability of industrial spare parts. The technology also involves calibration and organisation of the standard room.

The module unit is designed to impart to the trainee competencies required to maintain and calibrate precision measuring equipment. Trainees undertaking this module unit will require knowledge of Engineering Drawing, Engineering materials, Mathematics and basic Science.

19.2.2   General Objectives
By the end of the module unit, the trainee should be able to:
a) demonstrate safe working habits in the metrology laboratory
b) understand the working principles of measuring and inspection equipment used in the metrology laboratory
c) acquire the skills and knowledge required to do calibration to correct errors on instruments
d) care for tools and equipment

19.2.3   Module Unit Summary and Time Allocation

METROLOGY AND INDUSTRIAL MEASUREMENT I

Code	Sub module Unit	Content	Theory hrs	Pract Hrs	Time hrs
19.2.01	Standards Room Organization	• Organization of a standards room • Role of standards room • Calibration and certification • Function of Kenya Bureau of Standards	2	2	4
19.2.02	Measurement	• Standardization and interchange ability • Slip gauges and accessories • Reference surfaces	2	4	6
19.2.03	Inspection Gauges	• Gauging • Taylor's principle	2	4	6

		• Gauge tolerance • Construction and operation			
19.2.04	Comparators	• Comparative measurement • Types of comparators	2	6	8
19.2.05	Straightness and Flatness Testing	• Error expression • Precision spirit and electronic levels • Angle Dekkor • Uses	2	2	4
19.2.06	Angular Measurement	• Optical principles • Setting and reading • Autocollimator • Accessories	2	6	8
19.2.07	Roundness	• BS 3730 • Numerical assessment • Polar graphs	2	4	6
19.2.08	Kinematics	• Kinematic principles • Applications	4	4	8
19.2.09	Screw Thread Measurement	• Screw thread features • Screw thread fits • Screw thread measurement • Taylor's Principles	4	4	8
19.2.10	Interferometry	• Types of lights • Principle of measurement • Interferometers and their principles • Typical applications	4	2	6
19.2.11	Statistical Quality Control	• Statistical Quality Control– definition • Control charts and their use • Manufacturing considerations	4	4	8
19.2.12	Gear Measurement	• Gear tooth measurement • Gear errors	4	4	8
19.2.13	Surface Texture	• BS1134 • BS3634	4	4	8

		Surface texture analysis · Surface texture measurement			
Total			**38**	**50**	**88**

		Content

19.2.01   **STANDARDS ROOM ORGANIZATION**

Theory

19.2.01T0   *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) describe the organisation of standard room
b) describe role of standards room
c) explain the need for calibration
d) outline the role of Kenya Bureau of Standards (KEBS)

19.2.01C   *Competence*
The trainee should have the ability to:
   i) Organize a standards room
   ii) Interpret functions of Kenya Bureau of Standards
   iii) Control product quality
   iv) Care for tools and equipment

Content

19.2.01T1   Organization of standard room
   - Personnel required
   - Personnel authority and responsibility

19.2.01T2   Role of standards room
   - Measuring and gauging equipment
     o Checking
     o Control
     o Recommendation
   - Product control
     o Quality

19.2.01T3   Calibration and certification

19.2.01T4   Role of Kenya Bureau of Standards
   - Relevant Act of parliament

Practice

19.2.01P0   *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) organize a standards room
b) care for tools and equipment in the standard room

	Content	19.2.02C	*Competence*
19.2.01P1	Organisation of a standard room		The trainee should have the ability to:
19.2.01P2	Care and maintenance of tools and equipment in a standard room	i)	distinguish standardization and interchangeability
		ii)	use and maintain slip gauges and their accessories.
19.2.01P1	Organisation of a standard room	iii)	use and care for precision rollers and balls
		iv)	use and maintain combination bars and reference surfaces
	Suggested Learning Resources	v)	build up a given dimension using slip gauges

19.2.01P1 Organisation of a standard room

Suggested Learning Resources
- Metrology laboratory equipment
- Relevant Act of Parliament - Kenya Bureau of Standards (KEBS)

19.2.02   MEASUREMENT

Theory

19.2.02T0   *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) explain standardization and interchangeability
b) describe slip, gauges and their accessories
c) describe precision rollers and balls
d) explain combination bars
e) describe reference surface

19.2.02C   *Competence*
The trainee should have the ability to:
i) distinguish standardization and interchangeability
ii) use and maintain slip gauges and their accessories.
iii) use and care for precision rollers and balls
iv) use and maintain combination bars and reference surfaces
v) build up a given dimension using slip gauges

Content
19.2.02T1   Standardization and interchangeability of products
19.2.02T2   Slip gauges
- Requirements of lapped measuring surfaces of slip gauges
- Grades of slip gauges
- Standard procedures for maintaining accuracy during use of slip gauges
- Slip gauge accessories
  o Assemblies
19.2.02T3   Precision rollers and balls
- Care and uses
19.2.02T4   Combination bars
- Use limitation and source of errors

234

19.2.02T5   Reference surface
    -    Surface table
    -    Surface plate

Practice

19.2.02P0   *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a)   prepare slip gauges for wringing
b)   wring slip gauges to obtain a given length
c)   care for slip gauges, precision roller and balls
d)   use precision roller and balls

Content
19.2.02P1   Preparation of slip gauges
19.2.02P2   Wringing of slip gauges
19.2.02P3   Use of precision roller and balls
19.2.02P4   Care for slip gauges, precision rollers and balls and reference surface

Suggested Learning Resources
    -    Equipment in the metrology laboratory
    -    Slip gauges and accessories
    -    Precision rollers and bars

    -    Combination bars of reference surfaces

19.2.03   STRAITGHTNESS AND FLATNESS TESTING

Theory

19.2.03T0   *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a)   describe error expression
b)   describe precision spirit electronic levels
c)   describe uses of levels
d)   describe the construction and operation of angle dekkor
e)   describe alignment test

19.2.03C   **Competence**
The trainee should have the ability to:
i)   Describe error expression
ii)   Describe principle of operation and construction of precision spirit and electronic levels
iii)   Determine errors

Content
19.2.03T1   Error expression

- Straightness relative to mean line
- Flatness relative to mean plane

19.2.03T2 Precision spirit and electronic levels
- Principle of operation
- Construction

19.2.03T3 Uses of levels
- Flatness testing
- Straightness testing
- Levelling

19.2.03T4 Angle dekkor

19.2.03T5 Alignment test
- Test mandrels,
- Spirit level
- Application on machine tools

Practice

19.2.03P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) use spirit level for flatness test
b) use angle dekkor for straightness test
c) perform alignment test
d) analysis the results (determine errors)

Content
19.2.03P1 Use of spirit level
19.2.03P2 Use of angle dekkor
19.2.03P3 Use of dial test indicator (D.T.I)

19.2.03P4 Analyze of result

Suggested Learning Resources
- Equipment in metrology laboratory
  o Precision spirit level
  o Electronic level
  o Angle dekkor
  o Dial testing indicator
  o Surface plate
  o Surface table

19.2.04 COMPARATORS

Theory

19.2.04T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) explain comparative measurement
b) describe error correction in comparative measurement
c) describe measurement comparators and their measuring principles

19.2.04C *Competence*
The trainee should have the ability to:
i) Carryout comparative measurement

236

ii) Correct errors in comparative measurement
iii) Describe the working principle of various comparators
iv) Care and maintain a given comparator
v) Carry out measurements using comparator

Content
19.2.04T1 Comparative measurement
19.2.04T2 Error correction
- Cosine
- Sine
- Parallax
19.2.04T3 Comparators
- Mechanical
  o Dial Testing Indicator (D.T.I) (plunger type)
  o Sigma
  o Johanson Mikrokator
- Electrical
  o Pneumatic comparators
  o Optical comparators
  o Mechanical optical comparators
- Electrical comparators
  o Measuring head
  o Magnification
  o Advantages and

disadvantages of:
- Mechanical comparators

Practice

19.2.04P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) identify various types of comparators
b) carry out measurement using various comparators

Content
19.2.04P1 Use various comparators
- Mechanical
- Electrical
- Pneumatic
- Optical
- Mechanical optical
19.2.04P2 Carrying out measurement using various comparators
Suggested Learning Resources
- Metrology laboratory equipment
  o Dial Testing Indicator (D.T.I)
  o Sigma
  o Johanson Mikrokator
- Electrical comparator
- Pneumatic comparator

237

19.2.05 INSPECTION GAUGES

Theory

22.2.5T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) describe gauging
b) state Taylor's principle of gauging
c) describe disposition of gauge tolerance and use tables to calculate gauge dimensions
d) describe the construction and operation of various types of gauges
e) describe types of gap gauges
f) care and maintain inspection gauges

19.2.05C *Competence*
The trainee should have the ability to:
i) Use various gauges
ii) Identify various types of inspection gauges
iii) Apply Taylor's principle of gauging
iv) Use BS969 to calculate gauge dimensions

v) Set gap gauges
vi) Care and maintain inspection gauges
Content
19.2.05T1 Gauging description
19.2.05T2 Statement of Taylor's principle of gauging
19.2.05T3 Gauge tolerances
- Disposition from nominal size
- GO and NO GO
- Wear allowance
- Calculation of dimensions (BS 969)
- Maximum and minimum metal condition
- Tolerance buildup and geometrical tolerance
19.2.05T4 Construction and operation of gauges
- Plug gauges
- Ring gauges
19.2.05T5 Gap gauges
  o fixed
  o adjustable
- Step gauges
- Screw thread gauges
19.2.05T6 Care and maintenance

Practice

22.2.5P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) identify various inspection

238

b) use various inspection gauges
c) design inspection gauges using BS 969
d) care and maintain inspection gauges

Content
19.2.05P1 Identification of various inspection gauges
  - Plug gauge
  - Ring gauge
  - Fixed and adjustable gap gauge
  - Step gauge
  - Screw thread gauge
19.2.05P2 Using various inspection gauges
19.2.05P3 Designing inspection gauges using BS 969
19.2.05P4 Caring and maintaining inspection gauges

Suggested Learning Resources
Equipment in metrology laboratory
  - BS 969 table, BS 4500
  - Gauges
    Plug
    Ring
    Gap
    Step
    Screw

19.2.06   ANGULAR MEASUREMENT

Theory

19.2.06T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) explain optical principles and their uses
b) describe various angular measuring devices
c) describe the setup of angular measuring devices
d) care for and maintain angular measuring devices

19.2.06C *Competence*
The trainee should have the ability to:
 i) Use optical instruments in angular measurement
 ii) Use
      o Autocollimator
      o Angle gauges
      o Sine bar
      o Sine table
      o Clinometers
 iii) Use angle block in angular measurement
 iv) Test using angular measuring equipment and accessories

v) Demonstration

Content

19.2.06T1 Optical principles and typical uses
  - Auto collimator
  - Alignment tolerance

19.2.06T2 Angular measuring devices
  - Autocollimator
  - Angle gauges
  - Sine bar
  - Sine table
  - Clinometers

19.2.06T3 Principles and use of angle blocks

19.2.06T4 Uses of angle block and auto collimator to:
  - Calibrate a circular divided scale
  - Determine errors due to eccentricity of mounting
  - Check angles
  - Calibrate precision polygons
  - Perform alignment test on bores and surfaces

Practice

19.2.06P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) set up angular measuring devices
b) use angular measuring devices

c) care and maintain angular measuring devices

Content

19.2.06P1 Set up of angular measuring devices
  - Autocollimator
  - Sine bar
  - Sine table
  - Angle gauges
  - Clinometers
  - Angle gauges

19.2.06P2 Use of angular measuring devices
  - Calibrate a circular divided scale
  - Determine error due to eccentricity of mounting
  - Check angles
  - Calibrate precision polygons
  - Perform alignment test on bores and surfaces

19.2.06P3 Caring and maintaining angular measuring devices

Suggested Learning Resources
  - Metrology lab equipment
  - Autocollimator
  - Sine bar
  - Sine table
  - Clinometers
  - Angle block

19.2.07   ROUNDNESS

Theory

240

19.2.07T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) explain the provision of BS3730
b) describe polar graphs
c) describe the BS3730 provision to assess roundness error
d) care and maintain roundness testing devices

Content
19.2.07T1 BS3730 provision
19.2.07P2 Polar graphs
- Radial magnification
- Frequency filter
19.2.07P3 Caring and maintaining roundness testing devices

Practice

19.2.07P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) use BS 3730 provision to assess roundness error
b) set roundness testing devices
c) perform roundness test

Content
19.2.07P1 Provisions of BS 3730
- Polar graphs
- Radial magnification
19.2.07P2 Setting roundness testing devices
19.2.07P3 Assess roundness

19.2.07C **Competence**
The trainee should have the ability to:
i) Explain the provisions of BS3730
ii) Set roundness testing devices
iii) Assess roundness

Suggested Learning Resources
- Equipment in metrology laboratory
- Dial Testing Indicator

19.2.08 KINEMATICS

Theory

19.2.08T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) explain the principle of kinematics to instrument design
b) describe the application of kinematics in

241

various instruments to minimize error
c) identify systems operating on kinematics
d) gauging

a) identify system operating on kinematics principles
b) apply principles of kinematics in instrument design

19.2.08C   *Competence*
   i) The trainee should have the ability to:
   ii) Apply principles of kinematics in instrument design

Content

19.2.08T1 Principle of Kinematics
- Six degrees of freedom
- Constraints
- Location
- Flexible connections
- Thrust bar

19.2.08T2 Applications of kinematics
- Floating carriage micrometer
- Pitch measuring machine
- Gear rolling tester

19.2.08T3 Identifying systems operating on kinematics

19.2.08T4 Gauging

Practice

19.2.08P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:

Content
19.2.08P1 Systems operating on kinematics principles
- Floating carriage micrometer
- Pitch measuring machine
- Gear rolling tester

19.2.08P2 Apply kinematics on:
- floating carriage micrometer
- pitch measuring machine
- gear rolling tester

Suggested Learning Resources
- Equipment in metrology laboratory
- Floating carriage micrometer
- Gear rolling tester
- Pitch measuring machine

19.2.09   SCREW THREAD MEASUREMENT

Theory

19.2.09T0 *Specific Objectives*
By the end of the sub-module unit, the

trainee should be able
to:
a) describe features of
   a screw thread
b) describe screw
   thread fits
c) describe screw
   thread
   measurement
d) apply Taylor's
   principle in screw
   thread gauging

19.2.09C   *Competence*
           The trainee should
           have the ability to:
           i)   Describe features
                of a screw thread
           ii) Describe classes
                screw thread fits
           iii) Measure simple
                effective
                diameter using:
                - Two wire
                  system
                - 3 wire system
           iv) Apply Taylor's
                principle to
                design screw
                thread gauges
           Content
19.2.09T1 Screw thread features
           - Flank angle
           - Pitch
           - Effective diameter
           - Minor/major
             diameter
           - Root
           - Simple effective
             diameter
19.2.09T2 Screw thread fits
           - Classes of fits
             o Fine
             o Medium

             o Coarse
           - Standard grade
             designations
             o Fine fit
             o Medium fit
             o Coarse fit
19.2.09T3 Screw thread
           measurement
           - Two wire system
           - Three wire system
           - Measurement of
             simple effective
             diameter
           - Cumulative
             periodic pitch
             errors
           - Measurement of
             internal thread
             using stylus
19.2.09T4 Taylor's principle in
           design of screw thread
           gauges

           Practice

19.2.09P0 *Specific Objectives*
           By the end of the sub-
           module unit, the
           trainee should be able
           to:
           a) identify features
               of a screw thread
           b) perform screw
               thread
               measurement

           Content
19.2.09P1 Features of screw
           thread:
           - Flank angle
           - Pitch
           - Effective diameter

- Minor and major diameters
- Root
- Simple effective diameter

19.2.09P2   Measure features of screw thread:
- Two wire system
- Three wire system
- Simple effective diameter
- Cumulative periodic
- Internal thread using styles

Suggested Learning Resources
- Equipment in metrology laboratory
- Screw thread measuring machine

19.2.010   INTERFEROMETRY

Theory

19.2.10T0   *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) describe types of light
b) describe principles of measurement by interference of light waves
c) describe interferometers and their principle

d) explain typical applications of interferometry

19.2.10C   *Competence*
The trainee should have the ability to:
i) Name types of lights
ii) Use interference of light in length measurement
iii) Use interferometers for:
- Slip gauge testing
- Calibration
iv) Produce fringe patterns on various surfaces

Content

19.2.10T1   Types of light
- White
- Monochromatic

19.2.10T2   Principle of measurement
- Formation of fringes
- Spacing of fringes
- Relationship of fringe spacing and the difference in surface height and optical flat
- Effect of change in surface shape on fringes

19.2.10T3   Interferometers and their principle
- Length (N.P.L type)
- Flatness (N.P.L. type)

244

19.2.10T4 Typical applications
- Slip gauge testing
- Calibration
- Convex surface, concave surface, flat surface

Practice

19.2.10P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) produce fringe patterns on various surfaces
b) interpret the fringe patterns
c) use interferometry in a typical test

Content
19.2.10P1 Fringe patterns
- Optical
- Convex surface
- Concave surface
19.2.10P2 Interpretation of fringe patterns
19.2.10P3 Typical test
- Sleep gauge testing
- Calibration testing

Suggested Learning Resources
- Equipment in the metrology laboratory
- Interferometer

19.2.11 **STATISTICAL QUALITY CONTROL**

Theory

19.2.11T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) explain the term statistical quality control
b) explain the construction of control charts
c) explain the use of control charts to control production quality
d) explain manufacturing considerations in acceptance sampling schemes

19.2.11C *Competence*
The trainee should have the ability to:
i) Draw control charts
ii) Use control charts to control quality
iii) Select an appropriate sampling scheme

Content
19.2.11T1 Statistical quality control:
- definition
- justification
- application

19.2.011T2 Control charts
- simple average (X – chart)
- simple range (R – chart)
- fractional defective (P – chart)
- in process/post process methods of automatic dimensional control

19.2.11T3 Use of control charts
- direct and indirect open loop and closed loop systems
- calculation of average outgoing quality (AOQ) and construct (AOQ) curve from data

19.2.11T4 Acceptance sampling schemes

Practice

19.2.11P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) construct control charts
b) use control charts to control production quality

Content
19.2.11P1 Control charts:
- Simple average (X-chart)
- Simple range (R-chart)

- Fractional defective (P-chart)
- Automatic dimension control

19.2.11P2 Use of control charts
- Direct and indirect open loop and closed loop systems
- Calculation of average out going quality (AOQ) and construct (AOA) curve from data

Suggested Learning Resources
- Industrial visit
- Handout
- Textbook
- Trainer manual

19.2.12 GEAR MEASUREMENTS

Theory

19.2.12T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) describe gear tooth measurement by various methods
b) describe the principle and methods of measurement applied to helical gears
c) relate error to manufacture

d) operate gear tooth
measuring devices

19.2.12C   *Competence*
The trainee should
have the ability to:
  i) Measure gear
     tooth thickness
  ii) Set up gear rolling
      test machine to
      find gear pitch
      error and
      eccentricity of
      teeth

Content
19.2.12T1   Tooth thickness
  - Gear tooth vernier
  - Constant chord
    comparator
  - Measurement over
    roller
19.2.12T2   Helical gears
  - Gear rolling test
    machine
    o Pitch error
    o Eccentricity of
      teeth
  - Comparison of
    helical and spur
    gear elements
    o Circular pitch
    o Module
    o Tooth thickness
    o P.C.D.
    o Chordal
      thickness
    o Base diameter
    o Pitch
  - Typical gear errors
19.2.12T3   Error in involutes form
  - Optical projector
    and master drawing

  - Involutes profile
    testing machine
19.2.12T4   Operating gear tooth
measuring devices

Practice

19.2.12P0   *Specific Objectives*
By the end of the sub-
module unit, the
trainee should be able
to:
a) operate gear tooth
   measuring devices
b) measure gear
   parameters

Content
19.2.12P1   Operation of gear tooth
measuring machine
19.2.12P2   Measurement of gear
parameters
  - Circular pitch
  - Module
  - Tooth thickness
  - P.C.D.
  - Base diameter
  - Chordal thickness
  - Pitch

*Suggested Learning
Resources*
  - Equipment in the
    metrology
    laboratory
  - Gear rolling test
    machine

19.2.13   SURFACE TEXTURE

Theory

19.2.13T0   *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) explain surface finish terms using relevant standards
b) describe surface texture analysis methods
c) describe the construction and operation of surface texture measuring instruments
d) explain the effect of surface texture

19.2.13C   *Competence*
The trainee should have the ability to:
 i) Carryout a surface roughness test
 ii) Analyze surface texture using a given method

Content
19.2.13T1   Surface texture terminology
- Provision of relevant standards
  o BS1134
  o BS3634
- Terminologies
  o Lay
  o Waviness

  o Metre cut off length
  o Roughness

19.2.13T2   Surface texture analysis
- Peak valley height (Rz)
- Arithmetic mean deviation (Ra)

19.2.13T3   Surface texture measuring instruments
- Stylus instrument
- Mechanical roughness instrument
- Optical comparison
- Surface replicas

19.2.13T4   Surface texture effects
- Fatigue life
- Bearing properties
- Wear, manufacturing costs

Practice

19.2.13P0   *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
a) identify and operate various surface texture measuring devices
b) carry out surface texture test
c) analysis results of surface texture test

Content
19.2.11P1   Surface texture measuring and devices
- Stylus instrument

- Mechanical roughness instrument
- Optical comparison
- Surface replicas

19.2.13P2 Surface texture analysis
- Peak valley height (Rz)
- Arithmetic mean deviation (Ra)

19.2.13P3 Analysing results of surface texture test

Suggested Learning Resources
- Equipment in metrology laboratory
- Talysurf
- Profilometer
- profilograh