

# **Appendix L**

## **SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH (STEM) YOUTH APPRENTICESHIP**

### **ENGINEERING & TECHNOLOGY PATHWAY MECHANICAL/ELECTRICAL ENGINEERING (UNIT 4)**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 1. Apply manufacturing & mechanical/electrical systems principles

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite

Performance Standard Criteria

**Performance will be successful when learners:**

- Demonstrate Manufacturing and Mechanical and/or Electrical Engineering principles understanding based on **current knowledge and training**
- Comply with specifications, regulations, and codes during the design process

Learning Objectives

#### MANUFACTURING

- Recognize how manufacturing skills can aid those in an engineering role
- Define common processes used in the following manufacturing processes:
  - Machining
  - Cutting, drilling, and bonding
  - Joining & Welding
  - Finishing & Assembly
- Explain the function of the following manufacturing equipment:
  - CNC
  - Lathe
  - Milling Center
  - Machine Center
  - Router
  - Grinder
  - Welding equipment
  - Jigs and fixtures

#### MECHANICAL SYSTEMS

- Describe the simple machines
- Identify the characteristics of simple machines
- Explain the function of pulleys, gears, and belts
- Explain fluid power
- Illustrate how pressure distributes itself in a closed system

#### ELECTRICAL SYSTEMS

- Determine the basic requirements for an electrical circuit to function
- Determine the basic requirements of a series circuit
- Examine the differences and similarities of series and parallel circuits
- Analyze and describe the relationship between voltage, current and resistance
- Explore the relationship between electricity and magnetism
- Identify common components used in electronics

**Comments:**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 2. Interpret mechanical/electrical technical drawings

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite

Performance Standard Criteria

**Performance will be successful when learners:**

- Interpret mechanical and/or electrical technical drawings accurately as needed for job task
- Use appropriate terminology
- Identify basic elements of mechanical and/or electrical technical drawings
- Identify lines, views, symbols, and representations on the drawings as applicable
- Interpret dimensions and scale on the drawings as applicable
- Interpret product specifications
- Interpret (geometric) dimensioning and tolerancing symbols
- Analyze part prints

Learning Objectives

- Describe the relationship between Parts, Assemblies and Drawings
- List types and purposes of engineering technical drawings
- Describe the common conventions of engineering technical drawings for such things as layout, terminology, interpretation, appearance, size, etc.
- Compare standard views required for engineering technical drawings such as multiview, section, auxiliary, pattern, exploded
- Compare working drawings to assembly drawings
- Identify threads and thread terms
- Identify fasteners
- Identify gears and gearing terms
- Identify cams and cam terms
- Identify welding joints and welding terms & symbols
- Identify tolerancing fit symbols and feature control
- Identify surface finish symbols
- Identify electronic/electrical symbols and how to arrange the components

**Comments:**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 3. Develop the engineering problem & plan with team

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite

Performance Standard Criteria

**Performance will be successful when learners:**

- Review the engineering problem, project instructions, and/or specifications requirements with worksite professional
- Brainstorm possible solutions to meet project specifications with engineering team
- Identify engineering work piece/part/process to be designed
- Write a problem statement based on team input
- Create a decision matrix based on the problem statement
- Identify & plan requirements for research and drawing
  - Identify research needed prior to drawing
  - Identify critical features on the part/process
  - Identify the key control characteristics
  - Research previous FMEA for similar work pieces/parts/processes
  - Assess the seriousness of the failure effect on the next component or the user
  - Determine design methods or product features that help diagnose failure
- Review conclusions with worksite professional
- Document problem statement, planning and identification process as required

Learning Objectives

- Discuss the purpose and use of the problem statement
- List common research strategies used by engineers approaching a problem statement
- Define PFMEA (process failure mode and effects analysis) and FMEA (failure mode and effects analysis)
- Identify typical failure modes
- Discuss potential causes of typical failure modes
- Explain action to reduce or eliminate typical failure modes

**Comments:**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 4. Research physical limitations

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite

Performance Standard Criteria

**Performance will be successful when learners:**

- Refer to research strategies identified in the problem statement to direct research of physical limitations and constraints
- Obtain/contact appropriate resources for researching physical limitations of work piece/part/process
- Research physical constraints of limitations such as
  - Forces, shear, and moments acting on part/process
  - Statics
  - Equilibrium
  - Energy and energy requirements
  - Kinematics & mechanics
  - Electrical/electronics
- Use graphical and mathematical analysis to identify physical limitations
- Review research and conclusions with worksite professional
- Document physical research process as required

Learning Objectives

Force & Statics

- Define force, shear, and moments
- Define statics
- Identify forces acting on the object in a diagram
- Explain transmissibility of forces
- Analyze forces applied to structures and mechanical devices
- Identify the basic stress and vibration equations
- Determine shear and moment forces in a diagram
- Analyze loads applied to structures and mechanical devices
- Calculate moment of inertia of structural members
- Review the concepts of tension and compression and how they relate to statics

Equilibrium

- Define equilibrium
- Calculate the location of the center of gravity for a rigid body
- Solve equilibrium problems involving friction

Energy

- Define types of energy
- Define the possible types of power conversion
- Calculate work and power in mechanical systems

Kinematics

- Define kinematics
- Determine efficiency in a mechanical system
- Describe the motion of machine components including linkages, cams, gears, & belt drives

#### Electrical/Electronics

- Compare analog and digital electronics
- Compare combinational and sequential logic fundamentals
- Explain how design specifications are translated into logic circuits
- Determine efficiency in an electrical system

#### Math Analysis

- Describe common units of measure used in engineering
- Explain number rounding rules
- Review the laws of sine, cosine and tangent

#### **Comments:**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 5. Research required material properties

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite

Performance Standard Criteria

**Performance will be successful when learners:**

- Refer to research strategies identified in the problem statement to direct research of material properties and requirements
- Obtain/contact appropriate resources for researching material properties to meet requirements of part/process
- Research material properties such as applicable
  - Physical (such as density, strength, stress/strain, continuity, hardness, flexure)
  - Thermal factors (such as melting point, boiling point, conductivity, expansion, specific heat capacity)
  - Chemical (such as reactivity, flammability, enthalpy, oxidation, stability, toxicity)
  - Size needed
  - Costs
  - Recycling/sustainability
- Select a material and standard structural shape to fit design specifications
- Review research, testing, and conclusions with worksite professional
- Document material properties research as required

Learning Objectives

- Classify and describe the typical physical and chemical characteristics of metals, alloys, ceramics, glass, polymers and composites
- Compare non-destructive and destructive material property tests
- Explain how to conduct typical materials tests for strength, stress/strain relationships, hardness, flexure, etc.
- Explain typical physical properties considered for materials used in mechanical and/or electrical engineering
- Stress & Shear
  - Define stress, sheer stress, bending stress, combined stress
  - Identify principle stresses on an object
  - Define torsion
  - Examine the distribution of stress in an object subjected to bending moments
- Strain
  - Define strain
  - Explain relationship between stress and strain
  - Distinguish between ductile and brittle
- Inertia
  - Define moments of inertia
  - Explain the use of standard structural shape tables
  - Define the purpose and use of the section modulus

- Thermal Factors
  - Describe how heat treating affects a material's strength
  - Describe stresses due to thermal contraction and expansion
  - Describe deflection due to heating and cooling
  - Explain factors related to electrical conductivity

**Comments:**



## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 6. Research manufacturing/assembly process & limitations

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite

Performance Standard Criteria

**Performance will be successful when learners:**

- Refer to research strategies identified in the problem statement to direct research of manufacturing processes & limitations
- Obtain/contact appropriate resources for researching manufacturing processes & limitations of work piece/part/process
- Research manufacturing processes & limitations such as
  - Manufacturing processes to be used to fabricate and assemble part
  - Handling during manufacturing
  - Features to be added to ensure proper assembly orientation
- Research currently available parts and assemblies already in manufacture
  - Identify sources of part information (catalogs, Internet, design conventions, etc.)
  - Research available components & parts
  - Obtain specific component dimensions
- Review research and conclusions with worksite professional
- Document manufacturing process research as required

Learning Objectives

- Compare manufacturing processes and equipment used in molding/casting, heat treating, cutting, joining/welding, machining, and forming (shearing, bending, drawing, etc.)
- Discuss the importance of quality principles in the manufacturing of products
- Identify plastic processing
- Identify types of welds
- Identify machining equipment and processes
- Identify mechanical fasteners
- Discuss proper selection of fasteners
- Identify surface coatings
- Relate properties of materials to various manufacturing processes
- Identify the product assembly process
- Explain manufacturing fixturing
- Examine concerns related to fixturing during part assembly
- Describe the process of building electrical circuits for assemblies

**Comments:**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 7. Design prototype with team

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite

Performance Standard Criteria

**Performance will be successful when learners:**

- Review the problem statement identified
- Define the work piece/part/process engineering specifications based on preliminary research and testing
- Select mechanical and/or electrical elements by type and size
- Select materials to be used for prototype
- Determine form, fit, function, and relationship of components and assembly
- Integrate design for manufacturing and assembly
- Complete OR review completed engineering calculations for prototype
- Set initial tolerances based on preliminary research factors
- Estimate cost factors including labor, materials for fabrication, costs for assembly, testing, and/or installing
- **Prepare prototype technical drawings** to solve the engineering problem identified based on based on preliminary research and testing

Learning Objectives

- Define the purpose of mechanical and/or electrical product specifications
- Explain methods for selecting designs based of product specifications
- Describe how characteristics of function, stress analysis, and economics impact materials selection and design
- Discuss the impact of failure and effects analysis (FMEA) on design
- Explain design for manufacturing and assembly concepts
- Explain how to determine hole depth and proper thread
- Define tolerance
- List considerations for setting tolerances
- Compare dimensional tolerance to fit in mechanical engineering
- Explain how to perform common engineering calculations for such characteristics as
  - Bend allowances
  - Critical load
  - Angle of twist
  - Stress/strain
  - Moment of inertia
  - Energy conversion efficiency
  - Circuit resistance, current and voltage

**Comments:**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 8. Prepare prototype technical drawings

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite

Performance Standard Criteria

**Performance will be successful when learners:**

- Create technical draft(s) drawings for prototype fabrication based on engineering specifications and research
- Prepare working, assembly, and development drawings as required
  - Draw appropriate views of standard components
  - Position the components in relationship to other components
  - Select references
  - Dimension and fully constrain the drawing
  - Create pattern drawings for parts
  - Transfer parts into an assembly
- Simulate fit or motion to analyze problems, issues or processes
  - Edit features such as depth, direction, planes, attributes
  - Resolve failed features (redefine, reroute, reorder, delete)
  - Create and edit assemblies (insert, align, mate)
  - Create features in assemblies using mate features
- Review fastener selection based on strength, cost, material, appearance and ease of assembly during installation
- Detail drawing to request parts fabrication by machine, metal sheet or wood shops/departments
- Evaluate drawing by measuring dimensions and comparing with original specifications for form and function designated in engineering problem statement
- **Check, revise, & record drawing**

Learning Objectives

- Describe the following elements used in design drafts- base, extrusions, sweeps, blends, fillets, rounds, chamfers, patterns (arrays), revolve, holes, datum, rib, relation, cut, shell
- Define commonly used terms in mechanical tolerance
- Explain the use of International Tolerance grades, limits and fits
- Describe special features, symbols and annotations for the following mechanical/electrical assembly drawings
  - Sheet metal
  - Surfacing
  - Welding
  - Casting
  - Forging
  - Jig and fixture
  - Tool and die
  - Cam

- Spring
- Mechanical power transmission (belts, chains, and gears)
- Electrical power transmission (transformers, relays, circuits, resistors, breakers)
- Fasteners
- Revolution
- Electrical circuits

**Comments:**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 9. Assist to build prototype

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite
- while assisting a worksite professional

Performance Standard Criteria

**Performance will be successful when learners:**

- ***Prepare prototype technical drawing***
- Request parts fabrication by machine, sheet metal or wood shops
- Order commercial materials and/or parts needed for prototype
- Build models/prototypes
  - Operate drill press, grinders, engine lathe, soldering irons, or other machines to modify parts or to fabricate experimental parts for testing ***only if properly trained***
  - Assemble part(s) and components as specified in prototype drawing
- Verify assembly as indicated in prototype drawings
- Verify assembly of prototype with worksite professional

Learning Objectives

- Discuss reasons for building a prototype
- Define rapid prototyping
- Discuss how prototypes differ from final products
- Explain characteristics and limitations of prototypes

**Comments:**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 10. Assist to test & revise prototype

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite
- while assisting a worksite professional

Performance Standard Criteria

**Performance will be successful when learners:**

- Determine testing required based on engineering problem statement
- Create documents of testing procedures and scenarios
- **Assist to build prototype** of part or process
- Set up prototype and test apparatus
- Operate test controlling equipment to observe and record prototype test results
- Set up and conduct tests of complete units and components
- Test prototype
  - Test fit or motion
  - Test different scenarios to multiple variables
  - Test the feasibility of product/design
  - Test operational conditions
  - Test extreme conditions
- Record test procedures and testing information
- Record test results data
- Organize all testing data

Learning Objectives

- Explain the purpose of prototype testing
- Compare non-destructive and destructive tests
- Identify the basic functional requirements of a prototype in response to external force
- Discuss reasons for structural failure
- Identify common tests used to test structure and functionality of prototypes
- Describe typical extreme conditions tests
- Define PFMEA (process failure mode and effects analysis) and FMEA (failure mode and effects analysis)
- Identify typical failure modes
- Discuss potential causes of typical failure modes
- Explain action to reduce or eliminate typical failure modes

**Comments:**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 11. Assist to calculate & analyze prototype test results

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite
- while assisting a worksite professional

Performance Standard Criteria

**Performance will be successful when learners:**

- Obtain prototype testing data
- Calculate required capacities for work piece/part/process to obtain specified performance
- Select and use statistical tools to analyze and synthesize data and study performance
- Apply statistical tools to verify reliability and/or validity of the data
  - Verify accuracy and legibility of data recordings
  - Use IT tools to manipulate data into tables, graphs, spreadsheets as needed to evaluate prototype
  - Organize data into written and visual formats
- Analyze test results with engineering team in relation to design or rated specifications and test objectives
- Discuss changes in design, method of manufacture and assembly, and drafting techniques and procedures with team
- Make recommendations for changes in product or test methods
- Modify or adjust work piece/part/process/equipment to meet specifications
- Document all calculations, statistics, evaluations and modifications to prototype or process

Learning Objectives

- List common features considered when modifying or adjusting work pieces/parts/process(es) in prototype testing
- Define reliability and validity
- Describe how statistical tools are used to verify reliability and validity
- Statistics
  - Create a histogram of recorded measurements showing data elements or class intervals, and frequency
  - Calculate the mean, mode, median, and range of a data set
  - Describe the meaning of probability and how it applies to a set of data
  - Calculate the theoretical probability that an event will occur
- Explain how product liability is impacted by testing

**Comments:**

## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 12. Finalize part/process technical drawings

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite

Performance Standard Criteria

**Performance will be successful when learners:**

- Obtain and collate ALL data collected during prototype testing
- ***Assist to calculate & analyze prototype test results***
- Evaluate and discuss ALL prototype testing with engineering team
- Refer back to engineering problem statement
- Present final project recommendations to team, management, client, etc.
- Document project recommendations
- Revise engineering plan or drawings, rebuild, and retest new prototype OR
- Finalize work piece/part/process engineering plan and documents from prototype testing results
- Define the technical requirements for use

Learning Objectives

- Explain the process for re-engineering or reverse engineering failed prototype designs
- Identify different types of product support documentation (brochures, warranties, warning labels, user's manuals, etc.)
- Identify types of manufacturing related registers
- Explain the patent process
- Describe features involved in marketing a newly engineered product or process
- Explain how to develop a Plan for Procedure for manufacturing a product

**Comments:**



## Unit 4: Engineering & Technology Pathway Mechanical/Electrical Engineering

Competency

### 13. Apply quality concepts to project

Performance Standard Condition

**Competence will be demonstrated**

- at the worksite

Performance Standard Criteria

**Performance will be successful when learners:**

- Apply quality concepts/standards at all stages of engineering design
- Monitor and refer to customer requirements and specifications documents throughout process
- Follow written standards and procedures for all protocols and troubleshooting
- Communicate progress at each step of process
- Ensure decisions are justified with data
- Perform quality inspection of prototype and manufactured work pieces/parts/processes
- Document failures and errors
- Evaluate failures and errors for corrective actions taken
- Complete and monitor basic statistical process control charts
- Document all research, design, testing, and production activities
- Follow the process for change control of design, process and final product

Learning Objectives

- Discuss the concept of quality assurance
- Explain key features of a quality assurance system
- Compare quality assurance to quality control
- Define ISO 9000
- Explain the importance of documentation
- Define systems integration
- Discuss the importance of change control pre- and post- design
- Define risk analysis
- Discuss factors considered in risk/benefit analysis
- Define PFMEA (process failure mode and effects analysis) and FMEA (failure mode and effects analysis)
- Describe the use of statistics and control charts in the work place
- Discuss the basics of Lean Manufacturing
- Explain CQI (Continuous Quality Improvement) and ongoing evaluation of produced work pieces/parts/processes (run charts, statistical analysis, cp/cpk number, capability, cost, etc.)

**Comments:**