



TENNESSEE DEPARTMENT OF  
**EDUCATION**  
FIRST TO THE TOP

## Principles of Manufacturing

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<b>Primary Career Cluster:</b>	Advanced Manufacturing
<b>Consultant:</b>	Bethany King Wilkes, (615) 532-2844, <a href="mailto:Bethany.Wilkes@tn.gov">Bethany.Wilkes@tn.gov</a>
<b>Course Code:</b>	5922
<b>Co-requisite(s):</b>	<i>Algebra I, Geometry, Physical Science (recommended)</i>
<b>Credit:</b>	1 credit for core and two focus areas. 2 credits for all 35 standards.
<b>Grade Level:</b>	9
<b>Graduation Requirement:</b>	This course satisfies one of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing courses.
<b>Programs of Study and Sequence:</b>	This is the first course in the <i>Machining Technology, Electromechanical Technology, Mechatronics, and Welding</i> programs of study.
<b>Necessary Equipment:</b>	Refer to the Teacher Resources page.
<b>Aligned Student Organization(s):</b>	Skills USA: <a href="http://www.tnskillsusa.com">http://www.tnskillsusa.com</a> Brandon Hudson, (615) 532-2804, <a href="mailto:Brandon.Hudson@tn.gov">Brandon.Hudson@tn.gov</a> Technology Student Association (TSA): <a href="http://www.tntsa.org">http://www.tntsa.org</a> Amanda Hodges, (615) 532-6270, <a href="mailto:Amanda.Hodges@tn.gov">Amanda.Hodges@tn.gov</a>
<b>Coordinating Work-Based Learning:</b>	If a teacher has completed work-based learning training, he or she can offer appropriate placement. To learn more, please visit: <a href="http://www.tn.gov/education/cte/work_based_learning.shtml">http://www.tn.gov/education/cte/work_based_learning.shtml</a> .
<b>Available Student Industry Certifications:</b>	None
<b>Dual Credit or Dual Enrollment Opportunities:</b>	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
<b>Teacher Endorsement(s):</b>	070, 230, 231, 232, 233, (042 and 043), (042 and 044), (042 and 045), (042 and 046), (042 and 047), (042 and 077), (042 and 078), (042 and 079), (043 and 044), (043 and 045), (043 and 046), (043 and 047), (043 and 077), (043 and 078), (043 and 079), (044 and 045), (044 and 046), (044 and 047), (044 and 077), (044 and 078), (044 and 079), (045 and 046), (045 and 047), (045 and 077), (045 and 078), (045 and 079), (046 and 047), (046 and 077), (046 and 078), (046 and 079), (047 and 077), (047 and 078), (047 and 079), (077 and 078), (077 and 079), (078 and 079), 470, 477, 531, 537, 551, 552, 553, 554, 555, 556, 575, 582, 584, 585, 596, 598

**Required Teacher  
Certifications/Training:**

None

**Teacher Resources:**

<http://www.tn.gov/education/cte/Manufacturing.shtml>

## Course Description

*Principles of Manufacturing* is designed to provide students with exposure to various occupations and pathways in the Advanced Manufacturing career cluster, such as Machining Technology, Electromechanical Technology, Mechatronics, and Welding. In order to gain a holistic view of the advanced manufacturing industry, students will complete all core standards, as well as standards in two focus areas. Throughout the course, they will develop an understanding of the general steps involved in the manufacturing process and master the essential skills to be an effective team member in a manufacturing production setting. Course content covers basic quality principles and processes, blueprints and schematics, and systems. In addition, proficient students will advance from this course with a nuanced understanding of how manufacturing combines design and engineering, materials science, process technology, and quality. Upon completion of the *Principles of Manufacturing* course, students will be prepared to make an informed decision regarding which Advanced Manufacturing program of study to pursue. Standards in this course are aligned with Tennessee State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee State Standards in Mathematics.\*

The following implementation options are encouraged:

- 1 credit for Core and two focus areas (listed below)
- 2 credits for all 35 standards.

Core standards are required for both one and two credit implementation options.

**Core standards:** 1-22, 35

### **Focus Areas**

Machining Technology:

Mechatronics:

Electromechanical Technology:

Welding:

### **Standards**

23, 24, 25

26, 27, 28

29, 30, 31

32, 33, 34

## Program of Study Application

This is the first course in the *Machining Technology*, *Electromechanical Technology*, *Mechatronics*, and *Welding* programs of study. For more information on the benefits and requirements of implementing these programs in full, please visit the Advanced Manufacturing website at <http://www.tn.gov/education/cte/Manufacturing.shtml>.

## Course Standards

### **Safety**

- 1) Accurately read and interpret safety rules, including rules published by the (1) National Science Teachers Association (NSTA), (2) rules pertaining to electrical safety, (3) Occupational Safety and Health Administration (OSHA) guidelines, (4) American Society for Testing Materials, (4) ANSI Z49.1: Safety and Welding, Cutting, and Allied Processes, and (5) state and national code



requirements. Be able to distinguish between rules and explain why certain rules apply. (TN Reading 3, 4, 9)

- 2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, store, and maintain safe operating procedures with tools and equipment. (TN Reading 3, 4)

### **Overview of Manufacturing**

- 3) Define manufacturing and describe how it is used to solve problems. Research the five general steps of manufacturing (preparation, processing, assembly, finishing, and packaging). Select a product and trace its development through each of the five steps. For example, deliver a presentation explaining how a smart phone goes from raw materials to final packaged product. (TN Reading 2, 4)
- 4) Distinguish between primary and secondary processes involved in the manufacture of industrial goods into finished products. Summarize in a graphic illustration or narrative how different processes make use of specific manufacturing applications, such as the use of welding in assembling processes. Relate the specific operations required to implement the following secondary processes:
  - a. Casting and molding (e.g., sand casting)
  - b. Forming (e.g., metal forming)
  - c. Separating (e.g., machining)
  - d. Assembling (e.g., welding)
  - e. Direct digital and additive manufacturing (e.g., 3-D printing)
  - f. Finishing (e.g., electroplating)(TN Reading 4, 9; TN Writing 4)
- 5) Research the history of manufacturing. Summarize its evolution from the Industrial Age to the rise of mechanization and automation in the manufacturing industry. Create a timeline or infographic that identifies milestones in the industry that led to today's advanced manufacturing environments. For example, discuss both the history of the assembly line and the use of robots, describing how they transformed the manufacturing industry. (TN Reading 1; TN Writing 4)
- 6) Explain that manufacturing is a technological system that transforms raw materials into products in a central location (e.g., a factory). Technological systems include the following elements: inputs, processes, outputs, feedback, and goals. As a team, select a manufacturing system, such as metal fabrication, and use diagrams and other multimedia to demonstrate its operation. Identify each element and explain its role in the system. (TN Reading 1, 4; TN Writing 4)
- 7) Explore the onset of advanced manufacturing and explain how it applies information, automation, computation, software, sensing, and networking to make traditional processes more efficient. Describe how advanced manufacturing incorporates the use of modern materials and recent discoveries in physical and biological sciences. For example, report on the use of nanotechnology. (TN Reading 1, 4)



## Materials

- 8) Identify and describe a wide range of materials used in manufacturing: organic, inorganic, engineering (metallic, polymeric, ceramic, composite), and non-engineering (gases and liquids). Distinguish between the materials and provide examples of how they are converted into products. (TN Reading 1, 4)
- 9) In teams, research the major material properties: physical, mechanical, chemical, thermal, electrical/magnetic, acoustical, and optical. Considering the use of materials in the various areas of advanced manufacturing (e.g., welding, machining, mechatronics, and electromechanical technology), discuss the following:
  - a. Characteristics that make up the physical properties of a material
  - b. How the mechanical properties affect the way a material will react to forces or loads
  - c. How natural elements react with a material and affect its performance
  - d. Characteristics that make up thermal properties of a material (e.g., thermal resistance, thermal expansion, thermal emission, thermal shock resistance)
  - e. Three major groups of materials that carry an electrical current (e.g., conductors, semiconductors, resistors)
  - f. Two major properties that describe how a material reacts to sound waves (e.g., acoustical transmission, acoustical reflection)
  - g. Three general optical properties (e.g., color, light transmission, light reflection).Explain why these properties are important to the selection and application of materials in a production setting. (TN Reading 1, 2, 4, 6)

## Career Exploration

- 10) In teams, use an online editing tool to develop an informational paper or infographic illustrating various career opportunities and pathways in the advanced manufacturing industry (welding, mechatronics, machining technology, and electromechanical technology). The descriptions should contain definitions, job roles, professional societies, and applicable licenses and/or certifications associated with each career. Use a variety of sources to gather data, cite each source, and briefly describe why the chosen source is reliable. (TN Reading 1, 7, 8; TN Writing 2, 6, 8, 9)
- 11) Research the postsecondary institutions (colleges of applied technology, community colleges, and four-year universities) in Tennessee and other states that offer programs leading to careers in advanced manufacturing. Write an informative paper or develop an infographic identifying admissions criteria, the postsecondary programs of study, and the secondary courses that will prepare individuals to be successful in a postsecondary program. (TN Reading 1, 5; TN Writing 4)

## Layout and Measurement

- 12) Identify and demonstrate proper use of the following typical measuring tools. Determine when it is appropriate to use linear distance, diameter, and angle measuring tools, and record accurate and repeatable measurements, attending to appropriate units and quantities.
  - a. Tape rule
  - b. Machinist's rule
  - c. Bench rule



- d. Caliper
  - e. Divider
  - f. Depth gage
  - g. Micrometer
  - h. Square
  - i. Protractor
  - j. Combination set
- (TN Reading 1, 3, 4, 7; TN Writing 4; TN Math N-Q, G-GMD)

- 13) Explain why proper layout is critical to making parts properly. Select a typical part and correctly demonstrate the following steps, or use a similar multistep procedure, to lay out the shape of a part.
- a. Measure off the part size on standard stock.
  - b. Cut the part blank out of the standard stock.
  - c. Draw center lines for holes and arcs.
  - d. Locate holes and arcs.
  - e. Mark centers of holes.
  - f. Draw tangent lines.
  - g. Layout straight cuts.
- (TN Reading 3, 4, 5, 7; TN Writing 4; TN Math N-Q, G-GMD)

### **Blueprint Reading and Interpretation**

- 14) Define the differences in technique among freehand sketching, manual drafting, and computer-aided drafting (CAD), and describe the skills required for each. Create a two-dimensional orthographic (multiview) drawing incorporating labels, notes, and dimensions, using sketching/geometric construction techniques. Apply basic dimensioning rules and properly use different types of lines (e.g., object, hidden, center). The orthographic projections should include principle views of a simple object from top, front, and right sides. (TN Reading 3, 4, 5, 7; TN Writing 4; TN Math G-MG)
- 15) Compare and contrast the following types of engineering drawings. Describe the characteristics and explain the different applications of each drawing type. Identify and distinguish between symbols that are unique to the different pathways in advanced manufacturing (e.g., machining technology, electromechanical technology, mechatronics, and welding). For example, electromechanical technology often uses schematic symbols for common electrical components and machining technology often uses symbols for surface finishes.
- a. Detail drawings
  - b. Assembly drawings
  - c. Systems drawings
- (TN Reading 4, 9)
- 16) Inspect and interpret blueprints, schematic diagrams, or written specifications for manufacturing devices and systems. Explain how the pictorial representations relate to an actual project layout, verifying sufficient agreement as prescribed by specified tolerances. For example, use a hydraulic schematic to show how fluid travels through a hydraulic circuit in an actual system. (TN Reading 1, 5; TN Writing 7; TN Math N-Q, G-CO, G-GMD)



## Sequencing of Manufacturing Operations

- 17) In teams, investigate the role of a manufacturing engineer in designing efficient manufacturing systems. Create samples of the following documents which engineers often use to ensure that manufacturing operations are completed in a logical and efficient order. Use the sample documents to manage the completion of short projects and assignments in this course.

Documents include the following:

- a. Operation sheet
- b. Flow process chart
- c. Operations process chart

(TN Reading 1, 3, 7; TN Writing 4)

## Quality Assurance and Continuous Improvement

- 18) In teams, research the three basic types of data that are important to controlling the manufacturing of a product: product output data, quality control data, and labor data. Describe and explain each type, including sample illustrations of the various reports needed by analysts (e.g., production report, material rejection form, inspection report). Provide examples of how a process can be improved depending on the outcome of each data type. (TN Reading 1, 4, 7)

- 19) Examine common statistical processes to analyze data. As a class, develop standard procedures for analysis to apply to manufacturing projects throughout the course and program of study.

The procedures should include:

- a) Collection of data
- b) Analysis methods
- c) Interpretation of results

(TN Reading 1, 3, 4, 7; TN Writing 2, 4)

- 20) Define the concept of quality control in the manufacturing industry. Summarize the roles of various personnel involved in ensuring quality control over production, including those who make the products, those who design the processes, and those who inspect the finished products. Describe why quality control is important to manufacturing processes, including how it affects customers, retailers, and manufacturers. Provide examples of how quality control could be applied to various manufacturing practices like electromechanical technology, machining technology, mechatronics, and welding. (TN Reading 1, 4)

- 21) As a class, research quality improvement tools and strategies such as the Plan-Do-Check-Act cycle, and collaboratively create quality control guidelines and reports to reference as products are fabricated and assembled throughout the semester and program of study. Include plans for corrective action to address common quality problems. (TN Reading 1, 3, 4; TN Writing 2, 4)

- 22) Investigate the functions of process management in a manufacturing workplace: planning, organizing, directing, and controlling. Explain each function and describe the relationship between process management and quality assurance. For example, compare and contrast the costs of preventive maintenance, safety practices, and quality control with the costs of equipment repair, workplace accidents, and inefficient processes. (TN Reading 1, 3, 4, 9)



## Machining Technology

- 23) Demonstrate proper application of common machine shop hand tools. Identify the following tools and provide examples of how they should be used safely.
- Clamping devices
  - Pliers
  - Wrenches
  - Screwdrivers
  - Chisels
  - Hacksaws
  - Reamers
  - Hand taps
  - Dies

Given a specific machining assignment, select two or more of the above hand tools for the task. Explain why the tools were selected to complete the assignment. (TN Reading 1, 3, 4; TN Math N-Q, G-GMD)

- 24) Identify and explain the equipment, equipment setup, and techniques that apply to the following operations:
- Sawing
  - Drilling
  - Grinding
  - Milling

Given a specific machining assignment, comply with safe and efficient work practices and perform basic operations using both manual and machine-guided techniques. Properly set controls and speeds of the machines; remove and replace parts; and visually examine machined surfaces for meeting the given specifications. (TN Reading 1, 3, 4; TN Math N-Q, G-GMD)

- 25) Research the development of numerical control machines, including how computer numerical control (CNC) technology evolved. Compare and contrast CNC machines with manually controlled machines and identify the chief benefits associated with them. Demonstrate operation of a CNC machine to perform basic tasks. (TN Reading 1, 3, 4; TN Math N-Q, G-GMD)

## Mechatronics

- 26) In teams, research the history of mechatronics and summarize how it evolved into modern-day applications. Using the research findings, create an infographic or presentation that can be used to (a) explain the mechatronics field, (b) why it is critical to the advanced manufacturing industry, (c) the skills needed to be successful in this field, and (d) why there is a demand for mechatronics professionals. (TN Reading 1, 4, 7; TN Writing 2, 4)
- 27) Identify and describe the following components of a typical mechatronic system. Select a common machine, such as a robot or a copy machine, to illustrate an example of a mechatronic system. Using supporting evidence from the machine and/or its accompanying schematic, explain why the machine is considered a mechatronic system.
- Actuators
  - Sensors
  - Digital control devices



- d. Input devices
  - e. Output devices
  - f. Graphical displays
- (TN Reading 1, 2, 4, 7)

28) Log, store, and export data received from two or more sensors (e.g., vision/light, audio, and touch) in a robotic or automated system. Explain why these procedures would be useful in a manufacturing process and provide specific examples. (TN Reading 3, 4; TN Writing 4)

### **Electromechanical Technology**

29) Explain how belt drives and chain drives are used to transmit power in an electromechanical system. Compare and contrast the two drive types and describe the advantages and disadvantages of using each. (TN Reading 1, 2, 9)

30) Identify and define the following common electrical quantities, including the unit of measurement and symbol (abbreviation) for each unit.

- a. Current
- b. Voltage
- c. Resistance
- d. Conductance
- e. Power
- f. Charge

(TN Reading 1, 2, 7)

31) Compare and contrast the two types of fluid power systems (pneumatic and hydraulic). Describe and explain the components they have in common; then identify the characteristics that render certain advantages to using one system over the other. For example, heavy construction machinery often uses hydraulic systems because they have the ability to support heavy loads.

(TN Reading 1, 2, 9)

### **Welding**

32) Interpret welding-specific drawings and welding symbol information. Differentiating between drawings and blueprints, examine parts to determine the application of symbols from drawings, sketches, and blueprints. (TN Reading 1, 4, 7)

33) Examine given shop and assembly drawings for a weldment composed of five to ten components. Interpret the dimensions and write a plan describing the materials and tools needed to complete the assignment. Make the required cuts and execute the plan. (TN Reading 1, 3, 4, 7; TN Writing 2; TN Math N-Q, G-GMD)

34) Identify and explain the equipment, equipment setup, and techniques that apply to the following thermal cutting operations:

- a. Oxyfuel cutting
- b. Plasma-arc cutting
- c. Air carbon arc cutting
- d. Sawing





- e. Shearing
- f. Punching

Perform straight, shaped, and beveled cutting operations using both manual and machine-guided techniques. Properly use weld-washing techniques and visually examine cut surfaces for meeting the given specifications. (TN 1, 3, 4, 7; TN Writing 4; TN Math N-Q, G-GMD)

### Latest Trends in Advanced Manufacturing

35) Explore a range of new and emerging trends in advanced manufacturing. A trend could be the change in the types of skills needed in manufacturing, the use of computers, or the use of advanced materials in recent years. Examples include the following:

- a. Sensing, measurement, and process control
- b. Materials design, synthesis, and processing
- c. Digital manufacturing technologies
- d. Sustainable manufacturing
- e. Nanomanufacturing
- f. Flexible electronics manufacturing
- g. Biomanufacturing
- h. Additive manufacturing
- i. Industrial robotics
- j. Advanced forming and joining technologies

Research one or more of these trends in depth, and compile a presentation or a paper explaining both the technical aspects involved (i.e., what skills are needed) and the effects on businesses, workers, and society. (TN Reading 1, 4, 7; TN Writing 2, 8)

### Standards Alignment Notes

\*References to other standards include:

- TN Reading: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 9-10 Students (page 62).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN Writing: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 9-10 Students (pages 64-66).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3 and 10 at the conclusion of the course.
- TN Math: [Tennessee State Standards for Mathematics](#); Math Standards for High School: Numbers and Quantity, Geometry.
  - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able



to demonstrate quantitative and geometric reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.

- P21: Partnership for 21st Century Skills [Framework for 21st Century Learning](#)
  - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.





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## Principles of Machining I

<b>Primary Career Cluster:</b>	Advanced Manufacturing
<b>Consultant:</b>	Bethany King Wilkes, (615) 532-2844, <a href="mailto:Bethany.Wilkes@tn.gov">Bethany.Wilkes@tn.gov</a>
<b>Course Code:</b>	5929
<b>Pre-requisite(s):</b>	<i>Algebra I (3102), Principles of Manufacturing (5922), Recommended: Geometry (3108), Physical Science (3202)</i>
<b>Credit:</b>	1
<b>Grade Level:</b>	10
<b>Graduation Requirement:</b>	This course satisfies one of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing courses.
<b>Programs of Study and Sequence:</b>	This is the second course in the <i>Machining Technology</i> program of study.
<b>Necessary Equipment:</b>	Refer to the Teacher Resource page.
<b>Aligned Student Organization(s):</b>	Skills USA: <a href="http://www.tnskillsusa.com">http://www.tnskillsusa.com</a> Brandon Hudson, (615) 532-2804, <a href="mailto:Brandon.Hudson@tn.gov">Brandon.Hudson@tn.gov</a>
<b>Coordinating Work-Based Learning:</b>	If a teacher has completed work-based learning training, he or she can offer appropriate placement. To learn more, please visit: <a href="http://www.tn.gov/education/cte/work_based_learning.shtml">http://www.tn.gov/education/cte/work_based_learning.shtml</a> .
<b>Available Student Industry Certifications:</b>	TBD
<b>Dual Credit or Dual Enrollment Opportunities:</b>	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
<b>Teacher Endorsement(s):</b>	070, 230, 231, 232, 233, (042 and 043), (042 and 044), (042 and 045), (042 and 046), (042 and 047), (042 and 077), (042 and 078), (042 and 079), (043 and 044), (043 and 045), (043 and 046), (043 and 047), (043 and 077), (043 and 078), (043 and 079), (044 and 045), (044 and 046), (044 and 047), (044 and 077), (044 and 078), (044 and 079), (045 and 046), (045 and 047), (045 and 077), (045 and 078), (045 and 079), (046 and 047), (046 and 077), (046 and 078), (046 and 079), (047 and 077), (047 and 078), (047 and 079), (077 and 078), (077 and 079), (078 and 079), 470, 477, 531, 537, 551, 552, 553, 554, 555, 556, 575, 582, 584, 585, 596
<b>Required Teacher Certifications/Training:</b>	None
<b>Teacher Resources:</b>	<a href="http://www.tn.gov/education/cte/Manufacturing.shtml">http://www.tn.gov/education/cte/Manufacturing.shtml</a>

## Course Description

*Principles of Machining I* is designed to provide students with the skills and knowledge to be effective in production environments as a machinist, CNC operator, or supervisor. Students proficient in this course will demonstrate safety practices concerning machining technology, proper measurement and layout techniques, reading and interpreting drawings and blueprints, production design processes, and quality control procedures. Upon completion of the *Principles of Machining I* course, students will be knowledgeable about potential postsecondary education and career opportunities related to machining technology and will be prepared to enroll in more advanced machining courses in high school. Standards in this course are aligned with Tennessee State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee State Standards in Mathematics.\*

## Program of Study Application

This is the second course in the *Machining Technology* program of study. For more information on the benefits and requirements of implementing this program in full, please visit the Advanced Manufacturing website at <http://www.tn.gov/education/cte/Manufacturing.shtml>.

## Course Standards

### Safety

- 1) Maintain safety records and demonstrate adherence to industry-standard practices regarding general machine safety, tool safety, and fire safety to protect all personnel and equipment. For example, when operating tools and equipment, regularly inspect and carefully employ the appropriate personal protective equipment (PPE) as recommended by Occupational, Safety & Health Administration (OSHA) regulations, American Society for Testing Materials, ANSI Z49.1: Safety and Welding, Cutting, and Allied Processes, and state and national code requirements. Be able to distinguish between rules and explain why certain rules apply. Incorporate safety procedures and complete the safety test with 100 percent accuracy. (TN Reading 1, 2, 3, 4, 7; TN Math N-Q)
- 2) Adhering to proper safety guidelines, develop a schedule and create documents for a checklist to perform daily, weekly, and/or monthly routine maintenance on hand tools, conventional machines, and computer numerical control (CNC) machine tools. The checklist should also include, but is not limited to, cleaning the work area and appropriately handling and disposing of environmentally hazardous materials. (TN Reading 3; TN Writing 2)

### Overview of Machining Technology

- 3) In teams, research the evolution of machining technology, and describe how it has affected the workforce and the manufacturing industry in particular. Report on early machining tools, how power sources changed, basic machine tool operation, non-traditional machining processes, and automated machining processes. Cite evidence to support the information presented. (TN Reading 1, 4; TN Writing 4, 9)

### Career Exploration

- 4) Investigate how the role of a machinist has changed with the evolution of machining technology.



Develop an informational paper or infographic to report the various machining job categories and their characteristics. Research a range of postsecondary institutions (e.g., colleges of applied technology, community colleges, and four-year universities) and professional organizations (National Institute for Metalworking Skills [NIMS]) to identify the skills, education, and training requirements to become a machinist. (TN Reading 1, 4, 9; TN Writing 2, 4)

### **Measurement and Layout**

- 5) Given a specific machining task, select the appropriate tool and accurately measure solid shapes or simple parts. Record the measurements in both English and metric units using the correct number of significant figures. Perform basic mathematical calculations and/or calibrations using tools such as the following:
  - a. Micrometers
  - b. Verniers
  - c. Gages
  - d. Dial indicators
  - e. Helper measuring tools (e.g., calipers, telescoping gage, small hole gage)(TN Reading 1, 3, 5; TN Writing 4; TN Math G-GMD)
- 6) Calculate the speeds, feeds, and depth of cut for various machines and determine the tools needed for machining a simple part. Correctly interpret recorded measurements and use them to set up or adapt a process. (TN Reading 1, 3; TN Writing 4; TN Math N-Q)
- 7) Identify and explain the proper use of the following common layout tools used in machining technology. Given a specific machining task, use a multistep layout procedure to locate and mark lines, circles, arcs, and points for drilling holes and making cuts. Such as:
  - a. Lines: layout dye, scribe, divider, surface plate, v-blocks, straightedge, squares
  - b. Angles: plain protractor, vernier protractor(TN Reading 1, 3, 6; TN Writing 4; TN Math N-Q, G-GMD)

### **Blueprint Reading and Interpretation**

- 8) Demonstrate technical literacy in the symbols, lines, and figures devised by the American National Standards Institute (ANSI). Distinguish between the past and present metalworking symbols (e.g., counterbore, countersink, and drill) and explain why it is important to be familiar with both. (TN Reading 1, 4, 7, 8)
- 9) Classify and compare the different types of dimensions on drawings needed to produce a part or an object. Read and interpret drawings that are dimensioned in fractional inches, decimal inches, and in metric units. For example, drawings dimensioned in decimal parts of a unit indicate greater precision. (TN Reading 1, 4, 7; TN Math N-Q)
- 10) Examine and interpret drawings to manufacture an object. Report and define information necessary to complete a machining task, such as the materials to be used, required surface finish, tolerances, quantity of units, scale, assembly and subassembly instructions, past revisions, and the name of the object. Explain the interpretation of drawings and provide supporting evidence. (TN Reading 1, 4, 7; TN Math N-Q)



- 11) Given a set of machining drawings, distinguish between the detail and the assembly drawings. Compare and contrast the characteristics and applications of each. Describe a multistep procedure to use the drawings in order to complete a series of tasks related to a given assignment. For example, use the scale of a drawing to determine dimensions not explicitly shown on the drawing. (TN Reading 1, 3, 9)

## Materials

- 12) Using the following classifications, explain how metals are classified, identify general characteristics of each type, and describe related safety precautions that should be applied during machining procedures.
- Ferrous metals
  - Nonferrous metals
  - High-temperature metals
  - Rare metals
- (TN Reading 1, 3, 4, 9)
- 13) Investigate the chemical and physical properties of materials used in the machining process. Considering the following common materials, list the principle properties relevant to machining tasks.
- Carbon steels
  - Stainless steels
  - Structural steels
  - Cast iron
  - Aluminum
- (TN Reading 1, 4; TN Writing 4)

## Production Design Process to Machine Parts

- 14) Given a team assignment, formulate strategies to manufacture a simple part. The strategies should include designing a flow process that organizes equipment and materials needed for cutting, drilling, milling, grinding, and/or other machining operations. Also, organize a plan for layout, setup, and performance of tapping, countersinking, counterboring, and reaming as needed. Implement the above strategies to manufacture the part. (TN Reading 1, 3, 4; TN Writing 4; TN Math N-Q)
- 15) Simulate the work of a machining team to develop and manufacture a product idea, accounting for given specifications and potential constraints. Prior to manufacturing the product, use the following multistep process to outline a plan demonstrating how the product will be manufactured efficiently. The plan should include justification for the number of parts needed, how the parts were standardized, and the ability to process the parts.
- Develop initial designs
  - Refine designs
  - Create a conceptual model and prototype
  - Present design ideas
  - Obtain management approval for design
  - Manufacture the final product
- (TN Reading 1, 3; TN Writing 1, 4, 6, 7)



## Quality Control

- 16) Measure, weigh, and visually inspect machined parts. Record and compare data to given project specifications using class-defined analysis methods. Interpret and communicate results both written and verbally. If necessary, recommend changes that will reduce the number of product defects during the manufacturing process. (TN Reading 1, 3, 4, 7; TN Writing 1, 4; TN Math N-Q, G-GMD)
- 17) Drawing upon multiple resources, research both destructive and nondestructive testing used as quality control techniques to prevent manufacturing defects in machining technology. Explain the importance of accurate measuring tools that are calibrated by the National Institute of Standards Technology (NIST) guidelines. In addition, explore other testing techniques such as the use of coordinate measuring machines (CMM), use of optical comparators, radiographic inspection, magnetic particle inspection, ultrasonic inspection, and laser inspection. Compare and contrast these techniques and provide specific examples for when they are most appropriately used. Cite evidence to justify the examples. (TN Reading 1, 3, 9; TN Writing 1, 4, 5, 8)

## Standards Alignment Notes

\*References to other standards include:

- TN Reading: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 9-10 Students (page 62).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN Writing: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 9-10 Students (pages 64-66).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3 and 10 at the conclusion of the course.
- TN Math: [Tennessee State Standards for Mathematics](#); Math Standards for High School: Number and Quantity, Geometry (pages 58-83).
  - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate quantitative and geometric reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills [Framework for 21st Century Learning](#)



- Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.







TENNESSEE DEPARTMENT OF

**EDUCATION**

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## Advanced Electromechanical Technology

<b>Primary Career Cluster:</b>	Advanced Manufacturing
<b>Consultant:</b>	Bethany King Wilkes, (615) 532-2844, <a href="mailto:Bethany.Wilkes@tn.gov">Bethany.Wilkes@tn.gov</a>
<b>Course Code:</b>	TBD
<b>Pre-requisite(s):</b>	<i>Algebra (3102), Geometry (3108), Physical Science (3202), Principles of Manufacturing (5922), Introduction to Electromechanical (6091)</i>
<b>Credit:</b>	2
<b>Grade Level:</b>	11
<b>Graduation Requirement:</b>	This course satisfies two of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing courses.
<b>Programs of Study and Sequence:</b>	This is the third course in the <i>Electromechanical Technology</i> program of study.
<b>Necessary Equipment:</b>	Refer to the Teacher Resources page.
<b>Aligned Student Organization(s):</b>	Skills USA: <a href="http://www.tnskillsusa.com">http://www.tnskillsusa.com</a> Brandon Hudson, (615) 532-2804, <a href="mailto:Brandon.Hudson@tn.gov">Brandon.Hudson@tn.gov</a>
<b>Coordinating Work-Based Learning:</b>	If a teacher has completed work-based learning training, he or she can offer appropriate placement. To learn more, please visit: <a href="http://www.tn.gov/education/cte/work_based_learning.shtml">http://www.tn.gov/education/cte/work_based_learning.shtml</a> .
<b>Available Student Industry Certifications:</b>	None
<b>Dual Credit or Dual Enrollment Opportunities:</b>	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
<b>Teacher Endorsement(s):</b>	531, 537, 551, 552, 553, 554, 555, 556, 575, 582, 584, 585, 596, 598
<b>Required Teacher Certifications/Training:</b>	None
<b>Teacher Resources:</b>	<a href="http://www.tn.gov/education/cte/Manufacturing.shtml">http://www.tn.gov/education/cte/Manufacturing.shtml</a>

### Course Description

*Advanced Electromechanical Technology* is designed to provide students with the knowledge and skills to effectively perform basic industrial maintenance procedures in an advanced manufacturing facility. Students in this course develop proficiency in a vast array of electromechanical domains, including: fundamental safety practices in electromechanical technology, shielded metal arc welding (SMAW),

basic metal inert gas (MIG) welding, electrical systems, AC and DC motors, calibrating instruments, drive systems, pipe fabrication, hydraulic systems, pumps, digital electronics, programmable logic controllers (PLC), and troubleshooting procedures. Upon completion of the *Advanced Electromechanical Technology* course proficient students will be prepared to pursue postsecondary electromechanical technology programs and entry-level industrial maintenance technology careers in the advanced manufacturing industry. Standards in this course are aligned with Tennessee State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee State Standards in Mathematics.\* *This course is recommended for 2 credits.*

## Program of Study Application

This is the third course in the *Electromechanical Technology* program of study. For more information on the benefits and requirements of implementing this program in full, please visit the Advanced Manufacturing website at <http://www.tn.gov/education/cte/Manufacturing.shtml>.

## Course Standards

### Safety

- 1) Assess a given situation requiring the use of tools, equipment, and materials. Explain the applicability of various safety standards and procedures, and then safely demonstrate the use of the tools, equipment, and materials. For example, the hoisting of material requires lifting equipment of sufficient strength and applicability to the task, physical clearance from personnel, necessary alerting to others, and authorization to use the required equipment, as well as conformance to Occupational Safety and Health Administration (OSHA) policies for avoiding and reporting accidents associated with this type of activity. (TN Reading 2)
- 2) Accurately read and interpret safety rules, including rules published by the (1) National Science Teachers Association (NSTA), (2) National Electrical Code (NEC), (3) Occupational Safety and Health Administration (OSHA) guidelines, (4) American Society for Testing Materials; ANSI Z49.1: Safety and Welding, Cutting, and Allied Processes, and (5) state and national code requirements. Be able to distinguish between rules and explain why certain rules apply. (TN Reading 4, 5)
- 3) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, store, and maintain safe operating procedures with tools and equipment. (TN Reading, 4)

### Welding and Machining Operations

- 4) Interpret and use a welding sketch or drawing to demonstrate the proper setup of a shield metal arc welder. Use the shielded metal arc welding (SMAW) process and make single-pass and groove welds in the following positions:
  - a. Flat
  - b. Horizontal
  - c. Vertical
  - d. Overhead(TN Reading 3, 4; TN Math N-Q, G-GMD)



- 5) Examine a given set of specifications for welding operations and properly set up a metal inert gas (MIG) welder to demonstrate the following five basic weld joint designs. Distinguish between the weld joint designs and provide various scenarios of how they are best applied. For example, edge joints are usually welded on one side, whereas a butt joint can be welded on both sides.
- Lap joint
  - Butt joint
  - Corner joint
  - Edge joint
  - T-joint
- (TN Reading 3, 4, 9; TN Math N-Q, G-GMD)
- 6) Demonstrate the proper use of various types of grinders, such as hand-held and pedestal bench. Compare and contrast the process to use each grinder when performing cutting, smoothing, and deburring operations on a piece of metal. For example, use a grinder to cut and bevel pipe and plate prior to welding. (TN Reading 3, 4; TN Math N-Q, G-GMD)
- 7) Manage and coordinate the operation of the cutting pieces, feeds, and mounts associated with both manual and computer-numerical-controlled (CNC) machining tools to complete projects involving:
- Milling machines, such as indexing operations using a dividing head and rotary tables
  - Lathes, such as re-chase and internal threads, taper turning with taper attachments and compound rests, internal tapered surfaces, follower and steady rests
- For example, select the correct cutting tools and speeds for the CNC processes to create Delrin (plastic) shafts and gears for a class robotics project. (TN Reading 3, 7; TN Math N-Q, G-C, G-GMD, G-MG)

### Electrical Circuits

- 8) Identify the basic characteristics and distinguish between the operation of direct current (DC) and alternating current (AC) electricity. Explain how and why the different currents are used. Provide examples of devices that use AC and DC respectively. (TN Reading 3, 4)
- 9) Demonstrate an understanding of Ohm's law, and apply it to solving given problems in electrical systems. Defend the solution using supporting evidence that explains the cause and effect relationship between Ohm's law and each of the following:
- Voltage
  - Current
  - Resistance
  - Voltage drop
- (TN Reading 1, 2, 4; TN Writing 1, 4; TN Math N-Q, A-REI)
- 10) Examine electrical circuits and components. Solve various series-parallel circuit structures, using appropriate instruments to measure watts, volts, Ohms, and amps. Explain the multistep procedure used to solve each problem and justify the calculations using Ohm's law. (TN Reading 3, 4; TN Writing 1, 4; TN Math N-Q, A-REI)



- 11) Explain basic control wiring and wiring processes used in the electrical industry. Properly apply these processes by wiring and testing devices, control circuits, and systems. For example, wire and test electrical switches and devices used in a typical electromechanical system. (TN Reading 3, 4; TN Math N-Q)
- 12) Explain electron flow as it relates to electricity by creating a diagram or model to illustrate electron and induction flow. Use the model to also explain the role of magnetism and electromagnetic induction in electrical systems, including a comparison of the following magnetism concepts to their electrical counterparts:
- a. Reluctance to resistance
  - b. Field distance to voltage
  - c. Magnetic force to current
- (TN Reading 3, 4; TN Writing 2, 4)

### **Conductor Termination and Splices**

- 13) Research the National Electrical Code (NEC) and local code requirements for the splicing, terminating, and insulating of conductors. Using the research findings, write an explanation describing how and when it is appropriate to use wire nuts, crimp-on wire lugs, or mechanical compression connectors for making connections. Also include special considerations for making splices and connections to aluminum, as well as insulation systems applicable to common splices and terminations. (TN Reading 2, 3, 4, 9; TN Writing 2, 4, 7)
- 14) Complete a simulation of wiring for residential service. Select the appropriate size of wire nuts and complete multiple installations. Demonstrate wire terminations and splices by using the proper crimp-on wire lugs and mechanical compression connectors. Explain and justify the selection of parts with supporting evidence from the research findings (resulting from the previous standard). (TN Reading 2, 3,4 ; TN Math N-Q)

### **Fuses and Circuit Breakers**

- 15) Explore the characteristics and uses of fuses and circuit breakers. Apply this information to develop and explain a procedure that could be used to select a specific choice of fuse or circuit-breaker for over-current protection. (TN Reading 2, 3, 4; TN Math N-Q)
- 16) Identify various examples of fuses and circuit breakers. Examine the markings printed on a fuse and identify the characteristics of a fuse needing replacement. Using physical observation and technical manuals, explain how to classify a circuit breaker by its voltage, current, and interrupting-capacity ratings. (TN Reading 2, 3, 4, 9)
- 17) Following the correct electrical code practices for residential service, demonstrate the procedures to install, wire, test, and operate fuses and breakers in both single- and three-phase circuits. Demonstrate effective grounding practices, including the connection of ground wires and installation of bonding straps. (TN Reading 2, 3, 4, 6; TN Math N-Q)



## Schematic Interpretation

- 18) Review a basic process instrument diagram (PID) and a basic electrical elementary print. Interpret the symbols to identify the actual field devices of a process loop (PID) and control loop (electrical elementary print). Explain and document the basic operation of the devices and equipment for both the process (PID) and control (electrical elementary print) loops. (TN Reading 2, 3, 4)

## Single-Phase Transformer

- 19) Explain the operation of a basic single-phase transformer. Given the following scenarios, examine and confirm that the transformer is operating correctly. Write a brief justification supporting the conclusion of each examination. In groups or as a class, discuss results and provide constructive feedback.
- Single-phase step-up transformer
  - Single-phase step-down transformer
  - Single-phase isolation transformer
  - Single-phase current transformer
- (TN Reading 2, 3, 4; TN Writing 1, 4; TN Math N-Q)

## Conductors and Cables

- 20) Given a proposed addition to a commercial electrical system, properly select type and size of both conduit and conductors for an installation. Support the selection with evidence drawn from standards in the National Electrical Code (NEC) and local codes. (TN Reading 2, 3, 4, 9; TN Math N-Q)
- 21) Demonstrate an understanding of how to physically read and identify markings on conductors and cables according to industry standards such as the National Electrical Code (NEC). Explain how conductors and cables are categorized based upon wire size and gauge, insulation and jacket types, and voltage ratings. (TN Reading 2, 3, 4; TN Math N-Q)

## Conduit Installation

- 22) Given an assignment to install a specified run of electrical metal tubing (EMT) and polyvinyl chloride (PVC) conduit, create and execute a written plan of the procedure to be completed. The plan should include, but is not limited to the following:
- Where and why bends (e.g., stub, offset, saddle, parallel) will be used
  - How the material will be cut, reamed, installed, and secured
  - Drawings of how the conduit will be secured with clamps and fittings conforming to standards of the National Electrical Code (NEC) and local codes.
- (TN Reading 3, 4, 7; TN Writing 2, 4; TN Math N-Q)
- 23) Given an assignment to install a specified run of intermediate metal conduit (IMC) and rigid conduit, create and execute a written plan of the procedure to be completed. The plan should include, but is not limited to, the following:
- Where and why bends (e.g., stub, offset, saddle, parallel) will be used
  - How the material will be cut, reamed, installed, and secured



c. Drawings of how the conduit will be secured with clamps and fittings conforming to standards of the National Electrical Code (NEC) and local codes.  
(TN Reading 3, 4; TN Writing 2, 4; TN Math N-Q)

24) Develop a written plan, then set up and execute a cable pull through assorted conduit and cable tray configurations. The plan should include a list of the tools used, diagrams of puller systems used, an explanation of how the proper location was selected to start and end the conductor pull, as well as calculations for allowable pulling tension for a specified group of conductors. Justify the written plan with supporting evidence based on observations and prescriptions outlined in the National Electrical Code (NEC). (TN Reading 2, 3, 4, 8, 9; TN Writing 2, 4, 5; TN Math N-Q)

### Computers and Electronics

25) Given a set of logic statements and schematic circuits, construct the logic circuits described using the following:

- a. AND, OR, NOR, and XOR gates
- b. Flip-flops, counters, and gates

Document and define each logic gate including a drawing, a description of its function in a short sentence or paragraph, a specification of each truth table, and the equation for each gate. (TN Reading 2, 4; TN Writing 2, 4)

26) Given a working programmable logic controller (PLC), an operator interface, and interfacing computer, safely set up a communication loop in order to view and explain the program's purpose. Identify and explain the functions and interrelationships among the following PLC components:

- a. Power supply
- b. CPU
- c. Input modules
- d. Output modules
- e. Analog input and/or modules

(TN Reading 2, 3)

### Motors

27) Given a specified application in an electromechanical system, properly select a motor based upon its intended use. Using resources such as technical manuals and industry standards, determine the size, speed, operating voltage, and National Electrical Manufacturing Association (NEMA) type for the required motor. Present a justification of the selection to classmates. Be prepared to answer any questions with evidence to support the selection. (TN Reading 3, 4; TN Writing 1, 4; TN Math N-Q)

28) Consult multiple sources such as National Electrical Code (NEC), Occupational Safety and Health Administration (OSHA) regulations, and given installation drawings. Using this information, determine the required over-current protection, motor control circuits, conductor types and sizes, and conduit types and sizes for a given motor and application. Write a technical report that compares and contrasts the selections with those of other classmates. Provide supporting evidence for any selections that differ from classmates, and work together to come to a



consensus on requirements and collaboratively write a final report. (TN Reading 2, 3, 4, 9; TN Writing 2, 4, 6; TN Math N-Q)

- 29) Plan and execute the selection, installation, and wiring of the following motors. Document the plan and explain the detailed multistep process used to complete the procedure by the requirements of the National Electrical Code (NEC) and Occupational Safety and Health Administration (OSHA) regulations.
- DC motor (other than a permanent magnet motor)
  - Single-phase capacitor motor
  - Reversing three-phase motor
- (TN Reading 2, 3, 4; TN Writing 2, 4; TN Math N-Q)

### **Drive Systems**

- 30) Identify and demonstrate an understanding of the components in typical mechanical drive systems (e.g., gear and belt drive) within an industrial setting. Compare and contrast gear versus belt drives and explain the differences between them. Simulating a period of production downtime, safely and correctly disassemble and reassemble both a gear driven mechanical drive and a belt driven mechanical drive in a specified amount of time. (TN Reading 2, 3, 4; TN Math N-Q)

### **Calibration and Instrumentation**

- 31) Examine a smart instrument (used to measure pressure flow, temperature, or level) and its corresponding communicator. Identify the basic parameters of the instrument such as tag number and calibration range. Plan and execute the setup of a communication loop and demonstrate how to calibrate the instrument by changing various parameters. (TN Reading 3, 4; TN Math N-Q)

### **Hydraulic Systems**

- 32) Review drawings and interpret American National Standards Institute (ANSI) symbols to explain the function of a basic industrial hydraulic system. Develop a written text that outlines, describes, and logs recommended regular preventative maintenance on hydraulic equipment and controls. Use the text as a guide to execute the recommended procedures and record the details of the maintenance, explaining how the preventative maintenance will minimize failures in hydraulic equipment. (TN Reading 2, 3, 4, 9; TN Writing 1, 4)

### **Pumps**

- 33) Identify and explain the operation and basic parts of gear, centrifugal, and positive displacement pumps found in an industrial setting. Simulating a period of production downtime, safely and correctly disassemble and reassemble each type of pump (e.g., gear, centrifugal, and positive displacement) within a specified amount of time. (TN Reading 2, 3, 4; TN Math N-Q)



## Pipe Fabrication

- 34) Inspect and interpret assembly drawings for piping in a typical industrial setting. Given multiple general piping parts, select necessary parts to assemble both a bolted flange and a screw flange. Describe the multistep process used and provide evidence to support the selections that were made. (TN Reading 2, 3, 4; TN Math N-Q)

## Troubleshooting

- 35) Assess blueprints of a typical electromechanical system (e.g., motor driving a pump with a coupling, an instrumentation loop, etc.) and examine a given section of the system. Follow a troubleshooting procedure and identify the problems in a malfunctioning system within a specified time. Citing evidence from blueprints and other resources, document the problem(s), explain the nature of the malfunction, and prescribe a recommended solution. (TN Reading 2, 3, 4, 9; TN Writing 1, 4, 8; TN Math N-Q)

## Standards Alignment Notes

\*References to other standards include:

- TN Reading: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 11-12 Students (page 62).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN Writing: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 11-12 Students (pages 64-66).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3 and 10 at the conclusion of the course.
- TN Math: [Tennessee State Standards for Mathematics](#); Math Standards for High School: Number and Quantity, Algebra, Geometry (pages 58-83).
  - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate quantitative, algebraic, and geometric reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills [Framework for 21st Century Learning](#)
  - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.







TENNESSEE DEPARTMENT OF  
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## Digital Electronics

<b>Primary Career Clusters:</b>	Advanced Manufacturing and Science, Technology, Engineering, and Mathematics (STEM)
<b>Consultant:</b>	Bethany King Wilkes, (615) 532-2844, <a href="mailto:Bethany.Wilkes@tn.gov">Bethany.Wilkes@tn.gov</a>
<b>Course Code:</b>	5925
<b>Pre-requisite(s):</b>	<i>Algebra I (3102)</i>
<b>Credit:</b>	1
<b>Grade Level:</b>	10, 11, or 12
<b>Graduation Requirement:</b>	This course satisfies one of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing or STEM courses.
<b>Programs of Study and Sequence:</b>	This is the second course in the <i>Mechatronics</i> and <i>Technology</i> programs of study.
<b>Necessary Equipment:</b>	Refer to the Teacher Resources page.
<b>Aligned Student Organization(s):</b>	Skills USA: <a href="http://www.tnskillsusa.com">http://www.tnskillsusa.com</a> Brandon Hudson, (615) 532-2804, <a href="mailto:Brandon.Hudson@tn.gov">Brandon.Hudson@tn.gov</a> Technology Student Association (TSA): <a href="http://www.tntsa.org">http://www.tntsa.org</a> Amanda Hodges, (615) 532-6270, <a href="mailto:Amanda.Hodges@tn.gov">Amanda.Hodges@tn.gov</a>
<b>Coordinating Work-Based Learning:</b>	If a teacher has completed work-based learning training, appropriate placement can be offered. To learn more, please visit: <a href="http://www.tn.gov/education/cte/work_based_learning.shtml">http://www.tn.gov/education/cte/work_based_learning.shtml</a> .
<b>Available Student Industry Certifications:</b>	None
<b>Dual Credit or Dual Enrollment Opportunities:</b>	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
<b>Teacher Endorsement(s):</b>	070, 230, 231, 232, 233, (042 and 043), (042 and 044), (042 and 045), (042 and 046), (042 and 047), (042 and 077), (042 and 078), (042 and 079), (043 and 044), (043 and 045), (043 and 046), (043 and 047), (043 and 077), (043 and 078), (043 and 079), (044 and 045), (044 and 046), (044 and 047), (044 and 077), (044 and 078), (044 and 079), (045 and 046), (045 and 047), (045 and 077), (045 and 078), (045 and 079), (046 and 047), (046 and 077), (046 and 078), (046 and 079), (047 and 077), (047 and 078), (047 and 079), (077 and 078), (077 and 079), (078 and 079), 470, 477, 501, 502, 535, 537, 551, 552, 553, 554, 555, 556, 567, 582, 584, 585, 595, 596

<b>Required Teacher Certifications/Training:</b>	None
<b>Teacher Resources:</b>	<a href="http://www.tn.gov/education/cte/Manufacturing.shtml">http://www.tn.gov/education/cte/Manufacturing.shtml</a> , <a href="http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml">http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml</a>

## Course Description

*Digital Electronics* is intended to provide students with an introduction to the basic components of digital electronic systems and equip them with the ability to use these components to design more complex digital systems. Standards in this course outline what students must know and do in order to (1) describe basic functions of digital components (including gates, flip flops, counters, and other devices upon which larger systems are designed), (2) use these devices as building blocks to design larger, more complex circuits, (3) implement these circuits using programmable devices, and (4) effectively communicate designs and systems. Students develop additional skill in technical documentation when operating and troubleshooting circuits. Upon completion of the *Digital Electronics* course, students will be able to design a complex digital system and communicate their designs through a variety of media. Standards in this course are aligned with Tennessee State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee State Standards in Mathematics.\*

## Program of Study Application

This is the second course in the *Mechatronics* and *Technology* programs of study. For more information on the benefits and requirements of implementing these programs in full, please visit the Advanced Manufacturing and STEM websites at <http://www.tn.gov/education/cte/Manufacturing.shtml> and <http://www.tn.gov/education/cte/ScienceTechnologyEngineeringMathematics.shtml>.

## Course Standards

### Safety

- 1) Accurately read and interpret safety rules including (1) rules published by the National Science Teachers Association (NSTA), (2) rules pertaining to electrical safety, (3) Occupational Safety and Health Administration (OSHA) guidelines, and (4) state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply. (TN Reading 3, 4)
- 2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment. (TN Reading 3, 4)

### Citizenship and Career Exploration

- 3) In teams, develop a persuasive paper or presentation arguing for the importance of electrical and/or computer engineers' contributions to society. Select several such contributions as justification, and provide compelling evidence for how electrical/computer engineers' designs are used in everyday applications. Incorporate a variety of sources to gather data, including print and electronic; cite each source, and briefly describe why the particular source is reliable. (TN Reading 1, 7; TN Writing 1, 4, 6, 7, 8)



- 4) Research the postsecondary institutions in Tennessee that offer electrical engineering or electrical and/or computer engineering technology. Individually or in teams, develop a web page or similar artifact that identifies admissions criteria, the postsecondary programs of study, and the secondary courses that will prepare students for success after high school in electrical or computer engineering fields. Cite each source adhering to standard citation conventions used in engineering disciplines. (TN Reading 7, 9; TN Writing 2, 4, 6, 8)

### **Gates in Logic Circuits**

- 5) Identify each type of logic gate with a drawing, a description of its function in a short sentence or paragraph, a specification of each truth table, and the equation for each gate (buffer, inverter, AND, NAND, OR, NOR, XOR [difference], and XNOR [equivalence]), including the valid number of input(s) and output(s) for each gate. (TN Reading 2, 4; TN Writing 2, 4)
- 6) Define D and JK flip flops by including a drawing, a description of the function in a short sentence or paragraph, and a specification of each truth table and equation. The description should explain how the “clock” signal is related to the flip flop. (TN Reading 2, 4; TN Writing 4)
- 7) In teams, design three (or more) combinational (without a clock signal) devices to a scale that would be typically implemented in a medium-scale integrated circuit (MSI: typically 10-1000 gates). One of the devices should incorporate XOR / XNOR gates. Examples of devices include 4-bit or greater versions of the following: adder/subtractor, comparator, multiplexer, and calculator. Upon completion of the design, develop a technical presentation providing an overview of the device and its specifications, an accompanying schematic, and a list of the gates used. Present the project to classmates and refine the presentation based on their feedback. (TN Writing 2, 4, 6, 7, 10)
- 8) Working in teams, develop a web page or similar artifact detailing a rich description of one of the combinational projects, and including a schematic and summary of test results if a prototyping system is available in the classroom (Xilinx, Altera, or similar), physically test the project and report results. If possible, include a video of the test on the web page. Present the web page and project to the class, and revise the page based on peer feedback. (TN Writing 4, 6, 7, 10)
- 9) Design a counter with up to 32 states and write an explanatory text describing how the counter operates using technical and domain-specific vocabulary. Provide a state diagram and draw a schematic for the circuit using D or JK flip flops. (TN Reading 4, 7, TN Writing 2, 4, 7)

### **Counters in Logic Circuits**

- 10) In teams, design two (or more) sequential devices that utilize a counter. For example, design a traffic light system with two turn arrows. Create a poster presentation that could be shown at a science fair or career and technical student organization (CTSO) with a description of the device, an accompanying schematic, and a list of the gates used. (TN Writing 2, 4, 6, 7)



## Oscillators in Logic Circuits

- 11) In teams, design a clock signal using a 555-timer in an astable monovibrator configuration. Simulate the design and/or build a prototype and measure the output frequency. If instrumentation to measure the frequency is not available (an oscilloscope for example), a clock frequency timed using a stopwatch can be used as an alternative. Compare and contrast the prediction of the outcome with actual results. Develop a presentation to explain the circuit design, the prediction, and the results from the simulation or prototype. *Note: The instructor may wish to constrain the output frequency by supplying a resistor value and/or a capacitor value.* (TN Reading 3, 4; TN Writing 7; TN Math N-Q)
- 12) In teams, design a counter with between 16 and 32 states. Clock the counter using an oscillator of known frequency, and predict the frequency from each output (each bit in the counter). Simulate the counter to verify the prediction. If possible, the counter should be physically prototyped to verify the prediction and simulation. Calculate the error between the prediction and simulation or prototype. Produce a technical report using an online document processor such as Google docs. (TN Reading 3, 4; TN Writing 4, 6, 7; TN Math N-Q)

## Multiplexers in Signal Distribution

- 13) Design a circuit with 4-8 signals and use a multiplexer to select one of the signals as the output, then simulate the circuit. Develop and deliver a presentation describing the inputs, explaining the circuitry used to select the channel to output, and featuring a timing diagram illustrating the successful operation of the circuit. (TN Reading 3, 4; TN Writing 2, 4, 7)
- 14) In teams, design a 4-channel multiplexer using gates. Simulate or build a prototype of the circuit, and demonstrate it to the class. Participate in a class discussion that compares and contrasts the various designs exhibited. As a class, determine the best design and provide supporting evidence from observations and functionality to justify the decision. (TN Reading 3, 4; TN Writing 7)

## Functions of Analog and Digital Convertors

- 15) In teams, design a circuit using an A/D converter to measure the temperature in the room. Specify the assumptions made for minimum and maximum temperatures, and calculate the resolution (step) of the system. Upon completion of the circuit, write a technical specification of the design; then present the design and technical specifications to the class, including a graph showing the input and output values. Using the feedback from classmates, write a summary describing how the design could be revised and improved in future projects. *Note: Instructors may substitute a similar project in which a continuous and limited quantity is measured.* (TN Reading 3, 4; TN Writing 2, 4, 7; TN Math N-Q, A-REI, S-ID)
- 16) Using multiple print and digital sources, research the uses for A/D and D/A converters in a current technical device. For example, describe how data acquisition systems in race cars use A/D and D/A converters. Draw on the research findings to develop talking points and participate in a mock public forum on the uses for A/D and D/A converters. (TN Reading 3, 4, 5; TN Writing 4, 6, 7; TN Math N-Q)



## Program Microcontrollers

17) Sketch and describe a block diagram of a computer system, detailing at least the following components:

- a. Microcontroller / microprocessor
- b. Cache
- c. RAM (Random Access Memory)
- d. Large-scale memory
- e. Input devices
- f. Output devices (monitor[s])

Show the proper connections between each component, such as data bus and address bus connections. Using visual aids, present and explain the block diagram to the class. (TN Reading 1, 4; TN Writing 4, 5)

18) In teams, program a microcontroller-based system to perform a series of tasks. The microcontroller should be part of a larger system. Upon completion of the programming, write a technical report summarizing the functions and intended uses of the end product. Include the specifications of the series of tasks performed by the microcontroller and the programming code with comments for each function. Present the design to the class, and revise the report based on feedback from peers. (TN Reading 2, 3, 4, 9; TN Writing 2, 4, 5, 7, 8)

## Technical Documentation and Troubleshooting

19) Consult technical documents (such as data sheets, timing diagrams, operating manuals, and schematics) of digital components (TTL, CMOS, etc.) to develop a troubleshooting methodology for a digital circuit that could be used by a new technician. Create and deliver a presentation demonstrating the troubleshooting procedure for the class. (TN Reading 3, 4, 5, 7; TN Writing 2, 4, 9)

## Projects

20) In teams, identify a problem requiring a digital circuit (including A/D, D/A conversion and/or a microprocessor). Follow the design process to solve the problem using digital electronics. Develop a written report documenting the solution, including a background section describing the problem which cites written or electronic sources and documentation of each stage in the design process. Build a prototype proof-of-concept if feasible. Present the problem, the design process used, and the developed solution to the class and other technical or non-technical audience members (e.g., parents, teachers, school administrators, STEM professionals, etc.). The final report draft should be critiqued by a different student team or outside expert. Thereafter, incorporate feedback to refine the report and submit a final version. (TN Reading 6, 7, 8, 9; TN Writing 2, 4, 5, 6, 9, 10)



## Standards Alignment Notes

\*References to other standards include:

- TN Reading: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 9-10 Students (page 62).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN Writing: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 9-10 Students (pages 64-66).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 3 at the conclusion of the course.
- TN Math: [Tennessee State Standards for Mathematics](#); Math Standards for High School: Number and Quantity, Algebra, Statistics and Probability (pages 58-83).
  - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate quantitative, algebraic, and statistical reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills [Framework for 21st Century Learning](#)
  - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.





TENNESSEE DEPARTMENT OF  
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## Welding I

<b>Primary Career Cluster:</b>	Advanced Manufacturing
<b>Consultant:</b>	Bethany King Wilkes, (615) 532-2844, <a href="mailto:Bethany.Wilkes@tn.gov">Bethany.Wilkes@tn.gov</a>
<b>Course Code:</b>	TBD
<b>Pre-requisite(s):</b>	<i>Principles of Manufacturing (5922). Recommended: Algebra (3102), Geometry (3108), Physical Science (3202).</i>
<b>Credit:</b>	1
<b>Grade Level:</b>	10
<b>Graduation Requirement:</b>	This course satisfies one of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing courses.
<b>Programs of Study and Sequence:</b>	This is the second course in the <i>Welding</i> program of study.
<b>Necessary Equipment:</b>	Refer to the Teacher Resources page.
<b>Aligned Student Organization(s):</b>	Skills USA: <a href="http://www.tnskillsusa.com">http://www.tnskillsusa.com</a> Brandon Hudson, (615) 532-2804, <a href="mailto:Brandon.Hudson@tn.gov">Brandon.Hudson@tn.gov</a>
<b>Coordinating Work-Based Learning:</b>	If a teacher has completed work-based learning training, he or she can offer appropriate placement. To learn more, please visit: <a href="http://www.tn.gov/education/cte/work_based_learning.shtml">http://www.tn.gov/education/cte/work_based_learning.shtml</a> .
<b>Available Student Industry Certifications:</b>	None
<b>Dual Credit or Dual Enrollment Opportunities:</b>	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
<b>Teacher Endorsement(s):</b>	551, 552, 553, 554, 555, 556, 584, and BAT or AWS Industry Certification OR any other occupational endorsement plus Certified Welding Educator Certification.
<b>Required Teacher Certifications/Training:</b>	See above.
<b>Teacher Resources:</b>	<a href="http://www.tn.gov/education/cte/Manufacturing.shtml">http://www.tn.gov/education/cte/Manufacturing.shtml</a>

## Course Description

*Welding I* is designed to provide students with the skills and knowledge to effectively perform cutting and welding applications used in the advanced manufacturing industry. Students enrolled in this course will develop proficiency in fundamental safety practices in welding, interpreting drawings, creating computer aided drawings, identifying and using joint designs, efficiently laying out parts for fabrication, basic shielded metal arc welding (SMAW), mechanical and thermal properties of metals, and quality control. Upon completion of the *Welding I* course, students will understand the requirements to pursue the American Welding Society (AWS) Entry Welder qualification and examination and will be prepared to undertake more advanced welding coursework. Standards in this course are aligned with Tennessee State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee State Standards in Mathematics.\*

## Program of Study Application

This is the second course in the *Welding* program of study. For more information on the benefits and requirements of implementing this program in full, please visit the Advanced Manufacturing website at <http://www.tn.gov/education/cte/Manufacturing.shtml>.

## Course Standards

### Safety

- 1) Accurately read and interpret safety rules, including rules published by the (1) National Science Teachers Association (NSTA), (2) rules pertaining to electrical safety, (3) Occupational Safety and Health Administration (OSHA) guidelines, (4) American Society for Testing Materials; ANSI Z49.1: Safety and Welding, Cutting, and Allied Processes, and (5) state and national code requirements. Be able to distinguish between rules and explain why certain rules apply. Complete safety test with 100 percent accuracy. (TN Reading 3, 4; TN Writing 2, 4)
- 2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, store, and maintain safe operating procedures with tools and equipment. (TN Reading 3, 4)

### Career Exploration

- 3) Locate and assess the American Welding Society website and analyze its structure, policies, and requirements for the AWS Entry Welder qualification and certification. Explain a welder certification document, what steps are required to obtain the certification, and how to prepare for the examination. (TN Reading 2, 3, 4)

### Interpreting and Creating Drawings

- 4) Compare and contrast the architectural scale versus the engineering scale used in mechanical drawings. Describe their distinguishing characteristics. Define a scale and perform conversion calculations of various distances. (TN Reading 3, 4; TN Math N-Q)





- 5) Building on the knowledge of a two-dimensional drawing, create simple isometric (3-D pictorial) drawings, properly using lines (e.g., object, hidden, center), labels, and dimensioning techniques. (TN Reading 3, 4, 5, 7; TN Writing 4; TN Math G-MG)
- 6) Use computer aided drafting (CAD) software to create simple two-dimensional and three-dimensional drawings, accurately incorporating labels, notes, dimensioning, and line types to design drawings. Perform basic operations such as creating, saving files, opening files, storing files, and printing. (TN Reading 3, 4, 5, 7; TN Writing 4; TN Math G-MG)

### **Welding Design and Layout**

- 7) Identify, sketch, and explain the five basic weld joint designs (e.g., butt, lap, tee, outside corner, and edge). Find examples of various joint designs applied to structures on or around campus and take pictures to present to classmates. (TN Reading 1, 2, 7; TN Math G-GMD)
- 8) Demonstrate proper laying out of parts for fabrication by marking lines and locating points for cutting, bending, drilling, and assembling. Identify the factors that influence effective layout and explain how to maximize the desired outcome. For example, plan the placement of parts together so as to minimize the waste of stock material. (TN Reading 3, 4, 5, 7; TN Writing 4; TN Math N-Q, G-GMD)

### **Shielded Metal Arc Welding (SMAW)**

- 9) Safely set up equipment for shielded metal arc welding (SMAW). Identify and explain the equipment, equipment setup, and the electrical current used in the welding process. Drawing on multiple resources, compare and contrast SMAW with other welding and cutting processes such as oxyfuel gas welding (OFW), gas metal arc welding (GMAW), flux-cored arc welding (FCAW), and gas tungsten arc welding (GTAW). Write a brief informative paper discussing the distinguishing characteristics and primary advantages of each. (TN Reading 2, 4, 5, 7; TN Writing 2, 4)
- 10) Demonstrate how to make single- and multiple-pass fillet welds and groove welds with backing on plain carbon steel in the following positions. Prior to welding, sketch a cross section, including the dimensions of each weld demonstration.
  - a. Flat
  - b. Horizontal
  - c. Vertical
  - d. Overhead(TN Reading 3, 4, 5, 7; TN Writing 4; TN Math N-Q, G-GMD)
- 11) Research the American Welding Society (AWS) filler metal classification system and write a paper explaining the system, briefly discussing the multiple factors that affect electrode selection for shielded metal arc welding (SMAW). Using various electrodes, demonstrate how to make pad beads on plain carbon steel in the following positions.
  - a. Flat
  - b. Horizontal
  - c. Vertical
  - d. Overhead



Summarize the demonstration results of using various electrodes and explain the findings using supporting evidence from the AWS metal classification system. (TN Reading 2, 3, 4, 5, 7; TN Writing 2, 4; TN Math N-Q, G-GMD)

### Properties of Metals

12) Research the following mechanical properties of metals and their importance in the welding process.

- a. Tensile
- b. Strength
- c. Hardness
- d. Elasticity
- e. Ductility
- f. Toughness
- g. Brittleness

Create a chart or table that compares and contrasts the meaning of these properties. Explain the changes in the mechanical properties of weldments that occur during the welding process. (TN Reading 2, 4, 5, 6, 7; TN Writing 2, 4, 9)

13) Investigate the thermal properties of metals and their effects on welding processes. Describe and demonstrate techniques to mitigate the effects of thermal expansion and contraction that occur during the welding process. During the demonstrations, observe and record the changes that occur in the mechanical properties of weld and parent metals caused by heating and cooling. Write a report summarizing and explaining the findings. Justify all explanations with supporting evidence gathered from observations and welding principles. (TN Reading 3, 4, 5, 7, 8; TN Writing 2, 4, 5)

14) Design an experiment to test and compare the effect that thermal conductivity and specific heat have on various metals such as steel and aluminum. Record all observations and write a report to present the test results in an electronic format, integrating quantitative and visual information. The report should include, but should not be limited to, explaining the effect of thermal conductivity on the heating and cooling rates observed during the welding process, as well as the effect of specific heat on heat rates required for welding. (TN Reading 3, 4, 5, 7; TN Writing 2, 4, 5, 6, 7, 8, 9)

### Quality Control

15) Drawing upon multiple resources, research and write a text explaining the relationship between discontinuities and defects. Describe various examples of defects found in welded products. Also identify and explain both destructive and nondestructive tests used as quality control techniques to prevent manufacturing defects in welding. Compare and contrast these techniques and provide specific examples when they are most appropriately used. Cite evidence to justify the examples. (TN Reading 1, 3, 5, 7, 9; TN Writing 1, 4)

16) Measure and visually inspect welded products for acceptability to American Welding Society QC-10 standards. Record discontinuities and defects, and compare data to given project specifications using class-defined analysis methods. Interpret and communicate results both written and verbally. If necessary, recommend changes that will reduce the number of product



defects during the manufacturing process. (TN Reading 1, 3, 4, 7; TN Writing 1, 4; TN Math N-Q, G-GMD)

## Standards Alignment Notes

\*References to other standards include:

- TN Reading: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 9-10 Students (page 62).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN Writing: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 9-10 Students (pages 64-66).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3 and 10 at the conclusion of the course.
- TN Math: [Tennessee State Standards for Mathematics](#); Math Standards for High School: Number and Quantity, Geometry (pages 58-83).
  - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate on lesson planning. Students who are engaging in activities listed above should be able to demonstrate quantitative and geometric reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.
- P21: Partnership for 21st Century Skills [Framework for 21st Century Learning](#)
  - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.





TENNESSEE DEPARTMENT OF  
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## Welding II

<b>Primary Career Cluster:</b>	Advanced Manufacturing
<b>Consultant:</b>	Bethany King Wilkes, (615) 532-2844, <a href="mailto:Bethany.Wilkes@tn.gov">Bethany.Wilkes@tn.gov</a>
<b>Course Code:</b>	TBD
<b>Pre-requisite(s):</b>	<i>Principles of Manufacturing (5922), Welding I (TBD). Recommended: Algebra (3102), Geometry (3108), Physical Science (3202).</i>
<b>Credit:</b>	2
<b>Grade Level:</b>	11-12
<b>Graduation Requirement:</b>	This course satisfies two of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing courses.
<b>Programs of Study and Sequence:</b>	This is the third course in the <i>Welding</i> program of study.
<b>Necessary Equipment:</b>	Refer to the Teacher Resources page.
<b>Aligned Student Organization(s):</b>	Skills USA: <a href="http://www.tnskillsusa.com">http://www.tnskillsusa.com</a> Brandon Hudson, (615) 532-2804, <a href="mailto:Brandon.Hudson@tn.gov">Brandon.Hudson@tn.gov</a>
<b>Coordinating Work-Based Learning:</b>	If a teacher has completed work-based learning training, he or she can offer appropriate placement. To learn more, please visit: <a href="http://www.tn.gov/education/cte/work_based_learning.shtml">http://www.tn.gov/education/cte/work_based_learning.shtml</a> .
<b>Available Student Industry Certifications:</b>	American Welding Society Entry Welder
<b>Dual Credit or Dual Enrollment Opportunities:</b>	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
<b>Teacher Endorsement(s):</b>	551, 552, 553, 554, 555, 556, 584, and BAT or AWS Industry Certification OR any other Occupational license endorsement plus Certified Welding Educator Certification.
<b>Required Teacher Certifications/Training:</b>	See above.
<b>Teacher Resources:</b>	<a href="http://www.tn.gov/education/cte/Manufacturing.shtml">http://www.tn.gov/education/cte/Manufacturing.shtml</a>

## Course Description

*Welding II* is designed to provide students with opportunities to effectively perform cutting and welding applications of increasingly complexity used in the advanced manufacturing industry. Proficient students in this course will build on the knowledge and skills of the *Welding I* course and apply them in novel environments, while learning additional welding techniques not covered in previous courses. Specifically, students will be proficient in (1) fundamental safety practices in welding, (2) gas metal arc welding (GMAW), (3) flux cored arc welding (FCAW), (4) gas tungsten arc welding (GTAW), and (5) quality control methods. Upon completion of the *Welding II* course, proficient students will be eligible to complete the American Welding Society (AWS) Entry Welder qualification and certification. Standards in this course are aligned with Tennessee State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee State Standards in Mathematics.\*

## Program of Study Application

This is the third course in the *Welding* program of study. For more information on the benefits and requirements of implementing this program in full, please visit the Advanced Manufacturing website at <http://www.tn.gov/education/cte/Manufacturing.shtml>.

## Course Standards

### Safety

- 1) Accurately read and interpret safety rules, including rules published by the (1) National Science Teachers Association (NSTA), (2) rules pertaining to electrical safety, (3) Occupational Safety and Health Administration (OSHA) guidelines, (4) American Society for Testing Materials; ANSI Z49.1: Safety and Welding, Cutting, and Allied Processes, and (5) state and national code requirements. Be able to distinguish between rules and explain why certain rules apply. Complete safety test with 100 percent accuracy. (TN Reading 3, 4; TN Writing 2, 4)
- 2) Identify and explain the intended use of safety equipment available in the classroom. For example, demonstrate how to properly inspect, use, store, and maintain safe operating procedures with tools and equipment. (TN Reading 3, 4)

### Gas Metal Welding (GMAW)

- 3) Safely set up equipment for gas metal arc welding (GMAW). Identify and explain the equipment, equipment setup, power sources, and the electrical current used in the welding process. Drawing on multiple resources, research the advantages of using GMAW over conventional electrode-type arc (stick) welding. Write a brief informative paper distinguishing the characteristics. For example, explain why it is easier to control the small molten weld pool using the GMAW process. (TN Reading 2, 4, 5, 7, 9; TN Writing 2, 4)
- 4) Research the American Welding Society (AWS) filler metal classification system, and write a brief paper explaining the system, discussing the multiple factors that affect electrode selection for gas metal arc welding (GMAW). For example, the 80 in ER80S-D2 designates the minimum tensile strength of the deposited weld metal in thousands. (TN Reading 2, 3, 4, 5, 7; TN Writing 2, 4)



- 5) Using the gas metal arc welding (GMAW) process and various metal transfer methods (e.g., short-circuit, pulse-arc, globular, and spray transfer), demonstrate how to pad beads and make fillet welds on plain carbon steel in all feasible positions (e.g., horizontal, flat, vertical, overhead). Summarize the demonstration results, distinguishing between the metal transfer methods used, and explain the equipment adjustments made to change between metal transfer methods as if narrating a technical process to an audience. (TN Reading 3, 4, 5, 7; TN Writing 2, 4; TN Math N-Q, G-GMD)

### **Flux Cored Arc Welding (FCAW)**

- 6) Safely set up equipment for flux cored arc welding (FCAW). Identify and explain the equipment, equipment setup, power sources, and the electrical current used in the welding process. Drawing on multiple resources, research the advantages and limitations of FCAW. Write a brief informative paper distinguishing these characteristics. For example, determine which types of metals and alloys are most applicable for the use of FCAW. (TN Reading 2, 4, 5, 7, 9; TN Writing 2, 4)
- 7) Refer to previous research conducted on the filler metal classification system by the American Welding Society (AWS). Using proper domain-specific terminology, explain in a presentation to a technical audience the multiple factors that affect electrode and shielded gas selection for flux cored arc welding (FCAW). For example, manufacturers sometimes consider the exact composition of fluxes a trade secret and do not provide enough details to classify electrodes. As a result, AWS uses G for electrodes that have not been classified. (TN Reading 2, 4, 5, 7; TN Writing 2, 4)
- 8) Using various electrodes and the flux cored arc welding (FCAW) process, demonstrate how to pad beads and make fillet welds on plain carbon steel in all feasible positions (e.g., horizontal, flat, vertical, overhead). Over time, routinely document observations such as the effects of metal surface conditions, voltage drop, welding position, and wire feed speed. Summarize the demonstration results of using various electrodes and explain the findings using supporting evidence from the AWS metal classification system and other resources. (TN Reading 3, 4, 5, 7; TN Writing 2, 4; TN Math N-Q, G-GMD)
- 9) Identify and explain the following distinctive features about flux cored arc welding (FCAW): arc-control, oxidation-prevention, self-shielded FCAW, and gas-shielded FCAW. Describe and demonstrate specific examples of how metal transfer is affected by arc-control, self-shielded, and gas-shielded FCAW. Explain the importance of using recommended gas mixtures. (TN Reading 2, 4, 5, 7; TN Math N-Q)

### **Gas Tungsten Arc Welding (GTAW)**

- 10) Safely set up equipment for gas tungsten arc welding (GTAW). Identify and explain the equipment, equipment setup, power sources, and the electrical current used in the welding process. Drawing on multiple resources, compare and contrast water-cooled welding torches versus air-cooled welding torches used in GTAW. Write a brief paper distinguishing the characteristics and the appropriate applications of each torch type. For example, determine which torch is preferred in production welding contexts and explain why. (TN Reading 2, 4, 5, 7, 9; TN Writing 2, 4)



- 11) Refer to previous research conducted on the filler metal classification system by the American Welding Society (AWS). Discuss the multiple factors that affect electrode selection for gas tungsten arc welding (GTAW). For example, pure tungsten (EWP) is not typically used with alternating current (AC) welding of materials because it has poor heat resistance and electron emission. (TN Reading 2, 3, 4, 5, 7, 9; TN Writing 2, 4)
- 12) Using various electrodes and the gas tungsten arc welding (GTAW) process, demonstrate how to pad beads and make fillet welds on plain carbon steel, stainless steel, and aluminum in all feasible positions (e.g., horizontal, flat, vertical, overhead). Summarize the demonstration results of using various electrodes and explain the findings using supporting evidence from the AWS metal classification system and other resources. (TN Reading 3, 4, 5, 7; TN Writing 2, 4; TN Math N-Q, G-GMD)
- 13) Identify and explain the following distinctive features about gas tungsten arc welding (GTAW): arc-control, oxidation-prevention, and gas-shielded GTAW. Describe and demonstrate specific examples of how metal transfer is affected by various shielded gas GTAW (e.g., argon, helium, hydrogen, nitrogen). Identify which gases are noble inert gases and explain why this is a distinguishing characteristic. (TN Reading 2, 4, 5, 7, 9; TN Math N-Q, G-GMD)

### **Quality Control**

- 14) Measure and visually inspect welded products for acceptability to American Welding Society QC-10 standards. Record discontinuities and defects and compare data to given project specifications using class-defined analysis methods. Interpret and communicate results both written and verbally. If necessary, recommend changes that will reduce the number of product defects during the manufacturing process. (TN Reading 1, 3, 4, 7; TN Writing 1, 4; TN Math N-Q, G-GMD)
- 15) Drawing upon multiple resources, research nondestructive testing beyond visual inspection, such as penetrant inspection, magnetic particle inspection, radiographic inspection, and ultrasonic inspection. Describe how these tests are applied as quality control techniques to prevent manufacturing defects in welding. Compare and contrast these techniques and provide specific examples for when they are most appropriately used. Cite evidence to justify the examples. Demonstrate the proper use of the magnetic particle and penetrant inspection tests on weldment samples of gas metal arc welding (GMAW), flux cored arc welding (FCAW), and gas tungsten arc welding (GTAW) processes. (TN Reading 1, 3, 6, 9; TN Writing 1, 4; TN Math N-Q, G-GMD)
- 16) Describe and distinguish between the guided-bend test and the free-bend test. Explain when it is most appropriate to apply each test. Demonstrate the use of each test and properly document results on a mock qualification test record form conforming to the American Welding Society (AWS) requirements. For example, perform root- and face-guided bend tests on a butt joint weld coupon. (TN Reading 3, 4, 5, 7, 9; TN Writing 2, 4; TN Math N-Q, G-GMD)



## Industry Certification

- 17) Pursue the industry certification exam (e.g., American Welding Society SMAW module) using the shielded metal arc welding (SMAW) process. Demonstrate how to make multiple-pass open-butt groove welds on plain carbon steel in all feasible positions (e.g., horizontal, flat, vertical, overhead) conforming to American Welding Society quality standards. (TN Reading 3, 4, 5, 7, 9; TN Writing 2, 4; TN Math N-Q, G-GMD)
- 18) In preparation for industry certification exams (e.g., American Welding Society GMAW, FCAW, and GTAW modules), complete assigned team projects that incorporate the following welding processes in order to design, fabricate, evaluate, and test products made in this course. For each project, produce a technical report documenting illustrations, findings, and justifications for project solutions.
- Using the gas metal arc welding (GMAW) process and various metal transfer methods (e.g., short-circuit, pulse-arc, and spray transfer), demonstrate how to make a complete joint penetration weld on plain carbon steel in all feasible positions (e.g., horizontal, flat, vertical, overhead) conforming to American Welding Society quality standards.
  - Using the flux cored arc welding (FCAW) process, demonstrate how to make a complete joint penetration weld on plain carbon steel in all feasible positions (e.g., horizontal, flat, vertical, overhead) conforming to American Welding Society quality standards.
  - Using electrodes and the gas tungsten arc welding (GTAW) process, demonstrate how to complete joint penetration welds on plain carbon steel, stainless steel, and aluminum in all feasible positions (e.g., horizontal, flat, vertical, overhead) conforming to American Welding Society quality standards.
- (TN Reading 3, 4, 5, 7, 8, 9; TN Writing 2, 4, 5, 6, 7, 8, 9; TN Math N-Q, G-GMD)

## Standards Alignment Notes

\*References to other standards include:

- TN Reading: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 11-12 Students (page 62).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
- TN Writing: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12; Grades 11-12 Students (pages 64-66).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standards 3 and 10 at the conclusion of the course.
- TN Math: [Tennessee State Standards for Mathematics](#); Math Standards for High School: Number and Quantity, Geometry (pages 58-83).
  - Note: The standards in this course are not meant to teach mathematical concepts. However, the concepts referenced above may provide teachers with opportunities to collaborate with mathematics educators to design project-based activities or collaborate





on lesson planning. Students who are engaging in activities listed above should be able to demonstrate quantitative and geometric reasoning as applied to specific technical concepts. In addition, students will have the opportunity to practice the habits of mind as described in the eight Standards for Mathematical Practice.

- P21: Partnership for 21st Century Skills [Framework for 21st Century Learning](#)
  - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.





TENNESSEE DEPARTMENT OF  
**EDUCATION**  
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## Manufacturing Practicum

<b>Primary Career Cluster:</b>	Advanced Manufacturing
<b>Consultant:</b>	Bethany King Wilkes, (615) 532-2844, <a href="mailto:Bethany.Wilkes@tn.gov">Bethany.Wilkes@tn.gov</a>
<b>Course Code:</b>	5926
<b>Prerequisite(s):</b>	Minimum of 2 credits in an Advanced Manufacturing program of study.
<b>Credit:</b>	1
<b>Grade Level:</b>	11-12
<b>Graduation Requirement:</b>	This course satisfies one of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing courses.
<b>Programs of Study and Sequence:</b>	This is the fourth course in the <i>Machining Technology</i> , <i>Electromechanical Technology</i> , <i>Mechatronics</i> , and <i>Welding</i> programs of study.
<b>Necessary Equipment:</b>	Refer to the Teacher Resources page.
<b>Aligned Student Organization(s):</b>	Skills USA: <a href="http://www.tnskillsusa.com">http://www.tnskillsusa.com</a> Brandon Hudson, (615) 532-2804, <a href="mailto:Brandon.Hudson@tn.gov">Brandon.Hudson@tn.gov</a> Technology Student Association (TSA): <a href="http://www.tntsa.org">http://www.tntsa.org</a> Amanda Hodges, (615) 532-6270, <a href="mailto:Amanda.Hodges@tn.gov">Amanda.Hodges@tn.gov</a>
<b>Coordinating Work-Based Learning:</b>	If a teacher has completed work-based learning training, he or she can offer appropriate placement. To learn more, please visit <a href="http://www.tn.gov/education/cte/work_based_learning.shtml">http://www.tn.gov/education/cte/work_based_learning.shtml</a> .
<b>Available Student Industry Certifications:</b>	Manufacturing Skills Standards Council (MSSC) Certified Production Technician (CPT)
<b>Dual Credit or Dual Enrollment Opportunities:</b>	There are no known dual credit/dual enrollment opportunities for this course. If interested in developing, reach out to a local postsecondary institution to establish an articulation agreement.
<b>Teacher Endorsement(s):</b>	070, 230, 231, 232, 233, (042 and 043), (042 and 044), (042 and 045), (042 and 046), (042 and 047), (042 and 077), (042 and 078), (042 and 079), (043 and 044), (043 and 045), (043 and 046), (043 and 047), (043 and 077), (043 and 078), (043 and 079), (044 and 045), (044 and 046), (044 and 047), (044 and 077), (044 and 078), (044 and 079), (045 and 046), (045 and 047), (045 and 077), (045 and 078), (045 and 079), (046 and 047), (046 and 077), (046 and 078), (046 and 079), (047 and 077), (047 and 078), (047 and 079), (077 and 079), (078 and 079), 470, 477, 531, 537, 551, 552, 553, 554, 555, 556, 575, 582, 584, 585, 596, 598

**Required Teacher Certifications/Training:**

If students are assigned in work-based learning settings, teachers who have never taught this course must attend WBL training and earn the WBL Certificate provided by the Department of Education.

**Teacher Resources:**

<http://www.tn.gov/education/cte/Manufacturing.shtml>

## Course Description

*Manufacturing Practicum* is a capstone course intended to provide students with the opportunity to apply the skills and knowledge learned in previous Advanced Manufacturing courses within a professional, working environment. While continuing to add to their technical skillsets, students in this course assume increasing responsibility for overseeing manufacturing processes and managing complex projects. Specifically, proficient students work in teams to plan the production of a sophisticated product; develop troubleshooting and problem solving mechanisms to ensure that projects run smoothly; analyze output and compile professional reports; and connect practicum activities to career and postsecondary opportunities. For all projects undertaken in this course, students are expected to follow the focus area in their chosen program of study (*Machining Technology, Electromechanical Technology, Mechatronics, or Welding*), while also refining skills previously acquired to achieve deeper levels of mastery. Upon completion of the practicum, proficient students will be prepared for postsecondary study and career advancement in their chosen focus area. Standards in this course are aligned with Tennessee State Standards for English Language Arts & Literacy in Technical Subjects and Tennessee State Standards in Mathematics.\*

*Note: Practicum activities may take the form of work-based learning opportunities (such as internships, cooperative education, service learning, and job shadowing) or industry-driven project-based learning. As such, this course must be taught by a teacher with an active WBL Certificate issued by the Tennessee Department of Education and follow policies outlined in the Work-Based Learning Policy Guide available online at [http://www.tn.gov/education/cte/work\\_based\\_learning.shtml](http://www.tn.gov/education/cte/work_based_learning.shtml).*

## Program of Study Application

This is the fourth course in the *Machining Technology, Electromechanical Technology, Mechatronics, and Welding* programs of study. For more information on the benefits and requirements of implementing these programs in full, please visit the Advanced Manufacturing website at <http://www.tn.gov/education/cte/Manufacturing.shtml>.

## Course Standards

### Safety

- 1) Accurately read and interpret safety rules, including rules published by the (1) National Science Teachers Association (NSTA), (2) rules pertaining to electrical safety, (3) Occupational Safety and Health Administration (OSHA) guidelines, (4) American Society for Testing Materials, (4) ANSI Z49.1: Safety and Welding, Cutting, and Allied Processes, and (5) state and national code requirements. Be able to distinguish between rules and explain why certain rules apply. (TN Reading 3, 4)



- 2) Identify and explain the intended use of safety equipment available in the classroom. Demonstrate how to properly inspect, use, store, and maintain safe operating procedures with tools and equipment. (TN Reading 3, 4)

### **Advanced Manufacturing Careers**

- 3) Research local, regional, and national companies operating in advanced manufacturing industries. Synthesize findings into a written report or oral presentation profiling several companies and the production environments in which they operate, including the specific products they manufacture, the industries in which they are used, the long- and short-term employment projections, and their overall contributions to society. For example, report on three manufacturers within the aerospace industry and describe how the products they make support the transportation sector. (TN Reading 1, 2; TN Writing 7)
- 4) Conduct a job search within an advanced manufacturing focus area of choice, including but not limited to machining technology, electromechanical technology, mechatronics, and welding. Compare and contrast job opportunities across sample companies, and determine areas of growth. (TN Reading 9; TN Writing 4)
- 5) Analyze the requirements and qualifications for various advanced manufacturing job postings identified in the previous standard. Gather information from multiple sources, such as sample resumes, interviews with advanced manufacturing professionals, and job boards, to determine effective strategies for realizing career goals. Create a personal resume modeled after elements based on the findings above, then complete an authentic job application as part of a career search or work-based learning experience. (TN Reading 4, 9; TN Writing 4, 7, 8)

### **Professional Ethics and Legal Responsibilities**

- 6) Investigate national and international labor laws governing advanced manufacturing-related industries. Summarize the legal and professional consequences for breaking these laws, citing news media, company policies, and text from relevant legislation. For example, research Apple's stance on child and migrant labor, then compare the company's policy with independent reports on their manufacturing practices overseas. (TN Reading 1, 2, 6, 8, 9; TN Writing 1, 4, 6, 7)
- 7) Research the significance of patents in advanced manufacturing. Describe the process for securing a patent, and explain why patent protection is important for maintaining the integrity and quality of manufactured goods. Synthesize information from multiple sources, including the text of actual patent documents, in order to communicate the process to others. (TN Reading 2, 9)
- 8) Research a case study involving an ethical issue related to consumer safety in the context of advanced manufacturing. Examine a variety of perspectives surrounding the issue, then develop an original analysis explaining the impact of the issue on those involved, using persuasive language and citing evidence from the research. For example, discuss the legal and financial fallout resulting from the recall of a defective automobile part; draw on news media and related coverage to describe the implications of withholding knowledge of such a defect from the public. (TN Reading 1, 2, 8; TN Writing 1, 4, 6, 7)



## Advanced Process Management

- 9) In teams, research an industry need that can be met with a manufacturing product. If possible, meet with a potential client who could use such a product, and discuss the client's wants and needs. Research what materials, labor, equipment, and other inputs are necessary to complete production, then work as a team to develop a production plan, delegate responsibilities, and determine deadlines to meet the client's specifications. Present the plan with supporting graphics and data compiled from the research. (TN Reading 7; TN Writing 1, 2, 6)
- 10) Simulate the work of a plant operations manager or related position by formulating a detailed production schedule. Use diagrams, schematics, and floor plans to lay out production processes and assign sample shifts. Determine how each team member will contribute to the designated production project. (TN Reading 3, 7; TN Math G-GMD, G-MD)
- 11) Develop a logical decision tree to guide manufacturing processes for a range of products. Given a set of defined criteria and constraints, conduct if/then analyses to answer a variety of process-oriented questions. For example, follow a logical decision tree to determine when to employ serial, batch, or continuous manufacturing processes. (TN Reading 3, 4; TN Math F-IF)
- 12) Demonstrate the ability to apply statistical analysis to the evaluation of process outputs. For a given set of constraints, calculate the ideal production rate for a simulated product, then apply learnings toward original projects undertaken in this course. Using quality control methods learned in previous courses, determine criteria to maximize output and minimize product defects. (TN Reading 3; TN Math N-Q, A-CED, F-IF, S-ID)
- 13) Work together to assemble adequate documentation of production activities in the form of a team log, manual, or executive summary of production processes. Be able to explain to both lay and technical audiences how various aspects of the process work, including how the end product is created. Document constraints and criteria using domain-specific vocabulary and industry terminology. (TN Reading 3, 4, 5; TN Writing 2, 4, 7)
- 14) Execute all production plans undertaken in this course in line with resource constraints, deadlines, and all other specifications in order to meet the vision of a client or the expectations of a classroom-based project. Critique the quality of final products for their compliance with client or classroom specifications. Document product evaluations in a written format that can be easily interpreted by others. (TN Reading 3, 8; TN Writing 4, 6, 7)

## Troubleshooting, Problem Solving, and Quality Control

- 15) Work in teams to identify, diagnose, and troubleshoot malfunctions in advanced manufacturing equipment. Apply problem solving skills learned in previous courses to determine the source of the problem(s), assess the maintenance that will be required, and develop a multistep procedure for making corrections. Conduct the required maintenance according to outlined procedures, and critique the effectiveness of the corrective action. (TN Reading 3, TN Writing 2, 8)
- 16) Apply quality control methods learned in previous courses to regularly test and evaluate the quality of manufactured products created in this course. Drawing on associated industry



standards, develop quality benchmarks for measuring the acceptability of the end product. Formulate criteria for identifying defects, and make recommendations for reducing the number of defects based on observations. (TN Reading 3, 4; TN Math N-Q)

- 17) Record accurate and repeatable measurements to specified degrees of precision, attending to appropriate units as directed. When measurements misalign, make the necessary adjustments in order to eliminate the problem. For example, if a machining part is specified to be sized within an acceptable range of nanometers, adjust the CNC code to cut the part within a more accurate margin of error. (TN Writing 4; TN Math N-Q)

### **Portfolio**

- 18) Create a portfolio, or similar collection of work, that illustrates mastery of skills and knowledge outlined in the previous courses and applied in the practicum. The portfolio should reflect thoughtful assessment and evaluation of the progression of work involving the application of steps of the design process, as outlined by the instructor. The following documents will reside in the student's portfolio:

- a. Personal code of ethics
- b. Career and professional development plan
- c. Resume
- d. List of responsibilities undertaken through the course
- e. Examples of visual materials developed and used during the course (such as drawings, models, presentation slides, videos, and demonstrations)
- f. Description of technology used, with examples if appropriate
- g. Periodic journal entries reflecting on tasks and activities
- h. Feedback from instructor and/or supervisor based on observations

(TN Reading 7; TN Writing 4)

### **Communication of Project Results**

- 19) Produce technical reports highlighting the purpose, content, and use for all advanced manufacturing and production projects undertaken in this course. Cite evidence from multiple authoritative sources in order to justify design and production decisions and maximize client satisfaction (when applicable). Incorporate supporting graphics, sketches, and data as needed to summarize the technical specifications of products generated for each project. (TN Reading 1, 2, 3, 4, 5, 7, 8, 9; TN Writing 1, 5, 6, 7, 8, 9)
- 20) Upon completion of the practicum, develop a technology-enhanced presentation showcasing highlights, challenges, and lessons learned from the experience. The presentation should be delivered orally, but supported by relevant graphic illustrations, such as diagrams, flowcharts, and/or summary data generated from simulated operations and quality control analysis. Prepare the presentation in a format that could be presented to both a technical and a non-technical audience, as well as for a career and technical student organization (CTSO) competitive event. (TN Reading 1, 3, 7, 9; TN Writing 2, 4, 5, 6, 9)



## Standards Alignment Notes

\*References to other standards include:

- TN Reading: [Tennessee State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects](#); Reading Standards for Literacy in Science and Technical Subjects 6-12; Grades 11-12 Students (page 62).
  - Note: While not directly aligned to one specific standard, students who are engaging in activities outlined above should be able to also demonstrate fluency in Standard 10 at the conclusion of the course.
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