Department of Education | College, Career and Technical Education

May 2024

Principles of Manufacturing

Primary Career Cluster:	Advanced Manufacturing
Course Contact:	CTE.Standards@tn.gov
Course Code(s):	C13H05
Co-requisite(s):	*Algebra I* (G02X02, G02H00), *Geometry* (G02X03, G02H11), *Physical Science* (G03H00) (recommended)
Credit:	1 credit for core and two focus areas. 2 credits for all 35 standards.
Grade Level:	9
Elective Focus - Graduation Requirement:	This course satisfies one or two of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing courses.
POS Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition, when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the first course in the *Machining Technology, Industrial Maintenance Technology, Mechatronics,* and *Welding* programs of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Tennessee Student Industry Credentials:	Credentials are aligned with postsecondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	070, 157, 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, 522, 523, 531, 537, 551, 552, 553, 554, 555, 556, 557, 575, 580, 582, 584, 585, 596, 598, 700, 701, 705, 706, 707, 760, 982
Required Teacher Certifications/Training:	None
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-advanced-manufacturing.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

CTE courses provide students with an opportunity to develop specific academic, technical, and 21st century skills necessary to be successful in career and in life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards which feed into intentionally designed programs of study.

Students engage in industry relevant content through general education integration and experiences such as career & technical student organizations (CTSO) and work-based learning (WBL). Through these experiences, students are immersed with industry standard content and technology, solve industry-based problems, meaningfully interact with industry professionals and use/produce industry specific, informational texts.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

CTSOs are a great resource to put classroom learning into real-life experiences for your students through classroom, regional, state, and national competitions, and leadership opportunities. Below are CTSO connections for this course, note this is not an exhaustive list.

- Participate in CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, and Additive Manufacturing.

Using a Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-2.2, 9.2** | Conduct a workplace tour or visit.
- **Standards 3.1, 10.3-11.3, 12.2** | Have a guest speaker from industry.
- **Standard 4.1** | Have an industry person do online mentoring with a student.
- **Standard 5.2** | Visit a manufacturing facility to see how layout is done.
- **Standard 7.1** | Visit a facility to see how the engineer/manager determines how the operations will flow.
- **Standards 8.3-8.5** | Have a local industry representative visit the class to discuss the importance of quality control and process management.
- **Standard 13.1** | Partner with a local business to do a project or paper that focuses on the future of manufacturing.

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, Industrial Maintenance 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. Upon completion of this course, 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.

The following implementation options are encouraged:

- one credit for core and two focus areas (listed below), and
- two credits for all 35 standards.

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

Core standards: 1.1-8.5, 13.1

Focus Areas	**Standards**
Machining Technology	9.1, 9.2 9.3
Mechatronics	10.1, 10.2, 10.3
Industrial Maintenance Technology	11.1, 11.2, 11.3
Welding	12.1 12.2, 12.3

Course Standards

1. Safety

1.1 Safety Rules: Accurately read, interpret, and demonstrate adherence to **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.

1.2 Safety Equipment: 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.

1.3 Lock Out/Tag Out: Demonstrate **lock out/tag out procedures**.

2. Overview of Manufacturing

2.1 Manufacturing Overview: **Define manufacturing** and describe how it is used to solve problems. Identify 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, explain how a smart phone goes from raw materials to final packaged product.

2.2 Manufacturing Processes: Distinguish between **primary and secondary processes** involved in the manufacture of industrial goods into finished products. Explain 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. forging (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),
g. stamping (e.g., stamping press), and
h. injection Molds (e.g., injecting material into a mold).

2.3 Manufacturing Systems: Understand 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. Select a **manufacturing system**, such as metal fabrication, and **explain the operation of the system.** Identify each element and explain its role in the system.

2.4 Advanced Manufacturing: Explain how **advanced manufacturing** 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.

2.5 Additive Manufacturing: Explain **additive manufacturing** (3D printing). Identify different scenarios where additive manufacturing would be the preferred method of manufacturing.

3. Materials

3.1 Materials: 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.

3.2 Material Properties: Identify and describe 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); and
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.

4. Career Exploration

4.1 Manufacturing Careers: Identify and describe the various **career opportunities and pathways in the advanced manufacturing industry** (welding, mechatronics, machining technology, and industrial maintenance technology). The descriptions should contain job roles, and applicable licenses and/or certifications associated with each career.

4.2 Postsecondary Opportunities: Identify 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. Identify the postsecondary programs of study, and the secondary courses that will prepare individuals to be successful in a postsecondary program.

5. Layout and Measurement

5.1 Measurement: 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. Demonstrate measurements in both Standard (English) and Metric systems.

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

5.2 Layout: 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.

6. Blueprint Reading and Interpretation

6.1 Sketching and Drafting: 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.

6.2 Drawings: 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, industrial maintenance technology, mechatronics, and welding). For example, industrial maintenance 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

6.3 Interpretation: **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.

7. Sequencing of Manufacturing Operations

7.1 Sequencing: Explain why a manufacturing engineer **sequences** the operations while designing **efficient manufacturing systems**. Find 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, and
c. operations process chart.

8. Quality Assurance and Continuous Improvement

8.1 Data: Identify 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.

8.2 Data Analysis: Identify common statistical **processes to analyze data**. Describe 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, and
c. interpretation of results.

8.3 Quality Control: 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.

8.4 Quality Improvement: Identify **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.

8.5 Process Management: Identify 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.

9. Machining Technology

9.1 Hand Tools: Demonstrate proper application of **common machine shop hand tools**. Identify the following tools and provide examples of how they should be used safely.

a. clamping devices
b. pliers
c. wrenches
d. screwdrivers
e. chisels
f. hacksaws
g. reamers
h. hand taps
i. 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.

9.2 Equipment: Identify and explain the **equipment, equipment setup, and techniques that apply to the following operations:**

a. **sawing,**
b. **drilling,**
c. **grinding, and**
d. **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.

9.3 Computer Numerical Control (CNC): Explain 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.**

10. Mechatronics

10.1 History of Mechatronics: Describe the **history of mechatronics** and summarize how it evolved into modern-day applications. Explain the mechatronics field, the skills needed to be successful in this field, and why there is a demand for mechatronics professionals.

10.2 Mechatronics System: 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.

a. actuators
b. sensors
c. digital control devices
d. input devices
e. output devices
f. graphical displays

10.3 Data Usage: **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.

11. Industrial Maintenance Technology

11.1 Drives: Explain how **belt drives and chain drives** are used to transmit power in an industrial maintenance technology system. Compare and contrast the two drive types and describe the advantages and disadvantages of using each. Make a claim about the appropriate drive type for a given situation, citing data and evidence to support claim and address counterclaims.

11.2 Electricity: **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

11.3 Fluid Power: 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.

12. Welding

12.1 Welding Drawings: 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.

12.2 Material Cutting: 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.**

12.3 Welding Equipment: 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, and
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.

13. Trends in Advanced Manufacturing

13.1 Industry 4.0: Examine the changes to manufacturing due to the Fourth Industrial Revolution (Industry 4.0). 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. sustainable manufacturing;
d. nano manufacturing;
e. flexible electronics manufacturing;

f. bio manufacturing;
g. additive manufacturing – focus on how 3D printing is being used;
h. industrial robotics; and
i. advanced forming and joining technologies.

Research one or more of these trends in depth, and compile, review, and revise 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.

Standards Alignment Notes

*References to other standards include:

- 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.