TN Department of Education | College, Career and Technical Education

Principles of Manufacturing

Primary Career Cluster:	Advanced Manufacturing
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Course Code:	5922
Co-requisite(s):	*Algebra I* (0842, 3102)*, Geometry* (0843, 3108)*, Physical Science* (3202) (recommended)
Credit:	1 credit for core and two focus areas. 2 credits for all 35 standards.
Grade Level:	9
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.
Programs of Study and Sequence:	This is the first course in the *Machining Technology, Electromechanical Technology, Mechatronics,* and *Welding* programs of study.
Aligned Student Organization(s):	Skills USA: http://www.tnskillsusa.com Tracy Whitehead, (615) 532-2804, Tracy.Whitehead@tn.gov Technology Student Association (TSA): http://www.tntsa.org Tracy Whitehead, (615) 532-2804, Tracy.Whitehead@tn.gov
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://tn.gov/education/topic/work-based-learning.
Available Student Industry Certifications:	All Advanced Manufacturing POS: Machining Level 1- Measurement, Materials, and Safety Certification (NIMS) –and/or- Snap On Precision Measurement Instruments Certification
Dual Credit or Dual Enrollment Opportunities:	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.
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, 582, 584, 585, 596, 598, 700, 701, 705, 706, 707, 760
Required Teacher Certifications/Training:	None
Teacher Resources:	https://tn.gov/education/article/cte-cluster-advanced-manufacturing

Approved January 30, 2015; Amended January 25, 2018

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. 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:

- 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	**Standards**
Machining Technology	23, 24, 25
Mechatronics	26, 27, 28
Electromechanical Technology	29, 30, 31
Welding	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 https://tn.gov/education/article/cte-cluster-advanced-manufacturing.

Course Standards

Safety

1) 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, (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.

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.

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.

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~~ 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)
    h. Injection Molds (e.g., injecting material into a mold)

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.

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.

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.

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.

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.

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.

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.

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

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.

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.

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

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.

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

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.

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

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.

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.

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.

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.
    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.

24) Identify and explain the equipment, equipment setup, and techniques that apply to the following operations:
    a. Sawing
    b. Drilling
    c. Grinding
    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.

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.

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.

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.
    a. Actuators
    b. Sensors
    c. Digital control devices

d. Input devices
e. Output devices
f. Graphical displays

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.

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. Make a claim about the appropriate drive type for a given situation, citing data and evidence to support claim and address counterclaims.

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

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.

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.

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.

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.

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, 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.