College, Career and Technical Education

Published May 202~~4~~5

Career Cluster:

Advanced Manufacturing

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 15~~35~~ standards.
Grade Level:	9
Elective Focus Graduation Requirement:	This course satisfies one or two of the 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 Certification~~ss/Training~~:	Please refer to Occupational Educator Licensure Guidance for a full list. ~~Please refer to Occupational Educator Licensure Guidance for a full list.~~None

~~Approved January 30, 2015; Amended January 25, 2018; Amended November 11, 2020~~

Required Teacher 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~~21st-century skills necessary to be successful in ~~career~~ careers and ~~in~~ life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards ~~which~~ that feed into intentionally designed programs of study.

Students engage in ~~industry relevant~~industry-relevant content through general education integration and experiences such as career and~~&~~ technical student organizations (CTSO) and work-based learning (WBL). Through these experiences, students are immersed with ~~industry standard~~industry-standard content and technology, solve industry-based problems, meaningfully interact with industry professionals and use/produce ~~industry specific~~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~~industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill ~~demonstration~~demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, and Additive Manufacturing.

Using ~~a~~ Work-~~b~~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 the 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 complete~~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 (1) credit for Core and two focus areas as ~~(~~listed below~~)~~
- Two (2) credits for all 15~~35~~ standards.

Core standards are required for both one and ~~two credit~~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 ~~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, (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.

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~~smartphone goes from raw materials to final packaged product.

2.2 Manufacturing Processes: Distinguish between **primary and secondary processes** involved in the manufacturing~~e~~ 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. c~~C~~asting and molding (e.g., sand casting),
b. f~~F~~orging (e.g., metal forming),
c. s~~S~~eparating (e.g., machining),
d. a~~A~~ssembling (e.g., welding),
e. d~~D~~irect digital and additive manufacturing (e.g., 3-D printing),
f. f~~F~~inishing (e.g., electroplating),
g. s~~S~~tamping (e.g., stamping press), and
h. i~~I~~njection 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. c~~C~~haracteristics that make up the physical properties of a material;~~,~~

b. h~~H~~ow the mechanical properties affect the way a material will react to forces or loads;~~,~~
c. h~~H~~ow natural elements react with ~~a~~ material and affect its performance;~~,~~
d. c~~C~~haracteristics that make up thermal properties of a material (e.g., thermal resistance, thermal expansion, thermal emission, thermal shock resistance);~~,~~
e. t~~T~~hree major groups of materials that carry an electrical current (e.g., conductors, semiconductors, resistors);~~,~~
f. t~~T~~wo major properties that describe how a material reacts to sound waves (e.g., acoustical transmission, acoustical reflection);~~,~~ and
g. t~~T~~hree 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.

4.3 Career and Technical Student Organization Introduction: **Introduce the program's aligned CTSOs**, SkillsUSA and Technology Student Association (TSA), through an interactive activity, such as a classroom competition.

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. ~~t~~T~~T~~ape rule
b. M~~mM~~achinist's rule
c. B~~bB~~ench rule
d. C~~cC~~aliper
e. D~~dD~~ivider
f. D~~dD~~epth gage
g. M~~mM~~icrometer
h. S~~sS~~quare
i. P~~pP~~rotractor
j. C~~cC~~ombination 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. M~~mM~~easure off the part size on standard stock.
   b. C~~cC~~ut the part blank out of the standard stock.
   c. D~~dD~~raw center lines for holes and arcs.
   d. L~~lL~~ocate holes and arcs.
   e. M~~mM~~ark centers of holes.
   f. D~~dD~~raw tangent lines.
   g. L~~lL~~ayout 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 the 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. D~~dD~~etail drawings
   b. A~~aA~~ssembly drawings
   c. S~~sS~~ystems 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. o~~O~~peration sheet,
   b. f~~F~~low process chart, and
   c. o~~O~~perations 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. c~~C~~ollection of data,
b. a~~A~~nalysis methods, and
c. i~~I~~nterpretation 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. C~~cC~~lamping devices
b. P~~pP~~liers
c. W~~wW~~renches
d. S~~sS~~crewdrivers
e. C~~cC~~hisels
f. H~~hH~~acksaws
g. R~~rR~~eamers
h. H~~hH~~and taps
i. D~~dD~~ies

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. **s~~S~~awing,**
b. **d~~D~~rilling,**
c. **g~~G~~rinding, and**
d. **m~~M~~illing.**

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 the 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. A~~aA~~ctuators
b. S~~sS~~ensors
c. D~~dD~~igital control devices
d. I~~iI~~nput devices
e. O~~oO~~utput devices
f. G~~gG~~raphical 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 the 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. C~~c~~~~C~~urrent
b. V~~v~~~~V~~oltage
c. R~~r~~~~R~~esistance
d. C~~c~~~~C~~onductance
e. P~~p~~~~P~~ower
f. C~~c~~~~C~~harge

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 the 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. o~~O~~xyfuel cutting,
b. p~~P~~lasma-arc cutting,
c. a~~A~~ir carbon arc cutting,
d. s~~S~~awing,
e. s~~S~~hearing, and
f. p~~P~~unching.

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~~to meet 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. s~~S~~ensing, measurement, and process control;~~,~~
b. m~~M~~aterials design, synthesis, and processing;~~,~~
c. s~~S~~ustainable manufacturing;~~,~~
d. n~~N~~ano manufacturing;~~,~~
e. f~~F~~lexible electronics manufacturing;~~,~~

f. b~~B~~io manufacturing;~~,~~
g. a~~A~~dditive manufacturing – f~~F~~ocus on how 3D printing is being used;~~,.~~
h. i~~I~~ndustrial robotics;~~,~~
i. a~~A~~dvanced forming and joining technologies;~~,~~ and
~~i.~~j. electric vehicle manufacturing.

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.

13.2 Ethical Artificial Intelligence (AI): **Explore the ethical implications of AI usage** through interactive discussions and case studies, learning to identify bias, ensure fairness, and protect privacy in AI systems. **Develop** critical thinking **skills to evaluate the societal impact of AI technologies**, while fostering a sense of responsibility and ethical decision-making in their own use of AI tools.

14. Data Analysis

14.1 Data Analysis in Manufacturing: **Research the use of data** in the manufacturing career fields. Include data that is generated internally by businesses~~,~~ and externally by local communities, the state, and the nation. Explore examples of how data is used, including:

a. customer/c~~C~~lient use of products and services in manufacturing;~~,~~
b. demographics of end users of manufactured products;~~,~~
c. community, state, and national statistics related to manufacturing; and~~,~~
d. data that must be reported to another activity that impacts manufacturing.

15. Course Project

15.1 Course Project: Outline the **creation of an innovative product** that could be created to solve a specific problem in the school or community. Using the Engineering Design Process, outline the necessary steps for product development and include a description of how it solves the problem. For example, d~~D~~ocument the design process as a digital portfolio artifact.

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.

Introduction to Industrial Maintenance

Primary Career Cluster:	Advanced Manufacturing
Course Contact:	CTE.Standards@tn.gov
Course Code(s):	C13H28
Prerequisite(s):	*Principles of Manufacturing* (C13H05), *Algebra I (G02X02, G02H00)*, and *Physical Science (G03H00).* Note: *Algebra I* and *Physical Science* may be taken as co-requisites.
Credit:	1
Grade Level:	10
Elective Focus Graduation Requirement~~s~~:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other 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 second course in the *Industrial Maintenance Technology* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
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Teacher Endorsement(s):	477, 523, 531, 537, 551, 552, 553, 554, 555, 556, 557, 575, 580, 582, 584, 585, 596, 598, 700, 701, 705, 707, 760
Required Teacher Certifications~~/Training:~~	Please refer to Occupational Educator Licensure Guidance for a full list.~~None~~
Required Teacher 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/

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- Participate in contests that highlight job skill ~~demonstration~~demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, and Electronics Technology.

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 1.1-1.4** | Include a safety briefing in a visit to an industry partner/job site.
- **Standards 2.1, 2.3~~7~~** | Have the students create~~do~~ a project that is useful to a local employer. The employer can critique the student's drawing.
- **Standard 2.2** | Ask an industry representative ~~to~~ to discuss with students how often employees use math on the job.
- **Standards 2.4, 4.4** | Conduct troubleshooting with an employee responsible for troubleshooting.
- **Standards 3.1-3.3** | Visit a facility that uses multiple circuits and devices to learn how the company handles electronic and electrical equipment.
- **Standard 4.1** | Tour a w~~W~~orkplace ~~tours~~ or invite guest speakers. ~~can be helpful with this.~~
- **Standard 4.2** | Shadow an employee at a plant as they do this.

Course Description

Introduction to Industrial Maintenance is a foundational course that introduces students to basic industrial maintenance skills necessary in a manufacturing facility. Topics covered include safety, construction drawings, site layout, hand and power tools, linear and angular measurements, and application of algebraic and geometric principles to construction problems. Upon completion of this course, proficient students will be able to understand, describe, and troubleshoot industrial maintenance systems.

Course Standards

1. Safety

1.1 Safety Standards and Procedures: 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.

1.2 Hand and Power Tools: Assess a given situation requiring the use of hand and/or power tools. Select the **proper tool and accessories**, critique the readiness of the tool, **use the tool** to accomplish the desired task, and then return the tool and accessories to its proper storage. For example, creating a hole in aluminum requires the choice of the proper drill, drill bit, mounting hardware, lubricant, and safety procedures and precautions. The suitability of the drill bit is just one of many aspects that must be assessed and analyzed.

1.3 Rigging and Lifting: Analyze situations, create plans, and implement plans requiring the **use of rigging** to install and/or remove equipment and machinery. Perceive and critique the safety risks involved in the job. For example, contrast the implications of **lifting and positioning heavy objects** of small compact ~~shape~~ shapes versus those of large rotational moment.

1.4 Electrical Principles: Identify and evaluate situations that require **electrical circuits and electromechanical principles**. Develop and safely implement a plan to achieve the desired electromechanical objective. For example, recognize the power requirements for operating a 35 hp lathe, develop a wiring plan, and draft the details for a work order.

2. Problem Solving ~~&~~and Critical Thinking

2.1 Simple Drawings: Create **linear and angular drawings** to represent real-world physical scenarios in two and three dimensions. For example, based on physical requirements for a bracket, develop a plan ~~,~~ and create a drawing based on the required geometry for accurately fabricating the bracket, including precise linear and angular measures.

2.2 Mathematics: **Apply mathematics concepts to solve electronics and manufacturing industry problems**. For example, calculate the impact of the addition of random variables representing material dimensions that include several tolerances and dimensional allowances on the final combined work product.

2.3 Dimensional Drawings: Create **two- and three-dimensional scale drawings** using accepted dimensioning rules and measurement systems. For example, as part of a project to fabricate a custom-shaped metal block, develop ~~the~~ complete drawings that specify the dimensional details for each step of the construction process.

2.4 Basic Troubleshooting: Identify and demonstrate **basic troubleshooting** strategies appropriate for evaluating electronic circuits/systems and electromechanical devices. For example, in a relay-logic circuit with four display bulbs, develop and implement a troubleshooting strategy to remedy a bulb that fails to light.

3. Computers ~~&~~and Electronics

3.1 Electricity: Demonstrate understanding of the **operation of electrical circuits and devices** and relate it to the physical laws (such as Ohm's Law, Kirchhoff's Law, and power laws) that govern the **behavior of electrical circuits and devices**. Accurately apply these physical laws to solve problems. For example, calculate and support the consequence of the maximum volume of air that can be moved by an AC-powered 50 hp electric motor.

3.2 Electrical Circuits: Explain the interrelationships among sources of **current, voltage, resistance, and power in electric circuits**, both theoretical (illustrated) and actual by designing a direct current (DC) circuit of resistors and ~~LEDs, and~~LEDs and ~~predict~~predictinging~~ing~~ the likely current and power requirement. Discriminate among used resistors in a junk box, using the color codes to identify resistors of suitable value.

3.3 Electronic Testing: Assemble the required connections of electronic test equipment to **properly test the operation of basic electronic circuit** behavior and performance, using equipment such as a digital multimeter, oscilloscope, and resistance bridge. For example, design, assemble, and verify a passive analog filter able to block at least 6 dB of audio-level signals of frequency greater than 500 Hz.

4. Production ~~&~~and Processing

4.1 Industrial Maintenance Occupations: Investigate an assortment of **occupations and manufacturing processes that rely on electromechanical principles and technologies**, such as shipyard rigging, metalworking, agricultural mechanics, construction, and medical prosthetics. Write an informative text that summarizes the typical educational and certification requirements, working environments, and career opportunities for these occupations.

4.2 Quality Control: Analyze and describe a variety of **quality control constraints on manufacturing materials, parts, and processes** that impact the suitability of a given electromechanical production process. Collect and interpret data that includes, but is not limited to, physical and electrochemical properties such as size, mass, hardness, pH, temperature, conductivity, rate, and so forth, and synthesize the results to yield a clear, written documentation of the findings. For example, assist a quality assurance inspector who must carefully complete the steps of a standard inspection order to certify an incoming shipment of raw material by making several measurements and tests for conformance to specification.

4.3 Blueprints and Diagrams: Inspect and interpret **blueprints, schematic diagrams, or written specifications** for electromechanical devices and systems. Explain how pictorial representations relate to an actual project layout, verifying sufficient agreement as prescribed by specified tolerances. For example, create a proposed parts list for wiring a room addition based on electrical construction drawings, conforming to generally accepted building codes.

4.4 Troubleshooting: Given a malfunctioning electromechanical system, use resources such as blueprints, diagrams, and equipment manuals to **troubleshoot the machinery**. Develop and graphically illustrate at least three possible solutions to the problem. Select the optimal solution and justify the selection with evidence drawn from the resources listed above.

5. ~~—~~Team Project

5.1 Team Project with Data Analysis: As a team, **identify a problem** related to the program of study as a whole. **Research and utilize the Engineering Design Process to design a solution**. Document the following steps in an **engineering design notebook** for inclusion in the program portfolio. When possible, connect the problem to an existing SkillsUSA event.

a. **Problem Identification**: Brainstorm specific problems and challenges with the program of study. Conduct basic research to understand the scope and implications of the identified problem. Identify one problem as a focus area.

b. **Research and Analysis**: Conduct in-depth research on chosen topics related to the problem. Locate and analyze a dataset related to the problem.

c. **Review the S~~s~~tages of the Engineering Design Process**: D~~d~~efine the problem, research, brainstorm solutions, develop prototypes, test and evaluate, and iterate. Consider constraints such as cost, efficiency, and environmental impact during the design process.

d. **Project Implementation**: Assign specific roles within the design teams (e.g., project manager, researcher, designer, tester). Design a solution tailored to address the identified problem or scenario. Document progress through design journals, sketches, diagrams, and digital presentations. (Note: Prototype is optional in Year 2 courses.)

e. **Presentation and Reflection**: Showcase the problem and solution to the class. Share the data that was analyzed and how it affected the solution. Discuss the design process and challenges. As a class, critically evaluate the effectiveness and feasibility of the solutions and propose potential improvements.

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.

Advanced Industrial Maintenance

Primary Career Cluster:	Advanced Manufacturing
Course Contact:	CTE.Standards@tn.gov
Course Code(s):	C13H29
Prerequisite(s):	*Algebra* (G02X02, G02H00), *Geometry* (G02X03, G02H11), *Physical Science* (G03H00), and *Introduction to Industrial Maintenance* (C13H28)
Credit:	2
Grade Level:	11
Elective Focus Graduation Requirement:	This course satisfies 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 third course in the *Industrial Maintenance Technology* program 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):	477, 523, 531, 537, 551, 552, 553, 554, 555, 556, 557, 575, 580, 582, 584, 585, 596, 598, 700, 701, 705, 707, 760
Required Teacher Certifications:	Please refer to Occupational Educator Licensure Guidance for a full list.
Required Teacher 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 careers and life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards that feed into intentionally designed programs of study.

Students engage in industry-relevant content through general education integration and experiences such as career and 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 students through classroom, regional, state and national competitions, and leadership opportunities. Below are CTSO connections for this course. Note that this is not an exhaustive list.

- Participate in the 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 demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, and Electronics Technology.

Using 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 1.1-1.3** | During a visit to an industry site, have the manager talk about safety in the workplace.
- **Standards 2.1-2.4** | Have the students work with a welder on a real project.
- **Standards 3.1-3.5, 9.1-9.3** | Have the students work with an electrician in the field.
- **Standards 4.1-4.2** | Contact an electrical inspector to talk with the class about National Electrical Code (NEC) and what they see in their role as inspectors.
- **Standards 5.1-5.3** | Work on-site with an electrician or maintenance technician.
- **Standards 8.1-8.2** | Have the students do a project that is supervised or evaluated by a manager at a local company.
- **Standards 11.1-16.1** | Visit a local industry with this equipment and have the students see it in operation and being maintained.
- **Standard 17.1** | Discuss troubleshooting with the employee responsible for troubleshooting.

Course Description

Advanced Industrial Maintenance is designed to provide students with the knowledge and skills to effectively perform 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 this course, proficient students will be prepared to pursue postsecondary electromechanical technology programs and entry-level industrial maintenance technology careers in the advanced manufacturing industry. ***This course is recommended for 2 credits.***

Course Standards

1. Safety

1.1 Safe Use of Tools, Equipment, and Materials: 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.

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

1.3 Safety in the Classroom: 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.

2. Welding and Machining Operations

2.1 Shielded Metal Arc Welding (SMAW): 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:

h. flat,
i. horizontal,
j. vertical, and
k. overhead.

2.2 Metal Inert Gas Welding (MIG): 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.

a. lap joint,
b. butt joint,
c. corner joint,
d. edge joint, and
e. T-joint

2.3 Grinding: **Demonstrate the proper use of various types of grinders**, such as hand-held and pedestal bench. Compare and contrast the process of using 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.

2.4 CNC Machines and Lathes: 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:

a. **milling machines**, such as indexing operations using a dividing head and rotary tables; and
b. **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.

3. Electrical Circuits

3.1 Direct and Alternating Currents: 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.

3.2 Ohm's Law: 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:

a. **voltage,**
b. **current,**
c. **resistance, and**
d. **voltage drop.**

3.3 Circuits: 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.

3.4 Wiring: 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.

3.5 Electron Flow: Explain **electron flow as it relates to electricity**. 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

4. Conductor Termination and Splices

4.1 Wire Nuts, Lugs, Connectors, and Splices: Understand the National Electrical Code (NEC) and local code requirements for the splicing, terminating, and insulating of conductors. Citing information found in code, explain 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.

4.2 Wiring: 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 (resulting from the previous standard).

5. Fuses and Circuit Breakers

5.1 Uses of Fuses and Circuit Breakers: Explain 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.

5.2 Types of Fuses and Circuit Breakers: 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.

5.3 Install Fuses and Circuit Breakers: Following the correct electrical code practices for residential service, demonstrate the procedures to **install, wire, test, and operate fuses and breakers** in both single-phase and three-phase circuits. Demonstrate effective grounding practices, including the connection of ground wires and installation of bonding straps.

6. Schematic Interpretation

6.1 Schematic Interpretation: 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.

7. Single-Phase Transformer

7.1 Single-Phase Transformer: 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.

a. single-phase step-up transformer
b. single-phase step-down transformer
c. single-phase isolation transformer
d. single-phase current transformer

8. Conductors and Cables

8.1 Conduits and Conductors: 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.

8.2 Identify Conductors and Cables: 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.

9. Conduit Installation

9.1 EMT and PVC Conduit Installation: 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:

a. where and why bends (e.g., stub, offset, saddle, parallel) will be used;
b. how the material will be cut, reamed, installed, and secured; and
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.

9.2 IMC and Rigid Conduit Installation: 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:

a. where and why bends (e.g., stub, offset, saddle, parallel) will be used;
b. how the material will be cut, reamed, installed, and secured; and
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.

9.3 Cable Pull: 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).

10. Computers and Electronics

10.1 Logic Circuits: Given a set of logic statements and schematic circuits, **construct the logic circuits** described using the following:
  a. AND, OR, NOR, and XOR gates; and
  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.

10.2 Programmable Logic Controllers: Given a working **programmable logic controller (PLC),** an operator interface, and interfacing computer, safely set up a communication loop 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, and
  e. analog input and/or modules.

11. Motors

11.1 Select a Motor: Given a specified application in an electromechanical system, properly **select a motor based upon its intended use**. Determine the size, speed, operating voltage, and National Electrical Manufacturing Association (NEMA) type for the required motor. Justify the selection by providing evidence to support the selection.

11.2 Determine motor details: Determine the required **over-current protection, motor control circuits, conductor types and sizes, and conduit types and sizes** for a given motor and application. Compare and contrast the selections by providing supporting evidence for the selections. Work together with classmates to come to a consensus on requirements and report the results.

11.3 Install Motors: **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.
  a. DC motor (other than a permanent magnet motor),
  b. Single-phase capacitor motor, and
  c. Reversing three-phase motor.

12. Drive Systems

12.1 Drive Systems: 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.

13. Calibration and Instrumentation

13.1 Calibration and Instrumentation: **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.

14. Hydraulic Systems

14.1 Hydraulic Systems: Review drawings and interpret American National Standards Institute (ANSI) symbols to explain the function of a **basic industrial hydraulic system**. Explain the recommended regular **preventative maintenance on hydraulic equipment and controls**. Execute the recommended procedures and record the details of the maintenance, explaining how the preventative maintenance will minimize failures in hydraulic equipment.

15. Pumps

15.1 Pumps: 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.

16. Pipe Fabrication

16.1 Pipe Fabrication: Inspect and interpret assembly drawings for **piping in a typical industrial setting**. Given multiple general piping parts, select the 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.

17. Troubleshooting

17.1 Troubleshooting: 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.

Standards Alignment Notes

*References to other standards include:

- P21: Partnership for 21st Century Skills

- 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.

Manufacturing Practicum

Primary Career Cluster:	Advanced Manufacturing
Course Contact:	CTE.Standards@tn.gov
Course Code~~(s)~~:	C13H08
Prerequisite(s):	Minimum of two credits in an Advanced Manufacturing program of study.
Credit:	1
Grade Level:	11-12
Elective Focus Graduation Requirement:	This course satisfies one 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 fourth course in the *Machining Technology, Industrial Maintenance Technology, Mechatronics,* and *Welding* programs of study.
Aligned Student Organization(s):	Skills USA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work Based Learning:	Teachers who hold an active WBL certificate may offer placement for credit when the requirements of the state board's WBL Framework and the Department's WBL Policy Guide are met. 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),(044and 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~~:	~~Some endorsements require NIMS industry certification to teach this course.~~ Please refer to Occupational Educator Licensure Guidance for a full list.~~Please refer Occupational Endorsement License Guide for a full list.~~

Required Teacher Training:	~~None~~Teachers must maintain an active WBL certificate by completing WBL Coordinator Training every two years to oversee this course for credit.

Course at a Glance

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

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

Work-Based Learning: Career Practicum is a capstone course intended to provide students with opportunities to apply the skills and knowledge learned in previous CTE and general education courses within a professional work environment. The course allows students to earn high school credit for select models of work-based learning, which allow students to interact with industry professionals in order to extend and deepen classroom work and support the development of postsecondary and career readiness knowledge and skills.

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~~industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill ~~demonstration~~demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, and Electronics Technology.

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

Practicum activities may take the form of work-based learning (WBL) opportunities, ~~(~~such as internships, cooperative education, service learning, ~~and~~ job shadowing, ~~)~~ or industry-driven project-based learning. These experiences must comply with the Work-Based Learning Framework guidelines established in SBE High School Policy 2.103. 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 https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.

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 2.1-2.2** | Participate in safety activities at their workplace (practicum site).
- **Standard 3.2-3.3** | Have a local manager from the industry discuss job searches and hiring.
- **Standard 4.1-4.2** | Have an industry person discuss how laws and patents impact their company.
- **Standard 5.4** | Have a local manager discuss their production plans.
- **Standard 6.1** | Participate in troubleshooting at their workplace (practicum site).
- **Standard 6.2** | Participate in quality control at their workplace (practicum site).
- **Standard 6.3** | Participate in measurements at their workplace (practicum site).
- **Standards 8.2** | Have a local industry representative critique the presentation.

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 will be able to 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, Industrial Maintenance 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.

Course Requirements

This capstone course aligns with the requirements of the Work-Based Learning Framework, ~~(~~established in Tennessee State Board High School Policy~~)~~, with the Tennessee Department of Education's Work-Based Learning Policy Guide, and with state and federal Child Labor Law. As such, the following components are course requirements:

Course Standards

1. Personalized Learning Plan

1.1 Personalized Learning Plan~~:~~: A student will have a **personalized learning plan** that identifies their long-term goals, demonstrates how the Work-Based Learning (WBL) experience aligns with their elective focus and/or high school plan of study, addresses how the student plans to meet and demonstrate the course standards, and addresses employability skill attainment in the following areas:

a. application of academic and technical knowledge and skills (embedded in course standards),
b. career knowledge and navigation skills,
c. ~~21st century~~21st-century learning and innovation skills, and
d. personal and social skills.

2. Safety

2.1 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.

2.2 Safety Equipment: 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.

3. Advanced Manufacturing Careers

3.1 Advanced Manufacturing Companies: Identify local, regional, and national **companies operating in advanced manufacturing industries**. Summarize the companies and the production environments in which they operate, including the specific products they manufacture, the industries in which they are used, the long-term 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.

3.2 Job Search: Conduct a **job search within an advanced manufacturing focus area of choice**, including but not limited to machining technology, industrial maintenance technology, mechatronics, and welding. Compare and contrast job opportunities across sample companies and determine areas of growth.

3.3 Resume and Application: Analyze the requirements and qualifications for various advanced manufacturing job postings identified in the previous standard. Summarize 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.

4. Professional Ethics and Legal Responsibilities

4.1 Legal Responsibilities: Identify **laws impacting jobs in the student's program**. 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.

4.2 Patents: Research the significance of **patents in advanced manufacturing**. Describe the process for securing a ~~patent, and~~patent and explain why patent protection is important for maintaining the integrity and quality of manufactured goods. Summarize the patent process.

4.3 Ethics: 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, and 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.

5. Advanced Process Management

5.1 Manufacturing Process~~:~~: Use a selected **manufacturing process to be used with a project**. 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 develop a production plan, delegate responsibilities, and determine deadlines to meet the client's specifications.

5.2 Decisions in Manufacturing Process~~:~~: Develop a logical **decision tree to guide the manufacturing process** for the selected project. 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 conduct each step of the process.

5.3 Activities in Manufacturing Process~~:~~: 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.

5.4 Implement Manufacturing Process~~:~~: **Execute all production plans** undertaken in this course in line with resource constraints, deadlines, and all other specifications ~~in order to~~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.

6. Troubleshooting, Problem Solving, and Quality Control

6.1 Troubleshooting~~:~~: Identify, diagnose, and **troubleshoot malfunctions in advanced manufacturing equipment.** Apply ~~problem solving~~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.

6.2 Quality Control~~:~~: 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.

6.3 Measurement Adjustments~~:~~: 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~~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.

7. Portfolio

7.1 Portfolio:: 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 a 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 the technology used, with examples if appropriate;
g. periodic journal entries reflecting on tasks and activities; and
h. feedback from the instructor and/or supervisor based on observations.

8. Project

8.1 Project:: Complete a **project in the assigned program** (Industrial Maintenance Technology, Machining Technology, Mechatronics, or Welding).

8.2 Reports:: **Report on projects** completed as a student. Summarize the purpose, content, and use for all advanced manufacturing and production projects undertaken in this program. Include the technical specifications of products generated for each project. Prepare the report 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.

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.

Principles of Machining I

Primary Career Cluster:	Advanced Manufacturing
Course Contact:	CTE.Standards@tn.gov
Course Code(s):	C13H09
Pre requisite(s):	*Algebra I* (G02X02, G02H00), *Principles of Manufacturing* (C13H05) Recommended: *Geometry* (G02X03, G02H11), *Physical Science* (G03H00)
Credit:	1
Grade Level:	10
Elective Focus Graduation Requirement:	This course satisfies one 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 second course in the *Machining Technology* program of study.
Aligned Student Organization(s):	Skills USA: http://www.skillsusatn.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, 582, 584, 585, 596, 598, 700, 701, 705, 706, 707, 760, 982
Required Teacher Certifications~~/Training~~:	Please refer to Occupational Educator Licensure Guidance for a full list. ~~Please refer to Occupational Educator Licensure Guidance for a full list.Some endorsements require NIMS industry certification to teach this course. Please refer Occupational Endorsement License Guide for a full list.~~
Required Teacher 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~~21st-century skills necessary to be successful in careers and ~~in~~ life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards ~~which~~ that feed into intentionally designed programs of study.

Students engage in ~~industry relevant~~industry-relevant content through general education integration and experiences such as career and technical student organizations (CTSO) and work-based learning (WBL). Through these experiences, students are immersed with ~~industry standard~~industry-standard content and technology, solve industry-based problems, meaningfully interact with industry professionals, and use/produce ~~industry specific~~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 the CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing ~~industry specific~~industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill ~~demonstration~~demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, Additive Manufacturing, CNC Milling, and CNC Technician.

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.

- **Standard 1.2** | Include a safety briefing in a visit to an industry partner/job site.
- **Standard 2.1** | Visit an industry partner that has old and new machines.
- **Standard 3.1** | Visit an employer and talk with those employees about career options.
- **Standards 4.1-4.3** | Students can shadow an employee and see how important proper measurements are in machining.
- **Standards 5.1-5.4** | Have the students complete~~do~~ a project that is useful to a local employer. The employer can critique the student's drawings.
- **Standards 6.1-6.2** | Visit an industry that uses multiple materials to see how the materials are handled and how different materials perform.
- **Standards 7.1-7.2** | Set up a ~~student run~~student-run enterprise at the school that produces products for people at the school.
- **Standards 8.1-8.2** | Have a local industry person visit the class to discuss and demonstrate the importance of quality control.

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. Upon completion of this course, proficient students will demonstrate safety practices concerning machining technology, proper ~~measurement~~measurement, ~~and~~ layout techniques, reading and interpreting drawings and blueprints, production design processes, and quality control procedures. Upon completion of this 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.

Course Standards

1. Safety

1.1 Demonstrate Safety: 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 ~~&~~and 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.

1.2 Safety Guidelines: 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.

2. Overview of Machining Technology

2.1 Machining Technology: Describe **machining technology** and how it has affected the workforce and the manufacturing industry in particular. Summarize early machining tools, how power sources changed, basic machine tool operation, non-traditional machining processes, and automated machining processes.

3. Career Exploration

3.1 Careers: Explain how the role of a machinist has changed with the evolution of machining technology. Describe the **various machining job categories** and their characteristics. Identify the skills, education, and training requirements to become a machinist. Summarize possible postsecondary institutions (e.g., colleges of applied technology, community colleges, and four-year universities) and professional organizations (National Institute for Metalworking Skills [NIMS]).

4. Measurement and Layout

4.1 Measuring Tools: 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. dial c~~C~~alipers,

d. gauges,
e. dial indicators, and
f. helper measuring tools (e.g., calipers, telescoping gauge, small hole ~~gage~~gauge).

4.2 Interpret Measurements: 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.

4.3 Layout: 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,~~.~~ s~~S~~uch as:
l. lines: layout dye, scriber, divider, surface plate, v-blocks, straightedge, squares; and
m. angles: plain protractor, vernier protractor.

5. Blueprint Reading and Interpretation

5.1 Symbols, Lines, and Figures: 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.

5.2 Dimensions: 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.

5.3 Interpret Drawings: 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.

5.4 Detail and Assembly Drawings: 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.

6. Materials

6.1 Metal Classifications: Using the following classifications, explain **how metals are classified,** identify the general characteristics of each type, and describe related safety precautions that should be applied during machining procedures.
a. F~~f~~errous metals
b. ~~n~~Nonferrous metals
c. ~~h~~High-temperature metals
d. ~~r~~Rare metals

6.2 Materials: Investigate the chemical and physical **properties of materials** used in the machining process. Considering the following common materials, list the principal properties relevant to machining tasks.

a. ~~c~~Carbon steels
b. ~~s~~Stainless steels
c. ~~s~~Structural steels
d. ~~c~~Cast iron
e. ~~a~~Aluminum

7. Production Design Process to Machine Parts

7.1 Manufacture a Part: Determine 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 the layout, set up, and performance of tapping, countersinking, counterboring, and reaming as needed. Implement the above strategies to manufacture the part.

7.2 Production Design Process: Develop and manufacture a product idea, accounting for given specifications and potential constraints. Prior to manufacturing the product, use the following multi-step 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.

a. Develop~~develop~~ initial designs.
b. R~~r~~efine designs.
c. Create~~create~~ a conceptual model and prototype.
d. Present~~present~~ design ideas.
e. Obtain~~obtain~~ management approval for the design.
f. M~~m~~anufacture the final product.

~~.~~

8. Quality Control

8.1 Measure and Weigh Parts: **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.

8.2 Testing: Explain 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~~ of when they are most appropriately used. Cite evidence to justify the examples.

9. Team Project

9.1 Team Project with Data Analysis: As a team, **identify a problem** related to the program of study as a whole. **Research and utilize the Engineering Design Process to design a**

solution. Document the following steps in an **engineering design notebook** for inclusion in the program portfolio. When possible, connect the problem to an existing SkillsUSA event.

f. **Problem Identification**: Brainstorm specific problems and challenges with the program of study. Conduct basic research to understand the scope and implications of the identified problem. ~~Identfy~~Identify one problem as a focus area.
g. **Research and Analysis**: Conduct in-depth research on chosen topics related to the problem. Locate and analyze a dataset related to the problem.
h. **Review the ~~s~~Stages of the Engineering Design Process**: define the problem, research, brainstorm solutions, develop prototypes, test and ~~evlauate~~evaluate, and iterate. Consider ~~constratints~~constraints such as cost, efficiency, and ~~enviromental~~environmental impact during the design process.
i. **Project Implementation**: Assign specific roles within the design teams (e.g., project manager, researcher, designer, tester). Design a solution tailored to address the identified problem or scenario. Document progress through design journals, sketches, diagrams, and digital ~~prsesentations~~presentations. (Note: Prototype is optional in the Year 2 course.)
j. **~~Presentaion~~Presentation and Reflection**: Showcase the problem and solution to the class. Share the data that was analyzed and how it affected the solution. Discuss the design process and challenges. As a class, critically evaluate the effectiveness and feasibility of the solutions and propose potential improvements.

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.

Principles of Machining II

Primary Career Cluster:	Advanced Manufacturing
Course Contact:	CTE.Standards@tn.gov
Course Code~~(s)~~:	C13H06
Prerequisite(s):	*Algebra I* (G02X02, G02H00), *Geometry* (G02X03, G02H11), *Physical Science* (G03H00), and *Principles of Machining I* (C13H09). Recommended co-requisite: *Physics* (G03H20)
Credit:	2
Grade Level:	11
Elective Focus Graduation Requirement:	This course satisfies two of the three credits required for an elective focus when taken in conjunction with other 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 third course in the *Machining Technology* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.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, 582, 584, 585, 596, 598, 700, 701, 705, 706, 707, 760, 982
Required Teacher Certifications~~/Training~~:	Please refer to Occupational Educator Licensure Guidance for a full list.~~Some endorsements require NIMS industry certification to teach this course. Please refer Occupational Endorsement License Guide for a full list.~~
Required Teacher 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

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Students engage in ~~industry relevant~~industry-relevant content through general education integration and experiences such as career and technical student organizations (CTSO) and work-based learning (WBL). Through these experiences, students are immersed with ~~industry standard~~industry-standard content and technology, solve industry-based problems, meaningfully interact with industry professionals, and use/produce ~~industry specific~~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~~industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill ~~demonstration~~demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, Additive Manufacturing, CNC Milling, and CNC Technician.

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 1.1-1.3** | Students can shadow an employee and see how important proper measurements are in machining.
- **Standard 2.1** | Include a safety briefing in a visit to an industry partner/job site.
- **Standards 3.1, 5.1** | Set up a ~~student run~~student-run enterprise at the school that produces products for people in the school.
- **Standard 4.1** | Produce a product that is evaluated or used by a local company.
- **Standard 5.4** | Do a project that is used by ~~a~~ local industry or evaluated by local industry managers.

Course Description

Principles of Machining II is an ~~advanced level~~advanced-level contextual course that builds on the introductory skills learned in the entry-level manufacturing and machining courses, stressing the concepts and practices in a production environment supported by advanced machining and engineering facilities. Working with the course instructor and team members in a cooperative learning environment, students will design, produce, and maintain products that are defined by detailed technical specifications. Emphasis is placed on quality control, safety engineering codes and standards, and production-grade machining systems, building on the learner's past knowledge, current experiences, and future conduct as a career machinist. Upon completion of this course, proficient students will be able to examine blueprints and specification drawings to plan and implement the manufacture of products~~,~~ and machine parts to specifications using both manual and computer-controlled machine tools. Students will also be able to measure, examine, and test completed products to check for defects and conformance to specifications.

Course Standards

1. Measurement and Mathematical Concepts for Machining

1.1 Measurement: Determine the appropriate units and record accurate and repeatable **measurements of length, diameter, and thickness** to complete projects using the following:

a. rules, gauges, calipers, and micrometers;
b. tools equipped with dials, vernier scales, and digital readouts;
c. both metric and English scales;
d. appropriate standards of accuracy and precision; and
e. satisfactory tolerances permissible for a given task.

For example, while grinding a piece to a specified thickness, measurements with a metric vernier caliper are used to achieve a value within the tolerance specified by the drawing.

1.2 Measurement of Angles: Determine the appropriate units and record accurate and repeatable **measurements of angles** to complete projects by:

a. applying principles of trigonometry, Cartesian geometry, and/or polar geometry, distinguishing when and which principles apply to a given machining task; and
b. using angle gauges, a plate protractor, a universal bevel protractor with a vernier scale, square, and/or a sine bar and gauge blocks, or adjustable parallel.

For example, measure the angle formed by two surfaces of a machined part to the nearest 0.01 degree using a sine bar.

1.3 Measurement of Material Properties: Determine the appropriate units and record accurate and repeatable **measurements of material properties** such as hardness, pH, and load/elongation test curves of stress, strain, modulus, and yield. Interpret test values and ~~curves, and~~curves and use calculated results to make informed decisions. For example, measure the Rockwell hardness of a piece of stainless steel to determine the recommended cutting speed with a carbide-tipped cutting tool.

2. Safety

2.1 Safety: 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 and Health Administration (OSHA) regulations. Incorporate safety procedures and complete safety ~~test~~ tests with 100 percent accuracy.

3. Design

3.1 Interpret Drawings: Visualize and **interpret engineering drawings** for projects to:

a. create an accurate bill of materials;
b. identify and interpret geometric dimensioning, ~~and~~ tolerancing symbols, and nomenclature; and

c. identify primary and secondary datums.

For example, ~~lay out~~layout correctly dimensioned bolt holes in a radial pattern specified by a ~~drawing, and~~drawing and select the proper tools to complete the required operations.

3.2 Plan to Handle Materials~~:~~: Anticipate the **consequences and handling requirements of metals, alloys, ceramics, polymers, and composites to properly and safely handle and machine these materials**. For example, research the material properties for the bill of materials for a project in preparation for choosing cutting tools, speeds, and handling.

4. Operations & Control

4.1 Operation of Machining Tools~~:~~: 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 advanced projects involving:

a. milling machines, such as indexing operations using a dividing head and rotary tables;
b. lathes, such as re-chase and internal threads, taper turning with taper attachments and compound rests, internal tapered surfaces, follower and steady rests; and
c. grinders, such as grinding pieces between centers, operating radius dressers, cylindrical grinders, and inside diameter (ID) grinders.

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.

4.2 Heat-Treatments~~:~~: Correctly, safely, and efficiently **schedule, configure, administer, and verify heat-treatments to machined parts** according to blueprint specifications. For example, while properly attired and equipped, use an oven or torch to harden and temper a W1-grade steel bolt to yield a hardened, tamper-proof bolt.

5. Production & Processing

5.1 Planning for Production~~:~~: Solve manufacturing-related problems by analyzing and weighing the constraining factors including **schedule, cost, materials, and equipment**,~~,~~ as well as productivity, regulations, maintenance, and quality. For example, as part of an assigned machining project, draft, obtain approval, and implement a schedule for completion, including ordering materials, planning the sequence of machining and stepwise approvals, and determining a target for final delivery, justifying all recommendations with supporting evidence.

5.2 Quality Control~~:~~: **Employ statistical quality control test methods and techniques**,~~,~~ especially on large volume processes,~~,~~ to minimize defects and waste due to poor quality. For example, use statistical sampling, measuring, and charting to monitor and detect the need for corrective action on a mass production of thread cutting. Upon completion of testing, draft a written report documenting the findings in the proper format that a quality control inspector would deliver to a supervisor or other superior.

5.3 New Machining Technologies~~:~~: Explore and develop one's skills with **new and emerging machining and manufacturing technologies**, such as 3D printing, laser etching, computer-controlled machining, and digital manufacturing methods. For example, produce a small plastic part using a 3D printer, and then produce the same part with a CNC production method using G- and M-codes; compare the material cost and waste, manpower, scheduling, etc. of the two methods and provide written justification to persuade a prospective manufacturer, wholesaler, or other supplier why one method is more cost-effective, efficient, or profit-maximizing than the other.

5.4 Solve a Manufacturing Problem~~.~~: Demonstrate and practice teamwork, problem-solving, and decision-making skills required for success as a career machinist in a manufacturing environment. Applying the skills acquired in the previous standards, examine **a given manufacturing problem to research and plan a solution that will result in the creation of a prototype for a manufactured product**. This process will include but is not limited to the following:

a. reading and interpreting relevant engineering drawings;
b. assessing prototyping processes;
c. using engineering drawings as a planning tool for programming software to design the prototype;
d. crafting appropriate documentation and justification of decisions made in the design process~~,~~ for the purposes of explaining as well as persuading; and
e. creating a presentation for the design and construction of the manufactured product.

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.

Digital Electronics

Primary Career Clusters:	Advanced Manufacturing and STEM
Course Contact:	CTE.Standards@tn.gov
Course Code(s):	C13H07
Pre requisite(s):	*Algebra I* (G02X02, G02H00)
Credit:	1
Grade Level:	10
Elective Focus Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing or *STEM* courses.
Program of Study (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 second course in the *Mechatronics* and *Technology* 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):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 210, 211, 212, 213, 214, 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), 413, 414, 415, 416, 417, 418, 449, 470, 477, 501, 502, 519, 523, 531, 537, 551, 552, 553, 554, 555, 556, 557, 567, 575, 582, 584, 585, 595, 596, 598, 700, 701, 705, 707, 740, 760, 982
Required Teacher Certifications~~/Training:~~	Please refer to Occupational Educator Licensure Guidance~~Occupational Endorsement License Guide~~ for a full list.
Required Teacher Training:	None
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-advanced-manufacturing.html https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.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~~21st-century skills necessary to be successful in ~~career~~ careers and ~~in~~ life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards ~~which~~ that feed into intentionally designed programs of study.

Students engage in ~~industry relevant~~industry-relevant content through general education integration and experiences such as career and technical student organizations (CTSO) and work-based learning (WBL). Through these experiences, students are immersed with ~~industry standard~~industry-standard content and technology, solve industry-based problems, meaningfully interact with industry professionals, and use/produce ~~industry specific~~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.~~,~~ N~~n~~ote this is not an exhaustive list.

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

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

Sustained and coordinated activities ~~that relate~~related 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 1.1-1.2** | Include a safety briefing in a visit to an industry partner/job site.
- **Standards 2.1-2.2** | Visit an employer and talk with those employees about career options.
- **Standards 3.3-3.4, 6.2-7.1, 8.2, 10.1** | Complete~~Do~~ a project that is used by local industry or evaluated by local industry managers.
- **Standards 5.1-5.2** | Have an industry person visit the class to talk about and demonstrate the importance of logic circuits on the job.
- **Standard 9.1** | Discuss troubleshooting with an employee responsible for troubleshooting.

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. Proficient students will be able 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~~ skills in technical documentation when operating and troubleshooting circuits. Upon completion of the *Digital Electronics* course, proficient students will be able to design a complex digital system and communicate their designs through a variety of media.

Course Standards

1. Safety

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

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, and maintain safe operating procedures with tools and equipment.

2. Citizenship and Career Exploration

2.1 Citizenship: Explain the **importance of electrical and/or computer engineers' contributions to society.** Select several 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.

2.2 Postsecondary: Identify the **postsecondary institutions** in Tennessee that offer electrical engineering or electrical and/or computer engineering technology. Individually or in teams, develop and publish information 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.

3. Gates in Logic Circuits

3.1 Logic Gates: 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.

3.2 Flip Flops: 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.

3.3 Combinational Devices: 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, provide 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.

3.4 Combinational Project: Develop and publish information 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. Present the project to the class, and revise based on peer feedback.

3.5 Diagram and Schematic: 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 flips.

4. Counters in Logic Circuits

4.1 Counter: Design two (or more) **sequential devices that utilize a counter**. For example, design a traffic light system with two turn arrows. Explain the project with a description of the device, an accompanying schematic, and a list of the gates used.

5. Oscillators in Logic Circuits

5.1 Astable Monovibrator: 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. 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.*

5.2 Counter: In teams, **design a counter** with between 16 and 32 states. Clock the counter using an oscillator of known ~~frequency, and~~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 to summarize findings.

6. Multiplexers in Signal Distribution

6.1 Multiplexer: Design a circuit with 4-8 signals and **use a multiplexer** to select one of the signals as the output, then simulate the circuit. Explain the circuit 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.

6.2 Multiplexer with Gates: In teams, design a **4-channel multiplexer using gates**. Simulate or build a prototype of the ~~circuit, and~~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.

7. Functions of Analog and Digital Convertors

7.1 Analog and Digital Counters: 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~~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.*

7.2 Uses for Converters: Explain 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.

8. Physical Computing and Program Microcontrollers

8.1 Computer System: 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, and
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.

8.2 Microcontroller: **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, explain 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.

8.3 Physical Computing: Create a system to **demonstrate how hardware is connected to code**. For example, ~~:~~ write code, assemble the hardware components, run the code, and assess if the hardware does the intended action.

9. Technical Documentation and Troubleshooting

9.1 Troubleshooting: 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. Explain the troubleshooting procedure.

~~**Projects**~~

10. Team Project

10.1 Team Project with Data Analysis: As a team, **identify a problem** related to the program of study as a whole. **Research and utilize the Engineering Design Process to design a solution**. Document the following steps in an **engineering design notebook** for inclusion in the program portfolio. When possible, connect the problem to an existing SkillsUSA event.

k. **Problem Identification**: Brainstorm specific problems and challenges with the program of study. Conduct basic research to understand the scope and implications of the identified problem. Identify one problem as a focus area.

l. **Research and Analysis**: Conduct in-depth research on chosen topics related to the problem. Locate and analyze a dataset related to the problem.

m. **Review the Stages of the Engineering Design Process**: D~~d~~efine the problem, research, brainstorm solutions, develop prototypes, test and evaluate, and iterate. Consider constraints such as cost, efficiency, and environmental impact during the design process.

n. **Project Implementation**: Assign specific roles within the design teams (e.g., project manager, researcher, designer, tester). Design a solution tailored to address the identified problem or scenario. Document progress through design journals, sketches, diagrams, and digital presentations. (Note: Prototype is optional in the Year 2 course.)

o. **Presentation and Reflection**: Showcase the problem and solution to the class. Share the data that was analyzed and how it affected the solution. Discuss the design process and challenges. As a class, critically evaluate the effectiveness and feasibility of the solutions and propose potential improvements.

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.

Mechatronics I

Primary Career Cluster:	Advanced Manufacturing
Course Contact:	CTE.Standards@tn.gov
Course Code~~(s)~~:	C13H16
Prerequisite(s):	*Algebra I* (G02X02, G02H00), *Geometry* (G02X03, G02H11), *Physical Science* (G03H00), *Digital Electronics* (C13H07), or Robotics & Automated Systems (C13H15)
Credit:	1
Grade Level:	11
Elective Focus Graduation Requirements:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other 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 third course in the *Mechatronics* program of study.
Aligned Student Organization(s):	Skills USA: 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):	157, 232, 233, 470, 477, 523, 537, 551, 552, 582, 596, 701, 760, 982
Required Teacher Certifications~~/Training:~~	Please refer to Occupational Educator Licensure Guidance for a full list.~~None~~
~~Required Teacher 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~~21st-century skills necessary to be successful in ~~career~~ careers and ~~in~~ life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards ~~which~~ that feed into intentionally designed programs of study.

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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.~~,~~ N~~n~~ote 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~~industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill ~~demonstration~~demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, Additive Manufacturing, Mechatronics, and Electronics Technology.

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.

- **Standard 2.1** | Include a safety briefing in a visit to an industry partner/job site.
- **Standards 3.4 -3.5, 4.5 |** Complete~~Do~~ a project that is used by local industry or evaluated by local industry managers.
- **Standard 4.7** | Ask an industry representative to discuss how often employees do maintenance on various systems.
- **Standards 5.1-5.2** | Discuss troubleshooting with an employee responsible for troubleshooting.

Course Description

Mechatronics I is an applied course in the manufacturing cluster for students interested in learning more about careers as a mechatronics technician, maintenance ~~technician~~technician, electromechanical ~~technician~~technician, and manufacturing ~~engineer~~engineer. This first of two courses covers basic electrical and mechanical components of mechatronics systems as well as their combined uses with instrument controls and embedded software designs. Upon completion of this course, proficient students are able to describe and explain basic functions of physical properties and electrical components within a mechatronic system. They can logically trace the flow of energy through a mechatronic system and can communicate this process to others. They know how to effectively use technical documentation such as data sheets, schematics, timing diagrams, and system specifications to troubleshoot basic problems with equipment. Finally, they develop strategies to identify, localize, and correct malfunctioning components and equipment.

Course Standards

1. Mechatronics Overview

1.1 History of Mechatronics: Explain the historical development of the **four facets of a mechatronic system** (mechanical systems, electronic systems, computers, and control systems) and explain their chief applications in modern society.

1.2 Flow of Energy: Describe the **flow of electrical and mechanical energy** in the system. Create a computational model to represent the transfer of energy from one component to ~~others~~ another in a system.

2. Safety

2.1 Safety Rules: **Interpret safety rules**, including but not limited to rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA), and state and national code requirements. **Apply the rules** accordingly while working on electrical and mechanical ~~components, and~~components and explain why certain rules apply.

3. Electronics

3.1 Roles of Electrical Components: Demonstrate an understanding of the specific **roles of various electrical components** discerned in a circuit schematic by correctly **predicting the effects of changing selected parameter values**. For example, predict the effect of halving a resistor's value. Compare and contrast these roles and explain how electronic designs vary within a given system or module.

3.2 Direct Current Circuits: **Create, measure, and analyze basic director current (DC) circuits** prescribed by schematics using Ohm's law, Kirchhoff's law, and Watt's law to predict and verify circuit behavior. Apply understanding of these laws to troubleshoot simple circuits, and document the steps required to remedy the trouble.

3.3 Behavior of Direct Current Circuits: Create, measure, and analyze circuits prescribed by schematics to **predict and verify the behavior of series versus parallel DC circuits** or resistances. Where unexpected behavior is observed, cite specific evidence to explain the observations.

3.4 Operation of Components: Explain the **physical operation of electromagnetic and electrostatic components** (such as coils, solenoids, relays, and various sensors) in a mechatronic system. Interpret resolved work orders by analyzing underlying issues and explaining the correct physical operation of the included components.

3.5 Report on Circuit Behavior: Create, measure, and analyze circuits prescribed by schematics to **predict and verify the behavior of the electrical and physical properties of components** (such as resistors, capacitors, diodes, transformers, relays, and power supplies). **Report findings** explaining the typical application and operation in circuits of the previously listed components, citing measurement and/or observed evidence supporting the explanation.

4. Mechanical

4.1 Mechanical Components~~:~~: Demonstrate understanding of the specific **role of various mechanical components** in mechatronic systems, discerning in a system schematic the effects of various design parameters on the system behavior. For example, predict the effect of a larger gear size. Compare and contrast these roles in the context of mechatronic systems, modules, and subsystems, explaining how designs vary within a given system or module.

4.2 Behavior of Components~~:~~: Create, measure, and analyze mechanical systems prescribed by drawings to **predict and verify the behavior of the physical operation of components** in a mechatronic system, including but not limited to:

a. springs and spring-like effects,
b. dampers and energy dissipation, and
c. masses (weights).

Report findings and outline the typical application in systems of the components listed above, citing the observed behavior to support explanations.

4.3 Mechanical Drives~~:~~: Interpret technical information in design problems to **analyze forces, speeds, torque, and power for mechanical drives** including:

a. gears, cams, screws, and levers;
b. belt and chain drives;
c. flywheels; and
d. motors and generators.

Explain the typical **application and operation in systems of the components** listed above, citing measurement and/or observed evidence to support explanations. Create equations that describe relationships to solve the design problems and justify the solutions.

4.4 Motors~~:~~: Research and measure the behavior of different types of **alternating current (AC) motors and direct current (DC) motors, comparing and contrasting behaviors,** and drawing inferences from the observations to create a checklist for use by a technician to **ensure proper functioning of equipment.**

4.5 Mechanical Properties~~:~~: Design an experiment to observe and measure the **mechanical properties and behavior of shafts, couplings, and sealing devices** with and without proper lubrication. Document research and measurement results in a technical report to be used by other technicians.

4.6 Power Transmission~~:~~: Demonstrate understanding of **power transmission components**, such as clutches and brakes, by measuring the operation of working automotive equipment. Explain the **role of each component** and how they work together in a system.

4.7 Maintenance and Adjustments~~:~~: Assess the **required maintenance for a variety of mechatronic system components** in a mechatronic device and carry out the **necessary adjustments to the system.** Document and justify the adjustments in an equipment log that can be easily referenced by technicians and engineers.

5. Technical Documentation and Troubleshooting

5.1 Troubleshooting:: Assess a mechatronic system using technical documents (such as data sheets, timing diagrams, operating manuals, and schematics)**. Troubleshoot the malfunctions** in electrical components. Record and analyze test results and prepare written testing documentation to justify a solution.

5.2 Report:: Verify by observation and measurement of the parts, relationships, and behavior depicted by the technical data sheets for the mechanical and electrical components within a mechatronic system. **Create a report to be used by another technician maintaining and operating these components and drives.**

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.

Robotics & Automated Systems

Primary Career Cluster:	Advanced Manufacturing and STEM
Course Contact:	CTE.Standards@tn.gov
Course Code~~(s)~~:	C13H15
Prerequisite(s):	*Algebra I* (G02X02, G02H00); *Geometry* (G02H11); *Physical Science* (G03H00); and *Chemistry* (G03H12) or *Physics* (G03H20)
Credit:	1
Grade Level:	11
Focus Elective Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *Advanced Manufacturing* or *STEM* courses.
Program of Study (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 third course in the *Mechatronics* and *STEM* program of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
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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):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 210, 211, 212, 213, 214, 230, 232, 233, 413, 414, 415, 416, 417, 418, 449, 470, 477, 519, 531, 535, 537, 582, 595, 596, 700, 740, 760, 982
~~**Required Teacher Certifications:**~~	Please refer to Occupational Educator Licensure Guidance for a full list.
Required Teacher ~~Certifications/~~Training:	None~~.~~
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-advanced-manufacturing.html https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html

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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~~industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill ~~demonstration~~demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, Engineering Technology, and Robotics.
- Use Standard 3.2 for the student to present to the class using the CTSO format.

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 1.1-1.2** | Include a safety briefing in a visit to an industry partner/job site.
- **Standard 2.1-2.2** | Invite a local employer to discuss how robots are used in their facility.
- **Standard 3.1-3.2** | Visit a local company and talk with those employees about career options.
- **Standard 6.1-7.2, 9.1** | Have the students complete~~do~~ a project that is useful to a local employer. The employer can critique the student's project.
- **Standard 8.2** | Invite~~Visit~~ a local industry person to visit the class to discuss and demonstrate the importance of quality control.

Course Description

Robotics & Automated Systems is an applied course for students who wish to explore how robots and automated systems are used in industry. Upon completion of this course, proficient students will have an understanding of the historical and current uses of robots and automated systems; programmable circuits, interfacing both inputs and outputs; ethical standards for engineering and technology professions; and testing and maintenance of robots and automated systems.
Note: Standards in this course are presented sequentially for students' learning progression; however, instructors may tailor the order of course standards to their specifications. Students are expected to use

engineering notebooks to document procedures, design ideas, and other notes for all projects throughout the course.

Course Standards

1. Safety

1.1 Safety Rules~~:~~: Accurately read and interpret **safety rules**, including but not limited to rules published by the National Science Teachers Association (NSTA), rules pertaining to electrical safety, Occupational Safety and Health Administration (OSHA) guidelines, and state and national code requirements. Be able to distinguish between the 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, and maintain safe operating procedures with tools and equipment.

2. Robotics Overview

2.1 History of Robotics~~:~~: Research **the historical use of robotics** from textbooks, news media, and other informational texts. Create a presentation concerning the various uses of robotics. For example, explore areas such as the surgical field, space exploration, agriculture, and advanced manufacturing.

2.2 Use of Robots~~:~~: **Explain why robots should be used in certain circumstances**. Include the use of collaborative robots (cobots) in manufacturing facilities. Cite textual evidence to support claims. ~~(~~F~~f~~or example, assemble evidence from medical journals to support a claim that the use of robots has lowered costs and increased efficiency among medical providers~~)~~. Other examples may derive from the areas identified in standard 2.1. Defend original arguments and debate peer perspectives using claim(s) and counterclaim(s) developed in the persuasive essay.

3. Career Exploration

3.1 Robotic Careers~~:~~: Report on **jobs in industries, organizations, and careers in Tennessee and other states that use robotics**, ~~(~~such as Nissan in Automotive Manufacturing~~)~~. Include work activities involved, postsecondary education needed, and skills necessary for these careers. ~~(~~These could range from industry certifications to degrees in robotics engineering.~~)~~

3.2 Robot Impacts~~:~~: Research the **ethical considerations involved in developing new and modifying existing robotic technologies**. For example, investigate the National Society of Professional Engineers' (NSPE) Code of Ethics for Engineers or the Computer Ethics Institute's Ten Commandments of Computer Ethics. Select an existing technology and describe the ethical dilemmas faced by both producers and consumers of that technology, such as trade-offs between individual versus societal benefits or unforeseen consequences to the environment. For example, examine why some workers and labor unions may view robots as a threat to their jobs.

4. Programming

4.1 Robotic Programming~~.~~: Create a flowchart of a **program for a robotic system**. Convert the flowchart into a **working program**. Test, modify, and optimize the program. Write a technical report evaluating the performance of the program. Support all claims with specific examples.

4.2 Data~~.~~: **Log, store, and export data** received from two or more sensors ((~~for example~~e.g., vision/light, audio, and touch) in a robotic or automated system. Explain why these procedures would be useful and provide specific examples.

5. Engineering Design and Science & Engineering Practices

5.1 Engineering Design Process~~.~~: **Compare and contrast the following engineering design process with the eight practices of science and engineering** (Achieve, 2013). Based on observations, explain how the engineering design process and the science and engineering practices overlap, and describe how they might be used in automated systems design.

Engineering Design Process	Science and Engineering Practices
a) Identify the problem	a) Asking questions (for science) and defining problems (for engineering)
b) Identify criteria and specify constraints	b) Developing and using models
c) Brainstorm possible solutions	c) Planning and carrying out investigations
d) Research and generate ideas	d) Analyzing and interpreting data
e) Explore alternative solutions	e) Using mathematics and computational thinking
f) Select an approach	f) Constructing explanations (for science) and designing solutions (for engineering)
g) Write a design proposal	g) Engaging in argument from evidence
h) Develop a model or prototype	h) Obtaining, evaluating, and communicating information
i) Test and evaluate	
j) Refine and improve	
k) Create or make a product	
l) Communicate results	

6. Computers and Electronics

6.1 Robots as Machines~~.~~: Create an explanatory presentation that describes the parts necessary to make a robot and distinguishes it from a computer and a non-robotic machine. Parts necessary to make a robot include~~:~~ (1) having a microprocessor for a brain~~,~~ (2) sensors for input and output, (3) controls, and (4) motors. The presentation should include an informative report that describes various types of sensors (~~for example~~e.g., auditory, visual, heat, etc.) and a summary of how sensors provide input. It should also describe various types of output (~~for example~~e.g., motors, mechanisms, speakers, light, etc.) and discuss how sensors provide output.

6.2 Programming~~.~~: Design, develop, and test a **program to control a robotic system** and robotic subsystems. The program should be able to receive data from a robot's input devices, process the data, and create outputs based on the inputs received. Present the robotic system to the class and provide details on the methodology used to design and develop the program~~,~~ justifying selections as appropriate.

6.3 Feedback Loops~~.~~: Utilize **feedback loops in a robotic system**. For example, create a demonstration scenario and program a robot that requires the following: start, stop, or change motion within a robotic or automated system based on sensor input~~,~~ provided by two or more sensors, ~~(~~such as vision/light, audio, and touch~~)~~.

7. Mechanics

7.1 Mechanics in Robots~~.~~: Use **mechanical tools, such as motors, gears, and gear trains in the construction of a robotic or automated system**. Identify where forces are acting upon various points on the system and document with simple diagrams. Use the concepts of force, torque, and mechanical advantage to calculate the force acting upon the points in the system.

7.2 Robotic Work~~.~~: Develop a system to **demonstrate force, torque, work, and power acting upon or being done by a robotic or automated system**. Justify the design by creating mathematical models that show the calculations.

8. Testing, Maintenance, Documentation, and Quality Assurance

8.1 Measure Outputs~~.~~: Use appropriate instruments to **measure and record electrical, light, and audio outputs of a robotic system.** Compare measured data to acceptable norms for the system. Document whether the system is performing within accepted parameters and cite evidence to support the claims. Perform maintenance or follow recommended procedures to correct malfunctions or underperformance within the system. Write a justification for any maintenance that is performed~~,~~ citing data obtained from test results.

8.2 Maintenance~~.~~: Create a service and maintenance report on a robotic or automated system. The report should include text explaining the **maintenance and corrective measures** conducted. It should also include text justifying whether the system is functioning properly or recommending additional measures to correct any issues within the system. Finally, it should include text recommending quality-assurance policies and procedures to ~~assure~~ ensure the continuing operation of the system within acceptable parameters and text describing corrective procedures to be used when the system is malfunctioning or operating below optimal performance.

9. Projects

9.1 Robot Project~~.~~: Working in a team, **design and create a robotic solution to a given problem**. Incorporate the engineering design process, as well as science and engineering practices, to develop a solution that meets the criteria for entries in a regional, state, or national robotics competition. Maintain an engineering notebook to document the details of the project. Write a technical paper including the ~~(see~~ components ~~of the report~~ below,~~)~~ and develop a presentation describing the solution and development process for the team solution. The technical paper should include, but is not limited to:

a. background,
b. problem definition,
c. design constraints,
d. methodology,
e. data analysis (e.g., charts, graphs, and calculations),
f. results/problem solution (include engineering drawings), and
g. conclusions and recommendations for future research.

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.

Mechatronics II

Primary Career Cluster:	Advanced Manufacturing
Course Contact:	CTE.Standards@tn.gov
Course Code(s):	C13H17
Prerequisite(s):	*Mechatronics I* (C13H16) and *Physics* (G03H20) Note*:* *Physics* (G03H20) may be taken as a co-requisite.
Credit:	1
Grade Level:	12
Elective Focus Graduation Requirements:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other 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 fourth and final course in the *Mechatronics* program of study.
Aligned Student Organization(s):	Skills USA: 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):	157, 232, 233, 470, 477, 523, 537, 551, 552, 582, 596, 701, 760, 982
~~**Required Teacher Certifications/Training:**~~	~~None~~
Required Teacher Certification:	Please refer to Occupational Educator Licensure Guidance for a full list.
Required Teacher 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~~21st-century skills necessary to be successful in careers and~~ in~~ life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards ~~which ~~that feed into intentionally designed programs of study.

Students engage in ~~industry relevant~~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~~industry-standard content and technology, solve industry-based problems, meaningfully interact with industry professionals, and use/produce ~~industry specific~~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~~industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill ~~demonstration~~demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, Additive Manufacturing, Mechatronics, and Electronics Technology.

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.

- **Standard 1.1** | Include a safety briefing in a visit to an industry partner/job site.
- **Standard 2.2** | Have an employee at a local company explain decisions made related to control systems.
- **Standard 2.6** | Have the students complete~~do~~ a project that is useful to a local employer. The employer can critique the student's illustration.
- **Standards 3.1-3.2** | Create~~Do~~ a project that is used by local industry or evaluated by local industry managers.
- **Standard 4.1** | Ask an industry representative to discuss how often employees use documents and logs on the job.
- **Standard 4.2** | Discuss troubleshooting with an employee responsible for troubleshooting.

Course Description

Mechatronics II is an advanced course in the manufacturing career cluster for students interested in learning more about such careers as mechatronics technician, maintenance technician, or electromechanical technician. Following the groundwork of mechanics and electronics laid in *Mechatronics I*, this course covers the basics of pneumatic, electro pneumatic, and hydraulic control circuits in a complex mechatronic system. In addition, the course addresses basic digital logic and programmable logic controllers (PLCs) employed in the mechanical, electronic, and control systems in a mechatronics system. Upon completion of this course, proficient students are able to explain the inter-relationships of components and modules within a complex mechatronic system. They understand the differences between hydraulic and pneumatic fluid power and can explain the scientific principles that apply. They also use technical documentation, ~~(~~such as datasheets, circuit diagrams, displacement step diagrams, timing diagrams, and function charts,~~)~~ to troubleshoot and resolve malfunctioning pneumatic and hydraulic components and circuits. They demonstrate understanding of the role of programmable logic controllers (PLC) in mechatronic systems and the ability to write, debug, and run basic ladder logic.

Course Standards

1. Safety

1.1 Safety: Accurately read and interpret **safety rules**, including, but not limited to, the rules ~~of~~ for handling high-pressure pneumatics and hydraulics. Analyze the implications of the various rules and employ them accordingly while working on mechatronic systems with control system components, explaining why certain rules apply.

2. Fluid Power Systems

2.1 Pneumatic and Hydraulic Components: Demonstrate an understanding of the interrelationships and specific roles of (electro) **pneumatic and hydraulic components** and modules within a complex mechatronic system. For example, explain the expected changes in one or more systems on other components and modules in the total mechatronic system.

2.2 Pneumatic and Hydraulic Differences: Identify the **differences between hydraulic and pneumatic fluid power** and justify decisions surrounding when to use control systems based on one component as opposed to the other.

2.3 Pneumatic and Hydraulic Principles: Create laboratory setups or simple control systems that apply **hydraulic and pneumatic principles** such as Boyle's Law and Pascal's Law. Apply these principles to solving problems and troubleshooting mechatronic systems, explaining the reasoning behind each step.

2.4 Components of Fluid Power Systems: Conduct research to identify the basic **components and functions in a fluid power system** using real-world examples of hydraulic/pneumatic systems. Summarize and explain this information.

2.5 Properties of Components: Measure and analyze basic **physical properties of ~~(~~electro~~)~~ pneumatic and hydraulic components**, ~~(~~such as cylinders, directional control valves, regulators, flow control valves, pumps, and motors,~~)~~ within a given system. Interpret resolved work orders by analyzing underlying issues and explaining the correct physical operation of the included components.

2.6 Flow of Fluid Energy: Describe the **flow of fluid energy** in a given mechatronic system or subsystem. Create a graphic illustration to represent the transfer of energy from one component to ~~others~~ another in the system.

3. Computers and Control Systems

3.1 Programmable Logic Controllers~~.~~: Explain the different roles of **programmable logic controllers** (PLCs) in complex mechatronic systems, modules, and subsystems, and be able to verbally describe their components and operation to others. Explain the basic components of a PLC, addressing how the role of a PLC varies in different systems, ~~(~~such as mechatronic systems, modules, and subsystems~~)~~.

3.2 Flow of Information~~.~~: Demonstrate understanding of the **flow of information** in a given mechatronic system or subsystem, ~~,~~focusing on the control function of PLCs in the system. Describe the flow of information to/from an equipment operator.

3.3 Boolean Logic~~.~~: Given a control scenario, ~~,~~bound by several logical parameters, create **Boolean logic equations** to prescribe the use of logic gates in the implementation of the scenario. Show how they apply to the functioning of a real-world mechatronics system~~,~~ explaining the reasoning involved.

3.4 Codes~~.~~: Demonstrate understanding of **hexadecimal, decimal, octal, binary, 2s complement, and binary coded decimal (BCD) values** as used in a common PLC. Explain how these codes are relevant to mechatronic systems.

3.5 PLC Programming~~.~~: Convert wiring and ladder diagrams for simple logic chores into **PLC programs** that use common instructions such as digital, logical, compare, compute, move, file, sequencer, and program control instruction sets.

4. Technical Documentation and Troubleshooting

4.1 Maintenance Assessment~~.~~: Referencing technical documents, ~~s (~~such as data sheets, circuit diagrams, displacement step diagrams, timing diagrams, function charts, operations manuals, and schematics,~~)~~ for pneumatic and hydraulic components within a mechatronic system, **assess the required maintenance** for such systems~~,~~ taking appropriate measurements where needed, and perform the necessary adjustments on these systems. Document and justify adjustments in an equipment log that can be referenced by technicians and engineers.

4.2 Troubleshooting~~:~~: **Troubleshoot malfunctioning pneumatic and hydraulic systems**. Identify the source of the problem(s), plan a multistep procedure to correct the malfunction, implement the plan, and verify the corrective action. Document the cause of the malfunction and justify the procedure used to correct it.

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.

Welding I

Primary Career Cluster:	Advanced Manufacturing
Course Contact:	CTE.Standards@tn.gov
Course Code(s):	C13H12
Pre-requisite(s):	*Principles of Manufacturing* (C13H05) Recommended: *Algebra* (G02X02, G02H00), *Geometry* (G02X03, G02H11), and *Physical Science* (G03H00)
Credit:	1
Grade Level:	10
Elective Focus Graduation Requirement:	This course satisfies one 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 second course in the *Welding* program of study.
Aligned Student Organization(s):	Skills USA: http://www.skillsusatn.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):	551, 552, 553, 554, 555, 556, 557, 584, 705, OR any other Occupational License endorsement with AWS Industry Certification, BAT, or Certified Welding Educator Certification
Required Teacher Certifications/Training:	~~In addition, the teacher must hold one of the following current/valid industry certifications: American Welding Society (AWS), Certified Welding Inspector (CWI), Certified Welding Educator (CWE), Certified Radiographic Interpreters, Certified Welding Engineer (CWEng), Certified Robotic Arc~~ Welder (CRAW), Certified Welding Fabricator, Certified Welder OR Bureau ~~of Apprenticeship Training certification (BAT), or NOCTI Welding.~~ Please refer to Occupational Educator Licensure Guidance for a full list. ~~Please refer to Occupational Educator Licensure Guidance for a full list.~~
Required Teacher 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~~21st-century skills necessary to be successful in ~~career~~ careers and ~~in~~ life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards ~~which~~ that feed into intentionally designed programs of study.

Students engage in ~~industry relevant~~industry-relevant content through general education integration and experiences such as career and technical student organizations (CTSO) and work-based learning (WBL). Through these experiences, students are immersed with ~~industry standard~~industry-standard content and technology, solve industry-based problems, meaningfully interact with industry professionals, and use/produce ~~industry specific~~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~~industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill ~~demonstration~~demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, Additive Manufacturing, and Welding.

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 1.1-1.2** | Include a safety briefing in a visit to an industry partner/job site.
- **Standard 2.1** | Visit a local company and discuss with those employees the various career options.
- **Standard 3.2** | Ask an industry representative to discuss how often welders use drawings on the job.
- **Standard 5.1** | Ask an industry representative to discuss how often the different types of welds are used on the job.
- **Standard 6.2** | Ask an industry representative to discuss the impact of different materials ~~to~~ on a welder on the job.
- **Standards 7.1-7.2** | Ask an industry representative to discuss the importance of quality control.
- **Standard 8.4** | Complete~~Do~~ a project that is used by ~~a~~ local industry or evaluated by local industry managers.

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. Proficient students will develop proficiency in fundamental safety practices in welding, interpreting drawings, creating ~~computer aided~~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 this course, proficient students will be able to sit for the AWS SENSE Entry Level Welder certification and will be prepared to undertake more advanced welding coursework.

Course Standards

1. Safety

1.1 Safety: 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. Complete the safety test with 100 percent accuracy.

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.

2. Career Exploration

2.1 Welder Qualifications: 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.

3. Interpreting and Creating Drawings

3.1 Interpret Drawings: **Interpret drawings to weld.** 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.

3.2 Create Drawings: 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.

4. Welding Design and Layout

4.1 Basic Weld Joints: 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.

5. Shielded Metal Arc Welding (SMAW)

5.1 Set Up for SMAW: 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. 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).

5.2 SMAW Welding: Demonstrate how to **make single-pass and multiple-pass fillet welds and groove welds** with backing on plain carbon steel in the following positions:~~.~~

a. f~~F~~lat,
b. h~~H~~orizontal,
c. v~~V~~ertical, and
d. o~~O~~verhead.

Prior to welding, sketch a ~~cross section~~cross-section, including the dimensions of each weld demonstration.

5.3 Metal Classification and SMAW: Explain the American Welding Society (AWS) filler **metal classification system**. Summarize 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. f~~F~~lat,
b. h~~H~~orizontal,
c. vertical, and
d. overhead

Summarize the demonstration results of using various electrodes and explain the findings using supporting evidence from the AWS metal classification system.

6. Properties of Metals

6.1 Mechanical Properties of Metals: Summarize the following **mechanical properties of metals** and their importance in the welding process.

a. ~~t~~Tensile
b. ~~s~~Strength
c. ~~h~~Hardness
d. ~~e~~Elasticity
e. ~~d~~Ductility
f. ~~t~~Toughness
g. ~~b~~Brittleness

Explain the changes in the mechanical properties of weldments that occur during the welding process.

6.2 Thermal Properties of Metals: 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 the weld and parent metals caused by heating and cooling.

6.3 Heat Effect of Metals: Demonstrate the **effects of heat on different metals** such as steel and aluminum. Explain the differences. Explain 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.

7. Quality Control

7.1 Discontinuities and Defects: Explain 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.

7.2 Inspection: 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. If necessary, recommend changes that will reduce the number of product defects during the manufacturing process.

8. Welding Procedure Specification Development

8.1 Welding Elements: **Identify various welding elements**. Define the following elements and locate them in the American Welding Society (AWS) Specification for Welding Procedure and Performance Qualification (AWS B2.1/B2.1M):

a. joint design,
b. base metal,
c. filler metal,
d. position,
e. preheat and interpass,
f. heat treatment,
g. shielding gas, and
h. electrical.

8.2 Elements Effects on Welding: Summarize the variables associated with the above elements and their **effects on welding processes**. Describe techniques to mitigate the effects of these variables that can occur during the welding process.

8.3 Welding Procedure Specification: Read and interpret an example of a **welding procedure specification** and observe demonstrations of qualified welders to understand the proper procedures involved in conducting a welding procedure test. Explain how to properly use the welding procedure specifications that impacts a welding procedure test. Include the following:

a. code requirements,
b. materials,
c. documentation,
d. destructive testing, and

e. inspection and evaluation.

8.4 Welding Procedure Test: Explain how to conduct a welding procedure specification and a **welding procedure test**. Steps must include:

a. properly setting up welding equipment for the process being tested;
b. properly select base material and filler metal (gas shielding if required);
c. gathering equipment needed to capture welding variables;
d. properly set up test coupon (per code, or as performed in production);
e. properly document data as coupon is being welded;
f. performing visual inspection;
g. performing destructive testing; and
h. completing the Welding Procedure Specification document.

9. Team Project

9.1 Team Project with Data Analysis: As a team, **identify a problem** related to the program of study as a whole. **Research and utilize the Engineering Design Process to design a solution**. Document the following steps in an **engineering design notebook** for inclusion in the program portfolio. When possible, connect the problem to an existing SkillsUSA event.

p. **Problem Identification**: Brainstorm specific problems and challenges with the program of study. Conduct basic research to understand the scope and implications of the identified problem. Identify one problem as a focus area.
q. **Research and Analysis**: Conduct in-depth research on chosen topics related to the problem. Locate and analyze a dataset related to the problem.
r. **Review the Stages of the Engineering Design Process**: Define the problem, research, brainstorm solutions, develop prototypes, test and evaluate, and iterate. Consider constraints such as cost, efficiency, and environmental impact during the design process.
s. **Project Implementation**: Assign specific roles within the design teams (e.g., project manager, researcher, designer, tester). Design a solution tailored to address the identified problem or scenario. Document progress through design journals, sketches, diagrams, and digital presentations. (Note: Prototype is optional in the Tear 2 course.)

Presentation and Reflection: Showcase the problem and solution to the class. Share the data that was analyzed and how it affected the solution. Discuss the design process and challenges. As a class, critically evaluate the effectiveness and feasibility of the solutions and propose potential improvements.

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.

Welding II

Primary Career Cluster:	Advanced Manufacturing
Course Contact:	CTE.Standards@tn.gov
Course Code~~(s)~~:	C13H10
Pre requisite(s):	*Welding I* (C13H12) Recommended: *Algebra* (G02X02, G02H00), *Geometry* (G02X03, G02H11), *Physical Science* (G03H00)
Credit:	1-2 credits
Grade Level:	11-12
Elective Focus Graduation Requirement:	This course satisfies 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 third course in the *Welding* program of study.
Aligned Student Organization(s):	Skills USA: http://www.skillsusatn.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):	551, 552, 553, 554, 555, 556, 557, 584, 705, or~~OR~~ any other Occupational License endorsement with AWS Industry Certification, BAT, or Certified Welding Educator Certification.
Required Teacher Certifications~~/Training~~:	~~In addition, the teacher must hold one of the following current/valid industry certifications: American Welding Society (AWS), Certified Welding Inspector (CWI), Certified Welding Educator (CWE), Certified radiographic Interpreters, Certified Welding Engineer (CWEng), Certified Robotic Arc Welder (CRAW), Certified Welding Fabricator, Certified Welder OR Bureau of Apprenticeship Training certification (BAT), or NOCTI Welding.~~Please refer to Occupational Educator Licensure Guidance for a full list.
Required Teacher 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~~21st-century skills necessary to be successful in careers and ~~in~~ life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards ~~which~~ that feed into intentionally designed programs of study.

Students engage in ~~industry relevant~~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~~industry-standard content and technology, solve industry-based problems, meaningfully interact with industry professionals, and use/produce ~~industry specific~~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~~industry-specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill ~~demonstration~~demonstrations. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, Additive Manufacturing, and Welding.

Using ~~a~~ Work-based Learning (WB) 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 1.1-1.2** | Include a safety briefing in a visit to an industry partner/job site.
- **Standards 2.3, 3.3, 4.3 |** Have the students complete~~do~~ a project that is useful to a local employer. The employer can critique the ~~student~~ student's work.
- **Standards 5.1-5.3** | Have an industry person visit the class to discuss and demonstrate the importance of quality control.
- **Standard 6.1** | Ask an industry representative to discuss welding efficiency on the job.

Course Description

Welding II is designed to provide students with opportunities to effectively perform cutting and welding applications of ~~increasingly~~ increasing complexity used in the advanced manufacturing industry. Proficient students 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 or the AWS SENSE Advanced Welders qualifications and certifications.

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. Complete the safety test with 100 percent accuracy.

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.

2. Gas Metal Welding (GMAW)

2.1 GMAW Equipment: 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. Explain the characteristics and advantages of using GMAW over conventional electrode-type arc (stick) welding. For example, explain why it is easier to control the small molten weld pool using the GMAW process.

2.2 Metal Classification for GMAW: Explain the American Welding Society (AWS) **filler metal classification system**. Explain 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.

2.3 Weld with GMAW: 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.

3. Flux Cored Arc Welding (FCAW)

3.1 FCAW Equipment: 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.

3.2 Metal Classification for FCAW: Refer to previous research conducted on the **filler metal classification system** by the American Welding Society (AWS). Using proper domain-specific terminology, explain 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.

3.3 Weld with FCAW: 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). 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.

3.4 Distinctives of FCAW: 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.

4. Gas Tungsten Arc Welding (GTAW)

4.1 GTAW Equipment: 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. Compare and contrast water-cooled welding torches versus air-cooled welding torches used in GTAW. Explain the characteristics and the appropriate applications of each torch type. For example, determine which torch is preferred in production welding contexts and explain why.

4.2 Metal Classification for GTAW: 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.

4.3 Weld with GTAW: 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.

4.4 Distinctives of GTAW: 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.

5. Quality Control

5.1 Inspection~~:~~: **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.

5.2 Testing~~:~~: Explain **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.

5.3 Bend Tests~~:~~: 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.

6. Welding Efficiency

6.1 Efficiency~~:~~: **Analyze and differentiate among various types of elements that can directly impact welding efficiency**. Explain the following types of elements and details how their purposes and characteristics can directly affect efficiency:

n. a~~A~~rc time,
o. o~~O~~perating f~~F~~actor,
p. d~~D~~eposition r~~R~~ate (wire feed speed),
q. e~~E~~lectrode e~~E~~fficiency,
r. t~~T~~ravel s~~S~~peed,
s. w~~W~~eld s~~ S~~ize,
t. p~~P~~oor f~~F~~it, and
u. d~~D~~efects/r~~R~~epairs.

6.2 Wire Feed Speed and Weld Size~~:~~: **Explain how wire feed speed and weld size ~~influences~~ influence efficiency.** Demonstrate the consequences of using different variables in relation to wire feed speed and weld size. Upon completion of the work, explain and justify observations identifying different methods used and their final impact on efficiency.

6.3 Fillet and Groove Welds~~:~~: Explain the differences between **f~~F~~illet and g~~G~~roove w~~W~~elds**. Summarize their purposes and characteristics, the costs associated with each weld, and a calculation of how long it would take a welder to successfully create each type.

7. Industry Certification and Portfolio

7.1 Industry Certification~~:~~: **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.

7.2 Project~~:~~: Complete assigned team projects that **incorporate the following welding processes ~~in order to~~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. Compile photographs of each project, along with technical documentation, into a **portfolio of work**.

a. 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.
b. 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.
c. 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.

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.