Department of Education | College, Career and Technical Education

May 2023

Engineering Design I

Primary Career Cluster:	Science, Technology, Engineering, and Mathematics (STEM)
Course Contact:	CTE.Standards@tn.gov
Course Code(s):	C21H05
Prerequisite(s):	*Principles of Engineering & Technology* (C21H04), *Algebra I* (G02X02, G02H00), and *Physical Science* (G03H00) or *Biology* (G03H03)
Co-requisite:	*Geometry* (G02X03, G02H11)
Credit:	1
Grade Level:	10
Focus Elective Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other *STEM* courses. In addition, this course satisfies one lab science credit requirement for graduation.
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 *Engineering* 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 Student Industry Credentials:	Credentials are aligned with post-secondary 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/content/tn/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, 413, 414, 415, 416, 417, 418, 230, 232, 233, 449, 470, 477, 519, 531, 595, 596, 700, 740, 760, 982
Required Teacher Certifications/Training:	Teachers who have never taught this course must attend training provided by the Department of Education.
Teacher Resources:	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

There is no one way to create meaningful learning experiences for students. There are best practices available that data and students say impact long-term student learning. One of those best practices is to put student learning in context with their experiences.

Career and Technical Student Organizations (CTSOs) provide an opportunity for students to display their learning in the classroom and through regional, state, and/or national competition. Work-based Learning (WBL) consists of sustained and coordinated work-based activities that relate to the course content. These activities should occur at every level through a program of study. Below is a listing of possible CTSO connections and WBL activities for this course. This listing is intended to be an idea starter and not a comprehensive listing.

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

Putting the classroom learning into real life experiences is often what creates a meaningful learning experience for students, one that lasts beyond the exam and course. CTSOs are a great resource to create this type of learning for your students. They are also a great resource to showcase your students learning through regional, state, and national competitions. Possible connections for this course include the following. This is not an exhaustive list.

- Participate in CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration, interviewing skills, community service activities, extemporaneous speaking, and job interview.
- Participate in leadership activities such as National Leadership and Skills Conference, National Week of Service, 21st Century Skills.

For more ideas and information, visit Tennessee SkillsUSA at http://www.skillsusatn.org/ and Technology Student Association (TSA): http://www.tntsa.org.

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 1.1-2.2** | Invite an industry representative to discuss career exploration and safety protocols.
- **Standards 3.1-4.1** | Invite an engineer to discuss the Engineering design process.
- **Standards 5.1-5.3** | Visit a local company with this equipment and have the students see a demonstration.
- **Standards 6.1-6.4** | Partner with an industry rep to do project for a local company.
- **Standards 7.1-7.2** | Invite an engineer professor to provide an interactive demonstration.
- **Standards 8.1-8.4** | Guest speaker on Energy.
- **Standards 9.1-9.4** | Complete an integrated project with an industry partner.
- **Standards 10.1-11.1** | Do a project for a local employer that will be evaluated by industry professionals.

For more ideas and information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html

Course Description

Engineering Design I is a fundamental course in the STEM cluster for students interested in developing their skills in preparation for careers in engineering and technology. The course covers essential knowledge, skills, and concepts required for postsecondary engineering and technology fields of study. Upon completion of this course, proficient students are able to describe various engineering disciplines, as well as admissions requirements for postsecondary engineering and engineering technology programs in Tennessee. They will also be able to identify simple and complex machines; calculate various ratios related to mechanisms; explain fundamental concepts related to energy; understand Ohm's Law; follow the steps in the engineering design process to complete a team project; and effectively communicate design solutions to others.

Note: 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. Incorporate safety procedures and complete safety test with 100 percent accuracy.

2. Career Exploration

2.1 Engineering Disciplines: In teams, use an online editing tool to develop an artifact **illustrating various engineering disciplines** (e.g., civil, mechanical, electrical, chemical, biomedical, computer, agricultural, industrial, and aerospace). The descriptions should contain definitions, job roles, professional societies, and applicable licenses and/or certifications associated with each discipline. Use a variety of sources to gather data, cite each source, and briefly describe why the chosen source is reliable.

2.2 Post-Secondary Opportunities: Research the **postsecondary institutions** (colleges of applied technology, community colleges, and four-year universities) in Tennessee and other states **that offer engineering or engineering technology programs**. Write an informative paper or develop an infographic identifying admissions criteria, the postsecondary programs of study, and the secondary courses that will prepare individuals to be successful in a postsecondary engineering or engineering technology program.

3. Engineering Design Process

3.1 Engineering Practices and the Engineering Design Process: Compare and contrast the following **engineering design process** with the following **eight common practices of science and engineering** (Achieve, 2013). Based on observations, explain how the engineering design process and the practices overlap. Present findings to the class.

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	

4. Problem-Solving Format

4.1 Problem Solving Format: Apply a **problem-solving format for assigned engineering problems**. The format should include the ***problem statement*** **with illustration** (e.g., free body diagram), what is *given,* what the student is asked to *find,* a list of assumptions, a list of equations to be used to solve the problem, and the step-by-step solution.

5. Engineering Drawing**

5.1 Types of Engineer Drawings: Define the **differences in technique** among freehand sketching, manual drafting, and computer-aided drafting (CAD), and describe the **skills required for each**. Create a two-dimensional orthographic (multiview) drawing incorporating labels, notes, and dimensions, using sketching/geometric construction techniques. Apply basic dimensioning rules and properly use different types of lines (e.g., object, hidden, center). The orthographic projections should include principle views of a simple object from top, front, and right sides.

5.2 Isometric Drawings: Building on the knowledge of a two-dimensional drawing, create **complex isometric (3-D pictorial) drawings, properly using lines** (e.g., object, hidden, center), **labels, and dimensioning techniques.**

5.3 2D and 3D Drawings: Use CAD software to create simple **two-dimensional and three-dimensional drawing**s, accurately **incorporating labels, notes, dimensioning, and line**

types to design drawings. Perform basic operations such as creating, saving files, opening files, storing files, and printing.

**Students who successfully completed Principles of Engineering and Technology *will already have foundational skills in Engineering Drawing, however these concepts should be reviewed. If students have not taken the* Principles *class, please cover these standards in full.*

6. Work, Force, Power & Machines

6.1 Simple Machines: Drawing on relevant technical documents, define and identify at least **one application for each of the six simple machines** listed below. Describe each with sketches and proper notation in an engineering notebook.

a. Inclined plane
b. Wedge
c. Lever
d. Wheel and axle
e. Pulley
f. Screw

In addition, define a combination of two or more simple machines working together as a compound machine, and identify at least one application of the compound machine.

6.2 Project Completion: In teams, document the **process of completing a simple project**, such as building or using one or more simple machines. Participate in and describe each engineering design process step in an engineering notebook. Create a physical prototype or model based on the constraints specified in the project and the data gathered in the process of development.

6.3 Force, Work, and Power: Calculate **force, work, and power**, and **apply these formulae to solve engineering problems** as outlined by the instructor. Articulate specific scenarios in which an engineer must calculate force, work, and power.

6.4 Mechanical Advantage: Calculate the **ideal mechanical advantage and actual mechanical advantage,** and explain to classmates what this concept means in the context of engineering. Given a specified engineering problem, calculate the efficiency of a machine when the ideal mechanical advantage and actual mechanical advantage are known.

7. Mechanisms

7.1 Mechanisms: Explain the **definition of a mechanism**. Interpret technical information in design problems to identify types of mechanisms such as:

a. linkages,
b. cam and follower,
c. bearings,
d. gears,
e. sprockets and chain, and
f. drives.

Explain the typical application and operation in systems of the components listed above, citing measurement and/or observed evidence to support explanations.

7.2 <u>Relationships used to solve engineering problems</u>: Create equations that describe **relationships to solve engineering problems** using formulae such as **gear ratio**, **speed ratio, torque, and torque ratio**. For example, understand that if a gear ratio is 2, the input gear must make two complete revolutions to every one revolution that the output gear makes.

8. Energy

8.1 <u>Energy</u>: Write an explanatory text defining **energy**, in particular its **use in engineering, drawing on engineering texts and other technical documents**. In addition, identify and explain the different forms of energy. The explanation should include the categorization of various forms of energy such as potential or kinetic.

8.2 <u>Concept of Heat</u>: Draw on engineering texts and other technical documents to synthesize and explain **the concept of heat**. Include definitions of the **different temperature scales** such as Fahrenheit, Celsius, and Kelvin. Furthermore, explain the three **forms of heat transfer**: conduction, convection, and radiation.

8.3 <u>Units of Energy</u>: Understand and solve problems in specific engineering contexts involving **conversion from one unit of energy** such as British Thermal Units (Btu), Joule (J), and Calorie (cal) **to another**. Use this information to calculate the heat needed to change temperature.

8.4 <u>Renewable and Nonrenewable Energy Resources</u>: Research print and electronic sources published by government, nonprofit, or engineering organizations to define different **renewable energy sources** such as **biomass, hydroelectric power, geothermal, wind, and solar**, as well as **nonrenewable energy sources** such as **petroleum, natural gas, coal, and nuclear energy**. In teams, create and deliver a presentation justifying the use of one energy source for their local community; the presentation must contain at least one summary table or graphic. In addition, the presentation should provide an analysis demonstrating the advantage of their selected source over others.

9. Electrical Systems

9.1 <u>Subatomic Particles</u>: Describe the **subatomic particles** (e.g., nucleus, proton, neutron, and electron) that make up an atom. Explain how the particles **relate to electricity**, including characteristics that make materials either conductors or insulators, and explain the relationship between the flow of charge and electrical current at the subatomic and atomic level.

9.2 <u>Voltage, Current, and Resistance</u>: Define, compare, and contrast **voltage, current, and resistance**, incorporating appropriate graphic illustrations (such as diagrams) to complement the narrative. Identify **sources of voltage** as well. For example, a battery is a source of voltage, and one end of the battery represents a positive charge, while the other end represents a negative charge.

9.3 <u>Ohm's Law</u>: Calculate voltage, current, and/or resistance in a DC circuit using Ohm's law ($V = IR$). Explain **how Ohm's Law relates voltage, current, and resistance**, citing technical examples for illustration. For example, if voltage remains constant and resistance decreases, the current will increase. Given a physical circuit, demonstrate how to measure each using a digital multimeter. Where unexpected behavior is observed, cite specific evidence to explain the observations. Prepare an informative report comparing calculated values with measured values and include an explanation of any sources of error.

9.4 Function of Series and Parallel Circuits: Explain **how series and parallel circuits function**, including identification of their chief components, characteristics, and differences. Solve problems involving series and parallel circuits including calculating equivalent resistance and calculating voltage and/or current through elements within a circuit.

10. Computer Software for Engineering Problem Solving

10.1 Using computer tools to solve problems: Use **computer tools**, such as spreadsheet software (e.g., Microsoft Excel), analytical/scientific software (e.g., MATLAB), and/or programming software (e.g., Microsoft Visual Basic) **to solve at least one problem from the content** described in the standards above. Examples may include the use of spreadsheets to input data from experimental tests and create graphs for presentation, or the use of MATLAB to solve a system of equations.

11. Team Project

11.1 Team Project: As a team, **identify a problem in the school or community**. Draft a problem statement to guide a project incorporating engineering concepts from at least three of the content sections (i.e., electrical systems, energy, mechanisms, etc.) outlined above. Follow the engineering design process to solve the problem. Each team will develop a paper following the format of a typical technical report (see components of the report below). Upon completion of the report, create and deliver a presentation for a CTSO event using appropriate citation conventions. Refine the report as would a team of engineers by incorporating feedback from the presentation. The written report should include, but is not limited to:

a) background,
b) problem definition,
c) design constraints,
d) methodology,
e) data analysis (e.g., charts, graphs, calculations),
f) results/Problem solution (including 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.