

Lakewood High School

Department of Engineering Technology



Principles of Engineering
Curriculum [POE 21]
(2022 update)

Original Adoption:	August 20, 2018
Created by:	PLTW – Project Lead the Way
Revised on:	March 17, 2022
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Principles of Engineering 21 Curriculum	
Content Area: Engineering	
Course Title: Principles of Engineering [POE 21]	Grade Level: 10-12
Unit 1: Energy and Power Lesson 1.1: Mechanisms Lesson 1.2: Energy Sources Lesson 1.3: Energy Applications Lesson 1.4: Design Project: Energy and Power	17 days 9 days 10 days 13 days
Unit 2: Materials and Structures Lesson 2.1: Statics Lesson 2.2: Material Properties Lesson 2.3: Material Testing Lesson 2.4: Design Problem: Materials and Structures	14 days 11 days 10 days 5 days
Unit 3: Control Systems Lesson 3.1: Machine Control Lesson 3.2: Fluid Power Lesson 3.3 Design Problem: Control Systems	16 days 15 days 15 days
Unit 4: Statistics and Kinematics Lesson 4.1 Statistics Lesson 4.2 Kinematics	5 days 24 days

Philosophy

The curriculum will provide expert instruction for the NGSS. We will implement the NGSS with confidence to ensure our students master 21st century science skills. We will combine instruction in Science and Engineering Practices, Disciplinary Core Ideas, and Cross-Cutting Concepts to meet the rigor of the Performance Expectations within the NGSS.

Principles of Engineering (POE) is a high school-level survey course of engineering. The course exposes students to some of the major concepts that they will encounter in a postsecondary engineering course of study. Students have an opportunity to investigate engineering and high-tech career POE gives students the opportunity to develop skills and understanding of course concepts through activity-, project-, and problem-based (APPB) learning. Used in combination with a teaming approach, APPB learning challenges students to continually hone their interpersonal skills, creative abilities, and problem-solving skills based upon engineering concepts. It also allows students to develop strategies to enable and direct their own learning, which is the ultimate goal of education.

Students will demonstrate both level 1 and level 2 career components in this course. NEPRIS will be utilized to watch videos of people working in our industry. It also allows us to “invite” guest speakers into our classroom to interact with our students. Students may also interact with industry partners on a weekly or biweekly basis, to follow designs from inception to completion, with the engineers performing the work. Students may opt to participate in the community service work performed by the Technology Student Association (TSA). Fundraisers currently exist for several National campaigns on health and wellness.

Career Ready Practices:

Through instruction in life and career skills, all students acquire the knowledge and skills needed to prepare for life as citizens and workers in the 21st century. For further clarification see NJ World Class Standards at www.NJ.gov/education/aps/cccs/career/

- **CRP1.** Act as a responsible and contributing citizen and employee.
- **CRP2.** Apply appropriate academic and technical skills.
- **CRP4.** Communicate clearly and effectively and with reason.
- **CRP5.** Consider the environmental, social and economic impacts of decisions.
- **CRP6.** Demonstrate creativity and innovation.
- **CRP7.** Employ valid and reliable research strategies.
- **CRP8.** Utilize critical thinking to make sense of problems and persevere in solving them.
- **CRP11.** Use technology to enhance productivity.
- **CRP12.** Work productively in teams while using cultural global competence.

9.3 – Career & Technical Education (CTE) Content Area: 21st Century Life and Careers:

These standards outline what students should know and be able to do upon completion of a CTE Program of Study.

ARCHITECTURE & CONSTRUCTION CAREER CLUSTER®

Number Standard	Statement
9.3.12.AC.1	Use vocabulary symbols and formulas common to architecture and construction
9.3.12.AC.2	Use architecture and construction skills to create and manage a project.
9.3.12.AC.6	Read, interpret and use technical drawings, documents and specifications to plan a project.
PATHWAY:	CONSTRUCTION (AC-CST)
9.3.12.AC-CST.3	Implement testing and inspection procedures to ensure successful completion of a construction project.
9.3.12.AC-CST.5	Apply practices and procedures required to maintain jobsite safety.
9.3.12.AC-CST.8	Demonstrate the construction crafts required for each phase of a construction project.
9.3.12.AC-CST.9	Safely use and maintain appropriate tools, machinery, equipment and resources to accomplish construction project goals.
PATHWAY:	DESIGN/PRE-CONSTRUCTION (AC-DES)
9.3.12.AC-DES.1	Justify design solutions through the use of research documentation and analysis of data.
9.3.12.AC-DES.6	Apply the techniques and skills of modern drafting, design, engineering and construction to projects.
9.3.12.AC-DES.7	Employ appropriate representational media to communicate concepts and project design.
BUSINESS MANAGEMENT AND ADMINISTRATION CAREER CLUSTER®	
CAREER CLUSTER® :	BUSINESS MANAGEMENT AND ADMINISTRATION (BM)
9.3.12.BM.1	Utilize mathematical concepts, skills and problem solving to obtain necessary information for decision-making in business.
9.3.12.BM.6	Implement, monitor and evaluate business processes to ensure efficiency and quality results.
INFORMATION TECHNOLOGY CAREER CLUSTER®	
PATHWAY:	PROGRAMMING & SOFTWARE DEVELOPMENT (IT-PRG)
9.3.IT-PRG.6	Program a computer application using the appropriate programming language.
9.3.IT-PRG.10	Design, create and maintain a database.

Suggested Options for Differentiation

- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.

Collaborate with after-school programs or clubs [TSA] to extend learning opportunities.

Follow all IEP modifications/504 plan

- * Teacher tutoring
- * Peer tutoring
- * Cooperative learning groups
- * Modified assignments
- * Differentiated instruction

Presentation accommodations allow a student to:

- * Listen to audio recordings instead of reading text
- * Work with fewer items per page or line and/or materials in a larger print size
- * Hear instructions orally
- * Have another student share class notes with him
- * Be given an outline of a lesson
- * Use visual presentations of verbal material, such as word webs and visual organizers

Response accommodations allow a student to:

- * Give responses in a form (oral or written) that's easier for him
- * Use a spelling dictionary or electronic spell-checker – available on the core page

Setting accommodations allow a student to:

- * Work or take a test in a different setting, such as a quiet room with few distractions
- * Sit where he learns best (for example, near the teacher)

Timing accommodations allow a student to:

- * Take more time to complete a task or a test during lunch or afterschool
- * Have extra time to process oral information and directions
- * Take frequent breaks, such as after completing a task

Scheduling accommodations allow a student to:

- * Take more time to complete a project
- * Take a test in several timed sessions or over several days with prior notification

Organization skills accommodations allow a student to:

- * Use an alarm to help with time management
- * Mark texts with a highlighter

Unit 1	Lesson 1.1 - Mechanisms	Duration: 17 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]</p> <p>HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]</p> <p>HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]</p>		
The Student Learning Objectives above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Analyzing and Interpreting Data</p> <ul style="list-style-type: none"> - Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. <p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.). <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a 	<p>PS3.A - Energy - Definitions of Energy</p> <p>At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HSPS3-2), (HS-PS3-3)</p> <p>PS3.B - Energy - Conservation of Energy and Energy Transfer</p> <ul style="list-style-type: none"> - Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) - Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1), (HS-PS3-4) - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) - The availability of energy limits what can occur in any system. (HS-PS3-1) <p>PS3.D - Energy - Energy in Chemical Processes and Everyday Life</p> <ul style="list-style-type: none"> - Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4) 	<p>Cause and Effect: Mechanism and Prediction</p> <ul style="list-style-type: none"> - Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. - Systems can be designed to cause a desired effect. - Changes in systems may have various causes that may not have equal effects. <p>Systems and System Models</p> <ul style="list-style-type: none"> - Systems can be designed to do specific tasks. <p>Energy and Matter: Flows, Cycles, and Conservation</p> <ul style="list-style-type: none"> - Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior. - The total amount of energy and matter in closed systems is conserved. - Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. - Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

<p>problem.</p> <ul style="list-style-type: none"> - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). 		
Supporting and Additional Standards		
Mathematics		
<p>N.Q.1 – Quantities - Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.</p> <p>N.Q.2 – Quantities - Define appropriate quantities for the purpose of descriptive modeling.</p> <p>N.Q.3 – Quantities - Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.</p> <p>A.SSE.1 - Seeing Structure in Expressions - Interpret expressions that represent a quantity in terms of its context.</p> <p>A.SSE.1.a - Seeing Structure in Expressions - Interpret parts of an expression, such as terms, factors, and coefficients.</p> <p>A.SSE.1.b - Seeing Structure in Expressions - Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret $P(1+r)^n$ as the product of P and a factor not depending on P.</p> <p>A.CED.1 - Creating Equations - Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.</p> <p>A.CED.4 - Creating Equations - Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law $V = IR$ to highlight resistance R.</p> <p>A.REI.3 - Reasoning with Equations and Inequalities - Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.</p>		

Instructional Plan - Lesson 1.1 - Mechanisms

Instructional Plan - Lesson 1.1 - Mechanisms	
Suggested Activities	Resources “Project Lead The Way “
Activities (A) Projects (P) Problems (B)	Knowledge / Skills
<p>Activity 1.1.0 Career Professional Interview</p> <p>Activity 1.1.1.A Simple Machines Investigation</p> <p>Activity 1.1.2.A Simple Machines Practice Problems</p> <p>Activity 1.1.3.A.VEX Gears</p> <p>Activity 1.1.4.A Pulleys, Drives, & Sprockets</p> <p>Activity 1.1.5.A Gears, Pulleys, Drives, & Sprockets Practice Problems</p> <p>Activity 1.1.6.P.VEX Compound Machine Design</p>	<ul style="list-style-type: none"> • K1, S1 • S2, S3, S4, S5, S9, S10 • S3, S4, S7 • S4, S5 • S4 • S3, S4 • S3,S4, S5, S6, S7, S8, S9, S10
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...
<ul style="list-style-type: none"> • U1 – (Career Exploration) Engineers and engineering technologists apply math, science, and discipline-specific skills to solve problems. • U2 – (Career Exploration) Engineering and engineering technology careers offer creative job opportunities for individuals with a wide variety of backgrounds and goals. • U3 – Most mechanisms are composed of gears, sprockets, pulley systems, and simple machines. • U4 – Mechanisms are used to redirect energy within a system by manipulating force, speed, and distance. • U5 – Mechanical advantage ratios relate input forces to output forces in mechanisms; efficiency ratios relate input work to output work for those mechanisms. • U6 – (<i>Design Process</i>) Technical communication can be accomplished in oral, written, and visual forms and must be organized in a clear and concise manner. • U7 – (<i>Design Process</i>) Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships. (Same as U4 in Lesson 1.4.) 	<ul style="list-style-type: none"> • Q1 – What are some different types of occupations within the engineering pathway? • Q2 – What are some common responsibilities of engineers? • Q3 – Identify a mechanism in your household. Why do you think that particular mechanism is designed the way it is? • Q4 - What are some strategies that can be used to make everyday mechanisms more efficient? • Q5 - Describe one situation in which an engineer would want to include a mechanism with a mechanical advantage greater than one? What is the advantage in this case? • Q6 - How could designing a solution to a mechanical problem without regard to efficiency be problematic?
KNOWLEDGE: Students will ...	Skills Students will ...
<ul style="list-style-type: none"> • K1 – Identify the steps in an engineering design process and describe the activities involved in each step of the process. U1 • K2 – Explain the concept of proportion and how it relates to freehand sketching. U4 • K3 – Identify and describe a variety of brainstorming techniques and rules for brainstorming. U2 • K4 – Differentiate between invention and innovation. U1 • K5 – Identify and differentiate between the work of an engineer and the work of a scientist. U5 • K6 – Identify and differentiate between mechanical, electrical, civil, and chemical engineering fields. U5 	<ul style="list-style-type: none"> • S1 – Generate and document multiple ideas or solution paths to a problem through brainstorming. U1, U2, U4 • S2 – Describe the design process used in the solution of a particular problem and reflect on all steps of the design process. U1 • S3 – Utilize an engineering notebook to clearly and accurately document the design process according to accepted standards and protocols to prove the origin and chronology of a design. U1, U3, U4 • S4 – Create sketches or diagrams as representations of objects, ideas, events, or systems. U4 • S5 – Explain the contributions of engineers from different engineering fields in the design and development of a product, system, or technology. U5 • S6 – Review and evaluate the written work of peers and make recommendations for improvement. U3

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Activity 1.1.0 Career Professional Interview - Careers in engineering and engineering Technology	<ul style="list-style-type: none"> • 1.0.A.RU Professional Interview Rubric • Essential Questions 	•1.0.A.RU Professional Interview Rubric
Activity 1.1.1.A Simple Machines Investigation	<ul style="list-style-type: none"> • Essential Questions • Simple Machine Calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Conclusion Questions • Simple Machine Calculations
Activity 1.1.2.A Simple Machines Practice Problems	<ul style="list-style-type: none"> • Essential Questions 	• Simple Machine Calculations
Activity 1.1.3.A .VEX Gears	<ul style="list-style-type: none"> • Essential Questions • Gear Calculations • Student responses to presentation examples 	• Gear Calculations
Activity 1.1.4.A Pulleys, Drives, & Sprockets	<ul style="list-style-type: none"> • Essential Questions • A Pulleys, Drives, & Sprockets Calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Conclusion Questions • Pulley, Drives, & Sprockets Calculations
Activity 1.1.5.A Gears, Pulleys, Drives, & Sprockets Practice Problems	<ul style="list-style-type: none"> • Essential Questions 	• Gear, Pulley, Drives, & Sprockets Calculations
Activity 1.1.6.P .VEX Compound Machine Design	<ul style="list-style-type: none"> • Essential Questions • 1.1.6.P.RU Compound Machine Design Rubric 	• 1.1.6.P.RU Compound Machine Design Rubric
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum

<http://pltw.org>

Lynda.com (Online Tutorials)

<http://lynda.com>

Principles of Engineering

Brett Handley, Craig Coon, and David M. Marshall

Developed specifically for the PLTW POE course to support lesson concepts. © 2002

NEPRIS - Connecting Industry to Every Classroom

<http://nepris.com>.

ROBOTC® - Robot programming language

<http://www.robotc.net/>

VEX® Robotics platform

<https://www.vexrobotics.com/>

Logger Pro® - Data collection and analysis software

<https://www.vernier.com/>

REDDIT - engineering is a forum for engineering professionals to share information, knowledge, experience

<https://www.reddit.com/r/engineering/>

Teacher Notes:

Unit 1	Lesson 1.2: Energy Sources	Duration: 9 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>HS.PS3.3 – Energy Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.</p> <p>HS.PS3.4 – Energy Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).</p> <p>HS.ESS3.1 - Earth and Human Activity Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.</p> <p>HS.ESS3.2 - Earth and Human Activity Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.</p> <p>HS.ESS3.4 - Earth and Human Activity Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.</p> <p>HS.ETS1.1 - Engineering Design Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.</p>		
<p>The Student Learning Objectives above were developed using the following elements from the NRC document A Framework for K-12 Science Education:</p>		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Developing and Using Models</p> <ul style="list-style-type: none"> - Design a test of a model to ascertain its reliability. - Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. - Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. - Develop a complex model that allows for manipulation and testing of a proposed process or system. - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. <p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> - Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. - Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. 	<p>PS3.A - Energy - Definitions of Energy</p> <ul style="list-style-type: none"> - “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5) - Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HSPS3-1), (HS-PS3-2) - At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HSPS3-2), (HS-PS3-3) <p>PS3.B - Energy - Conservation of Energy and Energy Transfer</p> <ul style="list-style-type: none"> - Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) - Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1), (HS-PS3-4) - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) - The availability of energy limits what can occur in any system. (HS-PS3-1) 	<p>Cause and Effect: Mechanism and Prediction</p> <ul style="list-style-type: none"> - Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. - Systems can be designed to cause a desired effect. - Changes in systems may have various causes that may not have equal effects. <p>Systems and System Models</p> <ul style="list-style-type: none"> - Systems can be designed to do specific tasks. - Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. - Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. <p>Energy and Matter: Flows, Cycles, and Conservation</p> <ul style="list-style-type: none"> - Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior. - The total amount of energy and matter in closed systems is conserved. - Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. - Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. - Energy drives the cycling of matter within and between

- Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.

Using Mathematics and Computational Thinking

- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
- Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.)

Constructing Explanations and Designing Solutions

- Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Engaging in Argument from Evidence

- Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Obtaining, Evaluating, and Communicating Information

- Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
- Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

PS3.D - Energy - Energy in Chemical Processes and Everyday Life

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4)
- Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. (secondary to HS-PS4-5)
- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary to HS-LS2-5)

ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)

ETS1.B - Engineering Design - Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

ETS1.C - Engineering Design - Optimizing the Design Solution

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

ESS3.A - Earth and Human Activity - Natural Resources

- Resource availability has guided the development of human society. (HS-ESS3-1)
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

ESS3.C - Earth and Human Activity - Human Impacts on Earth Systems

- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)

ESS3.D - Earth and Human Activity - Global Climate Change

- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)

systems.

Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Instructional Plan - Lesson 1.2: Energy Sources

Suggested Activities	Resources “Project Lead The Way “
Activities (A) Projects (P) Problems (B)	Knowledge / Skills
<p>Activity.1.2.1 Energy Sources</p> <p>Activity.1.2.2 Energy Distribution</p> <p>Activity.1.2.3 Electrical Circuits</p> <p>Activity.1.2.4 Circuit Calculations</p> <p>Activity.1.2.5 Mechanical System Efficiency</p>	<ul style="list-style-type: none"> • K1, S1 • K1 • S3, S7 • S3, S7 • S2, S3, S4, S5, S6
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...
<ul style="list-style-type: none"> • U1 – Energy sources for consumption are varied, including nonrenewable, renewable, and inexhaustible sources. • U2 – Energy sources for consumption are harnessed or mined, often stored and transported, and converted to other forms of energy. • U3 – Energy often needs to be converted from one form to another to meet the needs of a given system. • U4 – Energy can be transformed to do work. • U5 – Efficiency describes how much energy or power is transformed in the manner desired. • U6 – Power is the rate at which energy is transformed. • U7 – The relationship among voltage, current, and resistance determines the behavior of electricity in a circuit. • U8 – Electricity involves the motion of electrons and the electrical properties of a material (e.g., whether it is a conductor, an insulator, or a semiconductor) are determined by its atomic structure. • U9 – (<i>Design Process</i>) Effective presentations are the result of preparation, are tailored to suit the purpose and audience, and are improved by attending to posture, gestures, appearance, eye contact, and time constraints. (Same as U6 of Lesson 1.4.) 	<ul style="list-style-type: none"> • Q1 – Choose a specific energy production source. Explain why it is considered “clean.” In what ways may it not be so “clean?” • Q2 – How might innovation of current technology involved with energy production provide energy more efficient? • Q3 – What alternative energy source would be best implemented in your community? Explain why. • Q4 – Choose a specific energy production source. What • Q5 – What is one possible way that “lost” energy might be collected in your home or school and transformed for a useable purpose? • Q6 – What are the advantages and disadvantages of wiring a house with either series or parallel circuits?
KNOWLEDGE: Students will ...	Skills Students will ...
<ul style="list-style-type: none"> • K1 – Describe the characteristics of various sources of energy. U1, U2 • K2 – Know types of nonrenewable, renewable, and inexhaustible energy sources. U1, U2 • K3 – Know the equations for work and power. U4,U5,U6 • K4 – Know the equation for calculation the efficiency of a system. U5 • K5 – Know the equations related to describing the characteristics of simple circuits. U7 	<ul style="list-style-type: none"> • S1 – (<i>Design Process</i>) Prepare and deliver a brief summary based on research. U9 • S2 – Calculate work and power. U3, U4, U5, U6 • S3 – Correctly use a digital multimeter as a voltmeter, ohmmeter, or ammeter. U7 • S4 – Calculate electrical power developed in a circuit. U6, U7 • S5 – Calculate mechanical power developed when lifting an object. U4, U6 • S6 – Determine efficiency of a system that converts an electrical energy to a mechanical energy. U3, U4, U5, U6, U7 • S7 – Calculate circuit resistance, current, and voltage using Ohm’s law, including circuits with elements in series and/or parallel. U7 • S8 – Compare and contrast the behavior of electrical circuits with parallel and series circuit designs. U7

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Activity.1.2.1 Energy Sources	<ul style="list-style-type: none"> • 1.2.1.A.RU Energy sources Rubric • Essential Questions 	<ul style="list-style-type: none"> • 1.2.1.A.RU Energy sources Rubric • Conclusion Questions
Activity.1.2.2 Energy Distribution	<ul style="list-style-type: none"> • Essential Questions 	<ul style="list-style-type: none"> • Conclusion Questions
Activity.1.2.3 Electrical Circuits	<ul style="list-style-type: none"> • Essential Questions • Student responses to presentation examples. 	<ul style="list-style-type: none"> • Demonstration of simulated circuits. • Demonstration of physical circuit. • Conclusion Questions
Activity.1.2.4 Circuit Calculations	<ul style="list-style-type: none"> • Essential Questions 	<ul style="list-style-type: none"> • Calculations and Conclusion Questions
Activity.1.2.5 Mechanical System Efficiency	<ul style="list-style-type: none"> • Essential Questions • Student responses to presentation examples. 	<ul style="list-style-type: none"> • Calculations and Conclusion Questions • Demonstration of mechanical system.
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials	
<p>Project Lead the Way (PLTW) Curriculum http://pltw.org</p> <p>Lynda.com (Online Tutorials) http://lynda.com</p> <p>Principles of Engineering Brett Handley, Craig Coon, and David M. Marshall Developed specifically for the PLTW POE course to support lesson concepts.© 2002</p> <p>NEPRIS - Connecting Industry to Every Classroom http://nepris.com.</p>	<p>ROBOTC® - Robot programming language http://www.robotc.net/</p> <p>VEX® Robotics platform https://www.vexrobotics.com/</p> <p>Logger Pro® - Data collection and analysis software https://www.vernier.com/</p>
Teacher Notes:	

Unit 1	Lesson 1.3: Energy Applications	Duration: 10 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>HS.PS3.3 - Energy Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.</p> <p>HS.PS3.4 - Energy Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).</p> <p>HS.ESS3.1 - Earth and Human Activity Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.</p> <p>HS.ESS3.2 - Earth and Human Activity Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.</p> <p>HS.ESS3.4 - Earth and Human Activity Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.</p> <p>HS.ETS1.1 - Engineering Design Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.</p>		
The Student Learning Objectives above were developed using the following elements from the NRC document A Framework for K-12 Science Education :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Developing and Using Models</p> <ul style="list-style-type: none"> - Develop a complex model that allows for manipulation and testing of a proposed process or system. - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. <p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> - Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. - Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. - Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. <p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Use mathematical, computational, and/or algorithmic 	<p>PS3.A - Energy - Definitions of Energy</p> <ul style="list-style-type: none"> - "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5) - Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HSPS3-1), (HS-PS3-2) - At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HSPS3-2), (HS-PS3-3) <p>PS3.B - Energy - Conservation of Energy and Energy Transfer</p> <ul style="list-style-type: none"> - Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) - Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1), (HS-PS3-4) - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) - The availability of energy limits what can occur in any 	<p>Cause and Effect: Mechanism and Prediction</p> <ul style="list-style-type: none"> - Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. - Systems can be designed to cause a desired effect. - Changes in systems may have various causes that may not have equal effects. <p>Systems and System Models</p> <ul style="list-style-type: none"> - Systems can be designed to do specific tasks. <p>Energy and Matter: Flows, Cycles, and Conservation</p> <ul style="list-style-type: none"> - Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior. - The total amount of energy and matter in closed systems is conserved. - Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

<p>representations of phenomena or design solutions to describe and/or support claims and/or explanations.</p> <ul style="list-style-type: none"> - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.). <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). 	<p>system. (HS-PS3-1)</p> <p>PS3.D - Energy - Energy in Chemical Processes and Everyday Life</p> <ul style="list-style-type: none"> - Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4) <p>ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> - Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3) - Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) <p>ETS1.B - Engineering Design - Developing Possible Solutions</p> <ul style="list-style-type: none"> - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) <p>ETS1.C - Engineering Design - Optimizing the Design Solution</p> <ul style="list-style-type: none"> - Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6) - Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) <p>ESS3.D - Earth and Human Activity - Global Climate Change</p> <ul style="list-style-type: none"> - Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5) 	
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Instructional Plan - Lesson 1.3: Energy Applications

Suggested Activities	Resources “Project Lead The Way “
Activities (A) Projects (P) Problems (B)	Knowledge / Skills
Activity.1.3.1 Solar Hydrogen System Project.1.3.2 Fuel Cell Technology Activity.1.3.3 Thermodynamics Project.1.3.4 Renewable Insulation	- K1, K2, K3, S1, S2 - K1, K2, K3, S1, S2 - K4, S4 - K4, S3, S4
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...
<ul style="list-style-type: none"> • U1 – Selecting sources of energy for human consumption requires consideration of efficiency of energy transformations, of the quantities of energy needed and available, of the rates at which energy is needed and available, and of the accessibility of the power source to the point of consumption. • U2 – Energy systems can include multiple energy sources that can be combined to convert energy into useful forms. • U3 – Hydrogen fuel cells and solar cells are two of the many options for transforming energy to power human needs. • U4 – The flow of heat energy in a system is related to material properties and system design, and by considering the thermodynamics of a system, an engineer can predict and manipulate the amount of energy transferred. • U5 – (Design Process) Engineers use a design process to create solutions to existing problems. (Same as U2 of Lesson 1.4.) • U6 – (Design Process) Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships. (Same as U4 of Lesson 1.4.) 	<ul style="list-style-type: none"> • Q1 – In what innovative ways could the efficiency of electricity production using solar cells be maximized throughout the day? • Q2 – Describe how hydrogen fuel cells could become a viable way of producing energy for vehicles. What advancements in technology and infrastructure need to take place to make its usage more common? • Q3 – A hydrogen fuel cell by itself is not sufficient to power much of anything in our society. How could fuel cells be configured to produce enough voltage and current to a system? • Q4 – What are some materials in your home that provide prevent energy transfer from inside your home to the outside environment? Which of the three forms of energy transfer are they attempting to limit? • Q5 – Which of the three forms of energy transfer are the materials in your home inhibiting the least? What could be done to change that?
KNOWLEDGE: Students will ...	Skills Students will ...
<ul style="list-style-type: none"> • K1 – Explain that hydrogen fuel cells transform chemical energy stored in hydrogen gas to electrical energy and heat, converting hydrogen and oxygen into water. U1, U2, U3 • K2 – Describe the use of reversible fuel cells as electrolyzers to store electrical energy for later use. U1, U2, U3 • K3 – Describe the use of solar cells to convert light energy into electricity. U1, U2, U3 • K4 – Describe convection, conduction, and radiation as they relate to thermal energy transfer. U4 	<ul style="list-style-type: none"> • S1 – Test and apply the relationships among voltage, current, and resistance in series and parallel circuits that incorporate photovoltaic cells and hydrogen fuel cells. U1, U2, U3 • S2 – Design a system to convert solar power to mechanical power using photovoltaic and fuel cells. U1, U3, U5, U6 • S3 – Design, construct, and test insulation materials for reducing thermal energy transfer. U4 • S4 – Calculate the rate at which energy is transferred by conduction and radiation through materials having various R-values. U4

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Activity.1.3.1 Solar Hydrogen System	<ul style="list-style-type: none"> • Essential Questions • Calculations and measurements 	<ul style="list-style-type: none"> • Conclusion Questions
Project.1.3.2 Fuel Cell Technology		<ul style="list-style-type: none"> • Conclusion Questions • Presentation of designed solution
Activity.1.3.3 Thermodynamics	<ul style="list-style-type: none"> • Essential Questions • Student responses to presentation examples 	<ul style="list-style-type: none"> • Conclusion Questions • Thermodynamic Calculations
Project.1.3.4 Renewable Insulation	<ul style="list-style-type: none"> • 1.3.4.P.RU Renewable Insulation Rubric • Essential Questions 	<ul style="list-style-type: none"> • 1.3.4.P.RU Renewable Insulation Rubric • Conclusion Questions • Thermodynamic Calculations
Unit Assessment Items Summative – EoC	-- All items	-- All items
Core Instructional and Supplemental Materials		
<p>Project Lead the Way (PLTW) Curriculum http://pltw.org</p> <p>Lynda.com (Online Tutorials) http://lynda.com</p> <p>Principles of Engineering Brett Handley, Craig Coon, and David M. Marshall Developed specifically for the PLTW POE course to support lesson concepts.© 2002</p> <p>NEPRIS - Connecting Industry to Every Classroom http://nepris.com.</p>	<p>ROBOTC® - Robot programming language http://www.robotc.net/</p> <p>VEX® Robotics platform https://www.vexrobotics.com/</p> <p>Logger Pro® - Data collection and analysis software https://www.vernier.com/</p>	
Teacher Notes:		

Unit 1	Lesson 1.4: Design Project: Energy and Power	Duration: 13 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>HS.PS3.3 - Energy Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.</p> <p>HS.ESS3.4 - Earth and Human Activity Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.</p> <p>HS.ETS1.1 - Engineering Design Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.</p> <p>HS.ETS1.2 - Engineering Design Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.</p> <p>HS.ETS1.3 - Engineering Design Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.</p> <p>HS.ETS1.4 - Engineering Design Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.</p>		
The Student Learning Objectives above were developed using the following elements from the NRC document A Framework for K-12 Science Education :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Asking questions and defining problems</p> <p>Ask questions:</p> <ul style="list-style-type: none"> o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. o that arise from examining models or a theory, to clarify and/or seek additional information and relationships. o to determine relationships, including quantitative relationships, between independent and dependent variables. o to clarify and refine a model, an explanation, or an engineering problem. <ul style="list-style-type: none"> - Evaluate a question to determine if it is testable and relevant. - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. - Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. - Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. <p>Developing and Using Models</p> <ul style="list-style-type: none"> - Design a test of a model to ascertain its reliability. - Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships 	<p>Definitions of Energy</p> <ul style="list-style-type: none"> - “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5) - Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HSPS3-1), (HS-PS3-2) - At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HSPS3-2), (HS-PS3-3) <p>Conservation of Energy and Energy Transfer</p> <ul style="list-style-type: none"> - Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) - Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1), (HS-PS3-4) - Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) - The availability of energy limits what can occur in any system. (HS-PS3-1) 	<p>Patterns</p> <ul style="list-style-type: none"> - Empirical evidence is needed to identify patterns. <p>Cause and Effect: Mechanism and Prediction</p> <ul style="list-style-type: none"> - Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. - Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. - Systems can be designed to cause a desired effect. - Changes in systems may have various causes that may not have equal effects. <p>Systems and System Models</p> <ul style="list-style-type: none"> - Systems can be designed to do specific tasks. <p>Energy and Matter: Flows, Cycles, and Conservation</p> <ul style="list-style-type: none"> - Tracking energy and matter flows, into, out of, and within systems helps one understand their system’s behavior. - The total amount of energy and matter in closed systems is conserved. - Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. - Energy cannot be created or destroyed—only moves between one place and another place, between

<p>between systems or between components of a system.</p> <ul style="list-style-type: none"> - Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. - Develop a complex model that allows for manipulation and testing of a proposed process or system. - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. <p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> - Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. - Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. - Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. <p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.) - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. <p>Science and Engineering Practice - Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the 	<p>Energy in Chemical Processes and Everyday Life</p> <ul style="list-style-type: none"> - Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4) <p>ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> - Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3) - Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) <p>ETS1.B - Engineering Design - Developing Possible Solutions</p> <ul style="list-style-type: none"> - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) <p>ETS1.C - Engineering Design - Optimizing the Design Solution</p> <ul style="list-style-type: none"> - Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6) <p>ESS3.C - Earth and Human Activity - Human Impacts on Earth Systems</p> <ul style="list-style-type: none"> - Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) <p>ESS3.D - Earth and Human Activity - Global Climate Change</p> <ul style="list-style-type: none"> - Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5) 	<p>objects and/or fields, or between systems.</p>
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natural world operate today as they did in the past and will continue to do so in the future.

- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Engaging in Argument from Evidence

- Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.
- Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Obtaining, Evaluating, and Communicating Information

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
- Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Supporting and Additional Standards

Mathematics

N.Q.1 – Quantities Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 – Quantities Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 – Quantities Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Instructional Plan - Lesson 1.4: Design Project: Energy and Power

Suggested Activities	Resources “Project Lead The Way “
Activities (A) Projects (P) Problems (B)	Knowledge / Skills
Problem.1.4.1 Design Problem: Renewable Electrical Energy Design	<ul style="list-style-type: none"> • K1, S1, S2, S3, S4, S5
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...
<ul style="list-style-type: none"> • U1 – Design problems can be solved by individuals or in teams. • U2 – Engineers use a design process to create solutions to existing problems. • U3 – Design briefs are used to identify the problem specifications and to establish project constraints. • U4 – Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships. • U5 – Design teams conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions. • U6 – Effective presentations are the result of preparation, are tailored to suit the purpose and audience, and are improved by attending to posture, gestures, appearance, eye contact, and time constraints. 	<ul style="list-style-type: none"> • Q1 – How does a design team come to know what problem to solve? • Q2 – Why is it important for the team to come to a consensus on issues that arise? What are some reasons why the team leader should not dictate the direction of the group? • Q3 – What are two possible ways that a team could come to a consensus in a disagreement over a solution to a problem? • Q4 – Engineers follow the design process, when solving a problem. What possible problems could arise, if the design process is not followed?
KNOWLEDGE: Students will ...	Skills Students will ...
<ul style="list-style-type: none"> • K1 – Know the purpose of each part of a design brief. U3 • K2 – Describe a step-by-step, iterative design process. U2 	<ul style="list-style-type: none"> • S1 – Brainstorm and sketch possible solutions to an existing design problem. U1, U2, U4, U5 • S2 – Create a decision making matrix for their design problem. U1, U2 • S3 – Select an approach that meets or satisfies the constraints provided in a design brief. U1, U3 • S4 – Create a detailed pictorial sketch or use 3D modeling software to document a proposed design. U1, U2, U4 • S5 – Present a workable solution to a design problem. U1, U2, U4, U6

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Problem.1.4.1 Design Problem: Renewable Electrical Energy Design	<ul style="list-style-type: none"> • 1.4.1.P.RU Renewable Electrical Energy Design Rubric • Decision Matrix Rubric • Essential Questions 	<ul style="list-style-type: none"> • 1.4.1.P.RU Renewable Electrical Energy Design Rubric • Decision Matrix Rubric • Conclusion Questions • Presentation of Design Process
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials	
<p>Project Lead the Way (PLTW) Curriculum http://pltw.org</p> <p>Lynda.com (Online Tutorials) http://lynda.com</p> <p>Principles of Engineering Brett Handley, Craig Coon, and David M. Marshall Developed specifically for the PLTW POE course to support lesson concepts. © 2002</p> <p>NEPRIS - Connecting Industry to Every Classroom http://nepris.com.</p>	<p>ROBOTC® - Robot programming language http://www.robotc.net/</p> <p>VEX® Robotics platform https://www.vexrobotics.com/</p> <p>Logger Pro® - Data collection and analysis software https://www.vernier.com/</p>
Teacher Notes:	

Unit 2	Lesson 2.1: Statics	Duration: 14 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>Standards for Technological Literacy</p> <p>2.9-12.Y Students will develop an understanding of the core concepts of technology. Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.</p> <p>12.9-12.L Students will develop the abilities to use and maintain technological products and systems. L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.</p> <p>12.9-12.P Students will develop the abilities to use and maintain technological products and systems. P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.</p> <p>17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies. P. There are many ways to communicate information, such as graphic and electronic means.</p>		
<p>The Student Learning Objectives above were developed using the following elements from the NRC document A Framework for K-12 Science Education:</p>		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Asking questions and defining problems</p> <p>Ask questions:</p> <ul style="list-style-type: none"> o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. o that arise from examining models or a theory, to clarify and/or seek additional information and relationships. o to determine relationships, including quantitative relationships, between independent and dependent variables. o to clarify and refine a model, an explanation, or an engineering problem <ul style="list-style-type: none"> - Evaluate a question to determine if it is testable and relevant. - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. <p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions 		<p>Cause and Effect: Mechanism and Prediction</p> <ul style="list-style-type: none"> - Systems can be designed to cause a desired effect. <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> - The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. - Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. - Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). <p>Systems and System Models</p> <ul style="list-style-type: none"> - A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. - Systems can be designed to do specific tasks. - When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. - Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. - Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. <p>Structure and Function</p>

in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.)

Constructing Explanations and Designing Solutions

- Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Engaging in Argument from Evidence

- Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Obtaining, Evaluating, and Communicating Information

- Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
- Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

- The way an object is shaped or structured determines many of its properties and functions.
- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.
- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Stability and Change

- For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.
- Much of science deals with constructing explanations of how things change and how they remain stable.
- Feedback (negative or positive) can stabilize or destabilize a system.
- Systems can be designed for greater or lesser stability.

Instructional Plan - Lesson 2.1: Statics	
Suggested Activities	Resources “Project Lead The Way “
Activities (A) Projects (P) Problems (B)	Knowledge / Skills
Activity.2.1.0 Career Field Description Activity.2.1.1 Centroids Activity.2.1.2 Beam Deflection Activity.2.1.3 Free Body Diagrams Activity.2.1.4 Calculating Force Vectors Activity.2.1.5 Calculating Moments Activity.2.1.6 Step-by-Step Truss Calculations Activity.2.1.7 Calculating Truss Forces Activity.2.1.8 Truss Design	-- K1 -- S2 -- S3, S4 -- S1 --S1, S5 -- S5, S6 -- S5, S6, S7, S8 -- S5, S6, S7, S8 -- S5, S6, S7, S8, S9
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...
<ul style="list-style-type: none"> • U1 – Laws of motion describe how forces affect a body. • U2 – Applied forces are vector quantities with a defined magnitude, direction, and sense, and can be broken into vector components. • U3 – Free body diagrams are used to illustrate and calculate forces acting upon a given body. • U4 – Forces acting at a distance from an axis or point attempt or cause an object to rotate. • U5 – Structural member properties – including centroid location, moment of inertia, and modulus of elasticity – are important considerations for structure design. • U6 – Static equilibrium occurs when the sum of all forces acting on a body are equal to zero. • U7 – Under static equilibrium conditions, the laws of motion can be used to calculate external forces on a truss and internal forces in truss members. • U8 – (<i>Design Process</i>) Engineers and engineering technologists apply math, science, and discipline-specific skills to solve problems. (Same as U1 of Lesson 1.1.) • U9 – (<i>Career Exploration</i>) Engineering and engineering technology careers offer creative job opportunities for individuals with a wide variety of backgrounds and goals. (Same as U2 of Lesson 1.1.) 	<ul style="list-style-type: none"> • Q1 – Why is it crucial for designers and engineers to construct accurate free body diagrams of the parts and structures that they design? • Q2 – Why must designers and engineers calculate forces acting on bodies and structures? • Q3 – When solving truss forces, why is it important to know that the structure is statically determinate?
KNOWLEDGE: Students will ...	Skills Students will ...
<ul style="list-style-type: none"> • K1 – Differentiate between scalar and vector quantities. • K2 – Identify magnitude, direction, and sense of a vector. • K3 - Know beam deflection is related to cross sectional geometry and material properties. • K4 – Know the moment of inertia is related cross sectional geometry. • K5 – Know the modulus of elasticity defines the stiffness of an object related to material and chemical properties. • K6 – Know the forces acting on an object are in equilibrium. • K7 – Understand how Newton’s Laws are applied to determine the forces acting on an object. 	<ul style="list-style-type: none"> • S1 – Create free body diagrams of objects, identifying all forces acting on the object. U2, U3 • S2 – Mathematically locate the centroid of structural members. U4, U5 • S3 – Calculate the area moment of inertia of structural members. U5 • S4 – Calculate the deflection of a center-loaded beam from the beam’s geometry and material properties. U5, U7 • S5 – Calculate the x- and y-components of a given vector. U2 • S6 – Calculate moments or torques given a force and a point of application relative to a specified axis. U4 • S7 – Use equations of equilibrium to calculate unknown external forces on a truss. U2, U3, U4, U6, U7

	<ul style="list-style-type: none"> • S8 – Use the method of joints to calculate tension and compression forces in the members of a statically determinate truss. U2, U3, U6, U7 • S9 – Construct and destructively test a truss, and relate observations to calculated predictions. U2, U3, U5, U6, U7
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Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Activity.2.1.0 Career Field Description To be presented in 2 weeks	<ul style="list-style-type: none"> • 2.1.RU Career Field Description Rubric • Essential Questions 	<ul style="list-style-type: none"> • 2.1.RU Career Field Description Rubric • Presentation of career field description
Activity.2.1.1 Centroids	<ul style="list-style-type: none"> • Essential Questions • Centroid calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Conclusion Questions
Activity.2.1.2 Beam Deflection	<ul style="list-style-type: none"> • Essential Questions • Centroid calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Conclusion Questions • Graph of deflection vs. moment
Activity.2.1.3 Free Body Diagrams	<ul style="list-style-type: none"> • Essential Questions • Student responses to presentation examples 	<ul style="list-style-type: none"> • Conclusion Questions • Free body diagrams
Activity.2.1.4 Calculating Force Vectors	<ul style="list-style-type: none"> • Essential Questions • Force calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Calculations and Conclusion Questions
Activity.2.1.5 Calculating Moments	<ul style="list-style-type: none"> • Essential Questions • Moment calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Calculations and Conclusion Questions
Activity.2.1.6 Step-by-Step Truss Calculations	<ul style="list-style-type: none"> • Essential Questions • Truss calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Truss calculations
Activity.2.1.7 Calculating Truss Forces	<ul style="list-style-type: none"> • Essential Questions • Truss calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Truss calculations and Conclusion Questions
Activity.2.1.8 Truss Design	<ul style="list-style-type: none"> • Essential Questions 	<ul style="list-style-type: none"> • Conclusion Questions • Presentation of truss design and testing results
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum

<http://pltw.org>

Lynda.com (Online Tutorials)

<http://lynda.com>

Principles of Engineering

Brett Handley, Craig Coon, and David M. Marshall

Developed specifically for the PLTW POE course to support lesson concepts. © 2002

NEPRIS - Connecting Industry to Every Classroom

<http://nepris.com>.

ROBOTC® - Robot programming language

<http://www.robotc.net/>

VEX® Robotics platform

<https://www.vexrobotics.com/>

Logger Pro® - Data collection and analysis software

<https://www.vernier.com/>

Teacher Notes:

Unit 2	Lesson 2.2: Material Properties	Duration: 11 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
HS.PS1.1 - Matter and Its Interactions Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.		
The Student Learning Objectives above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Asking questions and defining problems</p> <p>Ask questions:</p> <ul style="list-style-type: none"> o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. o that arise from examining models or a theory, to clarify and/or seek additional information and relationships. o to determine relationships, including quantitative relationships, between independent and dependent variables. o to clarify and refine a model, an explanation, or an engineering problem <ul style="list-style-type: none"> - Evaluate a question to determine if it is testable and relevant. - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. <p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution 	<p>PS1.A - Matter and Its Interactions - Structure and Properties of Matter</p> <ul style="list-style-type: none"> - The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1) - The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3), (secondary to HS-PS2-6) 	<p>Cause and Effect: Mechanism and Prediction</p> <ul style="list-style-type: none"> - Systems can be designed to cause a desired effect. <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> - The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. - Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> - Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). <p>Systems and System Models</p> <ul style="list-style-type: none"> - A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. - Systems can be designed to do specific tasks. - When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. - Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. - Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. <p>Structure and Function</p> <ul style="list-style-type: none"> - The way an object is shaped or structured determines many of its properties and functions. - Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. - The functions and properties of natural and designed objects and systems can be inferred from their overall

<p>that reflects scientific knowledge and student-generated evidence.</p> <ul style="list-style-type: none"> - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). 		<p>structure, the way their components are shaped and used, and the molecular substructures of its various materials.</p> <p>Stability and Change</p> <ul style="list-style-type: none"> - For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand. - Much of science deals with constructing explanations of how things change and how they remain stable. - Feedback (negative or positive) can stabilize or destabilize a system. - Systems can be designed for greater or lesser stability.
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Supporting and Additional Standards

English Language Arts

- AS.W.2 – Writing** Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.
- AS.W.4 – Writing** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- AS.W.7 – Writing** Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.
- AS.W.8 – Writing** Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.
- AS.W.9 – Writing** Draw evidence from literary or informational texts to support analysis, reflection, and research.
- AS.W.10 – Writing** Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.
- AS.SL.2 - Speaking and Listening** Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
- AS.SL.4 - Speaking and Listening** Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.
- AS.SL.5 - Speaking and Listening** Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.
- AS.L.1 – Language** Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.
- AS.L.2 – Language** Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.
- AS.L.6 – Language** Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

Mathematics

- N.Q.1 – Quantities** Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- N.Q.3 – Quantities** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- G.GMD.3 - Geometric Measurement and Dimension** Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.
- G.GMD.4 - Geometric Measurement and Dimension** Identify the shapes of two-dimensional cross-sections of three-dimensional objects, and identify three-dimensional objects

generated by rotations of two-dimensional objects.

G.MG.1 - Modeling with Geometry Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.2 - Modeling with Geometry Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).

Instructional Plan - Lesson 2.2: Material Properties

Suggested Activities			Resources “Project Lead The Way “		
Activities (A) Projects (P) Problems (B)			Knowledge / Skills		
Activity.2.2.1 Product Analysis Activity.2.2.2 Manufacturing Processes Activity.2.2.3 Recycling			-- S1, S2, S3 -- S4 -- K1, S5		
UNDERSTANDINGS: Students will understand that ...			ESSENTIAL QUESTIONS: Students will keep considering ...		
<ul style="list-style-type: none"> • U1 – Materials are the substances from which all things are made and are built from the elements. • U2 – Materials can be categorized by their composition as pure elements, compounds, or mixtures, and are also typically classified as metallic, ceramic, organic, polymeric, or composite. • U3 – Materials can be categorized by intrinsic physical and chemical properties, including mechanical, thermal, electromagnetic, and chemical properties. • U4 – Material properties including recyclability and cost are important considerations for engineers when choosing appropriate materials for a design. • U5 – Material selection is based upon mechanical, thermal, electromagnetic, and chemical properties. • U6 – Raw materials undergo various manufacturing processes in the production of consumer goods. 			<ul style="list-style-type: none"> • Q1 – How does an engineer predict the performance and safety for a selected material? • Q2 – What are the advantages and disadvantages of utilizing synthetic materials designed by engineers? • Q3 – What ethical issues pertain to engineers designing synthetic materials? • Q4 – What did you learn about the significance of selecting materials for product design? • Q5 – How can an existing product be changed to incorporate different processes to make it less expensive and provide better performance? • Q6 – How does an engineer decide which manufacturing process to use for a given material? • Q7 – How do the recycling codes and symbols differ from state to state? 		
KNOWLEDGE: Students will ...			Skills Students will ...		
<ul style="list-style-type: none"> • K1 – List material properties that are important too design including mechanical, chemical, electrical, and magnetic. • K2 – Know common manufacturing processes related to create a product from raw materials. • K3 - Know the steps of product life cycle for a common product. 			<ul style="list-style-type: none"> • S1 – Conduct non-destructive tests for material properties on selected common household products including tests for continuity, ferrous metal, hardness, and flexure. U2, U5 • S2 – Measure or calculate weight, volume, mass, density, and surface area of selected common household products. U3, U5 • S3 – Identify the manufacturing processes used to create the selected common household product. U6 • S4 – Identify materials that can be recycled. U4 		
Evidence of Student Learning					
Activities (A) Projects (P) Problems (B)		Assessment FOR Learning		Assessment OF Learning	
Activity.2.2.1 Product Analysis		• Essential Questions		• Product analysis document and conclusion questions	
Activity.2.2.2 Manufacturing Processes		<ul style="list-style-type: none"> • Essential Questions • Student responses to presentation examples 		• Conclusion questions	
Activity.2.2.3 Recycling		• Essential Questions		• Essential Questions	

	• Student responses to presentation examples	• Recycling rubric
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials	
<p>Project Lead the Way (PLTW) Curriculum http://pltw.org</p> <p>Lynda.com (Online Tutorials) http://lynda.com</p> <p>Principles of Engineering Brett Handley, Craig Coon, and David M. Marshall Developed specifically for the PLTW POE course to support lesson concepts. © 2002</p> <p>NEPRIS - Connecting Industry to Every Classroom http://nepris.com.</p>	<p>ROBOTC® - Robot programming language http://www.robotc.net/</p> <p>VEX® Robotics platform https://www.vexrobotics.com/</p> <p>Logger Pro® - Data collection and analysis software https://www.vernier.com/</p>
<p>Teacher Notes:</p>	

Unit 2	Lesson 2.3: Material Testing	Duration: 10 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
HS.PS1.3 - Matter and Its Interactions Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.		
The Student Learning Objectives above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Asking questions and defining problems Ask questions:</p> <ul style="list-style-type: none"> o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. o that arise from examining models or a theory, to clarify and/or seek additional information and relationships. o to determine relationships, including quantitative relationships, between independent and dependent variables. o to clarify and refine a model, an explanation, or an engineering problem <ul style="list-style-type: none"> - Evaluate a question to determine if it is testable and relevant. - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. <p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution 	<p>PS1.A - Matter and Its Interactions - Structure and Properties of Matter</p> <ul style="list-style-type: none"> - The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3), (secondary to HS-PS2-6) 	<p>Patterns</p> <ul style="list-style-type: none"> - Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. - Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. - Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. - Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. - Mathematical representations are needed to identify some patterns. - Empirical evidence is needed to identify patterns <p>Cause and Effect: Mechanism and Prediction</p> <ul style="list-style-type: none"> - Systems can be designed to cause a desired effect. <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> - The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. - Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe direct Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). <p>Systems and System Models</p> <ul style="list-style-type: none"> - A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. - Systems can be designed to do specific tasks. - When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. - Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and

<p>that reflects scientific knowledge and student-generated evidence.</p> <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). 		<p>information flows—within and between systems at different scales.</p> <ul style="list-style-type: none"> - Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. <p>Structure and Function</p> <ul style="list-style-type: none"> - The way an object is shaped or structured determines many of its properties and functions. - Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. - The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. <p>Stability and Change</p> <ul style="list-style-type: none"> - For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand. - Much of science deals with constructing explanations of how things change and how they remain stable. - Feedback (negative or positive) can stabilize or destabilize a system. - Systems can be designed for greater or lesser stability.
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Supporting and Additional Standards
Mathematics
<p>N.Q.1 – Quantities Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.</p> <p>N.Q.2 – Quantities Define appropriate quantities for the purpose of descriptive modeling.</p> <p>N.Q.3 – Quantities Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.</p> <p>A.SSE.1 - Seeing Structure in Expressions Interpret expressions that represent a quantity in terms of its context.</p> <p>A.SSE.1.a - Seeing Structure in Expressions Interpret parts of an expression, such as terms, factors, and coefficients.</p> <p>A.SSE.1.b - Seeing Structure in Expressions Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret $P(1+r)^n$ as the product of P and a factor not depending on P.</p>

Instructional Plan - Lesson 2.3: Material Testing

Suggested Activities		Resources “Project Lead The Way “
Activities (A) Projects (P) Problems (B)	Knowledge / Skills	
Activity.2.3.1 Stress/Strain Calculations Activity.2.3.2 Tensile Testing	-- S1, S3 -- K1,K2, S2, S3	
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...	
<ul style="list-style-type: none"> • U1 – Material testing helps determine a product's reliability, safety, and predictability in function. • U2 – Engineers perform destructive and non-destructive tests on material specimens for the purpose of identifying and verifying the properties of various materials. • U3 – Material testing, including tensile testing, is conducted under standardized conditions to provide a reproducible evaluation of material properties. • U4 – Many properties related to a material's strength can be determined from a stress-strain curve for that material, including elastic range, proportional limit, modulus of elasticity, elastic limit, resilience, yield point, plastic deformation, ultimate strength, failure, and ductility • U5 – Stress-strain data points are used to construct a stress-strain curve and to identify and calculate sample material properties. 	<ul style="list-style-type: none"> • Q1 – Why is it critical for engineers to document all calculation steps when solving problems? • Q2 – How is material testing data useful? • Q3 – Stress strain curve data points are useful in determining what specific material properties? 	
KNOWLEDGE: Students will ...	Skills Students will ...	
<ul style="list-style-type: none"> • K1 – Distinguish between stress and strain. • K2 – Distinguish between elastic and plastic deformation. U4, U5 • K3 – Describe the relationship between the tensile force applied to a material and the elongation of the material as it deforms elastically, plastically, and then ruptures. U4, U5 • K4 – Define the modulus of elasticity 	<ul style="list-style-type: none"> • S1 – Calculate minimum or maximum design parameters to ensure a safe or reliable product using material strength properties. U1, U4, U5 • S2 – Measure axial force and elongation data of material samples and create stress-strain diagrams describing the intrinsic properties of the materials. U2, U3 • S3 – Identify and calculate test sample material properties using a stress-strain curve. U1, U2, U3, U4, U5 	
Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Activity.2.3.1 Stress/Strain Calculations	<ul style="list-style-type: none"> • Essential Questions • Student responses to presentation examples 	• Calculations and Conclusion Questions
Activity.2.3.2 Tensile Testing	<ul style="list-style-type: none"> • Essential Questions 	• Calculations and Conclusion Questions
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum
<http://pltw.org>

Lynda.com (Online Tutorials)
<http://lynda.com>

Principles of Engineering
Brett Handley, Craig Coon, and David M. Marshall
Developed specifically for the PLTW POE course to support lesson concepts. © 2002

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<http://nepris.com>.

ROBOTC® - Robot programming language
<http://www.robotc.net/>

VEX® Robotics platform
<https://www.vexrobotics.com/>

Logger Pro® - Data collection and analysis software
<https://www.vernier.com/>

Teacher Notes:

Unit 2	Lesson 2.4: Design Problem: Materials and Structures	Duration: 10 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>HS.ESS3.4 - Earth and Human Activity Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.</p> <p>HS.ETS1.2 - Engineering Design Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.</p> <p>HS.ETS1.3 - Engineering Design Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.</p> <p>HS.ETS1.4 - Engineering Design Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.</p>		
<p>The Student Learning Objectives above were developed using the following elements from the NRC document A Framework for K-12 Science Education:</p>		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Asking questions and defining problems Ask questions:</p> <ul style="list-style-type: none"> o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. o that arise from examining models or a theory, to clarify and/or seek additional information and relationships. o to determine relationships, including quantitative relationships, between independent and dependent variables. o to clarify and refine a model, an explanation, or an engineering problem <ul style="list-style-type: none"> - Evaluate a question to determine if it is testable and relevant. - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. <p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.) <p>Constructing Explanations and Designing Solutions</p>	<p>ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> - Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3) - Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) <p>ETS1.B - Engineering Design - Developing Possible Solutions</p> <ul style="list-style-type: none"> - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) <p>ETS1.C - Engineering Design - Optimizing the Design Solution</p> <ul style="list-style-type: none"> - Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6) 	<p>Patterns</p> <ul style="list-style-type: none"> - Empirical evidence is needed to identify patterns. <p>Mechanism and Prediction</p> <ul style="list-style-type: none"> - Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. <p>Cause and Effect: Mechanism and Prediction</p> <ul style="list-style-type: none"> - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. - Systems can be designed to cause a desired effect. <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> - The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. - Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. - Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. - Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). <p>Systems and System Models</p> <ul style="list-style-type: none"> - A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. - Systems can be designed to do specific tasks. - When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

- Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
- Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.
- Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Obtaining, Evaluating, and Communicating Information

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
- Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.
- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Structure and Function

- The way an object is shaped or structured determines many of its properties and functions.
- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.
- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Stability and Change

- For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.
- Much of science deals with constructing explanations of how things change and how they remain stable.
- Feedback (negative or positive) can stabilize or destabilize a system.
- Systems can be designed for greater or lesser stability.

Supporting and Additional Standards
Mathematics
<p>N.Q.1 – Quantities Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.</p> <p>N.Q.2 – Quantities Define appropriate quantities for the purpose of descriptive modeling.</p>

Instructional Plan - Lesson 2.4: Design Problem: Materials and Structures		
Suggested Activities	Resources “Project Lead The Way “	
Activities (A) Projects (P) Problems (B)	Knowledge / Skills	
Problem.2.4.1 Design Problem: Bridge Simulated Structural Design	-- K1, S1, S2, S3, S4	
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...	
<ul style="list-style-type: none"> • U1 – Design problems can be solved by individuals or in teams. • U2 – Engineers use a design process to create solutions to existing problems. • U3 – Design briefs are used to identify the problem specifications and to establish project constraints. • U4 – Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships. • U5 – Design teams conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions. 	<ul style="list-style-type: none"> • Q1 – What is a design brief? What are design constraints? • Q2 – Why is a design process so important to follow when creating a solution to a problem? • Q3 – What is a decision matrix and why is it used? • Q4 – What does consensus mean, and how do teams use consensus to make decisions? • Q5 – How do the properties and types of materials affect the solution to a design problem? 	
KNOWLEDGE: Students will ...	Skills Students will ...	
<ul style="list-style-type: none"> • K1 – Know the purpose of each part of a design brief. U3 • K2 – Describe a step-by-step, iterative design process. U2 	<ul style="list-style-type: none"> • S1 – Brainstorm and sketch possible solutions to an existing design problem. U1, U2, U4, U5 • S2 – Create a decision-making matrix for a design problem. U1, U2 • S3 – Select an approach that meets or satisfies the constraints provided in a design brief. U1, U3 • S4 – Create a detailed pictorial sketch or use 3D-modeling software to document a proposed design. U1, U2, U4 	
Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Problem.2.4.1 Design Problem: Bridge Simulated Structural Design	<ul style="list-style-type: none"> • Essential Questions 	<ul style="list-style-type: none"> • Conclusion Questions • Presentation of final simulated design
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials

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VEX® Robotics platform
<https://www.vexrobotics.com/>

Logger Pro® - Data collection and analysis software
<https://www.vernier.com/>

Teacher Notes:

Unit 3	Lesson 3.1: Machine Control	Duration: 16 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>Standards for Technological Literacy</p> <p>2.9-12.FF Students will develop an understanding of the core concepts of technology. FF. Complex systems have many layers of controls and feedback loops to provide information.</p> <p>12.9-12.L Students will develop the abilities to use and maintain technological products and systems. L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.</p> <p>12.9-12.P Students will develop the abilities to use and maintain technological products and systems. P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.</p> <p>17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies. P. There are many ways to communicate information, such as graphic and electronic means.</p>		
<p>The Student Learning Objectives above were developed using the following elements from the NRC document A Framework for K-12 Science Education:</p>		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in 		

scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).		
Supporting and Additional Standards		

Instructional Plan - Lesson 3.1: Machine Control	
Suggested Activities	Resources “Project Lead The Way “
Activities (A) Projects (P) Problems (B)	Knowledge / Skills
<p> Activity 3.1.0 Career, Demand, Salary, and Education Activity 3.1.1 Inputs and Outputs Activity 3.1.2 Basic Outputs Programming Activity 3.1.3 Basic Inputs Programming Activity 3.1.4 While and If-else Structures Activity 3.1.5 Variables and Functions Activity 3.1.6 Open and Closed Loop Systems Project 3.1.7 Machine Control Design </p>	<p> -- K4 --K1, S1 --K1, S1, S2, S3, S4 --K1, S1, S2, S3, S4, S5 -- K1, S1, S2, S3, S4, S5, S6, S7, S8 -- K1, S1, S2, S3, S4, S5, S6, S7, S8 -- K2, K3, S1, S2, S3, S4, S5, S6, S7 -- K1, K2, K3, S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14 </p>
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...
<ul style="list-style-type: none"> • U1 – Control systems are designed to provide consistent process control, reliability, and automation. • U2 – Control system algorithms are a sequence of instructions, often involving conditional statements and iterative loops. • U3 – Machines can use open-loop or closed-loop control systems; closed-loop control systems can use digital and/or analog sensor feedback to make decisions. • U4 – Complex algorithms are created by decomposing the algorithm into simple pieces and complex machine behavior can similarly be decomposed into simple component behavior. • U5 – Documentation – in the form of pseudocode, comments, and other documentation – can be an important part of creating and maintaining a computer program. • U6 – Version control can be an important part of creating and maintaining a computer program. • U7 – (<i>Design Process</i>) Design problems can be solved by individuals or in teams. (Same as U1 in Lesson 1.4) • U8 – (<i>Design Process</i>) Engineers use a design process to create solutions to existing problems. (Same as U2 in Lesson 1.4) • U9 – (<i>Design Process</i>) Engineers and engineering technologists apply math, science, and discipline-specific skills to solve problems. (Same as U1 of Lesson 1.1.) • U10 – (<i>Career Exploration</i>) Engineering and engineering technology careers offer creative job opportunities for individuals with a wide variety of backgrounds and goals. (Same as U2 of Lesson 1.1.) 	<ul style="list-style-type: none"> • Q1 – What are the advantages and disadvantages of using programmable logic to control machines versus monitoring and adjusting processes manually? • Q2 – What are some everyday seemingly simple devices that contain microprocessors, and what function do the devices serve? • Q3 – What questions must designers ask when solving problems in order to decide between digital or analog systems and between open or closed loop systems?

KNOWLEDGE: Students will ...	Skills Students will ...
<ul style="list-style-type: none"> • K1 – Distinguish between digital and analog data, and between the inputs and outputs of a computational system. U3 • K2 – Distinguish open and closed loop systems based on whether decisions are made using time delays or sensor feedback. U3 • K3 – Identify the relative advantage of an open-loop or closed-loop control system for a given technological problem. U3 • K4 – (<i>Career Exploration</i>) Describe the market demand and salary range for one type of engineer or engineering technician, and understand the education path that leads to that career. U8, U9 	<ul style="list-style-type: none"> • S1 – Choose appropriate input and output devices based on the need of a technological system. U1, U3 • S2 – Create a flow chart to describe an algorithm. U2, U5 • S3 – Create pseudocode to describe an algorithm. U2, U4, U5 • S4 – Analyze and describe an algorithm represented as a flowchart or as programming code. U2, U5 • S5 – Create a computer program to implement an algorithm, including conditional statements and iterations. U2, U3, U4, U5, U6 • S6 – Predict the behavior of a control system by examining the program it is going to execute. U2, U3, U4, U5 • S7 – Evaluate algebraic and logical expressions involving programming variables. U2, U5 • S8 – Use a variety of methods for finding, identifying, and correcting bugs in a program. U2, U3, U4, U5, U6 • S9 – Design and create a control system, including the inputs, computer program, and outputs, based on given needs and constraints. U1, U2, U3, U4, U5, U6, U7, U8 • S10 – (<i>Design Process</i>) Brainstorm and sketch possible solutions to an existing design problem. U1, U2, U3, U4, U7, U8 (Same as S1 of Lesson 1.4.) • S11 – (<i>Design Process</i>) Create a decision making matrix for a design problem. U7, U8 (Same as S1 of Lesson 1.4.) • S12 – (<i>Design Process</i>) Select an approach that meets or satisfies the constraints provided in a design brief. U1, U2, U3, U4, U7, U8 (Same as S1 of Lesson 1.4.) • S13 – (<i>Design Process</i>) Create a detailed pictorial sketch or use 3D modeling software to document a proposed design. U5, U7, U8 (Same as S1 of Lesson 1.4.) • S14 – (<i>Design Process</i>) Present a workable solution to a design problem. U1, U2, U4, U5, U7, U8 (Same as S1 of Lesson 1.4.)

Evidence of Student Learning

Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Activity 3.1.0 Career, Demand, Salary, and Education Explore facts related to a specific career field	<ul style="list-style-type: none"> • 3.1.RU Career Demand, Salary, & Education Rubric • Essential Questions 	<ul style="list-style-type: none"> • 3.1.RU Career Demand, Salary, & Education Rubric
Activity 3.1.1 Inputs and Outputs	<ul style="list-style-type: none"> • Essential Questions • Instructor signoff of student demonstrated program 	<ul style="list-style-type: none"> • Conclusion Questions
Activity 3.1.2 Basic Outputs Programming	<ul style="list-style-type: none"> • Essential Questions 	<ul style="list-style-type: none"> • Conclusion Questions • Print out of program
Activity 3.1.3 Basic Inputs Programming	<ul style="list-style-type: none"> • Essential Questions 	<ul style="list-style-type: none"> • Conclusion Questions • Print out of program
Activity 3.1.4 While and If-else Structures	<ul style="list-style-type: none"> • Essential Questions 	<ul style="list-style-type: none"> • Conclusion Questions • Print out of program
Activity 3.1.5 Variables and Functions	<ul style="list-style-type: none"> • Essential Questions 	<ul style="list-style-type: none"> • Conclusion Questions • Print out of program

Activity 3.1.6 Open and Closed Loop Systems	<ul style="list-style-type: none"> • Essential Questions 	<ul style="list-style-type: none"> • Conclusion Questions • Print out of program
Project 3.1.7 Machine Control Design	<ul style="list-style-type: none"> • 3.1.7.P.RU Machine Control Design Rubric (7 Problems) • Essential Questions 	<ul style="list-style-type: none"> • 3.1.7.P.RU Machine Control Design Rubric (7 Problems) • Conclusion Questions • Presentation of machine control design with program.
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum

<http://pltw.org>

Lynda.com (Online Tutorials)

<http://lynda.com>

Principles of Engineering

Brett Handley, Craig Coon, and David M. Marshall
Developed specifically for the PLTW POE course to support lesson concepts. © 2002

NEPRIS - Connecting Industry to Every Classroom

<http://nepris.com>.

ROBOTC® - Robot programming language

<http://www.robotc.net/>

VEX® Robotics platform

<https://www.vexrobotics.com/>

Logger Pro® - Data collection and analysis software

<https://www.vernier.com/>

Teacher Notes:

Unit 3	Lesson 3.2: Fluid Power	Duration: 15 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>HS.PS3.3 – Energy Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.</p> <p>HS.ETS1.3 - Engineering Design Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.</p>		
The Student Learning Objectives above were developed using the following elements from the NRC document A Framework for K-12 Science Education :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.). <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). 	<p>PS1.A - Matter and Its Interactions - Structure and Properties of Matter</p> <ul style="list-style-type: none"> - The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1) - The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3), (secondary to HS-PS2-6) 	

Supporting and Additional Standards

Instructional Plan - Lesson 3.2: Fluid Power

Suggested Activities	Resources “Project Lead The Way “
Activities (A) Projects (P) Problems (B)	Knowledge / Skills
Activity 3.2.1 Fluid Power Applications Activity 3.2.2 Pneumatic Demonstration Activity 3.2.3 Fluid Power Practice Problems Project 3.2.3 Pneumatic Brake Design (FT) Activity 3.2.4 Hydraulic Demonstration Project 3.2.5 Hydraulic Lift Design	-- K2, S1 -- K2, S1 -- K3, K4, S5, S6, S7 -- K2, S1, S2 -- K1, K2, S1, S3 -- K1, K2, S1, S4, S5
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...
<ul style="list-style-type: none"> • U1 – The two types of fluid power systems – pneumatics and hydraulics – have both common and distinguishing characters. • U2 – Fluid power is possible because in a system of confined fluid, pressure acts equally in all directions. • U3 – All fluid power systems have basic components and functions in common, including a reservoir or receiver, a pump or compressor, a valve, and a cylinder. • U4 – Fluid power systems are designed to transmit force over great distances, multiply an input force, and/or increase the distance that an output will move. • U5 – Laws about the behavior of fluid systems and standard conventions for calculating values within fluid systems aid in the design and understanding of such systems. • U6 – Standard schematic symbols and conventions are used to communicate fluid power designs. 	<ul style="list-style-type: none"> • Q1 – What impact does fluid power have on our everyday lives? • Q2 – Can you identify devices or systems that do not use fluid power that might be improved with the use of fluid power? • Q3 – What are similarities and differences of mechanical advantage in simple machines and hydraulic systems? • Q4 – Why are Pascal’s Law, the perfect gas laws, Bernoulli’s Principle, and other similar rules important to engineers and designers of fluid power systems?

KNOWLEDGE: Students will ...	Skills Students will ...
<ul style="list-style-type: none"> • K1 – Identify the advantages of hydraulic and pneumatic systems relative to each other. U1 • K2 – Identify and explain basic components and functions of fluid power devices. U3 • K3 – Distinguish between pressure and absolute pressure. U5 • K4 – Distinguish between temperature and absolute temperature. U5 	<ul style="list-style-type: none"> • S1 – Identify devices that utilize hydraulic and pneumatic power. U1 • S2 – Distinguish between hydrodynamic and hydrostatic systems. U1 • S3 – Design, create, and test a hydraulic device. U1, U2, U3, U4, U5, U6 • S4 – Design, create, and test a pneumatic device. U1, U2, U3, U4, U5, U6 • S5 – Calculate design parameters in a fluid power system utilizing Pascal’s Law. U2, U4, U5 • S6 – Calculate values in a pneumatic system utilizing the ideal gas laws. U2, U5 • S7 – Calculate flow rate, flow velocity, power, and mechanical advantage in a fluid power system. U5

Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Activity 3.2.1 Fluid Power Applications	<ul style="list-style-type: none"> • Essential Questions • Gear Calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Conclusion Questions • Student presentation
Activity 3.2.2 Pneumatic Demonstration	<ul style="list-style-type: none"> • Essential Questions 	<ul style="list-style-type: none"> • Conclusion Questions
Activity 3.2.3 Fluid Power Practice Problems	<ul style="list-style-type: none"> • Essential Questions • Gear Calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Practice Problems
Project 3.2.3 Pneumatic Brake Design (FT)	<ul style="list-style-type: none"> • 3.2.3.P.FT.RU Pneumatic Brake Design Rubric • Essential Questions 	<ul style="list-style-type: none"> • 3.2.3.P.FT.RU Pneumatic Brake Design Rubric • Conclusion Questions • Presentation of final design
Activity 3.2.4 Hydraulic Demonstration	<ul style="list-style-type: none"> • Essential Questions • Gear Calculations • Student responses to presentation examples 	<ul style="list-style-type: none"> • Conclusion Questions
Project 3.2.5 Hydraulic Lift Design	<ul style="list-style-type: none"> • 3.2.5.P.FT.RU Hydraulic Lift Design Rubric • Essential Questions 	<ul style="list-style-type: none"> • 3.2.5.P.FT.RU Hydraulic Lift Design Rubric • Conclusion Questions • Presentation of final design
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials	
<p>Project Lead the Way (PLTW) Curriculum http://pltw.org</p> <p>Lynda.com (Online Tutorials) http://lynda.com</p> <p>Principles of Engineering Brett Handley, Craig Coon, and David M. Marshall Developed specifically for the PLTW POE course to support lesson concepts. © 2002</p> <p>NEPRIS - Connecting Industry to Every Classroom http://nepris.com.</p>	<p>ROBOTC® - Robot programming language http://www.robotc.net/</p> <p>VEX® Robotics platform https://www.vexrobotics.com/</p> <p>Logger Pro® - Data collection and analysis software https://www.vernier.com/</p>
Teacher Notes:	

Unit 3	Lesson 3.3 Design Problem: Control Systems	Duration: 15 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>HS.PS3.3 - Energy Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.</p> <p>HS.ETS1.2 - Engineering Design Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.</p> <p>HS.ETS1.3 - Engineering Design Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.</p> <p>HS.ETS1.4 - Engineering Design Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.</p>		
The Student Learning Objectives above were developed using the following elements from the NRC document A Framework for K-12 Science Education :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> - Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, 	<p>ETS1.A - Engineering Design – Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> - Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3) - Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) <p>ETS1.B - Engineering Design – Developing Possible Solutions</p> <ul style="list-style-type: none"> - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) <p>ETS1.C - Engineering Design – Optimizing the Design Solution</p> <ul style="list-style-type: none"> - Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6) 	

<p>processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.</p> <ul style="list-style-type: none"> - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). 		
Supporting and Additional Standards		
Mathematics		
N.Q.3 – Quantities Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.		

Instructional Plan - Lesson 3.3 Design Problem: Control Systems	
Suggested Activities	Resources “Project Lead The Way “
Activities (A) Projects (P) Problems (B)	Knowledge / Skills
Problem .3.3.1 Design Problem: Materials Sorter	-- S1, S2, S3, S4, S5
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...
<ul style="list-style-type: none"> • U1 – Design problems can be solved by individuals or in teams. (Same as U1 of Lesson 1.4.) • U2 – Engineers use a design process to create solutions to existing problems. (Same as U2 of Lesson 1.4.) • U3 – Design briefs are used to identify the problem specifications and to establish project constraints. (Same as U3 of Lesson 1.4.) • U4 – Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships. (Same as U4 of Lesson 1.4.) • U5 – Design teams conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions. (Same as U5 of Lesson 1.4.) • U6 – Effective presentations are the result of preparation, are tailored to suit the purpose and audience, and are improved by attending to posture, gestures, appearance, eye contact, and time constraints. (Same as U6 of Lesson 1.4.) 	<ul style="list-style-type: none"> • Q1 – What is a design brief and what are design constraints? • Q2 – Why is a design process so important to follow when creating a solution to a problem? • Q3 – What is a decision matrix and why is it used? • Q4 – What does consensus mean, and how do teams use consensus to make decisions? • Q5 – How does the use of mechanisms affect the overall solution to a design problem?

KNOWLEDGE: Students will ...		Skills Students will ...	
<ul style="list-style-type: none"> • K1 – Know the purpose of each part of a design brief. U3 • K2 – Describe a step-by-step, iterative design process. U2 		<ul style="list-style-type: none"> • S1 – Brainstorm and sketch possible solutions to an existing design problem. U1, U2, U4, U5 • S2 – Create a decision making matrix for a design problem. U1, U2 • S3 – Select an approach that meets or satisfies the constraints provided in a design brief. U1, U3 • S4 – Create a detailed pictorial sketch or use 3D modeling software to document a proposed design. U1, U2, U4 • S5 – Present a workable solution to a design problem. U1, U2, U4, U6 	
Evidence of Student Learning			
Activities (A) Projects (P) Problems (B)		Assessment FOR Learning	
Assessment OF Learning			
Problem .3.3.1 Design Problem: Materials Sorter		<ul style="list-style-type: none"> • 3.3.1.P.RU Material Sorter Design Rubric • Essential Questions 	
Unit Assessment Items Summative – EoC		-- All items	
-- All items		-- All items	
Core Instructional and Supplemental Materials			
Project Lead the Way (PLTW) Curriculum http://pltw.org		ROBOTC® - Robot programming language http://www.robotc.net/	
Lynda.com (Online Tutorials) http://lynda.com		VEX® Robotics platform https://www.vexrobotics.com/	
Principles of Engineering Brett Handley, Craig Coon, and David M. Marshall Developed specifically for the PLTW POE course to support lesson concepts.© 2002		Logger Pro® - Data collection and analysis software https://www.vernier.com/	
NEPRIS - Connecting Industry to Every Classroom http://nepris.com .			
Teacher Notes:			

Unit 4	Lesson 4.1 Statistics	Duration: 5 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>Standards for Technological Literacy</p> <p>12.9-12.L Students will develop the abilities to use and maintain technological products and systems. L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.</p> <p>12.9-12.P Students will develop the abilities to use and maintain technological products and systems. P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.</p> <p>17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies. P. There are many ways to communicate information, such as graphic and electronic means.</p>		
<p>The Student Learning Objectives above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i>:</p>		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, 	<p>ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> - Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3) - Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) <p>ETS1.B - Engineering Design - Developing Possible Solutions</p> <ul style="list-style-type: none"> - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) <p>ETS1.C - Engineering Design - Optimizing the Design Solution</p> <ul style="list-style-type: none"> - Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6) 	

<p>assessing the evidence and usefulness of each source.</p> <ul style="list-style-type: none"> - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). 		
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Supporting and Additional Standards

Mathematics

<p>S.ID.1 - Interpreting Categorical and Quantitative Data Represent data with plots on the real number line (dot plots, histograms, and box plots).</p> <p>S.ID.2 - Interpreting Categorical and Quantitative Data Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.</p> <p>S.ID.3 - Interpreting Categorical and Quantitative Data Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).</p> <p>S.ID.4 - Interpreting Categorical and Quantitative Data Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.</p> <p>S.IC.1 - Making Inferences and Justifying Conclusions Understand statistics as a process for making inferences about population parameters based on a random sample from that population.</p> <p>S.IC.2 - Making Inferences and Justifying Conclusions Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. For example, a model says a spinning coin falls heads up with probability 0.5. Would a result of 5 tails in a row cause you to question the model?</p> <p>S.IC.4 - Making Inferences and Justifying Conclusions Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.</p> <p>S.CP.1 - Conditional Probability and the Rules of Probability Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events ("or," "and," "not").</p> <p>S.CP.2 - Conditional Probability and the Rules of Probability Understand that two events A and B are independent if the probability of A and B occurring together is the product of their probabilities, and use this characterization to determine if they are independent.</p> <p>S.CP.3 - Conditional Probability and the Rules of Probability Understand the conditional probability of A given B as $P(A \text{ and } B)/P(B)$, and interpret independence of A and B as saying that the conditional probability of A given B is the same as the probability of A, and the conditional probability of B given A is the same as the probability of B.</p> <p>S.CP.4 - Conditional Probability and the Rules of Probability Construct and interpret two-way frequency tables of data when two categories are associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities. For example, collect data from a random sample of students in your school on their favorite subject among math, science, and English. Estimate the probability that a randomly selected student from your school will favor science given that the student is in tenth grade. Do the same for other subjects and compare the results.</p> <p>S.CP.5 - Conditional Probability and the Rules of Probability Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. For example, compare the chance of having lung cancer if you are a smoker with the chance of being a smoker if you have lung cancer.</p> <p>S.CP.6 - Conditional Probability and the Rules of Probability Find the conditional probability of A given B as the fraction of B's outcomes that also belong to A, and interpret the answer in terms of the model.</p> <p>S.CP.7 - Conditional Probability and the Rules of Probability Apply the Addition Rule, $P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$, and interpret the answer in terms of the model.</p> <p>S.CP.8 - Conditional Probability and the Rules of Probability (+) Apply the general Multiplication Rule in a uniform probability model, $P(A \text{ and } B) = P(A)P(B A) = P(B)P(A B)$, and interpret the answer in terms of the model.</p> <p>S.CP.9 - Conditional Probability and the Rules of Probability (+) Use permutations and combinations to compute probabilities of compound events and solve problems.</p> <p>S.MD.7 - Using Probability to Make Decisions (+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).</p>
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Instructional Plan - Lesson 4.1 Statistics		
Suggested Activities	Resources “Project Lead The Way “	
Activities (A) Projects (P) Problems (B)	Knowledge / Skills	
Activity 4.1.0 Career Reflection, Abstract, Presentation Activity 4.1.1 Statistical Data Exploration Activity 4.1.2 Candy Statistics	-- S1 -- S2, S3, S4, S5, S6, S7, S8 -- S2, S3, S4, S5, S6, S7, S8	
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...	
<ul style="list-style-type: none"> • U1 – Engineers use statistics to make informed decisions based upon established principles. • U2 – Visual representations of data allow a person to understand and gain knowledge from the data. • U3 – Descriptive statistics produce an abstraction from data, allowing us to communicate a meaningful summary instead of unenlightening details. • U4 – The theoretical likelihood of an event can often be calculated based on a small number of simple assumptions. • U5 – Inferential statistics allow us to generalize by drawing conclusions from data based on the laws of theoretical probability. • U6 – (Design Process) Engineers and engineering technologists apply math, science, and discipline-specific skills to solve problems. (Same as U1 of Lesson 1.1.) • U7 – (Career Exploration) Engineering and engineering technology careers offer creative job opportunities for individuals with a wide variety of backgrounds and goals. 	<ul style="list-style-type: none"> • Q1 – Why is it crucial for designers and engineers to utilize statistics throughout the design process? • Q2 – Why is process control a necessary statistical process for ensuring product success? • Q3 – Why is theory-based data interpretation valuable in decision making? • Q4 – Why is experiment-based data interpretation valuable in decision making? 	
KNOWLEDGE: Students will ...	Skills Students will ...	
<ul style="list-style-type: none"> • K1 – Name measures of central tendency and variation and describe their meaning. • K2 – Distinguish between sample statistics and population statistics and know appropriate applications of each. 	<ul style="list-style-type: none"> • S1 – (<i>Career Exploration</i>) Evaluate how personal career interests align or do not align with one or more fields of engineering or engineering technology. U6 • S2 – Calculate the theoretical probability that a simple event will occur. U4 • S3 – Produce a frequency distribution to describe experimental results and create a histogram to communicate these results. U2, U3 • S4 – Calculate the probability of making a set of observations in a series of trials where each trial has two distinct possible outcomes. U4 • S5 – Apply AND, OR, and NOT logic to probability. U4 • S6 – Apply Bayes’ Theorem to calculate a probability in a manufacturing context. U4 • S7 – Calculate the central tendency of a data set, including mean, median, and mode. U3 • S8 – Calculate the variation in a set of data, including range, standard deviation, and variance. U3 	
Evidence of Student Learning		
Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Activity 4.1.0 Career Reflection, Abstract, Presentation	- 4.1.RU Career Reflection Abstract Presentation Rubric - Essential Questions	- 4.1.RU Career Reflection Abstract Presentation Rubric - Final student presentation

Activity 4.1.1 Statistical Data Exploration	- Essential Questions - Student responses to presentation examples	- Histogram and Conclusion Questions
Activity 4.1.2 Candy Statistics	- Essential Questions - Student responses to presentation examples	- Histogram and Conclusion Questions
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials

Project Lead the Way (PLTW) Curriculum

<http://pltw.org>

Lynda.com (Online Tutorials)

<http://lynda.com>

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VEX® Robotics platform

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Logger Pro® - Data collection and analysis software

<https://www.vernier.com/>

Teacher Notes:

Unit 4	Lesson 4.2 Kinematics	Duration: 24 days
Standards/Learning Targets		
Focus Standards (Major Standards)		
<p>HS.PS2.1 - Motion and Stability: Forces and Interactions Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.</p> <p>HS.PS3.3 - Energy Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.</p>		
<p>The Student Learning Objectives above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i>:</p>		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Asking questions and defining problems Ask questions:</p> <ul style="list-style-type: none"> o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. o that arise from examining models or a theory, to clarify and/or seek additional information and relationships. o to determine relationships, including quantitative relationships, between independent and dependent variables. o to clarify and refine a model, an explanation, or an engineering problem <p>- Evaluate a question to determine if it is testable and relevant.</p> <p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. - Apply techniques of algebra and functions to represent and solve scientific and engineering problems. - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. 	<p>ETS1.A - Engineering Design – Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> - Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3) <p>ETS1.B - Engineering Design – Developing Possible Solutions</p> <ul style="list-style-type: none"> - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) <p>ETS1.C - Engineering Design – Optimizing the Design Solution</p> <ul style="list-style-type: none"> - Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6) 	<p>Cause and Effect: Mechanism and Prediction</p> <ul style="list-style-type: none"> - Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> - Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). <p>Systems and System Models</p> <ul style="list-style-type: none"> - Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
- Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Obtaining, Evaluating, and Communicating Information

- Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
- Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Supporting and Additional Standards

English Language Arts

AS.W.5 - Writing

Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach.

AS.W.6 – Writing Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.7 – Writing Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

AS.W.8 – Writing Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

AS.W.9 – Writing Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 – Writing Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.2 - Speaking and Listening Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.L.1 – Language Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 – Language Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 – Language Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

Mathematics

N.RN.2 - The Real Number System Rewrite expressions involving radicals and rational exponents using the properties of exponents.

N.Q.1 – Quantities Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 – Quantities Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 – Quantities Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

N.VM.1 - Vector and Matrix Quantities (+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v , $|v|$, $\|v\|$, v).

N.VM.2 - Vector and Matrix Quantities (+) Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point.

N.VM.3 - Vector and Matrix Quantities (+) Solve problems involving velocity and other quantities that can be represented by vectors.

A.SSE.1 - Seeing Structure in Expressions Interpret expressions that represent a quantity in terms of its context.

A.SSE.1.a - Seeing Structure in Expressions Interpret parts of an expression, such as terms, factors, and coefficients.

A.SSE.1.b - Seeing Structure in Expressions Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret $P(1+r)^n$ as the product of P and a factor not depending on P .

A.CED.3 - Creating Equations Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.

A.CED.4 - Creating Equations Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law $V = IR$ to highlight resistance R .

A.REI.3 - Reasoning with Equations and Inequalities Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

A.REI.4 - Reasoning with Equations and Inequalities Solve quadratic equations in one variable.

F.TF.7 - Trigonometric Functions (+) Use inverse functions to solve trigonometric equations that arise in modeling contexts; evaluate the solutions using technology, and interpret them in terms of the context.

G.SRT.6 - Similarity, Right Triangles, and Trigonometry Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.

G.SRT.8 - Similarity, Right Triangles, and Trigonometry Use trigonometric ratios and the Pythagorean theorem to solve right triangles in applied problems.

G.MG.3 - Modeling with Geometry Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

S.ID.2 - Interpreting Categorical and Quantitative Data Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

Instructional Plan - Lesson 4.2 Kinematics	
Suggested Activities	Resources “Project Lead The Way “
Activities (A) Projects (P) Problems (B)	Knowledge / Skills
Activity 4.2.1 Self Propelled Vehicle Design Activity 4.2.2 Projectile Motion 4.2.3 Design Problem: Ballistic Device	-- K1, S2, S4, S5, S6 -- S3 -- K2, K3, S6, S7, S8, S9, S10
UNDERSTANDINGS: Students will understand that ...	ESSENTIAL QUESTIONS: Students will keep considering ...
<ul style="list-style-type: none"> • U1 – When working with bodies in motion, engineers must be able to distinguish and calculate distance, displacement, speed, velocity, and acceleration. • U2 – When air resistance is not taken into account, released objects will experience acceleration due to gravity, also known as freefall. • U3 – Projectile motion can be predicted and controlled using kinematics equations. • U4 – During projectile motion, velocity in the x-direction remains constant; while velocity in the y-direction changes at a constant rate due to gravity. • U5 – (Design Process) Design problems can be solved by individuals or in teams. (Same as U1 of Lesson 1.4.) • U6 – (Design Process) Engineers use a design process to create solutions to existing problems. (Same as U2 of Lesson 1.4.) • U7 – (Design Process) Design briefs are used to identify the problem specifications and to establish project constraints. (Same as U3 of Lesson 1.4.) • U8 – (Design Process) Working in a team requires effective communication, clear responsibilities, and attention to interpersonal relationships. (Same as U4 of Lesson 1.4.) • U9 – (Design Process) Design teams conduct research to develop their knowledge base, stimulate creative ideas, and make informed decisions. (Same as U5 of Lesson 1.4.) • U10 – (Design Process) Effective presentations are the result of preparation, are tailored to suit the purpose and audience, and are improved by attending to posture, gestures, appearance, eye contact, and time constraints. (Same as U6 of Lesson 1.4.) 	<ul style="list-style-type: none"> • Q1 – What are the relationships between distance, displacement, speed, velocity, and acceleration? • Q2 – Why is it important to understand and be able to control the motion of a projectile?
KNOWLEDGE: Students will ...	Skills Students will ...
<ul style="list-style-type: none"> • K1 – Describe freefall motion of a projectile as having constant velocity in the horizontal direction and uniformly accelerating motion in the vertical direction. U4 • K2 – (Design Process) Know the purpose of each part of a design brief. U7 • K3 – (Design Process) Describe a step-by-step, iterative design process. U6 	<ul style="list-style-type: none"> • S1 – Calculate distance, displacement, speed, velocity, and acceleration from data. U1, U2, U3, U4 • S2 – Design, build, and test a machine that efficiently channels mechanical energy when friction and limited input energy are significant constraints. U1 • S3 – Calculate acceleration due to gravity given data from a free-fall trajectory. U2, U4 • S4 – Calculate the x- and y-components of a projectile motion. U1, U3, U4 • S5 – Determine the angle needed to launch a projectile a specific range given the

	<p>projectile's initial velocity. U1, U2, U3, U4</p> <ul style="list-style-type: none"> • S6 – (<i>Design Process</i>) Brainstorm and sketch possible solutions to an existing design problem. U5, U6, U8, U9 • S7 – (<i>Design Process</i>) Create a decision making matrix for a design problem. U5, U6 • S8 – (<i>Design Process</i>) Select an approach that meets or satisfies the constraints provided in a design brief. U5, U7 • S9 – (<i>Design Process</i>) Create a detailed pictorial sketch or use 3D modeling software to document a proposed design. U5, U6, U7 • S10 – (<i>Design Process</i>) Present a workable solution to a design problem. U5, U6, U8, U9
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Evidence of Student Learning

Activities (A) Projects (P) Problems (B)	Assessment FOR Learning	Assessment OF Learning
Activity 4.2.1 Self Propelled Vehicle Design	- Essential Questions	- Conclusion Questions - Presentation of final design
Activity 4.2.2 Projectile Motion	- Essential Questions - Student responses to presentation examples	- Calculations and Conclusion Questions
4.2.3 Design Problem: Ballistic Device		- Conclusion Questions - Presentation of final design
Unit Assessment Items Summative – EoC	-- All items	-- All items

Core Instructional and Supplemental Materials

<p>Project Lead the Way (PLTW) Curriculum http://pltw.org</p> <p>Lynda.com (Online Tutorials) http://lynda.com</p> <p>Principles of Engineering Brett Handley, Craig Coon, and David M. Marshall Developed specifically for the PLTW POE course to support lesson concepts. © 2002</p> <p>NEPRIS - Connecting Industry to Every Classroom http://nepris.com.</p>	<p>ROBOTC® - Robot programming language http://www.robotc.net/</p> <p>VEX® Robotics platform https://www.vexrobotics.com/</p> <p>Logger Pro® - Data collection and analysis software https://www.vernier.com/</p>
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Teacher Notes: