*Through problems that engage and challenge, students explore a broad range of engineering topics, including mechanisms, the strength of materials and structures, automation, and motion. Students develop skills in problem solving, research, and design while learning strategies for design process documentation, collaboration, and presentation.*

*What type of engineer or engineering technologist would you like to be?*

Principles of Engineering (POE) is a foundation course of the high school engineering pathway. This survey course exposes students to some of the major concepts that they will encounter in a postsecondary engineering course of study. Through problems that engage and challenge, students explore a broad range of engineering topics, including mechanisms, the strength of materials and structures, automation, and kinematics. The course applies and concurrently develops secondary level knowledge and skills in mathematics, science, and technology.

Students have the opportunity to develop skills and understanding of course concepts through activity-, project-, and problem-based (APB) learning. By solving rigorous and relevant design problems using engineering and science concepts within a collaborative learning environment, APB learning challenges students to continually hone their interpersonal skills, creative abilities, and problem solving skills. Students will also learn how to document their work and communicate their solutions to their peers and members of the professional community. It also allows students to develop strategies to enable and direct their own learning, which is the ultimate goal of education.

The following is a summary of the units of study that are included in the course for the 2014-2015 academic year. Alignment with NGSS, Common Core, and other standards is available through the PLTW Alignment web-based tool.

**POE Unit Summary**

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|---|---|
| Unit 1 | Energy and Power (30%) |
| Unit 2 | Materials and Structures (24%) |
| Unit 3 | Control Systems (28%) |
| Unit 4 | Statistics and Kinematics (18%) |

## Unit 1: Energy and Power

The goal of Unit 1 is to introduce students to mechanisms, energy sources, and alternative energy applications. Students will gain an understanding of mechanisms through the application of theory-based calculations accompanied by lab experimentation.

They will also learn that as energy and power are transferred and transformed, losses to friction in the system will occur. Students will understand that such losses affect the overall efficiency of the system. They will have an opportunity to investigate thermal energy and alternative energy applications. Students will explore and gain

experiences relating to solar hydrogen systems and thermal energy transfer through materials.
The unit concludes with students working in teams to solve a design problem that focuses on energy and power. They will use the knowledge and understanding built through the previous learning events to create a solution to the problem. It is important for students to understand that an acceptable solution is one that fits the criteria and constraints of the design brief.

**Energy and Power Lesson Summary**

Lesson 1.1 Mechanisms
Lesson 1.2 Energy Sources
Lesson 1.3 Energy Applications
Lesson 1.4 Design Problem – Energy and Power

**Lesson 1.1 Mechanisms**
Throughout this course students will have an opportunity to learn about some of the major engineering and engineering technology fields available to them. In this unit students will interview a professional to learn more about that individual's career path and roles in their current position. The interview will be the first portion of a course-long career report.

Mechanisms are the basic components of most machines and consist of gears, sprockets, pulley systems, and simple machines. Today mechanisms can be found in everyday life from the basic components of a bicycle to the high-tech equipment used in the medical industry. Engineers and scientists use mechanisms to manipulate speed, distance, force, and function to meet a wide range of design and application requirements. Due to the wide range of applications involving mechanisms, it is important that designers and end-users understand the characteristics, applications, and limitations of mechanisms.

In Lesson 1.1 Mechanisms, students will gain an understanding of mechanisms through the application of theory-based calculations accompanied by lab experimentation.

**Lesson 1.2 Energy Sources**
Technological systems would not be possible without energy, work, and power. Although it is common to hear these terms used interchangeably in conversation, each is different and crucial to creating, using, or maintaining a technological system.

Most power used today is stored or made available when needed. In the past power that was created was often used immediately. A windmill might have been used to pump water or irrigate a field. A water wheel's rotary motion might have been used to ground grains into flour. These systems did not consist of many steps or processes between the energy source and its end use. Today's society demands that energy be stored and transported reliably and predictably to the end user. When energy and power change form, some of it is lost along the way to friction. Engineers are being challenged to find creative ways to generate energy and make systems more efficient.

**Lesson 1.3 Energy Applications**
Today's consumer demands effective energy management. Consumers rely on efficient and accessible energy to

power automobiles, homes, appliances, and electronics. National trends regarding energy management include appliance and home energy star ratings and the development of alternative and renewable energy sources. The Law of Conservation of Energy states that energy cannot be gained or destroyed but instead transferred from one form to another.

Understanding how energy is transferred from one form to another allows engineers to design efficient applications utilizing energy. We know that many sources of energy won't last forever, and that many sources of energy have negative consequences on the environment. In the past individuals were forced to harness power that humans or animals created from the energy stored in food. Power could also be harnessed from surrounding resources like wind, flowing water, heat from the sun, or from combustible materials like wood.

This lesson is designed to provide students with an opportunity to investigate thermal energy and alternative energy applications. Students will explore and gain experiences relating to energy transformations in solar hydrogen systems and thermal energy transfer through materials.

**Lesson 1.4 Design Problem – Energy and Power**
Problems exist everywhere, and they vary in their degree of complexity and importance. Regardless of how problems are identified or from where they come, engineers use the design process to creatively and efficiently solve problems.

Solutions to problems are sometimes created by teams. These teams work together, constantly communicating with each other, to create the desired product. The team may receive a problem for which they are expected to create a solution with very few constraints. This allows the team to think creatively and use their ingenuity.

In this lesson students will work in teams to solve a design problem that focuses on energy and power. They will use the knowledge and understanding developed throughout unit one to create a solution to the problem. It is important for students to understand that an acceptable solution is one that fits the criteria and constraints of the design brief.

## Unit 2: Materials and Structures

The goal of Unit 2 is for students to have a more concrete understanding of engineering through materials properties and statics. Students begin by learning about beam deflection and then forces on truss structures. They learn to identify forces acting on those structures and then gain the ability to calculate internal and external forces acting on those structures.

The students learn about material properties, which lead students to the ability to properly select a material for a given task. Creating new products to meet a given need or want is not the only concern in this area of study. How to reuse/recycle materials for continued and unique uses is also learned.

The primary way of studying materials properties in this unit is through destructive and non-destructive material testing on various materials. Tensile testing is the major destructive test. Students are engaged in how machines perform these tests and use either a classroom machine or a simulation to further their understanding of these processes.

This unit concludes with a design problem whereby students, working in teams, follow the design process to solve a design problem.

**Materials and Structures Lesson Summary**

Lesson 2.1 Statics
Lesson 2.2 Material Properties
Lesson 2.3 Material Testing
Lesson 2.4 Design Problem – Materials and Structures

**Lesson 2.1 Statics**
Statics is the basis for the study of engineering mechanics, specifically rigid-body mechanics. Statics is concerned with the equilibrium of bodies that are at rest or that move at a constant velocity. Using measurements of geometry and force, Archimedes studied statics concepts in ancient Greece. Most of his work centered on simple machines for construction of buildings.

In this lesson students will learn how to identify and calculate forces acting on a body when it is in static equilibrium. Students will calculate internal and external forces of a truss. They will use this knowledge to design, build, and test their own truss designs.

**Lesson 2.2 Material Properties**
Material properties are an important piece of information that engineers rely on when selecting the best material for a design solution. For instance in the 1988 Challenger space shuttle disaster, an o-ring seal failed, causing the death of seven astronauts. A misunderstanding about the limits of a material led to this accident.

Engineers often deal with the design of useful products that require materials with certain characteristics or properties. Complexity is increased when we consider that new materials are constantly being developed, and their application in new products drives economic growth. Engineers, therefore, must know how to make sense of the multitude of different materials available. When existing materials don't provide the desired properties, engineers create new materials called synthetics. Synthetic materials allow engineers to be extremely innovative when designing solutions to society's needs.

Sometimes the focus isn't on the creation of a new material, but on the creation of advanced recycling technology. Nike is one of several corporations assisting engineers with innovative recycling technology. For instance, Nike has worked with engineers to develop a method of recycling athletic shoes. The recycled shoes are ground up and used for the production of basketball courts, tracks, playgrounds, etc.

This lesson is designed to provide students with an opportunity to investigate the basic categories and properties of materials. Students will discover how products are made and how they are recycled once they are no longer useful.

**Lesson 2.3 Material Testing**
Material Testing is a critical process that determines whether a product is reliable, safe, and predictable in function. Material testing is basically divided into two major categories: destructive testing and nondestructive testing.

Destructive testing is defined as a process where a material is subjected to a load in a manner that will ultimately cause the material to fail. Machines have been developed specifically to conduct destructive testing. These machines exert force on the sample and record information such as resulting deformation, the amount of stress that builds up inside the sample, elastic behavior, strength, etc.

When non-destructive testing is performed on a material, the part is not permanently affected by the test. The part is usually still serviceable. The purpose of non-destructive testing is to determine whether the material contains imperfections.

Over many years, tests have been developed for measuring the common properties of engineering materials, including acoustical, electrical, magnetic, physical, optical, and thermal properties. But why is material testing so significant?

**Lesson 2.4 Design Problem – Materials and Structures**

Students have been exposed to the different types and properties of materials in previous lessons. They have also tested and been made aware of the importance of choosing the right material in regards to safety and environmental impacts. Students will now apply what they have learned to a design problem using the design process as their guide.

Problems exist everywhere, and they vary in their degree of complexity and importance. Regardless of how problems are identified or from where they come, engineers use the design process to creatively and efficiently solve problems.

Problems are most often solved by engineering teams. These teams work together, constantly communicating with each other, to create the desired product. The team may receive a problem for which they are expected to create a solution with very few constraints, with allows them to be quite creative.

In this lesson students will work in teams to solve a materials design problem. They will use the knowledge and understandings developed throughout the unit to solve the problem. It is important for students to understand that an acceptable solution is one that fits the constraints and specifications of the design brief.

## Unit 3: Control Systems

The goal of Unit 3 is for students to recognize the abundance of and infinite variety of computer use in our daily lives.

Students learn to control mechanical systems by recognizing computer outputs and gaining an understanding of how to write code to control them. They additionally experiment with various input devices and learn how they can adapt computer code to control computer outputs.

Furthermore students gain an understanding of fluid power, both hydraulic and pneumatic. They begin to recognize the power and control advantages of fluid power.

The unit concludes with students working in teams to solve a design problem that focuses on using control systems. They will integrate their prior knowledge, skills, and understandings from Unit 1: Simple Machines, Unit 2: Material Properties, and this unit. Students will decide what input devices to use, how to code their use, and the various output devices necessary to create a solution to the problem.

**Commercial Applications Lesson Summary**

Lesson 3.1 Machine Control
Lesson 3.2 Fluid Power
Lesson 3.3 Design Problem – Control Systems

**Lesson 3.1 Machine Control**
From iPods to automobiles, we use computers every day. Computers are sometimes so small and hidden that we don't even realize we're using a computer. Many of us never think about automobiles containing computers; however, today's vehicles are packed with tiny computers that regulate and monitor systems such as air bags and cruise control. How much more control will computers take from drivers in the future? What will drivers be willing to let their cars do for them? With GPS systems that provide routes and track speed, what are the barriers for autonomous cars?

In this lesson students will learn how to control mechanical processes using computer software and hardware. The software communicates through a hardware interface with different inputs and outputs.

**Lesson 3.2 Fluid Power**
The primary components and principles of fluid power systems allow industry and machinery to achieve a multitude of tasks. Although fluid power has been used throughout history, it is far from obsolete. In fact fluid power provides exceptional power advantages. Fluid power technologies impact areas from commercial farm machinery to respirator equipment used to provide oxygen to medical patients. Fluid power possesses some very important characteristics. Fluid power has a large amount of power per unit volume or mass. This is generally referred to as power density. Systems are able to multiply force. Another advantage is that fluid can change direction quickly without damaging a system. This allows engineers and designers to utilize flexible piping and hoses to transfer fluid in a variety of directions.

In this lesson students will be introduced to both pneumatic and hydraulic power. They will learn the basic components of each system and how they are designed to manipulate components through work and power. Students will see a clear connection to the previous lesson's applications regarding manipulating mechanisms using work and power.

**Lesson 3.3 Design Problem – Control Systems**
In previous lessons students were introduced to a variety of ways to transfer energy through mechanical systems. Some of those systems included simple machines, gear systems, pulley systems, sprocket systems, and fluid power. They also learned how to control different mechanisms by writing programs utilizing control software.
Students will now apply what they have learned to a design problem using the design process as their guide.
Problems exist everywhere, and they vary in their degree of complexity and importance. Regardless of how problems are identified or from where they come, engineers use the design process to creatively and efficiently solve problems.

Solutions to problems are oftentimes created by teams. These teams work together, constantly communicating with each other, to create the desired product. The team may receive a problem for which they are expected to create a solution with very few constraints. This allows the team to think creatively and use their ingenuity.
In this lesson students will work in teams to solve a design problem that focuses on control systems. They will use the knowledge and understanding gained throughout the course to create a solution to the problem. It is important for students to understand that an acceptable solution is one that fits the constraints and specifications of the design brief.

## Unit 4: Statistics and Kinematics

In Unit 4 students are engaged in learning to use statistics to evaluate an experiment. Later they begin a study of dynamics, specifically kinematics, and apply statistical skills to study freefall motion.

Students use theoretical and experimental data as a basis for learning statistical analysis. By collecting, organizing, and interpreting the data, students build the skills needed to understand data results.

They further use these new skills and knowledge to design a vehicle that will propel itself. Later, students will address the problem of designing a machine to accurately launch an object a specified distance. Examining projectile motion is at the core of this design problem.

**Commercial Building Design Lesson Summary**

Lesson 4.1 Statistics
Lesson 4.2 Kinematics

**Lesson 4.1 Statistics**
Statistics allow for informative decision-making formulated from theoretical and experimental data analysis. Data analysis has become so integrated into today's modern lifestyles that most individuals are unaware of its role in their daily lives. This can be seen in reality shows that base results upon contestants' national popularity and voting results. Box office movie rankings are based on weekend ticket sales. At an individual level, people use statistics for calculating gas mileage, green calculations such as average energy consumption, insurance rates, and calculating class rank and GPA.

In this lesson students will learn the processes of gathering, organizing, interpreting, and formulating an understanding of data through probability and statistics.

**Lesson 4.2 Kinematics**
While statics is concerned with bodies at rest or moving at a constant acceleration, dynamics is concerned with the accelerated motion of bodies. The study of dynamics developed much later than statics because of the need for accurate measurement of time. Galileo Galilee was a major early contributor, performing experiments with pendulums and falling bodies. Newton's development of the three fundamental laws of motion was the springboard for increased understanding and work by other scientists. The two major braches of dynamics are kinematics, which is concerned with the geometric aspects of motion, and kinetics, which is concerned with the

forces causing the motion.

In this lesson students will create a vehicle to learn important aspects of motion and freefall. Students will solve a problem that will help them to understand the kinematics concepts involved in projectile motion.