PLTW Engineering

Principles of Engineering | Course Outline

Explore how modern engineers are helping improve the world through diverse engineering fields such as product design, robotics, mechanical design, infrastructure, and sustainability. Learn the principles of engineering as well as the cutting-edge tools of robotics, 3-D modeling, programming, and prototyping that engineers are using to solve problems today and for the future!

Principles of Engineering is a full-year course designed to be a high school student's second exposure to the PLTW Engineering program and is appropriate for students in grades 9-12. In Principles of Engineering, students explore a broad range of engineering disciplines, careers, and design and solve real-world engineering problems.

This course introduces students to engineering concepts that are applicable to a variety of engineering disciplines and empowers them to develop technical skills through the use of engineering tools such as 3-D modeling software, hands-on prototyping equipment, programming software, and robotics hardware to bring their solutions to life. Students apply the engineering design process to solve real-world problems across a breadth of engineering fields such as mechanical, robotics, infrastructure, environmental sustainability, and product design and development.

Using PLTW's activity-, project-, problem-based (APB) instructional approach, students advance from completing structured activities to solving open-ended projects and problems that provide opportunities to develop planning and technical documentation skills, as well as in-demand, transportable skills such as problem solving, critical thinking, collaboration, communication, and ethical reasoning. The last is particularly important as the course encourages students to consider the impacts of engineering decisions.

Through individual and collaborative team activities, projects, and problems, students create solutions to problems as they practice common engineering design and development protocols, such as experimental design, testing, project management, and peer review.

The following is a summary of the units of study that are included in the course. The course requires a rigorous pace and contains more material than a skilled teacher new to the course will be able to complete in the first iteration. Giving students exposure to various engineering disciplines, developing their enthusiasm for engineering, and understanding the role, impact, and practice of engineering are primary goals of the course.

Principles of Engineering Unit Summary

Unit 0	Introduction to Product Design and Development
Unit 1	Mechanical Design
Unit 2	Application of Robotics
Unit 3	Energy in Action
Unit 4	Designing Infrastructure and Developing Sustainability

Unit 0: Introduction to Product Design and Development

This optional introductory unit creates space for schools who begin their PLTW Engineering pathway with Introduction to Engineering Design or Engineering Essentials to quickly review familiar topics and challenge students to reach new levels of understanding and application. It also allows schools that are new to the pathway to build upon strong fundamental skills. In the unit, students explore different careers while applying modern collaborative modeling tools to create new products that meet real needs. Student teams take on the role of a product development team using the engineering design process to solve problems and create value for others.

Students gain enduring understandings to key principles of engineering such as modeling, material selection, statistics, tolerance analysis, as well as testing design and analysis. Through these challenges, students apply and develop project management, communication, and other pivotal transportable skills to solve problems.

Product Design and Development

Lesson 0.1 Engineering Design Process

In Lesson 0.1, students review and apply their understanding of the engineering design process to design a shoe to meet the specific needs of a customer. They use information gathered in interviews to learn about their client, develop a detailed problem statement, apply different brainstorming techniques, visualize their solution through concept sketches, and create a decision matrix to select the best solution for their client's needs. Students build a prototype and create a testing plan, to test and iterate their design and share their results in a detailed presentation.

Lesson 0.2 Collaborative Modeling and Modern Product Design

In Lesson 0.2 students use a 3-D modeling software to learn different tools used to develop a detailed solution and are introduced to basic manufacturing techniques and practices. Students use a 3-D modeling software to modify an existing shoe model. Students learn manufacturing techniques and apply their knowledge to optimize a shoe design process.

Lesson 0.3 Material Choice and Testing

In Lesson 0.3 students experiment with different material options to determine which material properties are best paired with specific use cases and why. They design a test to gather meaningful data for a material that can be replicated consistently to cause an object to fail or break in a consistent manner. Students also model a shoe sole custom sized for their foot and choose a material that best meets the needs of a desired shoe application of their choice.

Lesson 0.4 Designing a Shoe For You

In the final lesson, students apply their knowledge gained through the entire unit to identify a client with a specific footwear need to design and develop a solution. They interview their client, document their engineering design process, create a 3-D model, develop a physical prototype, and iterate with their client to design a shoe tailored to their needs.

Unit 1: Mechanical Design

In Unit 1, students explore the foundational elements that make up complex mechanical devices and systems. They work collaboratively to solve real-world problems using their understanding of mechanical designs and motion to develop complex mechanisms. Students end the unit by working collaboratively and applying their knowledge to solve a real-world agricultural problem.

Students gain understanding of mechanical engineering concepts such as simple machines, energy, work, power, and mechanisms and apply them to solve engineering problems. Students continue to apply their project management, collaboration, communication, and additional key transportable skills throughout the unit. They continue to explore future career opportunities by conducting a professional interview of a professional of their choice.

Mechanical Design

Lesson 1.1 Simple and Compound Machines

In Lesson 1.1 students explore simple machines, where they are found, how they are used, and why they are the foundation of mechanical devices. They will explore the fundamentals of energy, work, and power then apply their understanding to maximize efficiency and power. Students then investigate the factors that impact pulley systems, how to maximize the efficiency of pulleys, and design their own pulley system in a simulation. Students discover the benefits and drawbacks of different gears and gear trains as well as how to optimize speed or torque through gear ratios. Finally, students use force and acceleration sensors as well as their understanding of simple machines to design a robot that can pull with the greatest force.

Lesson 1.2 Mechanisms

Students begin Lesson 1.2 by examining the four types of motion as well as their application in different mechanical devices. They apply their understanding of motion by designing and building a latch mechanism to fix a broken door. Students continue their understanding of motion by creating a variety of different mechanisms and explore how they convert one type of motion to another. The lesson ends with a motion conversion challenge where students work collaboratively to design, build, and test individual segments of a machine and combine their machines to make a large-scale device to solve a problem.

Lesson 1.3 Agricultural Solutions

In this unit problem, students apply their understanding of simple machines, compound machines, mechanisms, and motion to choose a real-world agricultural problem then design, test, and build a compound machine that solves the identified problem. They then pitch their solution to a team of potential investors in an informative and persuasive presentation.

Unit 2: Application of Robotics

In Unit 2, students explore the world of robotics and programming. They use their understanding of mechanical design, robotics, and programming to work collaboratively to develop solutions to real-world-problems. Students continue their career exploration through investigating different pathways to higher education and determine their best course of action to make themselves good candidates for postsecondary education opportunities.

Students learn concepts such as programming, using and applying sensors, and artificial intelligence. Students utilize their collaboration, communication, project management, and additional transportable skills throughout the unit to solve in-depth problems.

Application of Robotics

Lesson 2.1 Introduction to Robotics
Lesson 2.2 Robotics in Action
Lesson 2.3 Artificial Intelligence
Lesson 2.4 An Electronic Ensemble

Lesson 2.1 Introduction to Robotics
In this lesson, students begin their introduction to robotics by creating their own robot that moves forward without the use of wheels. They then investigate what constitutes a robot compared to other programmable mechanical devices. Students conclude this lesson with detailed research in the history of robotics and predict opportunities for the future of the field.

Lesson 2.2 Robotics in Action
In lesson 2.2 students develop best coding practices, differentiate between open and closed loop systems, apply conditional statements, utilize a variety of different sensors, and apply their understanding to solve a problem. Students build and program a simple robot vehicle that can drive as close as possible to an obstacle without the use of sensors. Students are then introduced to bumper and limit switches, a potentiometer, a servo motor, and optical sensors and program each device to solve different problems. They conclude this unit by applying their understanding of programming to design and build a robot that replicates an animal's behavior.

Lesson 2.3 Artifical Intelligence
Students continue their exploration of robotics with artificial intelligence and machine learning. They design and build a robot, using a supervised machine learning algorithm, a distance sensor, and a bumper switch to train their robot to give a physical greeting. Students then investigate ethical concerns involved in the implementation of artificial intelligence and conduct research to determine the best course of action in a given scenario. To finish this unit, students apply their understanding of artificial intelligence to design and build a robot that can help someone.

Lesson 2.4 An Electronic Ensemble
In this unit problem, students create a robotic system that can perform a piece of music. They research different instruments from around the world, construct a functional prototype of their chosen instrument, then design, build, and program a robot that can play their instrument. Students coordinate and collaborate with their individual robots and each other to create a system of robots that can play a piece of music.

Unit 3: Energy in Action

In this unit students explore energy more deeply and useful applications of it through electrical circuits, fluids, and kinematics. They begin the unit by exploring the relationships between circuit components, derive formulas, and apply their understanding to solve problems. Students then move into the world of fluids, the deep mathematical principles that govern them, and apply their knowledge to design their own fluid power system. They end the unit implementing their understanding of energy in motion through kinematics. Students also continue their career exploration journey by examining the financial aspects of attending a postsecondary institution.

Energy in Action

Lesson 3.1 Electrical Circuits
Lesson 3.2 Fluid Power
Lesson 3.3 Kinematics
Lesson 3.4 Integration of Circuits, Fluid Power, and Kinematics

Lesson 3.1 Electrical Circuits
In Lesson 3.1, students explore the basic components of electrical circuits and model them through a hands-on introduction. They then explore the basic elements of electricity and electrical circuits and build simple circuits with breadboards and online simulations. Students collect data to derive the formula for Ohm's Law then apply their understanding of Ohm's Law to solve problems. They then move into a comparison between series and parallel circuits and explore their similarities and differences. Students continue hands-on breadboarding and simulations to derive Kirchhoff's voltage and current laws. They end the lesson with a final project that applies all the skills acquired to design and build their own functional safe.

Lesson 3.2 Fluid Power
In this lesson, students learn the fundamentals of hydraulic and pneumatic fluid power. They begin by exploring the differences between hydraulic and pneumatic systems as well as common mathematical formulas that support fluid power engineering. Students the apply these concepts to complete a problem set surrounding fluid power mathematics. This lesson concludes with students designing and building their own working hydraulic system.

Lesson 3.3 Kinematics

In Lesson 3.3, students explore the physics of moving objects. They begin by experimentally measuring the gravitational constant. Then, students consider motion vertical and horizontal directions and derive the equations that govern horizontal projectile motion. This lesson culminates with an engineering design challenge where students are challenged to design and build a zipline and calculate where an object will land when dropped.

Lesson 3.4 Integration of Circuits, Fluid Power, and Kinematics

In this unit problem, students will combine their knowledge of electrical circuits and kinematics to design and build an automated golfer and a golf course. Students will also create two targets that trigger an LED to illuminate and another to produce a sound. This problem requires deep understanding of series and parallel circuits, fluid power, as well as horizontal and vertical motion.

Unit 4: Designing Infrastructure and Developing Sustainability

They investigate methods of designing infrastructure as well as various techniques to develop sustainable practices for the future. Students work collaboratively in teams to develop solutions to structural design problems, sustainable approaches, and transportation design needs that have a lasting impact on local and global communities.

Students gain an understanding of in-depth mathematical approaches to infrastructure design for static systems as well as apply statistical analysis and rigorous calculations to traffic and intersection design. They explore a variety of energy sources and a life cycle analysis to measure trade-offs in environmental dilemmas. Students continue to refine their project management, collaboration, communication, and additional key transportable skills to understand the impact of design choices on a large scale. Students conclude their career exploration by examining the future of different careers and how they will be affected by the adoption of artificial intelligence.

Designing Infrastructure and Developing Sustainability

4.1 Statics
4.2 Renewable Energy
4.3 Transportation
4.4 Infrastructure Redesign

Lesson 4.1 Statics

In Lesson 4.1, students explore various aspects of static structures and apply mathematical approaches to solve structural problems. They begin the lesson by applying an engineering design process to design and test a cantilever beam. Students then compare materials and their properties that impact beam deflection; they also use 3-D modeling software to analyze and investigate factors that impact beam deflection and solve an engineering design problem. Students analyze and solve systems through the use of free body diagrams, force vectors, moment calculations, and method of joints. They will also explore internal forces in materials and the relationship between stress and strain. Students culminate their understanding to design their own bridge truss to support a given load at the lowest cost.

Lesson 4.2 Renewable Energy

In lesson 4.2, students discover various sources of energy and research their effects on social, environmental, political, and economic systems to develop assertions and debate important environmental topics. They apply an engineering design process to design, construct, and test a device that converts the mechanical energy of falling water into electrical energy.

Lesson 4.3 Transportation

In lesson 4.3, students examine and apply various mathematical tools to analyze traffic flow, capacity, and speed limit to solve transportation problems. They use hands on experiments and spreadsheets to determine maximum traffic density, traffic flow rate, and calculate optimal speed limit. Students also model traffic flow at various intersections and use critical lane volume to improve an existing intersection. Students conclude the lesson by applying an engineering design process to solve a transportation need for a client with different abilities.

Lesson 4.4 Infrastructure Redesign

In the unit problem, students determine a building that needs to be remodeled with a renewable energy source, a structural element, and a new intersection that serves the building. They calculate how much energy they can gather from their chosen renewable energy source and determine if it is sufficient to replace existing energy sources for their building. Students identify a structure to model with a free body diagram and calculate the forces of each member of their chosen structure. Students analyze a map of their chosen building location to determine the most effective renewable energy source. Finally, they redesign an intersection based on an increased flow rate traveling to and from their remodeled building.