

Title: Engineering Geometry with Physics

Length of Course: Two Years/Units (4 semesters; 6 trimesters; 8 quarters)

Subject Area – Discipline: Mathematics (“c”) – Geometry

Subject Area – Discipline: Laboratory Science (“d”) – Physics

CTE Sector: Engineering and Architecture

CTE Pathway: Engineering Design

Grade Level(s): 9-10

Prerequisites: Algebra 1 or Integrated Math 1, required

Overview:

Engineering Geometry with Physics is designed as an introductory college and career preparatory course in physics and geometry with continuous integration of engineering CTE industry sector pathways (such as Engineering Design or Architectural and Structural Engineering). The course is comprised of a series of units that are guided by project-based learning strategies to ensure adequate ramping and integration of content knowledge and requisite skills in the three focus areas of Geometry, Engineering, and Physics. These units include: catapults, bridges, solar energy, wind energy and turbines, Archimedes screw, telescopes, energy efficient houses, musical instruments, and race cars. In order to gain an understanding that all new engineering discoveries have relied on the innovations of the past, each unit begins with a historical perspective and progress to the point where students in their design brief challenges are asked to make new innovations while keeping the spirit of the original innovation or technology.

The expected outcomes of *Engineering Geometry with Physics* are:

1. A mastery of Geometry standards satisfying a UC mathematics (“c”) requirement
2. An understanding of core Physics concepts
3. A project based learning environment that satisfies a UC “d” lab requirement
4. Experience applying an iterative design process
5. A detailed listing of literacy skills is listed below
6. Literacy Ramp
7. Partial list of science, math, language, and literary competencies:
8. Charts
9. Analysis of data
10. Construction, design, and limitations of various charts
11. Match data with appropriate chart
12. Graphs

13. Extrapolation
14. Scaling
15. Drawings and Photographs
16. Isometric and Orthogonal representations
17. 3D sketching
18. 2D to 3D constructions
19. Use context and visual cues to gain more information
20. Flow charts
21. Read and create flowcharts for various processes
22. Be fluent in flowcharting symbols
23. Maps, contour maps
24. Be fluent in scale
25. Analyze and interpret topographic and other symbolic representations of actual location
26. Diagrams
27. Interpret and construct appropriate diagrams for a given task
28. Label and caption drawings to add to understanding of displayed information
29. Tables
30. Construct and manipulate tables to adequately organize and display data
31. Analyze the contents of the table as it applies to the current project
32. Geometric proofs as applied to engineering projects
33. Understand and apply correct theorems to justify design choices
34. Apply the logic used in geometric proofs to reason through a design problem
35. Symbolic notation
36. Become fluent in different symbolic representations in science, and math
37. Utilize correct symbols in articulating ideas in drawings and explanations
38. Reading words with more
39. Learn to read with a scientific mind
40. Understand and interpret graphs and other representations of data and information in a scientific context
41. Use of standard geometric tools (i.e. compass, protractor, rulers)

Course Content:

NOTE: In each of the following units, students will be supplied a design brief that indicates all required aspects and desired functionality of the project. This design brief must include any and all measurement constraints, materials, and functions needed to complete the final product

Unit 1: Introduction to *Engineering Geometry & Physics*

Essential Question: How can the study of a catapult launch future invention?

Supporting Questions:

What is engineering design?

How is a catapult created to launch an object a desired distance?
What critical aspects of a catapult have been reapplied to modern technology?

Unit 1 Overview:

This unit is designed as an introduction and survey to the course. The unit grounds students in the scientific process as it relates to engineering and design through the cross disciplinary building of a working catapult. This catapult must be able to launch an object a desired distance set by the teacher. Students are introduced to social/cooperative learning models that are used throughout the course so special emphasis is put on establishing group norms and how to effectively brainstorm. Students explore key scientific literacy strategies including for example the vocabulary in geometry needed to understand proofs, congruency and congruency theorems. During the exploration, students will learn the necessary interpretive processes to translate quantitative or technical information into a variety of media forms and perform analyses intrinsic to the nature of the engineering process. Basic engineering presentation skills will be emphasized.

Although students use math and physics concepts to design the catapult, this will not be a highlighted part of the project. This project focuses on the engineering process that is used throughout the course with an emphasis on mechanical engineering. However, using the properties of similarity, students will also learn how to create a scale drawing with standard geometric tools like rulers, compasses, protractors.

Unit 1: Introduction to Engineering Geometry & Physics - Key Assignments

There are many online resources to give the teacher ideas on how to build a catapult, such as, <http://hubpages.com/hub/How-to-Build-a-Catapult---An-Illustrated-Guide>.

Students build ONE catapult, meeting the criteria outlined in the rules, designed to answer one of the following variables:

1. Distance - farthest distance thrown of a single projectile
2. Accuracy – nearest distance projectile impacts to two ground level targets
3. Strength – greatest mass of projectiles delivered to a vertical target

As part of the design process, students complete the following tasks to complete the catapult construction:

- Conduct short as well as more sustained research projects on the history of constructive design projects as background for their own.
- Create and submit a written proposal which included a scale drawing, a cost spreadsheet, and justification as to why the design works. Redesign and resubmit after analysis.
- Build the project with design constraints in an iterative fashion, making new drawings for any changes implemented.

Using engineering presentation models, the student will present their product including both an oral and a written component with attention to what worked, what did not, and any changes that should be implemented in a redesign with justification (evaluation of design). The student needs to highlight modern interpretations of the catapult and be able to discuss the similarities between the historic catapult and modern versions.

Unit 2: Building Bridges

Essential Question: How can a bridge close the gap to the future?

Supporting Questions:

How can you use geometry to design an efficient bridge?

How can you build a bridge with maximum load using as few materials as possible?

How does the geometric arrangement of the members of the bridge affect the distribution of forces?

How does the third law of motion apply to the non-moving components of a bridge?

Unit 2 Overview:

This unit entails the incorporation of geometry, engineering and physics to design and build a bridge with the highest efficiency. The students design, calculate, and construct a bridge using a set amount of materials for each student/group. This project focuses on the engineering process that is used throughout the course with an emphasis on mechanical, civil, and manufacturing engineering pathways.

For geometry, this unit focuses on congruent and similar polygons, particularly triangles. The students are able to apply geometric strategies to solve design problems by tying together the relationships of sides and angles in congruent triangles as well as parallel lines to help find congruent parts in triangles and parallelograms and prove parallelograms are congruent. Truss bridges in particular require parallel construction to ensure loads are evenly distributed, to avoid structural failure. Continuing with an introduction of trigonometry and similar triangles, the students use the Pythagorean theorem to see the special relationship of 30-60-90 degree triangles and 45-45-90 degree triangles, again to understand how to maintain structural strength and stability. These special relationships also tie together the meaning of similarity as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides. The students visualize relationships between two-dimensional and 3D objects, and are able to implement these relationships into a 2D and 3D model or bridge blueprint. They are exposed to coordinate geometry and are able to prove simple geometric theorems algebraically when their design is graphed. They also are introduced to radius and arc length of a circle towards the end of the unit to illustrate the various methods used to calculate support beams and cables in suspension and arch bridges.

This unit explores the concepts of forces and Newton's laws of motion as they relate to static structures such as bridges and buildings. Within bridges, the supporting members and the forces exerted on them are governed primarily by Newton's Second and Third Law of motion. In calculating and analyzing these forces, students need to be able to

identify action/reaction pairs at not only supporting structures in the bridge but also in the joints holding the bridge together. Structural members in bridges are often not aligned to purely vertical and horizontal axes, requiring students to resolve these vectors so they can be utilized in completing calculations and analyses of the forces acting within the bridge structure.

This unit also allows students to learn how civil engineers impact our daily lives, identify different areas of specialization, understand the benefits of a career in civil engineering, and identify the necessary skills to develop in high school.

Unit 2: Building Bridges - Key Assignments

Assignment 1: After lecturing on action-reaction forces and congruent angles, have students brainstorm at least 3 truss designs for a bridge and identify on their drawings the forces and angles. Students then construct small scale models of their trusses and test them for strength failure points.

Assignment 2: In groups, have students research at least 3 famous structures and create a presentation on how these structures function, identifying forces and angles.

Assignment 3: After discussing bridge terminology and introducing the manila folder bridge project, have students write up a proposal for their bridge design.

- Bridge terminology (trusses, top core, bottom core, rods (hollow/solid), and solids) and effectiveness of materials for various designs/types.
- Bridge project: Design and build an A-Truss/ King post bridge structure out of manila folders that sustains at least 5 kg at mid span and has an overall span of 30 cm. The bridge that has highest strength to weight ratio will be considered the best.
- Written proposal: Describing initial design of a truss bridge including a scale drawing, calculations of the amount and weight of the material used, and justification as to why the design will work.

Assignment 4: Truss calculations (stress/strain) to show effects of different variables. Students determine tensile and compressive forces within a truss system. Students the static determinacy, $2j = m + r$, to determine the stability of the truss system or bridge.

Assignment 5: Working drawings: Full-size sketch of bridge on grid-paper showing angles in each triangle and use of deductive reasoning and theorems to prove that top and bottom chords are parallel.

Assignment 6: Build/construct the bridge using your drawing and assembly plans.

Assignment 7: Oral presentation: Students describe the approach they took to designing their bridge, using geometry and physics vocabulary to justify their design.

Assignment 8: Test your bridge for maximum load and record your results. Calculate its strength to weight ratio.

Assignment 9: Written report: Students reflect on their design, what their initial thoughts were, what physics and geometry they used, what contributed to its collapse, and how they would change it if they were to build it again

Unit 3: Solar Energy

Essential Question: Why is solar energy so "hot"?

Supporting Questions:

How can we use the sun for energy?

How can we harvest the sun's energy?

How can we capture the sun's energy?

Unit 3 Overview:

This unit allows students to explore solar energy through researching the history of solar energy, the current applications of solar energy and the possibilities for solar energy in the future. Students create a solar water heater as their final product. Students explore how energy from the sun is converted into electrical and thermal energy. As the energy from the sun is transported via electromagnetic radiation, the electromagnetic waves encounter a solar cell; the conversion of this energy to electrical energy requires understanding of energy, work, and the law of conservation of energy. This electrical energy is then transported away from the generation unit using electrical circuits, requiring the understanding of Ohm's Law. Students also explore the world of thermodynamics and how the basic laws of thermodynamics can be used to harness the power of the sun. Concepts of heat flow through conduction, convection, and radiation will be explored as they apply to convection currents created with the solar collector and how fluids behave in such systems.

The concepts of coordinate geometry will be reinforced along with coordinates to prove simple geometric theorems algebraically. The students explore the surface area and shapes made by a cross-section of a three-dimensional object (such as a cylinder, a cube, or a prism). Understanding these shapes allow students to look at and measure a cross section of a solar collector to determine how to effectively harness the sun's energy on a determined target. They learn to apply the concepts of perimeter and area to find the volume of solids. They also apply concepts of density based on area and volume in modeling situations. Parallel lines, corresponding angles, and the theorems governing them will be explored as students diagram how light rays are reflected by a variety of shaped mirrors. Students testing and diagramming these mirrors will determine the most appropriate shapes for these mirrors based on the application of these theorems and geometric diagrams. These principles will be revisited in much more depth in Unit 6, Telescopes.

This project focuses on the engineering process that is used throughout the course with an emphasis on mechanical, electrical, and environmental engineering. This unit will cover the relationship between concepts such as: safety, system design, electrical and mechanical design, and subsystem design. Students review technical drawings such as blueprints. Students analyze and learn about incorporating the following systems into building a house: lighting, climate control, mechanical systems, electrical, and plumbing. Students develop a site analysis that considers passive energy techniques, sustainability, landscaping and construction.

Unit 3: Solar Energy - Key Assignments

Assignment 1: Students bring in an object from home to use as a solar water heating device (volume and initial water temperature will be controlled). Students measure water temperatures at predetermined intervals, and graph the results. Students draw conclusions about the most effective variables in solar water heater design (discussion points: surface area, volume, color, transparency, surface reflectance, shape, etc.).

Assignment 2: Students research the past, present, and future of solar energy and present their findings to the class. Teacher may decide to make this an individual written report with a brief summary in front of the class or a group oral presentation. Teacher may also decide to assign one third of the class the history of solar energy, one third its present applications, and one third future technologies of solar energy.

Assignment 3: Describing initial design of a solar water heater including a scale drawing, a cost spreadsheet, and use geometric proofs and coordinates in justification as to why the design will work. Instruct students on how to construct perpendicular lines, midpoints, and angle bisectors.

Assignment 4: Students build and test their initial design and measure water temperature over time. Students graph their results and discuss them with the class.

Assignment 5: Students describe what they learned from comparing their water heater to those of their classmates.

Assignment 6: Students redesign their solar water heater and sketch a scaled drawing with lengths and angles labeled.

Assignment 7: Students build and test their new solar water heater and graph the results.

Assignment 8: Students present a description of their design, using physics and geometry vocabulary to describe its advantages. Students also show their results to the class.

Assignment 9: Students produce a written evaluation describing the process they went through in designing their solar water heater, the physics and geometry used, and how they would change it if they were to redesign.

Unit 4: Windmills (Turbine Challenge)

Essential Question: The power of wind: A force for good or evil?

Supporting Questions:

What experiences have the students had with the power of wind?

How much energy does a wind farm turbine generate?

What does this mean in practical terms?

How efficient is the turbine?

How could this be improved?

Unit 4 Overview:

During this unit, students utilize the iterative design process and collaborative teaming to construct a wind turbine that generates enough electricity to power a small light bulb or other electronic device.

The students analyze the relations between interior angles and the remote exterior angle, vertical angle relationships, and the relationship of the angles formed when a transversal passes through two parallel lines. They learn that the measurements of a triangle sum up to 180 degrees, base angles of isosceles triangles are congruent. They prove geometric theorems using congruency; identify that the segment joining midpoints of two sides of a triangle is parallel to the third side and half the length; and the medians of a triangle meet at a point. Application of the Pythagorean theorem aids in solving trigonometric ratios. When exploring circles in the units, the students become familiar with key terminology of parts of a circle. The students identify and describe relationships among interior and exterior angles, chords, secants, and tangents to a circle. They also find arc lengths and areas of sectors of circles in order to properly construct wind turbines large enough to produce adequate power while still maintaining the required size constraints.

From the physics standpoint, this unit focuses on transforming energy from the wind into electrical energy through the processes of rotational mechanical energy. Electrical and gravitational potential energy as they relate to conservation of energy is stressed. This process requires the understanding that it is a force that causes rotation by the process of torque. Torque is dependent on the radius of rotation and the magnitude of the force acting. Understanding that centripetal force is a constant that points towards the center of a circle eases the calculation of centripetal acceleration ($a=v^2/r$). The rotation of the windmill causes a magnet to spin and induces an electrical current that can be transported away from the generation source using circuits to the location of need. To further understand this concept of direction of magnetic field affecting circuits, students will apply knowledge by constructing simple electrical circuits using magnetic materials.

Unit 4: Windmills - Key Assignments

Assignment 1: Students research the topic of turbines to discover the historical and modern applications. This research is presented to the class. After the presentation, the class is introduced to the design challenge of building a turbine of their own.

Assignment 2: Students construct simple series and parallel circuits using light bulbs, resistors, motors, and batteries. Students discover the relationship between voltage, resistance, and current through the use of a multimeter and derive the relationships in Ohm's Law. They also explore the relationships between electric motors and electric generators. Their findings from this assignment are presented to the class.

Assignment 3: Students rely on their research and the discoveries about electricity to come up with an initial design for their wind turbine. They experiment with different blade designs (surface area, shape, etc.) and materials and test them by simple means of lifting and winding capabilities. They explore the concepts of rotational dynamics and torque and how these concepts relate to the design challenge.

Assignment 4: Students come together in small teams to evaluate their designs using a decision matrix that allows them to rank aspects of their designs in order to choose the design that best suits the challenge. Once the students select their design, they formalize a plan to build their design. This plan must include scale drawings showing the explicit geometry formulas or proofs, as applied to buildings, and materials. This design is presented to the class.

Assignment 5: Student teams test their built windmills and collect data on electricity generated. They connect their windmill to a simple circuit containing a light bulb to verify that their design produces enough power to produce light. Student teams evaluate their windmill and brainstorm improvements, both structurally and mathematically, and how those improvements affect the performance of their windmill. The results of their testing is presented to the class.

Assignment 6: The student teams analyze their collected data and extrapolate their findings to a full scale version of their windmill. They scale up all materials, costs, and power generation, using the appropriate geometry to make the conversions. Students then compare their extrapolations to actual windmill or turbine costs and power output.

Unit 5: Archimedes Screw

Essential Question: How can we put a twist on liquids?

Supporting Questions:

What is a screw pump and how are they efficient?

How does gravity play a crucial role in the function of a screw pump?

How does a screw pump reduce the amount of force needed to lift liquids?
What is sacrificed when using a screw pump?

Unit 5 Overview:

Through incorporating the history and theory of screw pumps, students design and construct a working screw pump model. Students work in teams to build, test and evaluate their designs. Writing a technical report supports their designs with research on the historical context, present applications and future possibilities of the screw pump. Students present this information in a public forum.

In this unit students explore the relationships of force, energy, and gravity. As the screw applies a force to the liquid, work is done to transform rotational mechanical energy into gravitational potential energy by lifting the liquid to a higher elevation. This process requires work because the law of universal gravitation dictates that two objects with mass are attractive to each other requiring energy to move them further apart.

Coordinate geometry plays a key role in the standards covered. The students use coordinates to prove simple geometric theorems algebraically. The students visualize relationships between two-dimensional and three-dimensional objects, and implement these relationships into a 2D and 3D model as they take 2D blueprints and drawings and translate them into a working 3D model. Students also implement this skill set in the initial stages as they take a 3D idea in concept and begin sketching it in the drawings and design phase. The relationship between coordinate geometry and 2D/3D modeling will be used when exploring the construction of the Archimedes pump as it pertains to tube size, angles, and pump rate.

Unit 5: Archimedes Screw - Key Assignments

Unit 5 is in large part a practical application of geometric principles and concepts learned to date with an emphasis on transforming 2D representations into 3D models and 3D ideas into explicit 2D representations as this applies to producing technical drawings.

Assignment 1: Students research the Archimedes Screw to learn how this mechanism works as well as how it is still being used today. Students present their findings to the class either through oral presentation, web page creation, or poster.

Assignment 2: Students are given their design brief describing the Screw Pump project. In the design brief, there is a description of how much water or other liquid must be raised to a given height in a set period of time. Student teams brainstorm how they could create an Archimedes screw and what materials they could use that fulfill the design brief. They then produce schematics and instructions on how to build their pump and submit those for approval by the teacher.

Assignment 3: Students are asked to rethink how the screw pump could be used in a manner that is not currently in common acceptance. They then redesign their pump in

order to function in their proposed manner. Students submit their proposal with updated drawings, materials, and build instructions for approval.

Assignment 4: Students construct and test their redesigned screw pump and evaluate its performance based on anticipated functionality. They construct a written report encompassing the historical, modern, and proposed functionality as well as a discussion of the performance of their prototype.

Assignment 5: Students present the content of the written report orally including the applications of geometry and physics to the project.

Unit 6: Telescopes

Essential Question: How does viewing other worlds change the way we see?

Supporting Questions:

How do waves interact with mirrors and lenses?

How can we tell if the image we are seeing is real?

Why do we need to combine different types of lenses to produce a working telescopes?

Do all telescopes function the same way?

How do telescopes utilize lines, rays, chords, arcs, and secants?

Unit 6 Overview:

Students study aspects of optics, lenses, mirrors, and geometry to engineer a telescope that allows them to view objects at a reasonable distance from the observer. This project focuses on the engineering process that is used throughout the course with an emphasis on mechanical engineering. Students also practice public speaking and through the use of digital social media present their ideas and findings from the project.

Students explore the phenomena of electromagnetic energy, its waveform, anatomy and function. Understanding telescope design and its interactions with visible and invisible waves, students understand how waves are concentrated to allow a more detailed analysis of the information they carry through the universe. This concentration process is achieved through the use of mirrors and lenses using the concepts of reflection and refraction. Students may explore how weather may or may not affect data acquisition.

Using a variety of tools and methods, the students continue to make formal geometric constructions of congruent segments/angles, bisecting segments/angles, parallel lines, perpendicular bisectors, and various polygons inscribed in a circle or triangle to fully understand the construction of and object clarity of telescopes. When exploring spherical lenses and mirrors, the concepts of circles in the unit continue as students become familiar with key terminology for parts of a circle, identify and describe relationships among interior and exterior angles, chords, secants, and tangents as they apply to the determination of focal points in lenses and mirrors. They also find arc

lengths and areas of sectors of circles.

Unit 6: Telescopes – Key Assignments

Assignment 1: Students complete research on the history of the telescope and its progression to modern times. They present this research in the medium of their choice.

Assignment 2: Students follow the “Funland” Activity #78 in the accompanying Lab manual for Hewitt by Paul Robinson. This lab explores the relationships of concave and convex spherical mirrors and how they produce images that are virtual, real, enlarged, or reduced based on the geometry of the mirror and the relationship of distance between the object and the focal length of the mirror. This exploration reinforces the math and angles of lenses as an introduction to building their telescope. Other helpful labs that extend this exploration of mirrors and lenses are: The Camera Obscura #79, in which students learn how a basic camera obscura functions and how small volumes of air can act as a spherical lens; and Bifocals #82, in which the differing appearances of images produced are directly related to the differing geometries of the sections of the a bifocal lens.

Assignment 3: Students follow a standard optics bench lab in which they have to determine the focal length of spherical lenses and mirrors as well as predict and test whether the image produced by these mirrors and lenses will be real or virtual, inverted or right side up, and whether the image will be enlarged or reduced depending on the placement of the original object.

Assignment 4: Practice Problems exploring light rays and their interactions with spherical mirrors and lenses. These problems aid in students’ ability to predict how an image is refracted or reflected in mirrors and lenses to produce images in optical instruments.

Assignment 5: Practice problems exploring construction of circular sections and angles as related to the laws of reflection and refraction of light.

Assignment 6: Students are given the design brief describing the criteria they must follow to construct a telescope of their own. They must brainstorm and develop a proposal which includes detailed drawings and materials lists. This must be submitted for approval.

Assignment 7: Student teams build and test their telescope. They evaluate its performance against the criteria described in the design brief. Students present the telescope and design process through a multimedia presentation. This presentation must include the design and building process and discuss the results of their project as a presentation to the class. This discussion also includes how the core academic concepts from the unit apply to their telescope and results of the project.

Assignment 8: Students write a comparison contrast with data between the various group products.

Unit 7: Roller Coasters

Essential Question: How does a thrill ride keep us on track?

Supporting Questions:

How do roller coasters utilize different types of energy?

What is required to transform energy?

How does the use of similar triangles stabilize a roller coaster?

Why do roller coaster designers need to understand arcs and secants?

Unit 7 Overview:

In this unit within teams, the students design and engineer a roller coaster that integrates concepts from geometry and physics. The students showcase their knowledge in problem solving as a team. They come to a consensus on the materials used to fabricate a prototype and then conduct test simulations to determine whether their initial design specifications are met.

By exploring the workings of a roller coaster, students discover the interplay between kinetic and gravitational potential energy. They discover that both potential and kinetic energy can be transformed into one another and how friction and other forces are integrated into this process. Students also uncover the connection between kinetic energy and momentum, as well as how to calculate these quantities based on an object's physical properties such as mass and velocity. Newton's 2nd Law provides the basis for students to understand kinematic equations in one dimension, using acceleration to calculate time and velocity. Conceptually, students will unpack Newton's 3rd Law by looking at the interaction between the train and the track and the riders and their seats.

The students tie the relationships of sides and angles in congruent triangles as well as parallel lines to help find congruent parts in parallelograms and prove parallelograms are congruent. The definition of parallelogram is addressed more and the students are able to see that other polygons fall in the parallelogram category, such as rectangles and squares. From there students explore the properties of a right triangle and explore the relation of the side measurements to the complementary angles, leading into similar triangles and trigonometry. The students then are able to distinguish the relationship between the sine and cosine of complementary angles. These special relationships also tie together the meaning of similarity as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides. Coordinate geometry also plays a key role in the determination of slope and layout of the roller coaster track. The students use coordinates to prove simple geometric theorems algebraically and how the use of certain shapes can add stability and flexibility to the roller coaster structure.

Students develop a heightened and mature emphasis to understand the various forces that bear on and within structures, including axial force, shear, torsion, and moment. Students conduct evaluations of available building materials (e.g., steel and wood) considering their properties and effects on building form recognizing strengths and limitations. From this evaluation, a preliminary building plan is developed by using the appropriate materials. The stress-strain relationship of building structures and the laws of conservation of energy and momentum provide a way to predict and describe the movement of objects.

Unit 7: Roller Coasters - Key Assignments

Assignment 1: Students research the history of roller coaster and how they are designed and constructed today. They also need to research the modern technologies employed in current roller coasters.

Assignment 2: Students are given a challenge to determine the maximum potential and kinetic energy using factors of mass and height of a varying slope. The students document their data and findings in a lab report. At this point they can begin a preliminary design sketch of their proposed roller coaster.

Assignment 3: With the basis of kinetic and potential energy and slopes, the students discover different measurements of radii and arc lengths of a circle to help calculate potential or kinetic energy at each peak of the coaster to lead into centripetal force. The students investigate which materials to use and document a Bill of Materials.

Assignment 4: Students are introduced to velocity and acceleration. The students research in groups what the maximum gravitational force that is allowed for a human. From that, we tie that information together with assignment 3 and see if the calculations made meet the safety specifications of a roller coaster. The students then take their preliminary design and begin building prototypes which they then begin to test and evaluate effectiveness and safety. They are required to document all their findings and design changes in a lab journal.

Assignment 5: Students compare their current design to one other peer and discuss successes and possible shortfalls and illustrating how they overcame these shortfalls using specific geometry, physics and engineering concepts. All conversations are prompted and documented for review by the teacher.

Assignment 6: Students begin to write their business proposal: Why should I invest in your roller coaster? This proposal should include a discussion of how the use of geometry and physics has been incorporated into the design and safety aspects of the coaster.

Assignment 7: Students finalize their design specifications and documentation and put together an oral and written presentation with a finalized design drawing (PowerPoint optional). The final testing stages should be completed.

Unit 8: The Energy Efficient House

Essential Question: How can the sun make our house “cool”?

Supporting Questions:

What is the best way to design an energy efficient house?

How does insulation work?

Why is it important to orient your house in specific directions according to where you live?

Why is it important to allow the sun into your house in order to keep it cool?

Why is it important to be able to calculate the surface area and volume of a room or house?

How are ratios used to design an energy efficient house?

Unit 8 Overview:

Students learn current and future methodologies to minimize the use of electricity in residential dwellings through the use of thermodynamic principles. This involves correctly placing the house on a lot to maximize electrical efficiency. Students investigate which building materials allow them to maximize electrical efficiency. Students learn residential mechanical systems which include climate control, and electrical circuits. Students explore usage of strategic landscaping to maximize electrical efficiency. Students are preparing to design an energy efficient home or “green home” in this class. As part of their research students study green building practices and techniques as well as energy efficient designs like passive solar solutions for integration into their design. Students also learn types of renewable alternative energy sources such as solar energy and wind power. Using the Internet and a variety of sources and materials, students create a presentation with appropriate props explaining the design choices for their house based on their research, class lectures, and presentations. Students present the information in class as a sales pitch to a prospective buyer.

When testing insulating materials, students explain that quantities of energy tend to flow until they become distributed uniformly, and students brainstorm ways to slow down this process. Insulation functions to limit this flow of energy between interior and exterior environments of rooms, houses, and other structures. Students investigate the heat conductivity of various materials and develop explanations for the causes of high and low heat capacity by researching the molecular structures of materials and the ease in which thermal energy is transferred through these structures. Students discuss thermal energy as a function of temperature during these activities.

In this unit, the definition of a parallelogram is addressed in more depth and the students are able to see that other polygons fall into the parallelogram category, such as rectangles and squares, and from there explore the properties of a right triangle and the relation of the side measurements to the complementary angles. The concepts of volume and surface area become vital as students consider how energy and air flow are addressed in various configurations and orientations of rooms. They also learn to use coordinates to compute perimeters of polygons and areas of triangles and rectangles via the distance formula or midpoint formula as they sketch blueprints or technical drawings in the construction of the model. In some instances the students are able to use geometric shapes and their properties to describe objects in an application. Once the students are familiar with polygons and circles, they explore the shapes made by a cross-section of a three-dimensional object. They learn to apply the perimeter and area towards finding the volume of solids and determine how changes in dimensions affect the perimeter, area, and volume of common geometric figures and solids as they apply these to designing a house or other habitable structure. They are able to apply concepts of density based on area and volume in modeling situations, such as air flow and convection.

Students need to use modeling or CADD software to aid in the design of their energy efficient house as well as in the presentation and discussion of their final product. This final presentation can be accomplished by creating a website or PowerPoint showcasing the energy-efficient features of the house along with a discussion of why these features function to reduce the energy consumption of the house.

Unit 8: The Energy Efficient House - Key Assignments

Assignment 1: Given a topographical map and climate study, students determine the best orientation and placement of a house. As students are coming into the classroom and picking up handouts, the video is playing on the screen. The video "Graphisoft EcoDesigner: Informed Decisions" (available on YouTube) shows the students the use of "Building Orientation" in design and the use of software applications in achieving presentation format. Also include software applications. At this point, do CADD demonstrations on how to create the particular drawing the students create as their assignment. This allows the students to use prior knowledge in designing and applying the applications to the project.

Assignment 2: Students are given a sand box with an uneven terrain. Students are asked to make a flat plane or pad for a house to sit on. Students calculate the amount of earth (sand) redistributed in cubic inches. This assignment reinforces the ideas of volume of parallelograms and surface area in that excavated sections of terrain often mimic basic parallelograms in shape. Students needing to create a specific size pad for the house will have to know how to calculate the surface area of that pad and its relationship to the specific side of the parallelogram to be excavated from the terrain.

Assignment 3: Students learn about R-value, specific heat, convection and conduction as it relates to insulating a home. Students test various building materials by measuring

and recording the temperature on both sides of the materials when one side is exposed to a heat source for approximately 15 minutes. They then report on whether they would categorize each material as an insulator or conductor.

Assignment 4: This assignment builds upon the previous assignment. How can we efficiently keep the temperature of a room stable? Students investigate heat transfer between an outside environment and an insulated indoors environment with the goal of minimizing loss of heat using insulating materials.

Students then use a mock economy to purchase insulation and insulate a "paper box" house. The houses then are placed over a light bulb for a class period and the temperatures are measured inside and out. Students use a spreadsheet to determine the cost of the insulation to preserve a degree of temperature.

Assignment 5: Students research and report their findings about passive solar design and how the purposeful flow of heat can help a space maintain comfortable temperatures year round.

Assignment 6: Students begin "Project Layout" based upon the attached handout. Students work in groups and develop a multi-use software knowledge base when developing the project. Students use CADD modeling software, Microsoft Word, Microsoft Excel and Microsoft PowerPoint in developing the project. Students also be required to build a scaled model of the building and site they design. This allows them to look at the construction of their design and visualize its form and function of the building design. Students are allowed to use their creativity and architectural style using shape and color and how it all relates to orientation and "Green Construction." Students must take the 2D drawings from the blueprints and construct a 3D model, again reinforcing the relationship between 2D and 3D.

Assignment 7: Students complete their presentations in a classroom presentation setting. They are graded on their presentation skills as well as the content of the presentation. They are required to show pictures of their model during construction and the process of building a model from their design. They are required to indicate the style of their building and what makes it a "Green Building" and the effect it has on their lives in the future. They are also required to indicate the process of drawing the project in a CADD modeling program.

Unit 9: Building an Instrument

Essential Question: How will the future sound?

Supporting Questions:

How do the geometric properties affect the sound output of an instrument?

How does frequency and amplitude play a role in the production of sound?

How do harmonics play a role in the sound production of an instrument?

Unit 9 Overview:

As students investigate the designs of various musical instruments, they discover the fact that sound travels at different speeds through different mediums. Students utilize this fact to engineer instruments to produce various frequencies depending on the density and molecular structure of the material they choose. Throughout this unit, students research how sound is a longitudinal wave and transfers energy to our ear drum. This provides a deeper understanding of wave functions learned in Unit 6. Students discover how a string vibrating as a standing wave can produce a longitudinal wave in the air and that the frequency and speed of that wave is dependent on the medium it is traveling through.

When analyzing circles, the students derive the equation of a circle of given center and radius using the Pythagorean Theorem and complete the square to find the center and radius of a circle given by an equation. In some instances the students are able to use geometric shapes and their properties to describe objects in an application. They also learn to use coordinates to compute perimeters of polygons and areas of triangles and rectangles via the distance formula or midpoint formula. These concepts and relationships are employed in understanding how an instrument is tuned and the determination of the shape and size of its resonator.

Unit 9: Building an Instrument - Key Assignments

Description of unit project: In this project students explore the workings of current instruments and utilize those concepts to design and build a new musical instrument.

Assignment 1: Students complete practice problems dealing with frequency, period, amplitude, wave speed, wavelength, air columns, strings, and membranes.

Assignment 2: Students research the major families of instruments to learn what makes each family unique and how instruments within each family produce and modulate sound waves.

Assignment 3: Students complete the wave interference worksheet, which is designed as scaffolding to explore wave anatomy and the interactions between waves. Option is to use "Catch a Wave" activity, which explains how the longitudinal and transverse waves work, from support lab book by Robinson.

Assignment 4: Students complete the Individual instrument planning research to help define the function, construction, and type of instrument he or she is building. They must also include detailed drawings and a materials/cost analysis.

Assignment 5: Students complete the vibrations in air columns worksheet which is designed as scaffolding to explore how vibrations are formed and waves are propagated in closed and open tube columns.

Assignment 6: Students complete the vibrations in strings and membranes worksheet which is designed as scaffolding to explore how vibrations are formed and waves are propagated in strings and worksheets.

Assignment 7: Students begin constructing their instruments. They need to make careful calculations in the dimensions of their instruments in order to produce correct frequencies that correspond to notes on a standard musical scale.

Assignment 8: Students make a final presentation of their instruments and a discussion of how their instrument functions. Students discuss how their instrument generates vibrations and waves and how those vibrations are modified to produce different tones and frequencies.

Unit 10: Vehicle Efficiency

Essential Question: How do you move in circles to move forward?

Supporting Questions:

What makes a quality race car?

How can stored energy create rotation?

How do properties of a circle relate to forward motion of a car?

Unit 10 Overview:

In this unit, ideas in geometry, physics and engineering are explored through the design and construction of a model race car powered by a single mousetrap. This unit emphasizes two topical areas of physics: energy and rotation. Through the build and design aspects of the project students explore the connections between stored energy and mechanical energy and how they can be used to induce a rotation in the wheels to propel the car forward in a linear fashion. The geometry of the wheels and axle system has a direct effect on the performance of the car in terms of speed, accuracy of travel, and distance traveled.

Students refine their ability to apply the process of logical thought through application of geometric proofs and theorems. Students prove the slope criteria for parallel and perpendicular lines and use them to solve geometric problems. Transformations are also addressed in ways for the students to analyze the effects of rotation, reflection, and translation and also develop definitions for these transformations in terms of angles, circles, perpendicular lines, parallel lines, and line segments, and describe the rotations and reflections that carry onto itself in application to the design of various components of the car and its overall design. The students have an opportunity to also draw transformed figures with one transformation or a sequence of transformations to create congruent or similar figures. Proving congruency and similarity is implemented into all of the units we have developed.

The Physics of the car involve storing energy in the spring of the mousetrap and using that stored energy to move a lever arm. This motion causes a torque in the axle of the

wheel via a string that is attached to the lever arm and wound around the axle assembly. As the torque is applied, it causes the wheel and axle to rotate, propelling the car forward.

This project focuses on the engineering process that are used throughout the course with an emphasis on mechanical, automotive, electrical, and manufacturing engineering. Students experiment with aspects of the racecar to explore vehicle performance tasks– speed, power, accuracy, and how these performance tasks are affected by different aspects of the car.

This project is expected to be the last unit and therefore a culmination of the content and skills the students have learned throughout the course. Therefore the unit parallels a real world engineering project with marketing and business models, product specifications, complete documentation including manufacturing specifications, design reviews, product testing, advertising, and sale of the product, most likely on the web. The teacher can choose which aspects to include in detail for the project. The project results in a technical paper, a multi-purpose vehicle and a presentation.

Unit 10: Vehicle Efficiency - Key Assignments

Assignment 1: The students are given a challenge to design and build a vehicle using an instructor-supplied mousetrap that travels a maximum straight-line distance. Students have complete design freedom, with the exception of having to use the supplied mousetrap for propulsion, and purchased hobby store-type kits being prohibited. Students initially brainstorm and sketch ideas individually, then get into teams for an enhanced brainstorming design process. Team size depends on instructor preference and class size.

Assignment 2: Student teams brainstorm ideas for the design, construction, and function of their race car. They complete and submit detailed drawings, materials lists and costs, and assembly instructions for approval prior to building. They must take into account the physics and geometry concepts learned throughout the year in making their proposals.

Assignment 3: Student teams consolidate their ideas into a practical and efficient design. Mechanical drawings are produced, including bill of materials, orthographic, pictorial and assembly drawings with all required dimensions. Students begin procurement of materials at this point, with instructor approval required for all component parts. Students should be prepared to answer any engineering design questions presented by the instructor regarding their vehicle design.

Assignment 4: Student teams now enter into the manufacturing and construction phase of this unit. Students use adhesion, cohesion and/or mechanical fastening methods to produce their design. This stage requires extensive laboratory time and the manufacturing processes used depend on available resources and equipment. All construction and assembly procedures should be done in class under instructor

supervision with a strict adherence to all safety protocols.

Assignment 5: Student teams begin testing their vehicles and evaluating the results. Data is accumulated, recorded and examined. The instructor uses these test results to focus conversations on physics, geometry and engineering concept reinforcement. Re-design requires the iterative engineering design process to begin again and complete the cycle as many times as necessary. Extensive laboratory time is required for manufacturing and construction processes to continue.

Assignment 6: Students evaluate peer vehicles for constructive feedback using an instructor-designed rubric. The instructor can use this opportunity for stimulating class discussion in any area(s) that need additional input. The instructor also uses this time to reinforce the requirements of the technical report, oral presentation and final vehicle competition rules.

Assignment 7: Student teams assign individual duties for the final written technical report. Details on aspects of technical reporting have been covered throughout the course in most units and each team member must have a specified role in the project. Team members begin planning the oral presentation during this assignment. A breakdown of the technical writing process can be found in Appendix B.

Assignment 8: Race day! The instructor has the opportunity to build into the grading rubric many other aspects in addition to maximum displacement, such as aesthetics, creativity, materials, engineering, problem solving, teamwork, etc. All results should be carefully recorded, synthesized, evaluated and presented in the technical report and oral presentation.

Assignment 9: All members of the team play a role in the presentation of findings to the class. The instructor should have previously developed a rubric of specific aspects that should be covered (this rubric having been used in prior units) with the students being fully aware of the expectations required for a quality presentation, but should most definitely include a thorough discussion of the physics and geometry concepts utilized in the construction, testing, and redesign of their car.

Texts:

Title: Conceptual Physics [or district-adopted physics textbook]

Publication Date: 2006

Publisher: Boston: Pearson Education, Inc.

Author(s): Hewiitt, Paul

Usage: Primary Text

Title: Principles of Engineering [Engineering]

Publication Date: 2012

Publisher: Delmar, Clifton Park, NY: Delmar, Cengage Learning

Author(s): Handley, B. A., Marshall, D. M., & Coon, C.
Usage: Supplementary Text

Title: Laboratory Manual
Edition: To accompany Prentice Hall's Conceptual Physics
Publication Date: 2002
Publisher: Prentice Hall
Author(s): Paul Robinson
Usage: Supplementary Text

Title: Pre-Engineering [Engineering]
Publication Date: 2012
Publisher: Bothell, WA: McGraw Hill Education
Author(s): Harms, H. R., & Janosz, J. D.
Usage: Supplementary Text

Title: Engineering Drawing and Design [Engineering]
Edition: 5th Edition
Publication Date: 2012
Publisher: Delmar
Author(s): Madsen, D.A., Madsen, D.P.
Usage: Supplementary Text

Title: Architectural Drafting and Design [Architectural Engineering]
Edition: 6th Edition
Publication Date: 2011
Publisher: Delmar
Author(s): Jefferies, A., Madsen, D.
Usage: Supplementary Text

Title: Green Building: Principles and Practices in Residential Construction [Architectural Engineering]
Edition: 1st Edition
Publication Date: 2012.
Publisher: Delmar
Author(s): Kruger, A., Seville, C.
Usage: Supplementary Text

Title: [District Adopted Geometry Text]
Usage: Primary Text

Title: E-Text: CK-12.org (State adopted customizable electronic texts) for science, engineering, and math
Publisher: Key Curriculum Press
URL Resource(s): CK-12.org

Supplemental Materials:

Web Resources:

Teachers' Domain.org - searchable database from PBS series with curriculum resources tailored for classroom use. www.teachersdomain.org

PBS Teachers - supplemental curricular resources www.pbsteachers.org

American Wind Energy Society website - www.awes.org

Solar Energy Society website - www.ases.org

KQED Quest - www.kqed.org/quest (all units)

NOVA

"All About Forces"

"Pitch Perfect"

The Discovery Channel

Time Warp program:

<http://dsc.discovery.com/videos/time-warp-roller-coaster-science.htm>

Build it Bigger program "Roller Coasters"

<http://science.discovery.com/videos/build-it-bigger-coasters/>

Mythbusters

planetgreen.com

"Instrumental: Elemental Design"

National Science Foundation: www.nsf.gov

nsf.gov/discoveries

Wind turbines in wind tunnel

Department of Energy: www.energysavers.gov

Society for Automotive Engineering - www.sae.org

NSDL - National Science Digital Library - NSF Digital library www.nsl.org

My Brokers of Expertise - database and online teacher community site www.myboe.org

National Council of Teachers of Mathematics - www.nctm.org

National Science Teachers Association - www.nsta.org

International Technology and Engineering Educators association - www.iteea.org

Science Fridays from NPR - www.sciencefriday.com

ScienceMag.org - <http://news.sciencemag.org/sciencenow/>

KidWind.com - windmill and turbine parts supplier www.kidwind.org

CTE Online www.cteonline.org

engineering.com

Design brief: "Tacoma Narrows Bridges"

"Passive Solar Systems & Solar Hot Water"

"Screw Pumps- Modern Twists on a Classic Device"

"Buoyant Forces and Archimedes' Principle"

"Telescope"

Audio/Visual:

Stuart Little

Lord of the Rings

Monty Python and the Holy Grail

Graphisoft EcoDesigner

External Experts:

Local student chapters of professional engineering programs at universities.

Local chapters of professional engineering organizations (i.e. Society of Manufacturing Engineers, American Society of Mechanical Engineers, etc.

Professional Development:

Dedicated time for collaboration between Engineering/Physics/Geometry teachers to coordinate projects and sequencing

Recommended summer workshopping of integrated content standards between Engineering/Physics/Geometry

Recommended collaboration with local engineering education programs at university and/or community colleges.

Equipment/Supplies:

Standard set of general hand tools

Lenses and mirrors set

Standard set of manual drafting tools

CADD (Computer Aided Drafting and Design) software such as SolidWorks, Inventor, ArchiCAD, or AutoCAD.