Science
PLTW Introduction to Engineering Design
Grades 9-12

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Hillside Township School District

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District Mission Statement

The mission of the Hillside Public Schools is to ensure that all students at all grade levels achieve the New Jersey Core Curriculum Content Standards and make connections to real-world success. We are committed to strong parent-community school partnerships, providing a safe, engaging, and effective learning environment, and supporting a comprehensive system of academic and developmental support that meets the unique needs of each individual.

Academic Area Overview

The Hillside Township School District is committed to excellence. We believe that all children are entitled to an education that will equip them to become productive citizens of the twenty-first century. We believe that an education grounded in the fundamental principles of science will provide students with the skills and content necessary to become our future leaders.

A sound science education is grounded in the principles of inquiry and rigor. Children are actively engaged in learning as they model real-world scientific behaviors to construct knowledge. They have ample opportunities to manipulate materials in ways that are developmentally appropriate to their age. They work in an environment that encourages them to take risks, think critically, and make models, note patterns and anomalies in those patterns. Children are encouraged to ask questions, not just the "how" and the "what" of observed phenomena, but also the "why".

Our program provides teachers with cost-effective science materials that are aligned to state and national standards, incorporate instructional strategies that are research-based, and provides teachers with a deep understanding of science and the pedagogical underpinnings of science. Our teachers receive quality professional development through a district partnership with the Merck Institute for Science Education as well as the Martinson Foundation at Fairleigh Dickinson University. Our K-8 kit based program encourages "hands-on science" and is endorsed by the National Science Foundation.

Equality and Equity in Curriculum

The Hillside Township School District ensures that the district’s curriculum and instruction are aligned to the State’s Core Curriculum Content Standards and addresses the elimination of discrimination and the achievement gap, as identified by underperforming school-level AYP reports for State assessment, by providing equity in educational programs and by providing opportunities for students to interact positively with others regardless of race, creed, color, national origin, ancestry, age, marital status, affectional or sexual orientation, gender, religion, disability or socioeconomic status.

N.J.A.C. 6A:7-1.7(b): Section 504, Rehabilitation Act of 1973; N.J.S.A. 10:5; Title IX, Education Amendments of 1972
Hillside Township School District

Next Generation Science Standards

In 2014, NJ adopted the Next Generation Science Standards with the goal of ensuring our students graduate ready for college and career. The standards for science practice describe varieties of expertise that science educators at all levels should seek to develop in their students. These practices rest on important “processes and proficiencies” with longstanding importance in science education. The Science Framework emphasizes process standards of which include planning investigations, using models, asking questions and communicating information. Crosscutting concepts have value because they provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas. Throughout the year, students should continue to develop proficiency with the eight science practices. Crosscutting concepts can help students better understand core ideas in science and engineering. When students encounter new phenomena, whether in a science lab, field trip, or on their own, they need mental tools to help engage in and come to understand the phenomena from a scientific point of view. Familiarity with crosscutting concepts can provide that perspective. A next step might be to simplify the phenomenon by thinking of it as a system and modeling its components and how they interact. These preliminary studies may suggest explanations for the phenomena, which could be checked by predicting patterns that might emerge if the explanation is correct, and matching those predictions with those observed in the real world. More information regarding the Next Generation Science Standards can be found at:

http://www.nextgenscience.org/

Introduction to Engineering Overview

Introduction to Engineering Design (IED) is a high school level foundation course in the PLTW Engineering Program. In IED students are introduced to the engineering profession and a common approach to the solution of engineering problems, an engineering design process. Utilizing the activity-project-problem-based (APB) teaching and learning pedagogy, students will progress from completing structured activities to solving open-ended projects and problems that require them to develop planning, documentation, communication, and other professional skills. The objectives of this course are to apply the Next Generation Science Standards (NGSS) Crosscutting Concepts that bridge disciplinary boundaries, uniting core ideas throughout the fields of science and engineering. More information regarding standard alignment can be found here IED Standards
### Unit 1 Design Process

#### ENDURING UNDERSTANDINGS
- An engineering design process involves a characteristic set of practices and steps used to develop innovative solutions to problems.
- Brainstorming may take many forms and is used to generate a large number of innovative, creative ideas in a short time.
- Sketches, drawings, and images are used to record and convey specific types of information depending upon the audience and the purpose of the communication.
- Engineering consists of a variety of specialist subfields, with each contributing in different ways to the design and development of solutions to different types of problems.

#### ESSENTIAL QUESTIONS
- When solving an engineering problem, how can we be reasonably sure that we have created the best solution possible?
- What is the most effective way to generate potential solutions to a problem?
- How many alternate solutions are necessary to ensure a good final solution?
- What will be the biggest impact that engineering will have on society and your life in the 21st century?

#### Student Learning Objectives

**KNOWLEDGE**  
Students will know:

- **Design Process**
  - The steps in an engineering design process and describe the activities involved in each step of the process.
  - Concept of proportion and how it relates to freehand sketching.
  - Brainstorming techniques and rules for brainstorming.
  - Difference between invention and innovation.

**SKILLS & PRACTICES**  
Students will be able to:

- Generate and document multiple ideas or solution paths to a problem through brainstorming.
- Describe the design process used in the solution of a particular problem and reflect on all steps of the design process.
- Utilize an engineering notebook to clearly and accurately document the design process according to accepted standards and protocols to prove the origin and chronology of a design.
- Create sketches or diagrams as representations of objects, ideas, events, or systems.

**HS-ETS1-2**
**HS-ETS1-3**
**HS-ETS1-4**

9-10.W.1  
9-10.SL.1  
9-10.L.1  
9-10.RST.4  
1.9-12.L
Hillside Township School District

<table>
<thead>
<tr>
<th>The difference between the work of an engineer and the work of a scientist.</th>
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<tbody>
<tr>
<td>The difference between mechanical, electrical, civil, and chemical engineering fields</td>
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<tr>
<td>An engineering design process involves a characteristic set of practices and steps used to develop innovative solutions to problems.</td>
</tr>
<tr>
<td>Brainstorming may take many forms and is used to generate a large number of innovative, creative ideas in a short time.</td>
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<tr>
<td>Technical professionals clearly and accurately document and report their work using technical writing practice in multiple forms.</td>
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<td>Sketches, drawings, and images are used to record and convey specific types of information depending upon the audience and the purpose of the communication.</td>
</tr>
<tr>
<td>Engineering consists of a variety of specialist subfields, with each contributing in different ways to the design and development of solutions to different types of problems</td>
</tr>
</tbody>
</table>

**Key Terms:**
Assess, Assessment, Brainstorm, Client, Creativity, Criteria, Constraint, Design, Design Brief, Design Process, Design Statement, Designer, Engineer, Innovation, Invention, Iterative, Justifiable, Piling-on, Problem Identification, Product, Prototype, Research

| Explain the contributions of engineers from different engineering fields in the design and development of a product, system, or technology. |
| Review and evaluate the written work of peers, and make recommendations for improvement |

**PRACTICES:**
Engaging in Argument from evidence
Obtaining, Evaluating and Communicating Information
## Unit 2 Technical Sketching and Drawing

### ENDURING UNDERSTANDINGS

✓ Technical drawings convey information according to an established set of drawing practices which allow for detailed and universal interpretation of the drawing.
✓ Hand sketching of multiple representations to fully and accurately detail simple objects or parts of objects is a technique used to convey visual and technical information about an object.
✓ Two- and three-dimensional objects share visual relationships which allow interpretation of one perspective from the other.
✓ The style of the engineering graphics and the type of drawing views used to detail an object vary depending upon the intended use of the graphic.

### ESSENTIAL QUESTIONS

✓ How is technical drawing similar to and different from artistic drawing?
✓ What can cause a technical drawing to be misinterpreted or to be inadequate when conveying the intent of a design to someone unfamiliar with the original problem or solution?
✓ In what ways can technical drawings help or hinder the communication of problem solution in a global community?
✓ Why are spatial-visualization skills so important to engineering success?

### Student Learning Objectives

<table>
<thead>
<tr>
<th>KNOWLEDGE</th>
<th>SKILLS &amp; PRACTICES</th>
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<tr>
<td>Students will know:</td>
<td>Students will be able to:</td>
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</table>

#### Technical Sketching and Drawing

- Line types (including construction lines, object lines, hidden lines, and center lines) used on a technical drawing per ANSI Line Conventions and Lettering Y14.2M-2008 and explain the purpose of each line.
- Technical drawing representations including isometric, orthographic projection, oblique, and perspective views.
- Proper use of each technical drawing representation including isometric, orthographic projection, oblique, and perspective views.

- Apply tonal shading to enhance the appearance of a pictorial sketch and create a more realistic appearance of a sketched object.
- Hand sketch isometric views of a simple object or part at a given scale using the actual object, a detailed verbal description of the object, a pictorial view of the object, or a set of orthographic projections.
- Hand sketch 1-point and 2-point perspective pictorial views of a simple object or part given the object, a detailed verbal description of the object, a pictorial view of the object, and/or a set of orthographic projections.
- Select flat patterns (nets) that fold into geometric solid forms.
Technical drawings convey information according to an established set of drawing practices which allow for detailed and universal interpretation of the drawing.

- Hand sketching of multiple representations to fully and accurately detail simple objects or parts of objects is a technique used to convey visual and technical information about an object.
- Two- and three-dimensional objects share visual relationships which allow interpretation of one perspective from the other.
- The style of the engineering graphics and the type of drawing views used to detail an object vary depending upon the intended use of the graphic.

**Key Terms:**
- Cabinet Pictorial
- Center Line
- Construction Line
- Depth
- Dimension
- Dimension Line
- Documentation
- Drawing
- Edge
- Ellipse
- Extension Line
- Freehand
- Grid
- Height
- Hidden Line
- Isometric Sketch
- Leader Line
- Line Conventions
- Line Weight
- Long-Break Line
- Manufacture
- Measurement
- Multi-View Drawing
- Object Line
- Oblique Sketch
- Orthographic Projection
- Perspective Sketch
- Pictorial Sketch
- Plane
- Point
- Profile
- Projection Line
- Projection Plane
- Proportion
- Scale
- Section Lines
- Shading
- Short-Break Line
- Shape
- Sketch
- Solid
- Technical Working Drawing
- Three-Dimensional
- Tone
- Two-Dimensional
- Vanishing Point

Hand sketch orthographic projections at a given scale and in the correct orientation to fully detail an object or part using the actual object, a detailed verbal description of the object, or a pictorial and isometric view of the object.

- Determine the minimum number and types of views necessary to fully detail a part.
- Choose and justify the choice for the best orthographic projection of an object to use as a front view on technical drawings.

**PRACTICES:**
- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating and Communicating Information
# Unit 3 Measurement and Statistics

## ENDURING UNDERSTANDINGS

| ✔ Error is unavoidable when measuring physical properties, and a measurement is characterized by the precision and accuracy of the measurement. |
| ✔ Units and quantitative reasoning can guide mathematical manipulation and the solution of problems involving quantities. |
| ✔ Dimensions are included on technical drawings according to accepted practice and an established set of standards so as to convey size and location information about detailed parts and their features. |
| ✔ Statistical analysis of uni-variate data facilitates understanding and interpretation of numerical data and can be used to inform, justify, and validate a design or process. |
| ✔ Spreadsheet programs can be used to store, manipulate, represent, and analyze data efficiently |

## ESSENTIAL QUESTIONS

| ✔ Can statistics be interpreted to justify conflicting viewpoints? |
| ✔ Why is error unavoidable when making a measurement? |
| ✔ When recording measurement data, why is the use of significant figures important? |
| ✔ What would happen if engineers did not follow accepted dimensioning standards and guidelines but, instead, used their own individual dimensioning methods? |
| ✔ When measuring the length of a part, would an inaccurate (but precise) measuring instrument be more or less likely to indicate the actual measurement than an imprecise (but accurate) measuring instrument? |

## Student Learning Objectives

**Measurement and Statistics**

- General rules for dimensioning on technical drawings used in standard engineering practice.
- The differences between sample statistics and population statistics and know appropriate applications of each.
- The difference between precision and accuracy of measurement.

- Measure linear distances (including length, inside diameter, and hole depth) with accuracy using a scale, ruler, or dial caliper and report the measurement using an appropriate level of precision.
- Use units to guide the solution to multi-step problems through dimensional analysis and choose and interpret units consistently in formulas.
### 17.9-12.Q

- Error is unavoidable when measuring physical properties, and a measurement is characterized by the precision and accuracy of the measurement.
- Units and quantitative reasoning can guide mathematical manipulation and the solution of problems involving quantities.
- Dimensions are included on technical drawings according to accepted practice and an established set of standards so as to convey size and location information about detailed parts and their features.
- Statistical analysis of univariate data facilitates understanding and interpretation of numerical data and can be used to inform, justify, and validate a design or process.
- Spreadsheet programs can be used to store, manipulate, represent, and analyze data efficiently.

**Key Terms:**
- Accuracy, Arrowheads, Caliper, Class Interval, Convert, Data, Data Set, Dimension, Dimension Lines, Dot Plot, See line plot, Frequency, Graph, Histogram, International Organization for Standardization (ISO), International System of Units (SI), Line Plot, Mean, Measure, Median, Mode, Normal Distribution, Numeric Constraint, Precision, Scale, Scatter Plot, Significant Digits, Standard Deviation, Statistics, Unit, US Customary Measurement System, Variation

- Convert between different units within the same measurement system including the SI and US Customary measurement systems.
- Identify and correct errors and omissions in the dimensions applied in a technical drawings.
- Calculate statistics related to variation of data including (sample and population) standard deviation and range.
- Represent data with plots on the real number line (e.g., dot plots, histograms, and box plots).
- Use statistics to quantify information, support design decisions, and justify problem solutions.
- Use a spreadsheet program to store and manipulate raw data, perform calculations using formulas, and create and display a histogram to represent a set of data.
- Use the Empirical Rule to interpret data and identify ranges of data.
- Evaluate and compare the accuracy and precision of different measuring devices.

**PRACTICES:**
- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating and Communicating Information
# Unit 4 Modeling Skills

## Enduring Understandings

- Technical professionals use a variety of models to represent systems, components, processes and other designs including graphical, computer, physical, and mathematical models.
- Computer aided drafting and design (CAD) software packages facilitate the creation of virtual 3D computer models of parts and assemblies.
- Physical models are created to represent and evaluate possible solutions using prototyping technique(s) chosen based on the presentation and/or testing requirements of a potential solution.
- An equation is a statement of equality between two quantities that can be used to describe real phenomenon and solve problems.

## Essential Questions

- How should one decide what information and/or artifacts to include in a portfolio? Should a portfolio always include documentation on the complete design process?
- Did you use every possible type of model during the design and construction of your puzzle cube?
- How reliable is a mathematical model?

## Student Learning Objectives

**NGSS, CCSS & Technology**

| --- | --- | --- | --- | --- | --- | --- |

## Knowledge

**Students will know:**

- **Modeling Skills**
  - Explain the term “function” and identify the set of inputs for the function as the domain and the set of outputs from the function as the range.
  - Be familiar with the terminology related to and the use of a 3D solid modeling program in the creation of solid models and technical drawings.
  - Differentiate between additive and subtractive 3d solid modeling methods.

## Skills & Practices

**Students will be able to:**

- Develop and/or use graphical, computer, physical and mathematical models as appropriate to represent or solve problems.
- Fabricate a simple object from technical drawings that may include an isometric view and orthographic projections.
- Create three-dimensional solid models of parts within CAD from sketches or dimensioned drawings.
- Generate CAD multi-view technical drawings.
- Construct a testable prototype of a problem solution.
Technical professionals use a variety of models to represent systems, components, processes and other designs including graphical, computer, physical, and mathematical models.

Computer aided drafting and design (CAD) software packages facilitate the creation of virtual 3D computer models of parts and assemblies.

Physical models are created to represent and evaluate possible solutions using prototyping technique(s) chosen based on the presentation and/or testing requirements of a potential solution.

Technical professionals clearly and accurately document and report their work using technical writing practice in multiple forms.

An equation is a statement of equality between two quantities that can be used to describe real phenomenon and solve problems.

Solving mathematical equations and inequalities involves a logical process of reasoning and can be accomplished using a variety of strategies and technological tools.

A function describes a special relationship between two sets of data and can be used to represent a real world relationship and to solve problems.

Key Terms: Annotate, Assembly Drawing, Cartesian Coordinate System, Computer-Aided Design or Computer-Aided Drafting (CAD), Degree of Freedom, Design Brief,

- Analyze the performance of a design during testing and judge the solution as viable or non-viable
- Create a set of working drawings to detail a design project.
- Organize and express thoughts and information in a clear and concise manner.
- Utilize project portfolios to present and justify design projects.
- Use a spreadsheet program to graph bi-variate data and determine an appropriate mathematical model using regression analysis.
- Construct a scatter plot to display bi-variate data
- Solve equations for unknown quantities by determining appropriate substitutions for variables and manipulating the equations.
- Use function notation to evaluate a function for inputs in its domain and interpret statements that use function notation in terms of a context.
- Build a function that describes a relationship between two quantities given a graph, a description of a relationship, or two input-output pairs.
- Interpret a function to solve problems in the context of the data.
- Interpret the slope and the intercept of a linear function in the context of data.
- Compare the efficiency of the modeling method of an object using different combinations of additive and subtractive methods.

**PRACTICES:**
- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
### Unit 5 Geometry Design

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<tr>
<th>ENDURING UNDERSTANDINGS</th>
<th>ESSENTIAL QUESTIONS</th>
</tr>
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<tr>
<td>✓ Geometric shapes and forms are described and differentiated by their characteristic features.</td>
<td>✓ What advantage(s) do Computer Aided Design (CAD) and Drafting provide over traditional paper and pencil design? What advantages does paper and pencil design provide over CAD?</td>
</tr>
<tr>
<td>✓ Physical properties of objects are used to describe and model objects and can be used to define design requirements, as a means to compare potential solutions to a problem, and as a tool to specify final solutions.</td>
<td>✓ Which high school math topic/course, Algebra or Geometry, is more closely related to engineering?</td>
</tr>
<tr>
<td>✓ Computer aided design (CAD) and drafting software packages incorporate the application of a variety of geometric and dimensional constraints and model features to accurately represent objects.</td>
<td>✓ How does the material chosen for a product impact the design of the product?</td>
</tr>
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<thead>
<tr>
<th>Student Learning Objectives NGSS, CCSS &amp; Technology</th>
<th>KNOWLEDGE Students will know:</th>
<th>SKILLS &amp; PRACTICES Students will be able to:</th>
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<tbody>
<tr>
<td>9-10.SL.1 9-10.L.6 9-10.RST.3 G.MG.3 A.REI.3</td>
<td><strong>Geometry Design</strong></td>
<td><strong>SKILLS:</strong></td>
</tr>
<tr>
<td></td>
<td>• Identify types of polygons including a square, rectangle, pentagon, hexagon, and octagon.</td>
<td>• Solve real world and mathematical problems involving area and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, right prisms, cylinders, and spheres.</td>
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</tbody>
</table>
• Identify and differentiate geometric constructions and constraints (such as horizontal lines, vertical lines, parallel lines, perpendicular lines, collinear points, tangent lines, tangent circles, and concentric circles) and the results when applied to sketch features within a 3D solid modeling environment.  
• Distinguish between the meanings of the terms weight and mass.  
• Define the term “physical property” and identify the properties of length, volume, mass, weight, density, and surface area as physical properties.  
• Identify three-dimensional objects generated by rotations of two-dimensional shapes and vice-versa.  

Key Terms: Acute Triangle, Angle, Area, Axis, Center of Gravity, Centroid, Circle, Circumscribe, Cylinder, Density, Diameter, Ellipse, Fillet, Inscribe, Mass, Meniscus, Obtuse Triangle, Parallelogram, Pi (π), Polygon, Principal Axes, Prism, Quadrilateral, Radius, Rectangle, Regular Polygon, Right Triangle, Round, Square, Surface Area, Tangent, Title Block, Triangle, Vertex, Volume, Quadrilateral | • Create three-dimensional solid models of parts within CAD from sketches or dimensioned drawings.  
• Measure mass with accuracy using a scale and report the measurement using an appropriate level of precision.  
• Measure volume with accuracy and report the measurement with an appropriate level of precision.  
• Calculate a physical property indirectly using available data or perform appropriate measurements to gather the necessary data (e.g., determine area or volume using linear measurements or determine density using mass and volume measurements).  
• Solve volume problems using volume formulas for rectangular solids, cylinders, pyramids, cones, and spheres.  
• Use physical properties to solve design problems  
• Assign a specific material to a part and use the capabilities of the CAD software to determine the mass, volume, and surface area of an object for which a 3D solid model has been created.  
• Assign a density value to a new material and apply the material to a 3D solid model within CAD software in order to determine the physical properties of the object  

**PRACTICES:**  
• Asking Questions and Defining Problems  
• Developing and Using Models  
• Planning and Carrying Out Investigations  
• Analyzing and Interpreting Data  
• Constructing Explanations and Designing Solutions  
• Engaging in Argument from Evidence  
• Obtaining, Evaluating and Communicating Information |
## UNIT 6 Reverse Engineering

### ENDURING UNDERSTANDINGS

- Reverse engineering involves disassembling and analyzing a product or system in order to understand and document the visual, functional, and/or structural aspects of its design.
- Visual elements and principles of design are part of an aesthetic vocabulary that is used to describe the visual characteristics of an object, the application of which can affect the visual appeal of the object and its commercial success in the marketplace.
- Technical professionals use the results of reverse engineering for many different purposes such as discovery, testing, forensics, improvement or redesign, and producing technical documentation of a product.

### ESSENTIAL QUESTIONS

- Why are many consumer product designs not commercially successful?
- When, if ever, is it acceptable for a company to reverse engineer and reproduce a successful consumer product designed by another person/company?

### Student Learning Objectives

#### NGSS, CCSS & Technology

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<tr>
<th>KNOWLEDGE</th>
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<td>Students will know:</td>
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#### Unit 6 Reverse Engineering

- Identify and describe the visual principles and elements of design apparent in a natural or man-made object.
- Describe the process of reverse engineering.
- Explain the various reasons to perform reverse engineering including discovery, documentation, investigation, and product improvement.
- Technical professionals clearly and accurately document and report their work using technical writing practice in multiple forms.

#### SKILLS:

- Explain how the visual elements and principles of design affect the aesthetics and commercial success of a product.
- Perform a functional analysis of a product in order to determine the purpose, inputs and outputs, and the operation of a product or system.
- Perform a structural analysis of a product in order to determine the materials used and the form of component parts as well as the configuration and interaction of component parts when assembled.
### UNIT 7 Documentation

#### ENDURING UNDERSTANDINGS
- Computer aided drafting and design (CAD) software packages facilitate virtual modeling of assemblies and the creation of technical drawings.
- A degree of variation always exists between specified dimensions and the measurement of a manufactured object.
- A solution path is selected and justified by evaluating and comparing competing design solutions based on jointly developed and agreed-upon design criteria and constraints.
- Technical drawings convey information according to an established set of drawing practices which allow for detailed and universal interpretation of the drawing.
- The style of the engineering graphics and the type of drawings views used to detail an object vary depending upon the intended use of the graphic.

#### ESSENTIAL QUESTIONS
- What are the consequences to the final solution if the design problem is poorly communicated?
- How does one know that a given design solution is the best possible solution?
- What quality makes a set of drawings sufficient to adequately represent the design intent?
- Is it always necessary to indicate a tolerance for every dimension on a technical drawing?
- Which step of the design process is most important to successfully innovate or invent a new product?
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<tr>
<th>Unit 7 Documentation</th>
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<tbody>
<tr>
<td>- Identify and differentiate between size dimensions and location dimensions.</td>
<td>- Hand sketch a scaled full or half section view in the correct orientation to fully detail an object or part given the actual object</td>
</tr>
<tr>
<td>- Identify and correctly apply chain dimensioning or datum dimensioning methods to a technical drawing.</td>
<td>- Generate section views using CAD according to standard engineering practice.</td>
</tr>
<tr>
<td>- Identify dimensioning standards commonly used in technical drawing.</td>
<td>- Dimension a section view of a simple object according to a set of dimensioning standards and accepted practices.</td>
</tr>
<tr>
<td>- Identify the shapes of two-dimensional cross sections of three dimensional objects.</td>
<td>- Annotate working drawings according to accepted engineering practice. Include dimensioning according to a set of dimensioning rules, proper hole and thread notes, proper tolerance annotation, and the inclusion of other notes necessary to fully describe a part according to standard engineering practice.</td>
</tr>
<tr>
<td>- Identify, define and explain the proper use of a section view in technical drawing.</td>
<td>- Create specific notes on a technical drawing to convey important information about a specific feature of a detailed object, and create general notes to convey details that pertain to information presented on the entire drawing.</td>
</tr>
<tr>
<td>- Read and interpret a hole note to identify the size and type of hole including through, clearance, blind, counter bore, and countersink holes.</td>
<td>- Model and annotate through, clearance, blind, counter bore, and countersink holes.</td>
</tr>
<tr>
<td>- Identify and differentiate among limit dimensions, a unilateral tolerance, and a bilateral tolerance.</td>
<td>- Compare the effect of chain dimensioning and datum dimensioning on the tolerance of a particular specified dimension.</td>
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<tr>
<td>- Differentiate between clearance and interference fit.</td>
<td>- Determine the specified dimension, tolerance, upper limit, and lower limit for any given dimension and related tolerance shown on a technical drawing.</td>
</tr>
<tr>
<td>- Explain each assembly constraint (including mate, flush, insert, and tangent), its role in an</td>
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assembly model, and the degrees of freedom that it removes from the movement between parts.

- Specific notes (such as hole and thread notes), and general notes (such as general tolerances) in combination with dimensions are included on technical drawings according to accepted practice and an established set of standards so as to convey size and location information about detailed parts, their features, and their configuration in assemblies.

**Key Terms:**
Aligned Dimension, American National Standards Institute (ANSI), American Society of Mechanical Engineers (ASME), Audience Analysis, Auxiliary View, Baseline Dimensioning, Bilateral Tolerance, Blind Hole, Broken-Out Section, Chain Dimensioning, Clearance Fit, Counterbore, Countersink, Cutting Plane Line, Datum Dimensioning, Decision Matrix, Detail Drawing, Detail View, Fillet, Foreshorten, Full Section, Half Section, Interference Fit, International Organization for Standardization (IOS), Least Material Condition (LMC), Limit Dimensions, Local Notes, Location Dimension, Market Research, Part Drawing, Pitch, Reference Dimension, Section Lines, Section View, Size Dimension, Spotface, Taper, Tolerance, Transition fit, Unidirectional Dimension, Unilateral

- Determine the allowance between two mating parts of an assembly based on dimensions given on a technical drawing.
- Identify the type of fit given a drawing, a description, or a physical example of two mating parts.
- Create assemblies of parts in CAD and use appropriate assembly constraints to create an assembly that allows correct realistic movement among parts.
- Analyze information gathered during reverse engineering to identify shortcoming of the design and/or opportunities for improvement or innovation.
- Define and justify a design problem and express the concerns, needs, and desires of the primary stakeholders.
- Present and justify design specifications, and clearly explain the criteria and constraints associated with a successful design solution.
- Write a design brief to communicate the problem, problem constraints, and solution criteria.
- Support design ideas using a variety of convincing evidence.
- Jointly develop a decision matrix
- Clearly justify and validate a selected solution path.
- Create a set of working drawings to detail a design project.

**PRACTICES:**
- Asking Questions and Defining Problems
- Developing and Using Models
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
## ENDURING UNDERSTANDINGS

- Parametric computer aided design (CAD) software packages facilitate 3D virtual modeling of parts and assemblies using parameters, such as geometric constraints as well as numeric constraints used to determine the shape and size of geometry and models.
- A parametric numeric constraint can be represented by a function that mathematically describes the relationship between that dimension and other related dimension(s).
- Technical drawings convey information according to an established set of drawing practices which allow for detailed and universal interpretation of the drawing.
- The style of the engineering graphics and the type of drawing views used to detail an object vary depending upon the intended use of the graphic.

## ESSENTIAL QUESTIONS

- Are working drawings always necessary in order to communicate the design of a consumer product? Justify your answer.
- Animated assemblies are not typically included as part of the technical documentation of a design. How can 3D animated assembly models of an object or a proposed design be used in the design process? Beyond the design process?

### Student Learning Objectives

**KNOWLEDGE**

Students will know:

- Advanced Computer Modeling
  - Identify, define, and explain the proper use of an auxiliary view in technical drawing.

**SKILLS & PRACTICES**

Students will be able to:

- Use advanced modeling features to create three-dimensional solid models of complex parts and assemblies within CAD and with little guidance given the actual part using appropriate geometric and dimensional constraints.
- Formulate equations and inequalities to represent relationships between quantities.

### Student Learning Objectives

- 9-10.SL.1
- 9-10.L.6
- 9-10.RST.4
- A.SSE.1
- A.CED.3
- 8.9-12.H
Key Terms: Exploded Assembly, Formula, Numeric Constraint, Parameter, Parametric Modeling, Phantom Line, Ratio, Rib

- Using a CAD application, create relationships among part features and dimensions using parametric formulas.
- Create an exploded assembly view of a multi-part product. Identify each component of the assembly with identification numbers and create a parts list to detail each component using CAD.
- Perform a peer review of technical drawings and offer constructive feedback based on standard engineering practices.
- Hand sketch an auxiliary view in the correct orientation to fully detail an object or part given the actual object, a detailed verbal description of the object, a pictorial view of the object, or a set of orthographic projections.
- Generate an auxiliary view using CAD according to standard engineering practice

PRACTICES:
- Asking Questions

UNIT 9: DESIGN TEAM

ENDURING UNDERSTANDINGS

- Engineering has a global impact on society and the environment.
- Research derived from a variety of sources is used to facilitate effective development and evaluation of a design problem and a successful solution to the problem.
- Engineering design and practices are governed by ethics, values, and laws.
- Project planning tools and management skills are often used in the process of solving engineering design problems.

ESSENTIAL QUESTIONS

- Is it ever advantageous to create a design or solve a problem individually as opposed to using a team approach?
- What strategy would you use to form a design team in order to obtain the best solution possible?
- Do engineers need to be taught to be “ethical”?
<table>
<thead>
<tr>
<th>Student Learning Objectives NGSS, CCSS &amp; Technology</th>
<th>KNOWLEDGE</th>
<th>SKILLS &amp; PRACTICES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Team</strong></td>
<td>Students will know:</td>
<td>Students will be able to:</td>
</tr>
<tr>
<td>• Identify and describe the steps of a typical product lifecycle (including raw material extraction, processing, manufacture, use and maintenance, and disposal).</td>
<td>• Assess the development of an engineered product and the impact of the product on society and the environment.</td>
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<tr>
<td>• Identify and explain how the basic theories of ethics relate to engineering.</td>
<td>• Utilize research tools and resources to validate design decisions and justify a problem solution.</td>
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<tr>
<td>• Identify team member skill sets needed to produce an effective team.</td>
<td>• Summarize key ideas in information sources</td>
<td></td>
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<tr>
<td>• Define the term group norms and discuss the importance of norms in creating an effective team environment.</td>
<td>• Deliver organized oral presentations of work tailored to the audience.</td>
<td></td>
</tr>
<tr>
<td>• Identify the advantages and disadvantages of virtual design teams compared to traditional design teams.</td>
<td>• Organize and express thoughts and information in a clear and concise manner.</td>
<td></td>
</tr>
<tr>
<td>• In order to be an effective team member, one must demonstrate positive team behaviors and act according to accepted norms, contribute to group goals according to assigned roles, and use appropriate conflict resolution strategies.</td>
<td>• Participate on a virtual team using remote collaboration tools to support team collaboration and problem solving.</td>
<td></td>
</tr>
<tr>
<td>• Styles and modes of professional correspondence are tailored to the type of audience and intended goals.</td>
<td>• Identify appropriate technology to support remote collaboration</td>
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</tbody>
</table>

**SKILLS:**
- Style and modes of professional correspondence are tailored to the type of audience and intended goals.
Hillside Township School District

- Effective design teams can improve the efficiency and effectiveness of the design process

Key Terms: Arbitration, Attorney General, Carcinogen, Consensus, Critique, Environmental Protection Agency (EPA), Ergonomics, Ethics Evaluate, Gantt Chart, Hazard, Impact, Mediation, Negotiation, Norms, Occupation Safety and Health Administration (OSHA), Product Lifecycle, Protocol, Raw Material, Recycle, Refurbish, Refuse, Residue, Synergy, Trade-off, Virtual Team.

PRACTICES:
- Asking Questions and Defining Problems
- Developing and Using Models
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating and Communicating Information

UNIT 10: DESIGN CHALLENGE

ENDURING UNDERSTANDINGS

✓ An engineering design process involves a characteristic set of practices and steps used to develop innovative solutions to problems

ESSENTIAL QUESTIONS

✓ Engineering has been referred to as the “stealth” profession. Do you think this is an appropriate label?
✓ If you had to describe one strategy that would most help an engineer be a good and effective designer, what would it be?

Student Learning Objectives
NGSS, CCSS & Technology

KNOWLEDGE
Students will know:

SKILLS & PRACTICES
Students will be able to:
**Design Challenge**

- Identify the steps in an engineering design process and describe the activities involved in each step of the process

**Key Terms:** Design, solution, problem

<table>
<thead>
<tr>
<th>HS-ETS1-2</th>
<th><strong>SKILLS:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-ETS1-3</td>
<td>- Develop and document an effective solution to a problem that meets specific design requirements.</td>
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<tr>
<td>HS-ETS1-4</td>
<td>- Document and describe the design process used in the solution of a problem and reflect on all steps of the design process</td>
</tr>
</tbody>
</table>

**PRACTICES:**

- Asking Questions and Defining Problems
- Developing and Using Models
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
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### PLTW Introduction to Engineering

<table>
<thead>
<tr>
<th>TIME FRAME</th>
<th>TOPIC</th>
<th>PERFORMANCE TASKS</th>
<th>ACTIVITIES/PROJECTS</th>
<th>ASSESSMENTS</th>
<th>RESOURCES/INTERDISCIPLINARY CONNECTIONS</th>
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<tr>
<td>October 13 Days</td>
<td>Technical Sketching and Drawing</td>
<td>Unit 2 Technical Sketching and Drawing</td>
<td>Lesson 2.1 Isometric Sketches</td>
<td></td>
<td>Glass Box Theory, LineConvention.ppt, IsometricObliquePictorials.ppt, PerspectiveSketching.ppt</td>
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## Hillside Township School District

<table>
<thead>
<tr>
<th>October-November</th>
<th>Measurement and Statistics</th>
<th>Unit 3 Measurement and Statistics</th>
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<tr>
<td>16 Periods</td>
<td></td>
<td>Lesson 3.1a Linear Measurements with Metric Units</td>
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<tr>
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<td>Lesson 3.1b Linear Measurements with US Customary Units</td>
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<td>Lesson 3.2 Unit Conversion</td>
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<tr>
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<td>Lesson 3.3 Making Linear Measurements</td>
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<td>Lesson 3.4 Linear Dimensions</td>
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<td>Lesson 3.5 Applied Statistics</td>
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<td>Lesson 3.6 Instant Challenge: Fling Machine</td>
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<tr>
<td></td>
<td>Assessments: Group Tasks, Conclusion Questions, Peer/teacher assessment, Journal Entry, Student responses, Conversion Homework, Class Discussion, Instant challenge</td>
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<tr>
<td></td>
<td></td>
<td>The Ruler Game</td>
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<tr>
<td></td>
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<td>SI Measurement System.ppt</td>
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<tr>
<td></td>
<td></td>
<td>US Customary Measurement System.ppt</td>
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<tr>
<td></td>
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<td>Dial Calipers.ppt</td>
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<td></td>
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<td>Empirical Rule.ppt</td>
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<tr>
<th>November-December</th>
<th>Modeling Skills</th>
<th>Unit 4 Modeling Skills</th>
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<tbody>
<tr>
<td>19 Periods</td>
<td></td>
<td>Lesson 4.1 Puzzle Design Challenge</td>
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<td></td>
<td>Lesson 4.1a Puzzle Part Combinations</td>
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<td>Lesson 4.1b Engineering Graphics</td>
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<td>Lesson 4.1c Mathematical Modeling</td>
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<td>Lesson 4.1d Software Modeling Introduction</td>
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<td>Lesson 4.1 e Model Creation</td>
</tr>
<tr>
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<td>Lesson 4.2 Puzzle Cube Package (Optional)</td>
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<td>Assessments: Puzzle Design Challenge, Conclusion Questions, Class Discussion, Student Responses, Peer review of sketches, Student modeling, Journal Entry:</td>
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<tr>
<td></td>
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<td>Drawing Tool</td>
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<td>Auto Desk Design Academy</td>
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<td>Auto Desk Knowledge Network</td>
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<td>Additive and Subtractive Solid Modeling.ppt</td>
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<td>Assembly Constraints and Concepts.ppt</td>
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</tbody>
</table>
| December-January 15 Periods | Geometry Design | Unit 5 Geometry Design  
Lesson 5.1 Calculating Properties of Shapes  
Lesson 5.2 Geometric Constraints  
Lesson 5.2b Introduction to CAD Modeling Skills  
Lesson 5.3 Determining Density  
Lesson 5.4 Calculating Properties of Solids  
Lesson 5.5a CAD Model Features Part 1  
Lesson 5.5b CAD Model Features Part 2  
**Assessments:** Journal Entry, Student responses,  
Conclusion Questions, Extend your learning task responses,  
Small Group/Class Discussion,  
Instant Challenge: Choremaster, Summative – EoC | McMaster Carr Performance  
McMaster Carr Steel Alloys  
McMaster Carr Performance Plastics  
The Engineering Tool Box  
Geometric Shapes and Area.ppt  
Properties of Geometric Solids.ppt |
|---|---|---|
| January-February 15 Periods | Reverse Engineering | Unit 6 Reverse Engineering  
Lesson 6.1 Visual Principles and Elements of Design Identification  
Lesson 6.2 Visual Analysis Automoblox  
Lesson 6.3 Functional Analysis Automoblox  
Lesson 6.4 Structural Analysis Automoblox  
Lesson 6.5 Product Reverse Engineering Presentation  
**Assessments:** Peer assessment, Conclusion Questions,  
Small Group/Class Discussion, Student responses, Journal Entry, Product Reverse Engineering Presentation,  
Unit Assessment |  
http://www.automoblox.com/engineeringchallenges.org  
engineeringchallenges.org  
engineeringchallenges.org  
http://whatsnext.blogs.cnn.com/2012/03/30/make-your-own-medical-device-why-not/?hpt=hpc3  
Wood Working Joints  
Flyingtigers  
Adhesives  
Thermoplastics  
Modern Marvels  
Torx  
Self-Taping Screws  
Wood Fasteners, Joinery, and Adhesives.ppt  
Metal Fasteners, Joining, and Adhesives.ppt |
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<table>
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<tr>
<th>Months</th>
<th>Periods</th>
<th>Topic</th>
<th>Resources</th>
</tr>
</thead>
</table>
| February-March | 26 Periods | Documentation                             | Unit 7 Documentation
Lesson 7.1 More Dimensioning
Lesson 7.2 Sectional Views
Lesson 7.3 Tolerances
Lesson 7.4 Assembly Models
Lesson 7.5 Engineering Documentation
Lesson 7.6 Design Brief (Apollo 13)
Lesson 7.7 Automoblox Product Enhancement
**Assessments:** Peer assessment, Conclusion Questions, Self-assessment, Correction of responses, Journal Entry, student responses, Design Brief (Apollo 13), Unit Assessment Items
| Reverse Engineering and Functional Analysis.ppt | Dimensioning Standards.ppt,
Assembly Constraints.ppt
Documentation.ppt |
|--------|-----------|--------------------------------------------|---------------------------------------------------------------------------|
| March 14 Periods | Advanced Computer Modeling | Unit 8 Advanced Computer Modeling
Lesson 8.1 Model a Button Maker
Lesson 8.2 Parametric Constraints
Lesson 8.2a Parametric Constraints Practice (Optional)
Lesson 8.3 Auxiliary Views
Lesson 8.4 Working Drawings (Button Maker)
**Assessments:** Conclusion Questions
Peer comparison, Peer assessment and then revision of tasks, Small Group/Class Discussion, Self-evaluation and/or peer evaluation, Journal Entry, Instant Challenge: Air Vehicle, Unit Assessment |
| Parametric Modeling.ppt,
Exploded CAD Assembly Models.ppt
Animating Assembly Models and Exporting Video.ppt (Optional) |
| April 16 Periods | Design Team | Unit 9 Design Team
Lesson 9.1 Product Lifecycle
Lesson 9.2 Design Ethics Design Brief |
| [http://www.plasticsindustry.org/](http://www.plasticsindustry.org/),
[http://www.recycle.net/Plastic/index.html](http://www.recycle.net/Plastic/index.html) |
| Lesson 9.4 Team Norms | http://www.recycle.net/Wood/products/ |
| Lesson 9.5 Product Research | http://www.recycledproducts.org/ |
| Small Group/Class Discussion, Unit Assessment | http://www.rubber.com/rubber/a/rb8050.html |
| | http://www.recycle.net/recycle/Rubber/index.html |
| | http://www.tyrerecyclingsuccess.com/ |
| | http://www.trivitro.com/ |
| | http://www.wausautile.com/ |
| | http://www.world-aluminium.org/ |
| May -June 20 Periods | Design Challenge | Design Challenges Rubric |
| Design Challenge | Lesson 10.1 Design Challenge | |
| Assessments: Self/Peer review, Conclusion Questions, Design Challenges, Small Group/Class Discussion, Journal Entry, End of Unit Assessment | |