N Smith's PLTW Engineering Design GT – Midterm Exam

Total Test Items: 90 questions (3 sections with 30 questions per section)

Material allowed during test: PLTW formula sheet & calculator

Contents

Unit 1 Design Process - Overview

Preface

Each time that you solve a problem, a design process is used. Some processes are as simple as realizing that you are hungry for something new and then designing a new combination of foods. Process can be as complex as designing a clean water solution for a village in an emerging nation. The design process (i.e., method to solve a problem or create a new product) is a cornerstone of all engineering professions.

This lesson provides a foundation for engineering knowledge and professional practices that will be used through this and other pathway to engineering courses and throughout a student's career. Students will develop skills such as concept sketching, setting up, and maintaining an engineering notebook and portfolio.

Engineering is a professional practice that has evolved through centuries of experience. Learning concepts and practicing skills in this course will provide a foundation for a lifelong engineering career.

Understandings, Knowledge and Skills

Understandings	**Knowledge and Skills**
An engineering design process involves a characteristic set of practices and steps.	• Identify and define the terminology used in engineering design and development. • Identify the steps in an engineering design process and summarize the activities involved in each step of the process. • Complete a design project utilizing all steps of a design process, and find a solution that meets specific design requirements.
Research derived from a variety of sources (including subject matter experts) is used to facilitate effective development and evaluation of a design problem and a successful solution to the problem.	• Utilize research tools and resources (such as the Internet; media centers; market research; professional journals; printed, electronic, and multimedia resources; etc.) to gather and interpret information to develop an effective design brief.
A problem and the requirements for a successful solution to the problem should be clearly communicated and justified.	• 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.
Brainstorming may take many forms and is used to generate a large number of innovative, creative ideas in a short time.	• Generate and document multiple ideas or solution paths to a problem through brainstorming.
A solution path is selected and justified by evaluating and comparing competing design	• Clearly justify and validate a selected solution path.

solutions based on jointly developed and agreed-upon design criteria and constraints.	
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.	• Construct a testable prototype of a problem solution.
Problem solutions are optimized through evaluation and reflection and should be clearly communicated.	• Describe the design process used in the solution of a particular problem and reflect on all steps of the design process. • Justify and validate a problem solution. • Identify limitations in the design process and the problem solution and recommend possible improvements or caveats.
The scientific method guides the testing and evaluation of prototypes of a problem solution.	• Analyze the performance of a design during testing and judge the solution as viable or non-viable with respect to meeting the design requirements.
Geometric shapes and forms are described and differentiated by their characteristic features.	• Explain the concept of proportion and how it relates to freehand sketching.
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.	• Generate non-technical concept sketches to represent objects or convey design ideas.
Technical professionals clearly and accurately document and report their work using technical writing practice in multiple forms.	• Organize and express thoughts and information in a clear and concise manner. • Adjust voice and writing style to align with audience and purpose. • Support design ideas using a variety of convincing evidence. • 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. • Document information sources using appropriate formats.
Specific oral communication techniques are used to effectively convey information and communicate with an audience.	• Deliver organized oral presentations of work tailored to the audience. • Establish objectives for the presentation that are appropriate for the audience. • Facilitate engaging and purposeful dialog with the audience.
Sketches, drawings, and images are used to record and convey specific types of information depending upon the audience and the purpose of the communication.	• Create drawings or diagrams as representations of objects, ideas, events, or systems. • Select and utilize technology (software and hardware) to create high impact visual aids.

	• Use presentation software effectively to support oral presentations.
Engineering has a global impact on society and the environment.	• Define and differentiate invention and innovation. • Assess the development of an engineered product and discuss its impact on society and the environment. • Identify and discuss a Grand Challenge for Engineering (as identified by the National Academy of Engineering) and its potential impact on society and the environment.
Engineering consists of a variety of specialist sub-fields, with each contributing in different ways to the design and development of solutions to different types of problems.	• Identify and differentiate between mechanical, electrical, civil, and chemical engineering fields. • Describe the contributions of engineers from different engineering fields in the design and development of a product, system, or technology. • Differentiate between the work of an engineer and the work of a scientist.
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.	• Demonstrate positive team behaviors and contribute to a positive team dynamic.

Essential Questions (Unit-Specific)

1. How might we create the best possible solution to a problem?
2. What is the most effective way to generate potential solutions to a problem? How many alternate solutions should you generate?
3. What are the most pressing engineering/technical problems of our time?
4. What is an engineer? What types of work do engineers do?

Key Term	Definition
Assess	To thoroughly and methodically analyze accomplishment against specific goals and criteria.
Assessment	An evaluation technique for technology that requires analyzing benefits and risks, understanding the trade-offs, and then determining the best action to take in order to ensure that the desired positive outcomes outweigh the negative consequences. Techniques used to analyze accomplishments against specific goals and criteria. Examples of assessments include tests, surveys, observations, and self-assessment.
Brainstorm	A group technique for solving problems, generating ideas, stimulating creative thinking, etc. by unrestrained spontaneous participation in discussion.
Client	A person using the services of a professional person or organization.
Creativity	The ability to make or bring a new concept or idea into existence; marked by the ability or power to create.
Criteria	A means of judging. A standard, rule, or test by which something can be judged.
Constraint	1. A limit to a design process. Constraints may be such things as appearance, funding, space, materials, and human capabilities. 2. A limitation or restriction.

Design	1. An iterative decision-making process that produces plans by which resources are converted into products or systems that meet human needs and wants or solve problems. 2. A plan or drawing produced to show the look and function or workings of something before it is built or made. 3. A decorative pattern.
Design Brief	A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage thinking of all aspects of a problem before attempting a solution.
Design Process	A systematic problem-solving strategy, with criteria and constraints, used to develop many possible solutions to solve a problem or satisfy human needs and wants and to winnow (narrow) down the possible solutions to one final choice.
Design Statement	A part of a design brief that challenges the designer, describes what a design solution should do without describing how to solve the problem, and identifies the degree to which the solution must be executed.
Designer	A person who designs any of a variety of things. This usually implies the task of creating drawings or in some ways uses visual cues to organize his or her work.
Engineer	A person who is trained in and uses technological and scientific knowledge to solve practical problems.
Engineering Notebook	A book in which an engineer will formally document, in chronological order, all of his/her work that is associated with a specific design project.
Innovation	An improvement of an existing technological product, system, or method of doing something.
Invention	A new product, system, or process that has never existed before, created by study and experimentation.
Iterative	A process that repeats a series of steps over and over until the desired outcome is obtained.
Justifiable	Capable of being shown as reasonable or merited according to accepted standards.
Piling-on	An idea that produces a similar idea or an enhanced idea.
Problem Identification	The recognition of an unwelcome or harmful matter needing to be dealt with.
Product	A tangible artifact produced by means of either human or mechanical work, or by biological or chemical process.
Prototype	A full-scale working model used to test a design concept by making actual observations and necessary adjustments.
Research	The systematic study of materials and sources in order to establish facts and reach new conclusions.
Valid	Well-founded on evidence and corresponds accurately to the real world.

1.3 Engineering Notebook –

A. *formally document, in chronological order, all of his/her work that is associated with a specific design project*
B. Someone unfamiliar with work could take over project without additional information
C. recognized as a *legal document* that is used in patent activities

- Discovering the problem
- Research
- Sketches with labels and descriptions
- Brainstorming
- Calculations
- Your daily thoughts and ideas
- Pictures
- Expert input (names, positions, contact info, details of conversations)
- Work session and meeting summaries
- Test procedures, results, and conclusions
- Digital technical drawings
- Design modifications

D. CONTENTS

E. SECTIONS

a. Title Page

b. Table of Contents

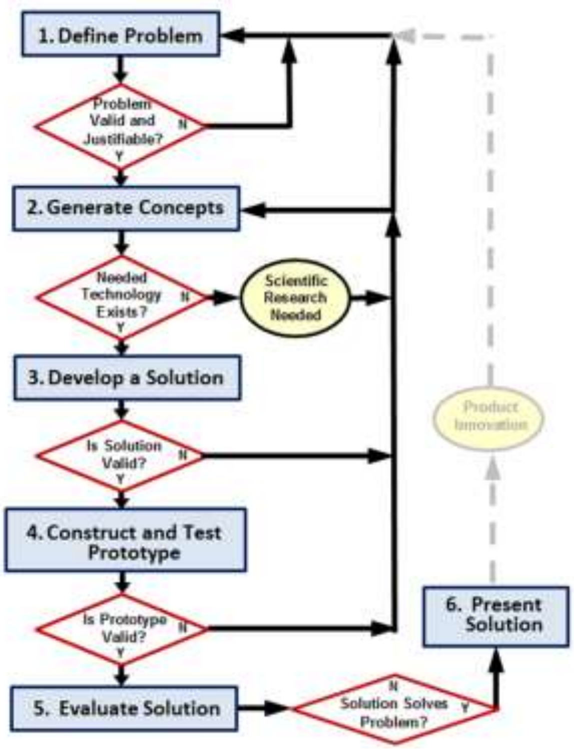
c. General Chronological Entries

d. References

e. Business/Expert Contacts

1.4 Brainstorming

1.5 Design Process *A design process is a systematic problem-solving strategy, with criteria and constraints, used to develop many possible solutions to solve or satisfy human needs or wants and to narrow down the possible solutions to one final choice.*



- Iterative
  - a process that repeats a series of steps over and over until the desired outcome is obtained

<u>1 Define the Problem</u> :

Identify a problem

Validate the problem

Who says it is a problem?

Needs and wants

Prior solutions

Justify the problem

Is the problem worth solving?

Create design requirements (specifications)

Criteria and constraints

***Design Brief* (Client / End User / Target Consumer, Problem Statement, Design Statement, Constraints)**

2. Generate Concepts:

Research
Brainstorm possible solutions
Consider additional design goals
Apply STEM principles
Select an approach

Decision Matrix

3. Develop a Solution

Create detailed design solution
Justify the solution path

Technical Drawings

4. Construct and Test Prototype

Construct a testable prototype
Plan prototype testing
Performance
Usability
Durability
Test prototype
collect test data
analyze test data

Test Report

5. Evaluate the solution

Evaluate solution effectiveness
Reflect on design
Recommend improvements
Optimize/Redesign the solution
[Return to prior design process steps, if necessary]
Revise design documents

Project Recommendations

6. Present the Solution

Document the project ***Project Portfolio***
Communicate the project ***Formal Presentation***

1.6 Engineering Disciplines

- **ENGINEERS – Research, Develop, Design, Supervise, Manage**
  - **Chemical**
    - **New fuels for rockets, reactors, and booster propulsion**
    - **Medicines, vaccines, serum, and plasma**
    - **Plastics, synthetics and textiles**
  - **Civil**

Space satellites	**Launch facilities**
Offshore structures	**Bridges**
Buildings	**Highways**
Transit systems	**Dams**

Airports	**Irrigation projects**
Collection and treatment for wastewater	**Treatment and distribution facilities for water**
Tunnels	

- **Electrical**
  - **Large electrical systems**
  - **Motors and generators**
  - **Electrical circuits in Buildings**
  - **Power transmission systems**
  - **Electrical generation plants**
- **Mechanical**
  - **Apply the principles of mechanics and energy to the design of machines and devices**
  - **Most often associated with devices that move but includes thermal designs as well as HVAC**
  - **Vibration analysis**
  - **Lubrication**
  - **Gears and bearing**

1.9 Research

- **Primary Research**
  - **Generating original information**
- **Secondary Research**
  - **Gathering information that has already been generated**
  - **Evaluate information – Authority, reliability, bias and currency**

Unit 2 Technical Sketching and Drawing - Overview

Preface

It is often said that a picture is worth a thousand words. This proverb is very true when communicating ideas to solve problems. To properly communicate technical information about objects that must be manufactured, fluency in the universal language of technical drawing is required. One of the first steps to learning this language is developing the ability to sketch.

Visualizing, communicating, exploring, and documenting ideas occur throughout the process of design. The process begins when a client and an engineer meet for the first time to define a problem; when research requires field measurements to be taken so that a scenario can be replicated; when an idea occurs during lunch and must be quickly recorded on a napkin before it is lost; when teams of people feed off each other's ideas and brainstorm possible solutions; when an engineer works out the details of a design solution so that it can be prototyped and tested; and when a solution has been proven to work and must be documented for reproduction.

Technical sketching differs from technical drawing: technical sketches are made with a pencil, paper, and an idea, while technical drawing advances a sketch to follow specific technical drawing guidelines that employ the use of tools, such as isometric graph paper and the aid of a computer. Likewise, technical sketching differs from artistic sketching. Technical sketches follow the same standards that govern the development of technical drawings except the sketches are done freehand.

As they advance in their experiences and skills through the course, students will learn basic rules of technical sketching in this lesson and will learn the drawing standards that apply. The understanding of technical sketching is critical for designers when effectively conveying their ideas about a product. Sketching is the beginning stage of product development. Students will learn how to sketch isometric, oblique, perspective, and multi-view sketches of various objects.

Understandings, Knowledge and Skills

Understandings	**Knowledge and Skills**
Brainstorming may take many forms and is used to generate a large number of innovative, creative ideas in a short time.	• Generate and document multiple ideas or solution paths to a problem through brainstorming.
Two- and three-dimensional objects share visual relationships which allow interpretation of one perspective from the other.	• Identify flat patterns (nets) that fold into geometric solid forms.
Geometric shapes and forms are described and differentiated by their characteristic features.	• Explain the concept of proportion and how it relates to freehand sketching.
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.	• Identify and define technical drawing representations including isometric, orthographic projection, oblique, perspective, auxiliary, and section views. • Identify the proper use of each technical drawing representation including isometric, orthographic projection, oblique, perspective, auxiliary, and section views.
Technical drawings convey information according to an established set of drawing practices which allow for detailed and universal interpretation of the drawing.	• Identify line types (including construction lines, object lines, hidden lines, cutting plane lines, section 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. • 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. • Apply tonal shading to enhance the appearance of a pictorial sketch and create a more realistic appearance of a sketched object.
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.	• Hand sketch 1-point and 2-point perspective pictorial views of a simple object or part given the object, a detailed verbal description or the object, a pictorial view of the object, and/or a set of orthographic projections. • 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 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 an isometric view of the object.
Sketches, drawings, and images are used to record and convey specific types of information depending upon the audience and the purpose of the communication.	• Create drawings or diagrams as representations of objects, ideas, events, or systems.

Essential Questions (Unit-Specific)

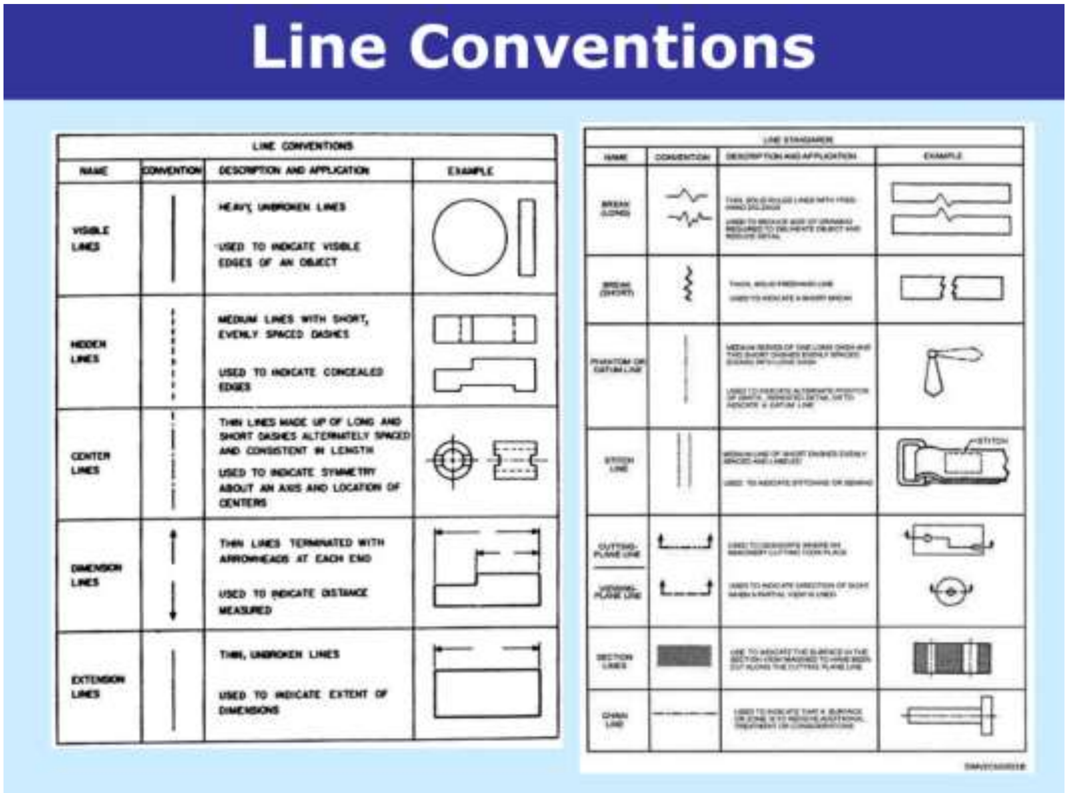
1. How can we clearly convey the intent of a design to someone unfamiliar with the original problem or the solution?
2. How is technical drawing similar to and different from artistic drawing?
3. What can cause a technical drawing to be inadequate or misinterpreted?

Key Term	Definition
Cabinet Pictorial	Oblique pictorial where depth is represented as half scale compared to the height and width scale.
Cavalier Pictorial	Oblique pictorial where height, width, and depth are represented at full scale.
Center Line	A line which defines the center of arcs, circles, or symmetrical parts.
Construction Line	lightly drawn lines to guide drawing other lines and shapes.
Depth	The measurement associated with an object's front-to-back dimension or extent of something from side to side.
Dimension	A measurable extent, such as the three principal dimensions of an object is width, height, and depth.
Dimension Line	A line which represents distance.
Documentation	1. The documents that are required for something or that give evidence or proof of something. 2. Drawings or printed information that contain instructions for assembling, installing, operating, and servicing.
Drawing	A formal graphical representation of an object containing information based on the drawing type.
Edge	The line along which two surfaces of a solid meet.
Ellipse	A regular oval shape, traced by a point moving in a plane so that the sum of its distances from two other points is constant, or resulting when a cone is cut by an oblique plane which does not intersect the base.
Extension Line	Line which represents where a dimension starts and stops.
Freehand	Sketching which is done manually without the aid of instruments such as rulers.
Grid	A network of lines that cross each other to form a series of squares or rectangles.
Height	The measurement associated with an object's top-to-bottom dimension.
Hidden Line	A line type that represents an edge that is not directly visible.
Isometric Sketch	A form of pictorial sketch in which all three drawing axes form equal angles of 120 degrees with the plane of projection.
Leader Line	Line which indicates dimensions of arcs, circles and detail.
Line	1. A long thin mark on a surface. 2. A continuous extent of length, straight or curved, without breadth or thickness; the trace of a moving point. 3. Long, narrow mark or band.
Line Conventions	Standardization of lines used on technical drawings by line weight and style.

Line Weight	Also called line width. The thickness of a line, characterized as thick or thin.
Long-Break Line	A line which indicates that a very long objects with uniform detail is drawn foreshortened.
Manufacture	To make something, especially on a large scale using machinery.
Measurement	The process of using dimensions, quantity, or capacity by comparison with a standard in order to mark off, apportion, lay out, or establish dimensions.
Multi-View Drawing	A drawing which contains views of an object projected onto two or more orthographic planes.
Object Line	A heavy solid line used on a drawing to represent the outline of an object.
Oblique Sketch	A form of **pictorial in** which an object is represented as true width and height, but the depth can be any size and drawn at any angle.
Orthographic Projection	A method of representing three-dimensional objects on a plane having only length and breadth. Also referred to as Right Angle Projection.
Perspective Sketch	A form of pictorial sketch in which vanishing points are used to provide the depth and distortion that is seen with the human eye.
Pictorial Sketch	A sketch that shows an object's height, width, and depth in a single view.
Plane	A flat surface on which a straight line joining any two points would wholly lie.
Point	A location in space.
Profile	An outline of an object when viewed from one side.
Projection Line	An imaginary line that is used to locate or project the corners, edges, and features of a three-dimensional object onto an imaginary two-dimensional surface.
Projection Plane	An imaginary surface between the object and the observer on which the view of the object is projected and drawn.
Proportion	1. The relationship of one thing to another in size, amount, etc. 2. Size or weight relationships among structures or among elements in a single structure.
Scale	1. A straight-edged strip of rigid material marked at regular intervals that is used to measure distances. 2. A proportion between two sets of dimensions used to develop accurate, larger or smaller prototypes, or models.
Section Lines	Thin lines used in a section view to indicate where the cutting plane line has cut through material.
Shading	The representation of light and shade on a sketch or map.
Short-Break Line	Line which shows where part is broken to reveal detail behind the part or to shorten a long continuous part.
Shape	A two-dimensional contour that characterizes an object or area, in contrast to three-dimensional form.
Sketch	A rough representation of the main features of an object or scene and often made as a preliminary study.
Solid	A three-dimensional body or geometric figure.
Technical Working Drawing	A drawing that is used to show the material, size, and shape of a product for manufacturing purposes.
Three-Dimensional	Having the dimensions of height, width, and depth.
Tone	The general effect of color or of light and shade in a picture.
Two-Dimensional	Having the dimensions of height and width, height and depth, or width and depth only.
Vanishing Point	A vanishing point is a point in space, usually located on the horizon, where parallel edges of an object appear to converge.
View	Colloquial term for views of an object projected onto two or more orthographic planes in a multi-view drawing.

Width	The measurement associated with an object's side-to-side dimension.

2.1 Line conventions –



LINE CONVENTIONS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
VISIBLE LINES		HEAVY, UNBROKEN LINES USED TO INDICATE VISIBLE EDGES OF AN OBJECT	
HIDDEN LINES		MEDIUM LINES WITH SHORT, EVENLY SPACED DASHES USED TO INDICATE CONCEALED EDGES	
CENTER LINES		THIN LINES MADE UP OF LONG AND SHORT DASHES ALTERNATELY SPACED AND CONSISTENT IN LENGTH USED TO INDICATE SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS	
DIMENSION LINES		THIN LINES TERMINATED WITH ARROWHEADS AT EACH END USED TO INDICATE DISTANCE MEASURED	
EXTENSION LINES		THIN, UNBROKEN LINES USED TO INDICATE EXTENT OF DIMENSIONS	

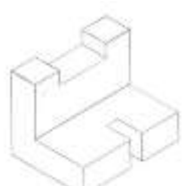
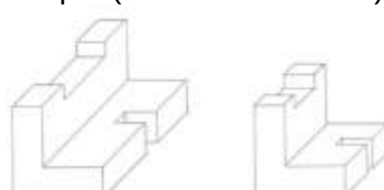
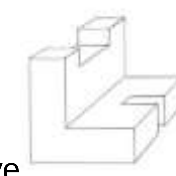
LINE STANDARDS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
BREAK (LONG)		[illegible]	
BREAK (SHORT)		[illegible]	
PHANTOM OR DATUM LINE		[illegible]	
STITCH LINE		[illegible]	STITCH
CUTTING-PLANE LINE		[illegible]	
VIEWING-PLANE LINE		[illegible]	
SECTION LINES		[illegible]	
CHAIN LINE		[illegible]	

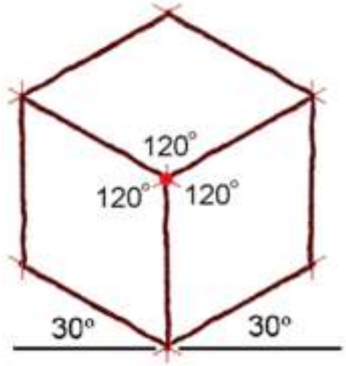
Precedence of Lines

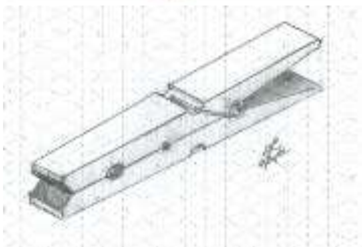
- Complex object sketches may require different line types to overlap
- Line precedence must be used
- Rules that govern line precedence in sketches and technical drawings
  - Object lines take precedence over hidden and center lines
  - Hidden lines take precedence over center lines
  - Cutting plane lines take precedence over all others

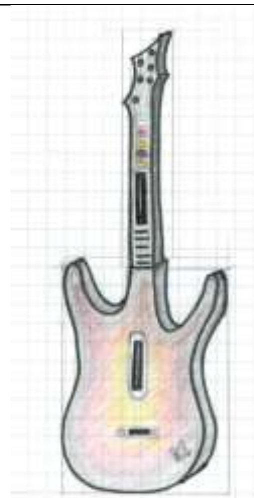
2.1 Pictorials

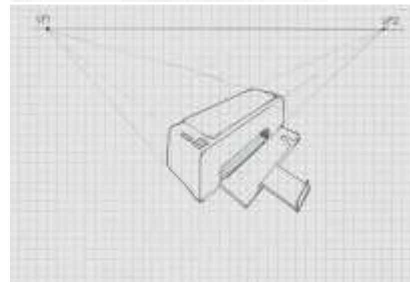
- 2D illustration of a 3D object
- Shows three faces of an object in one view
- Provides a realistic view of an object
- Three types:

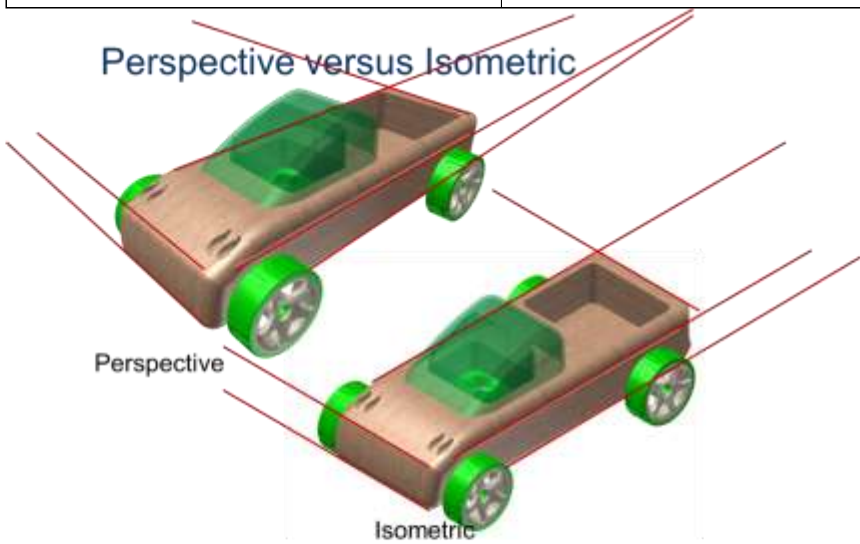
Isometric	Oblique (cavalier & cabinet)	
 *Isometric* means *equal measure*. Three adjacent faces on a cube will share a single point	 An *Oblique pictorial* starts with a straight-on view of one of the object's faces, which is often the front face	 Perspective most realistic three-dimensional view

- 

- 

- 





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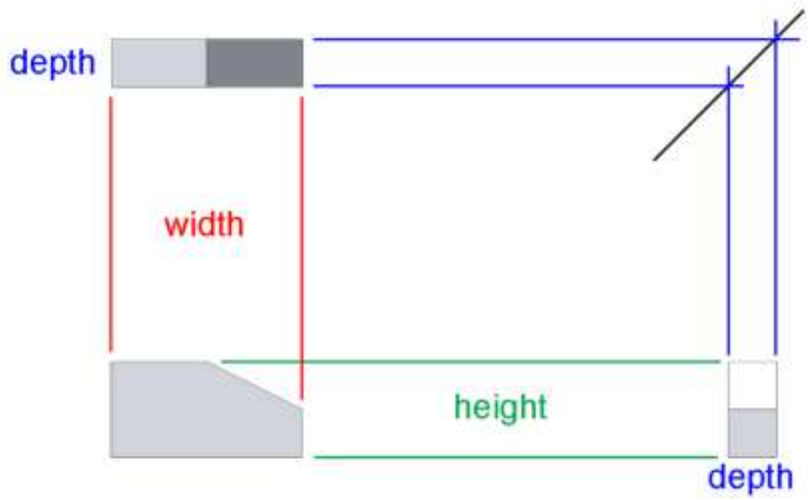
- **Multi-view or Orthographic**
    - Shows two or more two-dimensional views of a three-dimensional object.
    - Provides the shape description of an object.
    - When combined with dimensions, serves as the main form of communication between designers and manufacturers.
- how to select the front view
    - Most natural position or use
    - Shows best shape and characteristic contours
    - Longest dimensions
    - Fewest hidden lines
    - Most stable and natural position
- Orthographic projections share common dimensions
- A 45 degree **<u>mitre line</u>** can be used with construction lines to share information between right and top views

- 

Unit 3 Measurement and Statistics - Overview

Preface

The practice of measuring is older than recorded history. Every human civilization throughout history developed its own measuring tools and, along with them, its own measuring standards. It was through the establishment of measuring tools and standards that the Egyptians were able to build their giant pyramids and the Romans were able to build their roads and aqueducts. Shared understanding and communication established through standardization played a key role in their successful outcome. Standardization is what allows many people to work individually on parts that come together to form a finished product or system. Without measurement standards, manufactured parts would not be interchangeable and mass production could not exist. Measurement is so important that the founding fathers of the United States included it in the Constitution, giving Congress the power to set uniform standards for weights and measures. Today, the American National Standards Institute serves as the unifying force system for the measurement used in the United States. This lesson provides an introduction to measurement through the study of linear distance and angles.

Since the beginning of science, scientists have realized that laws of nature are not bound to the borders between kingdoms or countries, and that uniform standards of measure form the foundation for changing the secrets of the universe into human knowledge. In the midst of the French Revolution, scientists developed a new system of measurement that was simple, logical, and well-suited to the needs of both scientists and engineers. Since its inception 220 years ago, the metric system has spread throughout the industrialized world and is now the international standard for acquiring and communicating measurements.

In this lesson students will learn about measurement and statistics. They will apply what they have learned through

- Reading English and metric scales
- Converting measurements between U S Customary and SI units
- Performing precision measurement using dial calipers
- Applying correct dimensioning techniques to technical drawings
- Recording data with proper precision
- Performing basic statistical analysis
- Creating graphs of statistical information

Understandings, Knowledge and Skills

Understandings	Knowledge and Skills
An engineering design process involves a characteristic set of practices and steps.	• Identify and define the terminology used in engineering design and development. • Identify the steps in an engineering design process and summarize the activities involved in each step of the process. • Complete a design project utilizing all steps of a design process and find a solution that meets specific design requirements.
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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.	• Construct a testable prototype of a problem solution.
Problem solutions are optimized through evaluation and reflection and should be clearly communicated.	• Describe the design process used in the solution of a particular problem and reflect on all steps of the design process. • Identify limitations in the design process and the problem solution and recommend possible improvements or caveats.
The scientific method guides the testing and evaluation of prototypes of a problem solution.	• Analyze the performance of a design during testing and judge the solution as viable or non-viable with respect to meeting the design requirements.
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.	• Calculate statistics related to central tendency including mean, median, and mode. • 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. • Calculate statistics related to variation of data including (sample and population) standard deviation and range. • Distinguish between sample statistics and population statistics and know appropriate applications of each. • Use the Empirical Rule to interpret data and identify ranges of data that include 68 percent of the data, 95 percent of the data and 99.7 percent of the data.
Spreadsheet programs can be used to store, manipulate, represent, and analyze data.	• Use a spreadsheet program to store and manipulate raw data. • Use a spreadsheet program to perform calculations using formulas. • Use a spreadsheet program to create and display a histogram to represent a set of data.

	• Use function tools within a spreadsheet program to calculate statistics for a set of data including mean, median, mode, quartiles, range, and standard deviation.
Units and quantitative reasoning can guide mathematical manipulation and the solution of problems involving quantities.	• Use units to guide the solution to multi-step problems through dimensional analysis and choose and interpret units consistently in formulas. • Choose a level of precision and accuracy appropriate to limitations on measurement when reporting quantities. • Convert quantities between units in the SI and the US Customary measurement systems. • Convert between different units within the same measurement system including the SI and US Customary measurement systems.
Error is unavoidable when measuring physical properties, and a measurement is characterized by the precision and accuracy of the measurement.	• Define accuracy and precision in measurement. • Evaluate and compare the accuracy and precision of different measuring devices. • 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.
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.	• Identify and define technical drawing representations including isometric, orthographic projection, oblique, perspective, auxiliary, and section views.
Technical drawings convey information according to an established set of drawing practices which allow for detailed and universal interpretation of the drawing.	• Determine the minimum number and types of views necessary to fully detail a part. • Identify and correct errors and omissions in technical drawings including the line work, view selection, view orientation, appropriate scale, and annotations.
Dimensions, specific notes (such as hole and thread notes), and general notes (such as general tolerances) 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.	• Dimension orthographic projections and section views of simple objects or parts according to a set of dimensioning standards and accepted practices. • Identify and correctly apply chain dimensioning or datum dimensioning methods to a technical drawing. • Identify and correct errors and omissions in the dimensions applied in a technical drawing based on accepted practice and a set of dimensioning rules.
Hand sketching of multiple representations to fully and accurately detail simple objects or parts of objects is a technique used	• 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.

to convey visual and technical information about an object.	• 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. • Generate non-technical concept sketches to represent objects or convey design ideas.
Technical professionals clearly and accurately document and report their work using technical writing practice in multiple forms.	• Organize and express thoughts and information in a clear and concise manner. • Adjust voice and writing style to align with audience and purpose. • Support design ideas using a variety of convincing evidence. • 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.
Sketches, drawings, and images are used to record and convey specific types of information depending upon the audience and the purpose of the communication.	• Create drawings or diagrams as representations of objects, ideas, events, or systems.
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.	• Demonstrate positive team behaviors and contribute to a positive team dynamic.

Essential Questions (Unit-Specific)

1. How can statistical data and analysis be used to inform, justify, and validate a design or process?
2. If error is unavoidable in measurement, how can we indicate our confidence in the precision of a measurement we make?
3. What is dimensional analysis and how can it help solve problems involving quantities?
4. Why do engineers generally adhere to a set of dimensioning standards and guidelines?

Key Term	Definition
Accuracy	The degree of closeness of measurements of a quantity to the actual (or accepted) value.
Arrowheads	Arrowheads are used to indicate the end of a dimension line or leader.
Caliper	A measuring instrument having two adjustable jaws typically used to measure diameter or thickness.
Class Interval	A group of values that is used to analyze the distribution of data.
Convert	To change money, stocks, or units in which a quantity is expressed into others of a different kind.
Data	Facts and statistics used for reference or analysis.

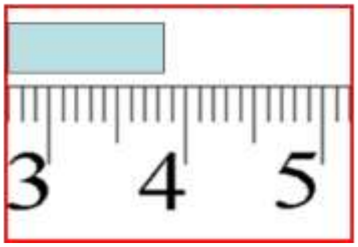
Data Set	A group of individual values or bits of information that are related in some way or have some common characteristic or attribute.
Dimension	A measurable extent, such as the three principal dimensions of an object as in width, height, and depth.
Dimension Lines	A line which represents distance.
Dot Plot	See line plot.
Frequency	The rate at which something occurs over a particular period or in a given sample.
Graph	A diagram showing the relation between variable quantities, typically of two variables measured along a pair of lines at right angles.
Histogram	A graph of vertical bars representing the frequency distribution of a set of data.
International Organization for Standardization (ISO)	A non-governmental global organization whose principal activity is the development of technical standards through consensus.
International System of Units (SI)	An international system of units of measurement consisting of seven base units.
Line Plot	A method of visually displaying a distribution of data values where each data value is shown as a dot or mark above a number line. Also known as a dot plot.
Mean	A measure of center in a set of numerical data, computed by adding the values in a list and then dividing by the number of values in the list.
Measure	To determine the size, amount, or degree of an object by comparison with a standard unit.
Median	A measure of center in a set of numerical data. The median of a list of values is the value appearing at the center of a sorted version of the list – or the mean of the two central values if the list contains an even number of values.
Mode	The value that occurs most frequently in a given data set.
Normal Distribution	A function that represents the distribution of variables as a symmetrical bell-shaped graph.
Numeric Constraint	A number value or algebraic equation that is used to control the size or location of a geometric figure.
Precision	The degree to which repeated measurements show the same result.
Scale	1. A straight-edged strip of rigid material marked at regular intervals and used to measure distances. 2. A proportion between two sets of dimensions used in developing accurate, larger or smaller prototypes, or models of design ideas.
Scatter Plot	A graph in the coordinate plane representing a set of bivariate data.
Significant Digits	The digits in a decimal number that carry meaning contributing to the precision or accuracy of the quantity.
Standard Deviation	The distance of a value in a population (or sample) from the mean value of the population (or sample).
Statistics	Collection of methods for planning experiments, obtaining data, organizing, summarizing, presenting, analyzing, interpreting, and drawing conclusions based on data.
Unit	A standard quantity in terms of which other quantities may be expressed.
US Customary Measurement System	System of measurement used in the United States.
Variation	A change or slight difference in condition, amount, or level.

3.1a Measurement SI

- The International System of Units (SI) is a system of units of measurement is also known as the metric system and uses powers of 10

- A measurement always includes a value, units and uncertainty
- Scientists and engineers often use significant digits to indicate the uncertainty of a measurement
- Significant digits are digits in a decimal number that carry meaning indicating the certainty of the value
- All digits you record for a measurement are considered significant

Best Estimate = 3.84 cm



3.1b Measurement US Customary

Precision and Accuracy

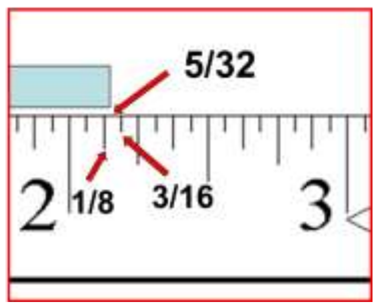
- Precision (repeatability) = The degree to which repeated measurements show the same result
- Accuracy = The degree of closeness of measurements of a quantity to the actual (or accepted) value

Measurement: Using a Fractional Scale

- How long is the rectangle?

What is the midpoint of 2 1/8 and 2 3/16?

$2\frac{5}{32}$ in.



3.2 Unit Conversion

Conversion of Units – SI System

Example: Convert 103.2 cm to meters

$$103.2\ \cancel{cm} \cdot \left(\frac{10^{-2}\ m}{1\ \cancel{cm}}\right) = 1.032\ m$$

Desired Unit

Given Unit

Powers of 10

$103.2 \cdot 10^{-2}$ m

$10.32 \cdot 10^{-1}$ m

$1.032 \cdot 10^{0}$ m

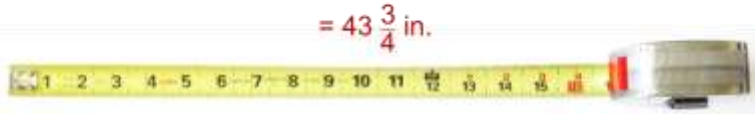
1.032 m

Power of 10	Prefix	Abbreviation
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p

$$3\text{ ft} - 7\frac{3}{4}\text{ in.} = 3\ \cancel{ft} \cdot \left(\frac{12\text{ in.}}{1\ \cancel{ft}}\right) + 7\frac{3}{4}\text{ in.}$$

$$= 36\text{ in.} + 7\frac{3}{4}\text{ in.}$$

$$= 43\frac{3}{4}\text{ in.}$$



Unit Conversions
Between U S and SI Systems

Use equivalency of units to create conversion factors

- Inches to centimeters:

Length	
1 m	= 3.28 ft
1 km	= 0.621 mi
1 in.	= 2.54 cm
1 mi	= 5280 ft
1 yd	= 3 ft

Desired Unit

$$\frac{2.54\text{ cm}}{1\text{ in.}}$$

Given Unit

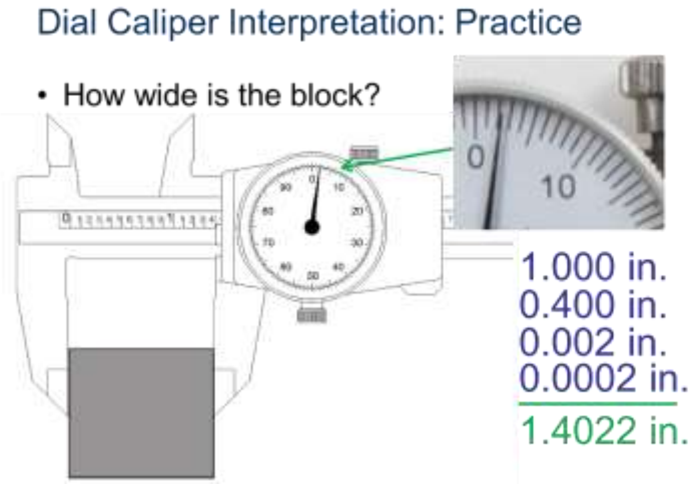
Equal to 1

1 L = 0.264 gal

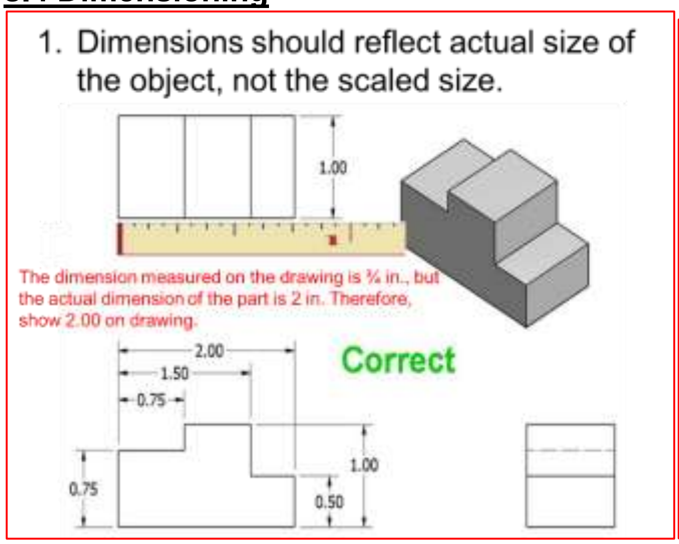
$$\frac{55\ \cancel{mi}}{\cancel{gal}} \cdot \left(\frac{0.264\ \cancel{gal}}{L}\right) \cdot \left(\frac{1\text{ km}}{0.621\ \cancel{mi}}\right) = 23\text{ km/L}$$

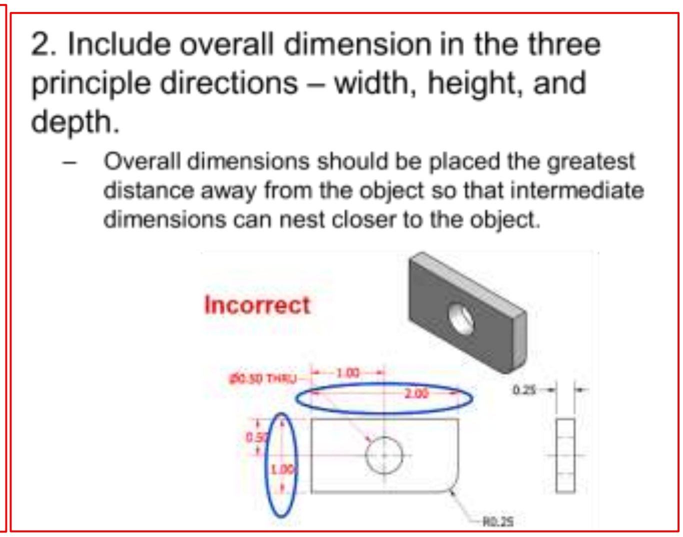
1 km = 0.621 mi

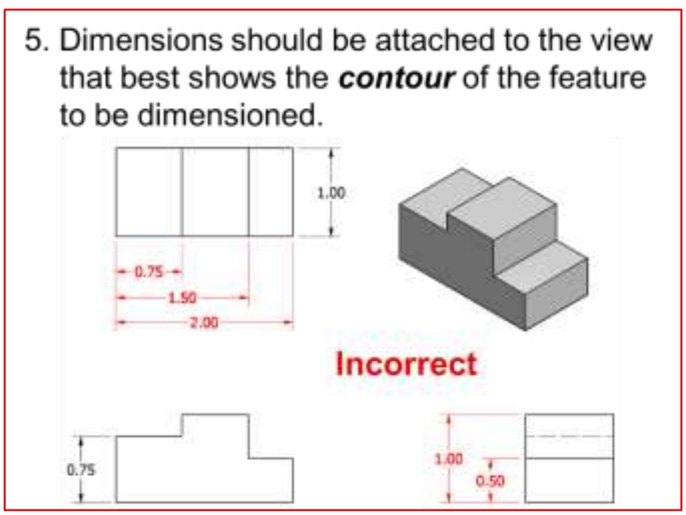
3.3 Dial Calipers

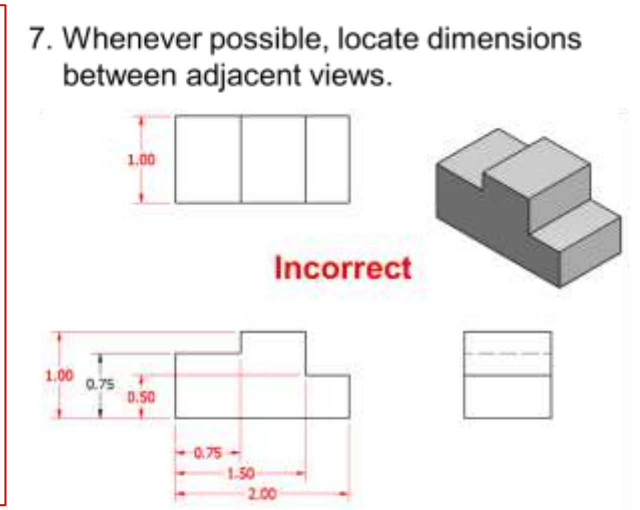


3.4 Dimensioning



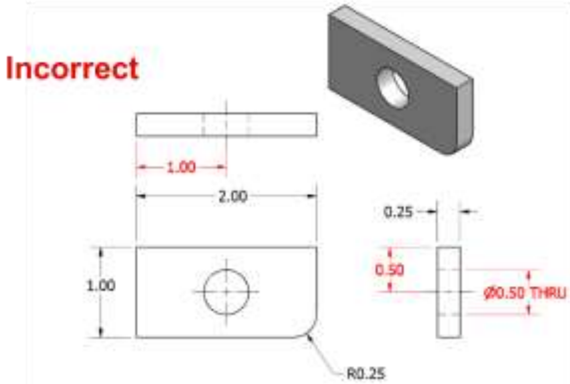






15. Holes should be located and sized in the view that shows the feature as a circle.

Incorrect



3.5 Statistics

Summary Statistics

Central Tendency

- "Center" of a distribution
  - Mean, median, mode

Variation

- Spread of values around the center
  - Range, standard deviation, interquartile range

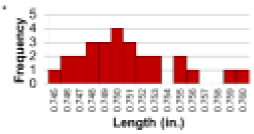
Distribution

- Summary of the frequency of values
  - Frequency tables, histograms, normal distribution

Histogram

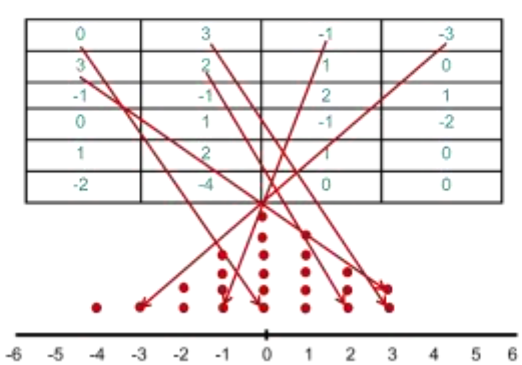
Distribution

- A histogram is a common data distribution chart that is used to show the frequency with which specific values, or values within ranges, occur in a set of data.
- An engineer might use a histogram to show the variation of a dimension that exists among a group of parts that are intended to be identical.



Dot Plot

Distribution



3.6 Inferential Statistics

Research and Statistics

- Often we do not have information on the entire population of interest
- Population versus sample
  - Population = all members of a group
- Sample = part of a population
- **Inferential statistics** involves *estimating* or *forecasting* an outcome based on an incomplete set of data
  - use **sample** statistics

Population versus Sample Standard Deviation

- Population Standard Deviation
  - The measure of the spread of data within a population.
  - Used when you have a data value for every member of the entire population of interest.
- Sample Standard Deviation
  - An estimate of the spread of data within a larger population.
  - Used when you do **not** have a data value for every member of the entire population of interest.
  - Uses a subset (sample) of the data to generalize the results to the larger population.

Given the ACT score of every student in your class, use the **population** standard deviation formula to find the standard deviation of ACT scores in the class.

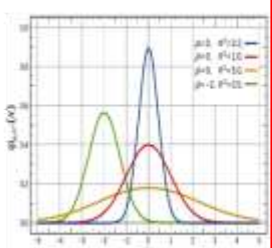
Given the ACT scores of every student in your class, use the **sample** standard deviation formula to estimate the standard deviation of the ACT scores of all students at your school.

Normal Distribution

Distribution

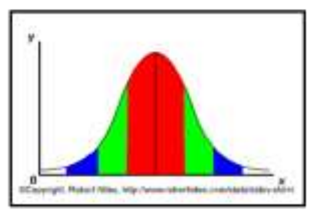
"Is the data distribution normal?"

- Translation: Is the histogram/dot plot bell-shaped?
  - Does the greatest frequency of the data values occur at about the mean value?
  - Does the curve decrease on both sides away from the mean?
  - Is the curve symmetric about the mean?



Empirical Rule

If the data are normally distributed:



- **68%** of the observations fall within **1 standard deviation** of the **mean**.
- **95%** of the observations fall within **2 standard deviations** of the **mean**.
- **99.7%** of the observations fall within **3 standard deviations** of the **mean**.

Assume that a statistical analysis resulted in the following:

Mean = $\bar{x}$ = 2.35 ft.

Sample standard deviation = s = 0.76 ft

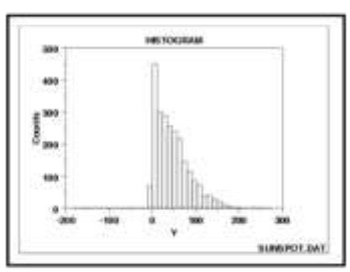
- Predict the range of travel distances within which **95%** of cotton balls would fall

$\bar{x} \pm 2s$: 2.35 – 2(0.76) = 0.83 ft

2.35 + 2(0.76) = 3.87ft

Prediction: Approximately 95% of the launches will result in a travel distance between 0.83 ft and 3.86 ft.

What if the data is not symmetric?



Histogram Interpretation: Skewed (Non-Normal) Right

Unit 4 Modeling Skills - Overview

Preface

Effectively applying a design process often involves a wide variety of modeling activities. During the initial phases of the design process, defining the problem and generating concepts brainstorming is often accompanied by concept modeling. Lists and mind maps are often used to document design ideas and concepts. As research is performed, graphical modeling and/or mathematical modeling can be used to represent gathered information. Graphical modeling can involve representing information in the form of charts, graphs, maps, or geometric figures. Mathematical modeling involves representing a phenomenon or behavior with an equation or a geometric representation. For instance, an environmental engineer who is developing a solution to handle and dispose of solid waste in an area for the next 20 years may wish to represent the volume of solid waste produced over the previous 20 years with a mathematical equation. The equation will allow the engineer to predict the waste production in the future.

Design ideas and alternatives are often modeled graphically. If the design solution involves a physical object, designers typically use sketching and drawing to represent design ideas. If the problem solution involves the design of systems or processes, charts, graphs, and maps may be employed to represent the proposed designs. Early in the design process, ideas are often sketched on paper for future refinement. As ideas are formalized, greater accuracy is required. This refinement may involve converting sketches to computer models and formal technical drawings.

Today, computers and software applications are tools often used in the solution of engineering problems. Computer modeling is frequently used to represent, analyze, document, and assess a design idea. Three-dimensional computer modeling of products allows designers to virtually create, manipulate, and test products and system prior to building and testing a physical model. A physical model is often desirable because it allows hands-on manipulation and testing of a product or system in its intended operating environment. However, computer modeling is especially helpful when building a physical model is difficult or expensive. For instance, in the case of large commercial and industrial buildings, which must be designed to carry a variety of load conditions, computer modeling provides an inexpensive means through which to model and test the load carrying capacity of the building structure. Or, if a chemical process is part of the design solution, a computer program can simulate the proposed process and efficiently allow adjustment of design factors (such as concentrations, temperature, and pressure) to hone in on a precise solution before large-scale physical testing is performed.

If the design process is applied to the design of a consumer product, it is almost always necessary to build a physical model for a variety of reasons. A physical model provides a representation of the design to which people can relate. They can see the design intent. And, when the physical model is built to the design specifications, the product can be used for the intended purpose and tested. In addition, physical models help potential consumers and investors understand the product and can improve the chances of gaining financial support and customers.

The testing phase of the design process can also involve a variety of modeling techniques. Before testing can be performed, the test(s) itself must be designed, which can require the use of concept, graphical, mathematical, computer and/or physical models. Physical models of the design are often used to allow testing of the actual product. Computer modeling is used to represent the product and test a design when physical testing is not feasible or is prohibitively expensive. The data gathered during the testing phase of the design process is often represented with graphical and/or mathematical modeling.

In this lesson students will learn how to create a product from conception to reality and will employ a variety of modeling techniques. They will do this by applying the design process steps first-hand in the creation of their product. Students will live the life of a product designer and create a solution to a problem that exists for a company.

Understandings

Students will understand that …

- **U1 –** Technical professionals use a variety of models to represent systems, components, processes and other designs including graphical, computer, physical, and mathematical models.
- **U2 –** Computer aided drafting and design (CAD) software packages facilitate the creation of virtual 3D computer models of parts and assemblies.
- **U3 –** 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.
- **U4 –** Technical professionals clearly and accurayely document and report their work using technical writing practice in multiple forms.
- **U5 –** An equation is a statement of equality between two quantities that can be used to describe real phenomenon and solve problems.
- **U6 –** Solving mathematical equations and inequalities involves a logical process of reasoning and can be accomplished using a variety of strategies and technological tools.
- **U7 –** 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.

Knowledge and Skills

KNOWLEDGE: Students will …

- **K1 –**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.
- **K2 –** 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.
- **K3 –** Differentiate between additive and subtractive 3d solid modeling methods

SKILLS: Students will …

- **S1** – develop and/or use graphical, computer, physical and mathematical models as appropriate to represent or solve problems.
- **S2 –** Fabricate a simple object from technical drawings that may include an isometric view and orthographic projections. U1, U5
- **S3 –** Create three-dimensional solid models of parts within CAD from sketches or dimensioned drawings using appropriate geometric and dimensional constraints. U1, U2
- **S4 –** Generate CAD multi-view technical drawings, including orthographic projections and pictorial views, as necessary, showing appropriate scale, appropriate view selection, and correct view orientation to fully describe a simple part according to standard engineering practice. U1, U2
- **S5 –** Construct a testable prototype of a problem solution. U1, U3
- **S6 –** Analyze the performance of a design during testing and judge the solution as viable or non-viable with respect to meeting the design requirements. U3
- **S7 –** Create a set of working drawings to detail a design project. U1, U2
- **S8 –** Organize and express thoughts and information in a clear and concise manner. U4
- **S9 –** Utilize project portfolios to present and justify design projects. U4
- **S10 –** Use a spreadsheet program to graph bi-variate data and determine an appropriate mathematical model using regression analysis. U1, U7
- **S11 –** Construct a scatter plot to display bi-variate data, investigate patterns of association, and represent the association with a mathematical model (linear equation) when appropriate. U1, U5
- **S12 –** Solve equations for unknown quantities by determining appropriate substitutions for variables and manipulating the equations. U6
- **S13 –** Use function notation to evaluate a function for inputs in its domain and interpret statements that use function notation in terms of a context. U7
- **S14 –** Build a function that describes a relationship between two quantities given a graph, a description of a relationship, or two input-output pairs. U1, U7
- **S15 –** Interpret a function to solve problems in the context of the data. U6, U7
- **S16 –** Interpret the slope (rate of change) and the intercept (constant term) of a linear function in the context of data. U1, U5
- **S17 –** Compare the efficiency of the modeling method of an object using different combinations of additive and subtractive methods. U2

Essential Questions

- **EQ1 –** 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?

- **EQ2 –** Did you use every possible type of model during the design and construction of your puzzle cube? Describe each model that you used?
- **EQ3 –** How reliable is a mathematical model?

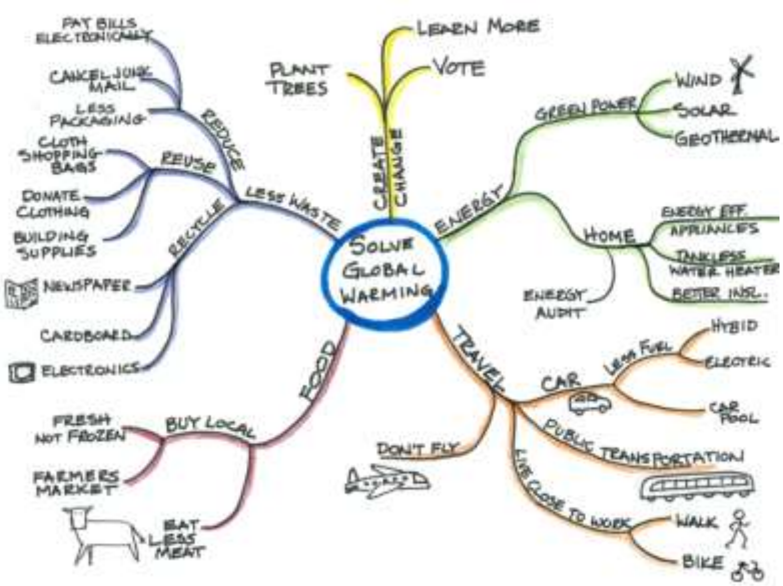
Key Term	Definition
Annotate	To add explanatory notes to a drawing.
Assembly	A group of machined or handmade parts that fit together to form a self-contained unit.
Assembly Drawing	A drawing that shows parts of an item when assembled.
Cartesian Coordinate System	A rectangular coordinate system created by three mutually perpendicular coordinate axes, commonly labeled X, Y, and Z.
Component	A part or element of a larger whole.
Computer-Aided Design or Computer-Aided Drafting (CAD)	1. When used in the context of design: the use of a computer to assist in the process of designing a part, circuit, building, etc. 2. When used in the context of drafting: the use of a computer to assist in the process of creating, storing, retrieving, modifying, plotting, and communicating a technical drawing.
Degree of Freedom	The variables by which an object can move. In assemblies, an object floating free in space with no constraints to another object can be moved along three axes of translation and around three axes of rotation. Such a body is said to have six degrees of freedom.
Design Brief	A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage thinking of all aspects of a problem before attempting a solution.
Design Statement	A part of a design brief that challenges the designer, describes what a design solution should do without describing how to solve the problem, and identifies the degree to which the solution must be executed.
Domain	The set of input values of a function.
Extrusion	1. A manufacturing process that forces material through a shaped opening. 2. A modeling process that creates a three-dimensional form by defining a closed two-dimensional shape and a length.
Function	1. A relationship from one set (called the domain) to another set (called the range) that assigns to each element of the domain exactly one element of the range. 2. The action or actions that an item is designed to perform.
Geometric Constraint	Constant, non-numerical relationships between the parts of a geometric figure. Examples include parallelism, perpendicularity, and concentricity.
Marketing	The promotion and selling of products or services.
Mathematical Modeling	The process of choosing and using appropriate mathematics and statistics to analyze empirical situations, to understand them better, and to improve decisions.
Mock-up	A model or replica of a machine or structure for instructional or experimental purposes. Also referred to as an Appearance Model.
Model	A visual, mathematical, or three-dimensional representation in detail of an object or design, often smaller than the original.
Origin	A fixed point from which coordinates are measured.
Packaging	Materials used to wrap or protect goods.
Pattern	A repeated decorative design.
Physical Model	A physical representation of an object. Prototypes and appearance models are physical models.

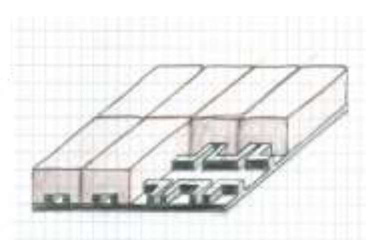
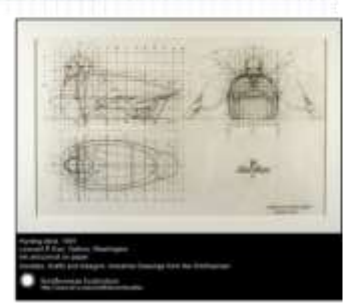
Plane	A flat surface on which a straight line joining any two points would wholly lie.
Portfolio	A collection of documents selected for a particular purpose which may contain reflection on the contents of the documents or the related purpose. Varieties of portfolio types exist and are used for different purposes (e.g., project portfolio, course portfolio, longitudinal or growth portfolio, showcase portfolio).
Prototype	A full-scale working model used to test and improve a design concept by making actual observations and necessary adjustments.
Range	The set of output values of a function.
Revolution	Creating a 3D solid or surface by revolving a 2D shape about an axis.
Rotation	Turning around an axis or center point.
Round	A rounded exterior blend between two surfaces.
Scale Model	An enlarged or reduced representation of an object that is usually intended for study purposes.
Scoring	Making an impression or crease in a box blank to facilitate bending, folding, or tearing.
Solid	A three-dimensional body or geometric figure.
Solid Modeling	A type of 3D CAD modeling that represents the volume of an object, not just its lines and surfaces.
Subassembly	An assembled part that is a part of a larger assembly.
Translation	Motion in which all particles of a body move with the same velocity along parallel paths.
Working Drawings	Drawings that convey all of the information needed to manufacture and assemble a design.

4.1 <u>Modeling</u>

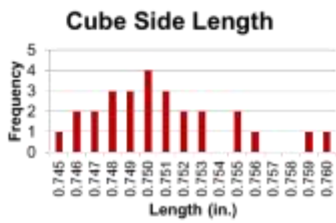
– Technical drawings are used to communicate engineering designs to those who will build the product. In order that the drawings are interpreted correctly by all stake holders, the drawings should be created using accepted standard practice and should include all information necessary to correctly manufacture and/or assemble the product.

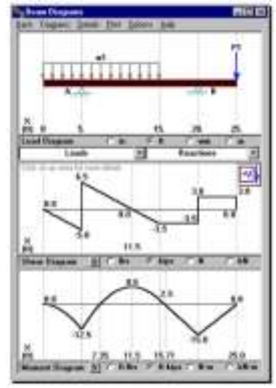
– **Concept Modeling:** Listing or mapping the concepts involved in a design or process under investigation.

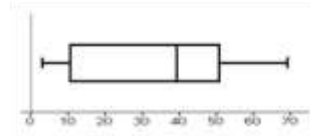


- **<u>Graphical Modeling</u>**: Representing information in the form of charts, graphs, maps, or geometric figures.
-



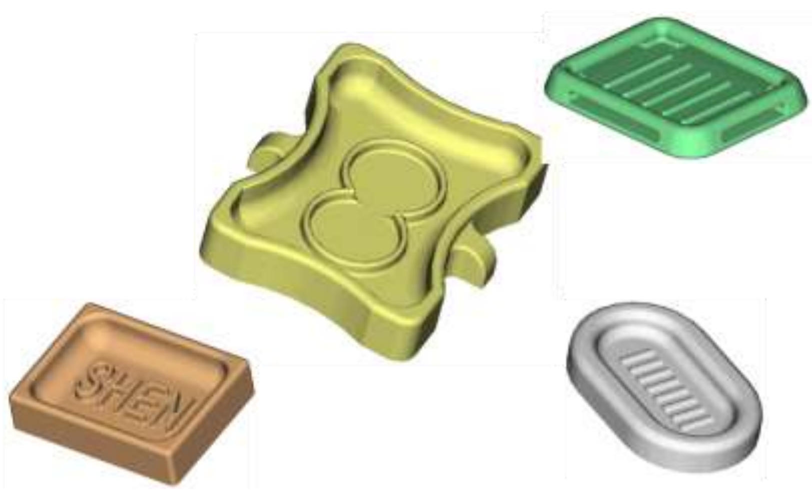




- **<u>Mathematical Modeling</u>:** Using mathematical equations or geometric representations to predict or model a phenomenon or behavior.

$$V = \pi r^2 h$$

- **<u>Computer Modeling</u>:** Using a computer and software to create a representation of an object or concept.
  - Example: Soap Dish Design (in Inventor)



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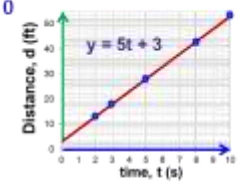
- **<u>Physical Modeling</u>:** Using physical materials to create a representation of an object or concept.
- **Mock-up:** An appearance model used to present the general concept of a design
- **Scale Model:** A representation of a design that is either larger or smaller than the actual model
- **Prototype**: A working model of the actual design

Function

A rule that takes an input, transforms it, and produces a *unique* output

- Can be represented by
  - a table that maps an input to an output
  - a graph
  - an equation involving two variables
- Domain – the set of inputs $t \geq 0$
- Range – the set of outputs $d \geq 3$

t	d
2	13
3	18
5	28
8	43
10	53



Correlation Coefficient, r

- Measure of strength of a linear relation
  - $-1 \leq r \leq 1$
    - $r = \pm 1$ is a perfect correlation
    - $r = 0$ indicates no correlation
- Positive r indicates a direct relationship
  - As one variable increases, so does the other
- Negative r indicates an inverse relationship
  - As one variable increases, the other decreases
- Strength of relationship
  - $r > 0.8$ is a strong correlation
  - $r < 0.5$ is a weak correlation

Coefficient of Determination, r^2

- Measure of how well the line represents the data
  - $0 \leq r^2 \leq 1$
- Portion of the variance of one variable that is predictable from the other
  - Example: $r^2 = 0.65$, 65% of variation in y is due to x. The other 35% is due to other variable(s).
- Square of the Correlation Coefficient

Making Predictions

- Use the trendline to make predictions
  - What is the sales projection for 2015?

    $t = 2015 - 2002 = 13$

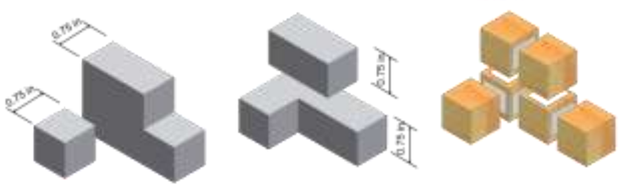
    $S(13) = 0.1335(13)+2.0269 = \$3.76$ million

$r^2 = 0.89$

$r = \sqrt{0.89}$

$= 0.94$

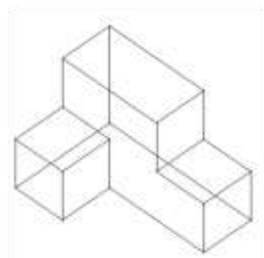
Additive Methods



Method 1 *Method 2* *Method 3*

Solid Modeling

Wireframe Model

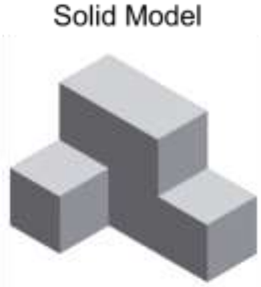


A *wireframe* model does not give the viewer an idea of surface appearance, nor does it provide information regarding mass properties.

Wireframes are not solid models.

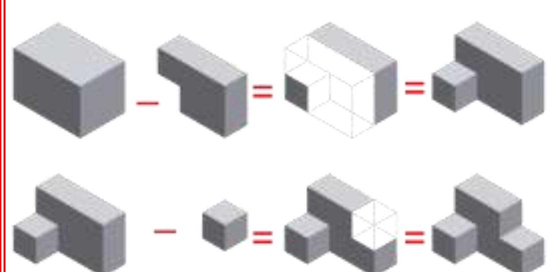
Solid Modeling

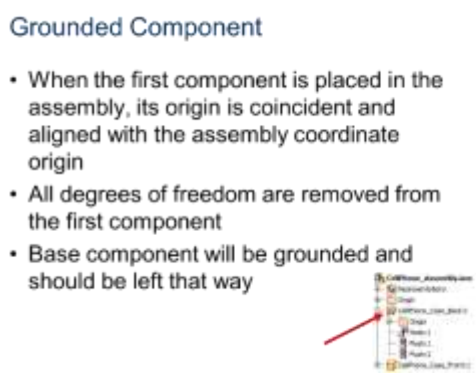
Solid Model

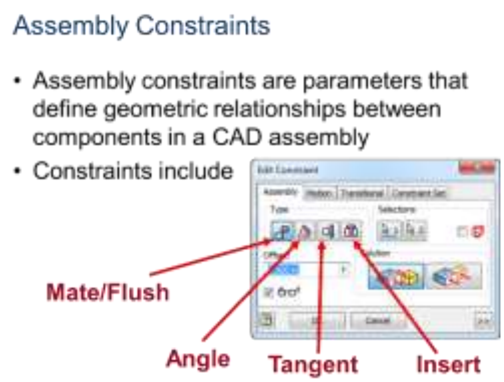


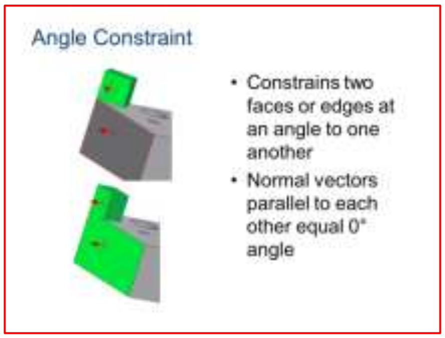
A *solid model* will show how an object's surfaces will appear, and provides information on surface area, volume, and weight.

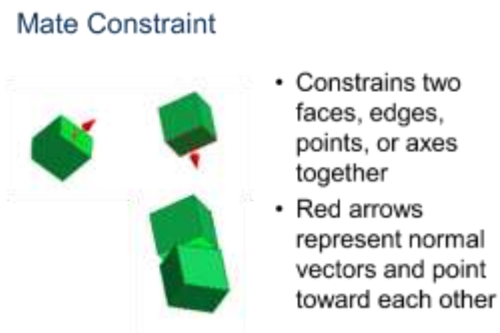
Subtractive Methods

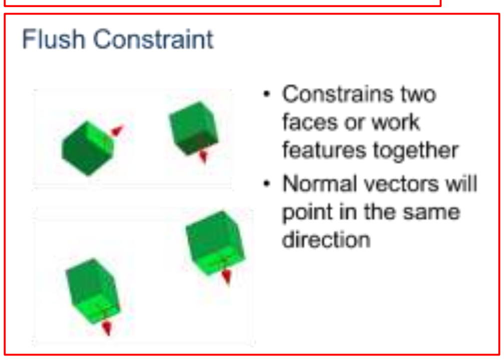


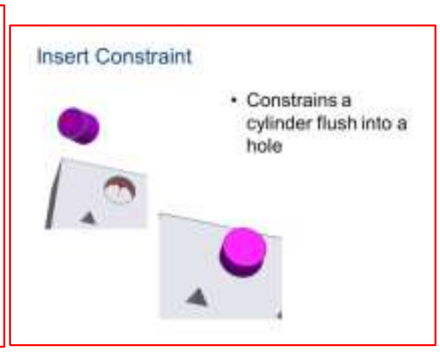


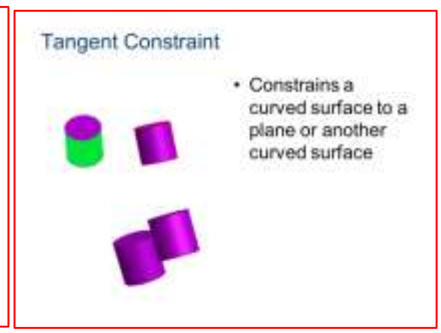


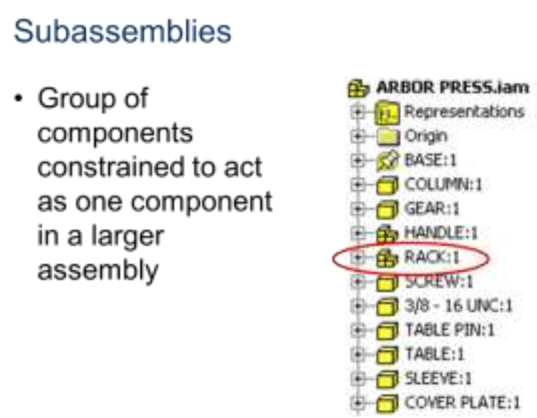


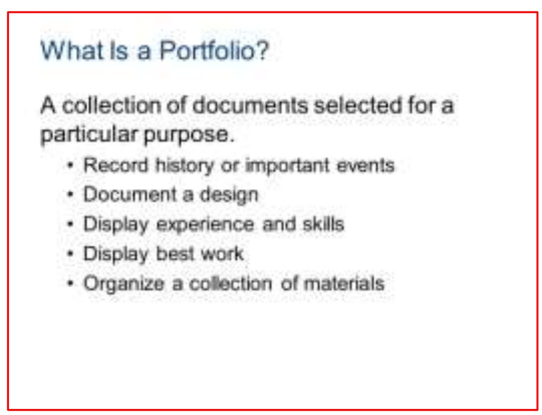












Unit 5 Geometry of Design - Overview

Preface

Geometric shapes are found everywhere. Take a moment to analyze products or objects you use every day. Geometric shapes and solids are the basis of these products. Engineers who have a strong understanding of these shapes, solids, and other geometric relationships can help designers develop and create solutions to a variety of problems. As designers progress through the design process and these design solutions are formalized, the level of accuracy and precision in the design specifications must increase. Conceptual sketches are converted to computer models and formal drawings, which include annotations describing the size and characteristics of the design features. A strong understanding of shapes and other geometric relationships is necessary to effectively and efficiently develop these computer and graphic representations.

Designers have used Computer Aided Design (CAD) programs for decades to refine ideas and generate images that manufacturers and other professionals can use to make profitable solutions to problems. The development of three-dimensional CAD solid modeling programs has resulted in significant increases in the quality of complex designs while drastically reducing the amount of time needed to produce those designs. Some engineers feel that the development of three-dimensional CAD solid modeling programs has made engineering more engaging and fun not to mention more accurate and precise.

Today's software that employs parametric design functionality requires an understanding of geometric relationships, such as perpendicular, parallel, and tangent. Students will transfer their knowledge of geometric relationships to parametric modeling.

In this lesson students will apply the skills learned in prior units. They will learn how to calculate the area of two-dimensional shapes. Students will also learn how to calculate the surface area, volume, and weight of three-dimensional solids and the interaction of volume and weight to determine material density. Students will also improve their skill in the use of CAD modeling software to enhance their understanding of plane and solid geometry.

Understandings

Students will understand that …

- **U1 –** Geometric shapes and forms are described and differentiated by their characteristic features.
- **U2 –** 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.
- **U3 –** 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.

Knowledge and Skills

KNOWLEDGE: Students will …

- **K1 –** Identify types of polygons including a square, rectangle, pentagon, hexagon, and octagon.
- **K2 –** Differentiate between inscribed and circumscribed shapes.
- **K3 –** Identify and differentiate geometric constructions and constraints (such as horizontal lines, vertical lines, parallel lines, perpendicular lines, colinear points, tangent lines, tangent circles, and concentric circles) and the results when applied to sketch features within a 3D solid modeling environment.
- **K4 –** Distinguish between the meanings of the terms weight and mass.
- **K5 –** Define the term "physical property" and identify the properties of length, volume, mass, weight, density, and surface area as physical properties.
- **K6 –** Identify three-dimensional objects generated by rotations of two-dimensional shapes and vice-versa.

SKILLS: Students will …

- **S1 –** 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. U1, U2
- **S2 –** Create three-dimensional solid models of parts within CAD from sketches or dimensioned drawings using appropriate geometric and dimensional constraints and model features. U1, U3
- **S3 –** Measure mass with accuracy using a scale and report the measurement using an appropriate level of precision. U2
- **S4 –** Measure volume with accuracy and report the measurement with an appropriate level of precision. U2
- **S5 –** 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). U2
- **S6 –** Solve volume problems using volume formulas for rectangular solids, cylinders, pyramids, cones, and spheres. U2
- **S7 –** Use physical properties to solve design problems (e.g., design an object or structure to satisfy physical constraints or minimize cost). U2

- **S8 –** Assign a specific material (included in the software library) 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.
- **S9 –** Assign a density value to a new material (not included in the software library) and apply the material to a 3D solid model within CAD software in order to determine the physical properties of the object.

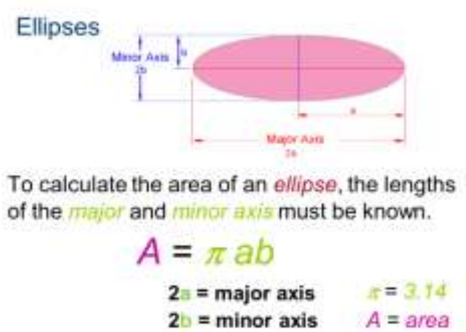
Essential Questions

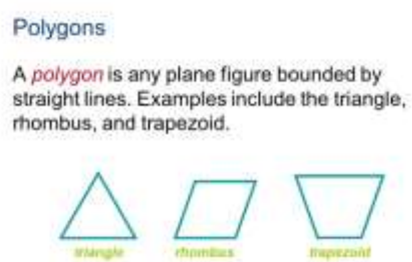
- **EQ1 –** What advantage(s) do Computer Aided Design (CAD) and Drafting provide over traditional paper and pencil design? What advantages does paper and pencil design provide over CAD?
- **EQ2 –** Which high school math topic/course, Algebra or Geometry, is more closely related to engineering? Justify your answer.
- **EQ3 –** How does the material chosen for a product impact the design of the product?

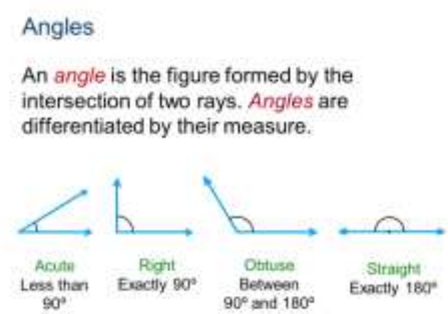
Term	Definition
Acute Triangle	A triangle that contains only angles that are less than 90 degrees.
Angle	The amount of rotation needed to bring one line or plane into coincidence with another, generally measured in radians or degrees.
Area	The number of square units required to cover a surface.
Axis	1. An imaginary line through a body, about which it rotates. 2. An imaginary line about which a regular figure is symmetrically arranged. 3. A fixed reference line for the measurement of coordinates.
Center of Gravity	A 3D point where the total weight of the body may be considered to be concentrated.
Centroid	A 3D point defining the geometric center of a solid.
Circle	A round plane figure whose boundary consists of points equidistant from the center
Circumscribe	1. A triangle located round a polygon such as a circle. 2 To draw a figure around another, touching it at points but not cutting it.
Cylinder	A solid composed of two congruent circles in parallel planes, their interiors, and all the line segments parallel to the axis with endpoints on the two circles.
Density	The measure of mass density is a measure of mass per volume.
Diameter	A straight line passing from side to side through the center of a circle or sphere.
Ellipse	A shape generated by a point moving in a plane so that the sum of its distances from two other points (the foci) is constant and equal to the major axis
Fillet	A curve formed at the interior intersection between two or more surfaces.
Inscribe	To draw a figure within another so that their boundaries touch but do not intersect.
Mass	The amount of matter in an object or the quantity of the inertia of the object.
Meniscus	The curved upper surface of a liquid column that is concave when the containing walls are wetted by the liquid and convex when not.
Obtuse Triangle	A triangle with one angle that is greater than 90 degrees.
Parallelogram	A four-sided polygon with both pairs of opposite sides parallel.
Pi (π)	The numerical value of the ratio of the circumference of a circle to its diameter of approximately 3.14159.
Polygon	Any plane figure bounded by straight lines.
Principal Axes	The lines of intersection created from three mutually perpendicular planes, with the three planes’ point of intersection at the centroid of the part.
Prism	A solid geometric figure whose two ends are similar, equal, and parallel rectilinear figures, and whose sides are parallelograms.
Quadrilateral	A four-sided polygon.
Radius	A straight line from the center to the circumference of a circle or sphere.

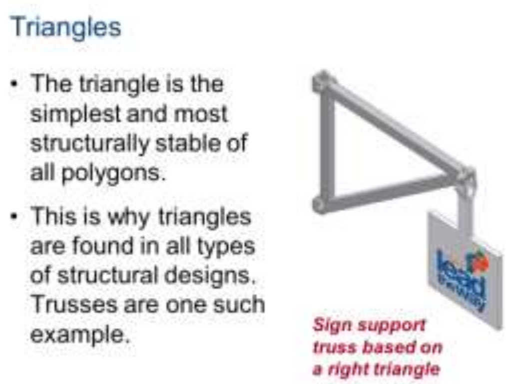
Rectangle	A parallelogram with 90 degree angles. A square is also a rectangle.
Regular Polygon	A polygon with equal angles and equal sides.
Right Triangle	A triangle that has a 90 degree angle.
Round	Two or more exterior surfaces rounded at their intersections.
Square	A regular polygon with four equal sides and four 90 degree angles.
Surface Area	The squared dimensions of the exterior surface
Tangent	A straight or curved line that intersects a circle or arc at one point only.
Title Block	A table located in the bottom right-hand corner of an engineering drawing that identifies, in an organized way, all of the necessary information that is not given on the drawing itself. Also referred to as a title strip.
Triangle	A polygon with three sides.
Vertex	Each angular point of a polygon, polyhedron, or other figure.
Volume	The amount of three-dimensional space occupied by an object or enclosed within a container.
Quadrilateral	A four-sided polygon.

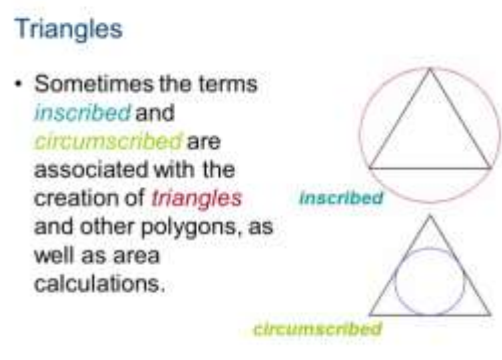
5.1 Geometric Shapes

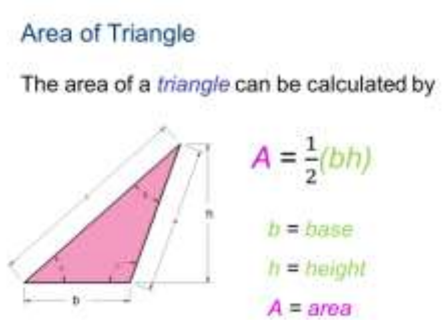


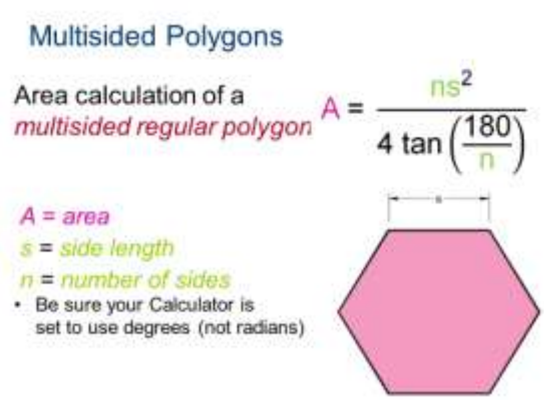












5.2 Geometric Constraints

Work Points

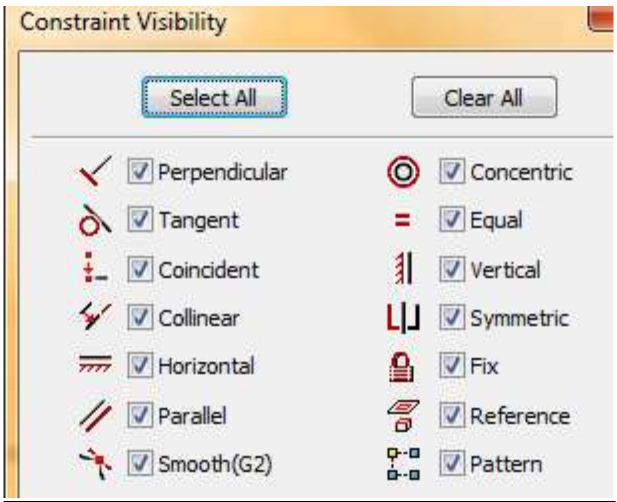
A ***work point*** is an independent entity whose location is defined in space. Work points may be placed or projected onto part faces, linear edges, or onto an arc or circle. Work points can be constrained to the center points of arcs, circles, and ellipses.

Work Axes

A ***work axis*** is a line that extends forever in two directions. Work axes are useful for locating the center of a hole or cylinder, are used in the creation of revolved features, and may be constrained to in assembly models.

Work Planes

Work planes are continuous two-dimensional planes that can be used to establish sketch planes. Assembly constraints can also be applied to work planes.

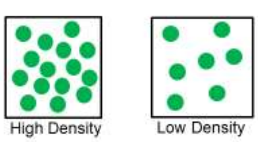


Parallel- every point on the lines are equal distance from each other; thus, the lines never intersect
Perpendicular- lines intersect at a 90 degree angle
Fix- keeps a point to a point on the coordinate system
Collinear- two lines to be the same line- the lay along the same line
Horizontal- causes line to be parallel to X axis
Vertical- causes line to be parallel to Y axis
Tangent- a line shares only one point with a circle or arc
Concentric- circles, arcs, or ellipses to have the same center point
Coincident- attaches two points together
Equal- causes lines have the same length and circles and arcs to have the same radius

5.3 Density

Density

- *Density* is a measure of the amount of matter per unit of volume



  - Objects more dense than water sink
  - Objects less dense than water float

Matter: Mass vs. Weight

- *Mass* is the amount of matter in an object or the quantity of the inertia of the object
- *Weight* is the force of gravity on mass

$$W = mg$$

W = weight
m = mass
g = acceleration of gravity

- Many materials are purchased by weight

Matter: Mass vs. Weight

Mass and *Weight* are often confused

- *US Customary units example*
  - A woman **weighs** 100 pounds

$$\mathbf{W = mg}$$

$$m = \frac{W}{g}$$

$$= \frac{100\ \text{lb}}{32.2\ \frac{\text{ft}}{\text{s}^2}} = 3.1\ \text{slugs}$$

  - Her **mass** is 3.1 slugs

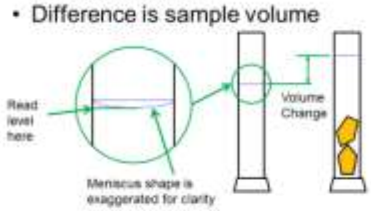
Mass and Weight: Measurement

- Balance – measures mass
  - Uses objects of known mass to find the unknown mass of an object
  - Measurement is unaffected by difference in gravity

- Scale – measures weight
  - Measures **force** caused by gravity
  - Measurement is affected by difference in the acceleration of gravity
  - May display a "mass" measurement reading by using an assumed acceleration of gravity to convert from weight to mass

Volume: Indirect Measure

- Record water level with only water
- Add samples
- Record new level
- Difference is sample volume

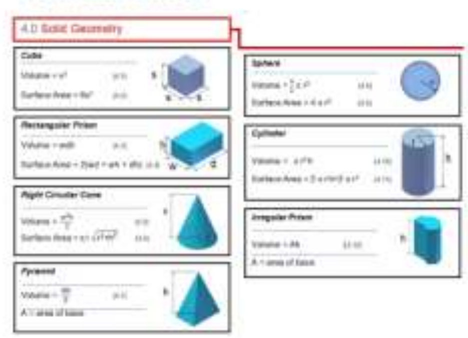


<u>5.4 Geometric Solid properties</u>

Properties of Solids

Volume, *mass*, *weight*, *density*, and *surface area* are properties that all solids possess. These properties are used by engineers and manufacturers to determine material type, cost, and other factors associated with the design of objects.

Formula Sheet

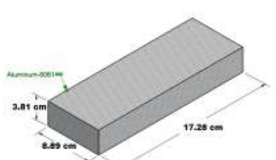


Calculating Mass

To calculate the *mass* (m) of any solid, its *volume* (V) and *mass density* (D_m) must be known.

$$m = VD_m$$

$D_{m\ (aluminum)} = 2.8\ g/cm^3$



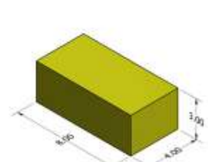
$m = VD_m$

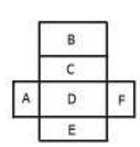
$m = (3.81cm)(8.89\ cm)(17.28\ cm)(2.71\ g/cm^3)$

$m = 1598.62\ g = 1.59862\ kg$

Calculating Surface Area

In order to calculate the *surface area* (SA) of a *rectangular prism*, the *area* (A) of each faces must be known and added together.





Area A = 3 in. x 4 in. = 12 in.^{2}
Area B = 4 in. x 8 in. = 32 in.^{2}
Area C = 3 in. x 8 in. = 24 in.^{2}
Area D = 4 in. x 8 in. = 32 in.^{2}
Area E = 3 in. x 8 in. = 24 in.^{2}
Area F = 3 in. x 4 in. = 12 in.^{2}
Surface Area = 136 in.^{2}

A wood board is one of a dozen different parts in a homemade robot kit. The width, depth, and height dimensions of the board are 3.5 x 17 x 1.5 inches, respectively. The board is made from southern yellow pine, which has an air dry weight density of .021 lb/in.^{3}.

a. What is the volume of the wood board?

b. What is the surface area of the wood board?

c. What is the weight of the wood board?

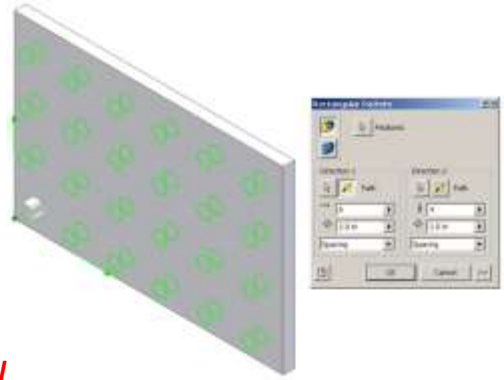
d. If one gallon of paint will cover 57,600 square inches, how many gallons would be needed to give two coats of paint to 25,000 boards? Round your answer to the nearest gallon.

e. What will the total cost be to ship the 25,000 boards to a facility for assembling into the finish kit form if the shipping rate is $4.25 per pound?

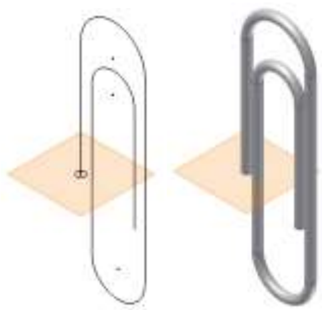
5.5 CAD modeling

REVOLVE

CIRCULAR PATTERN



RECTANGULAR PATTERN



SWEEP

5.6 Physical Property Analysis