Introduction to Engineering Design

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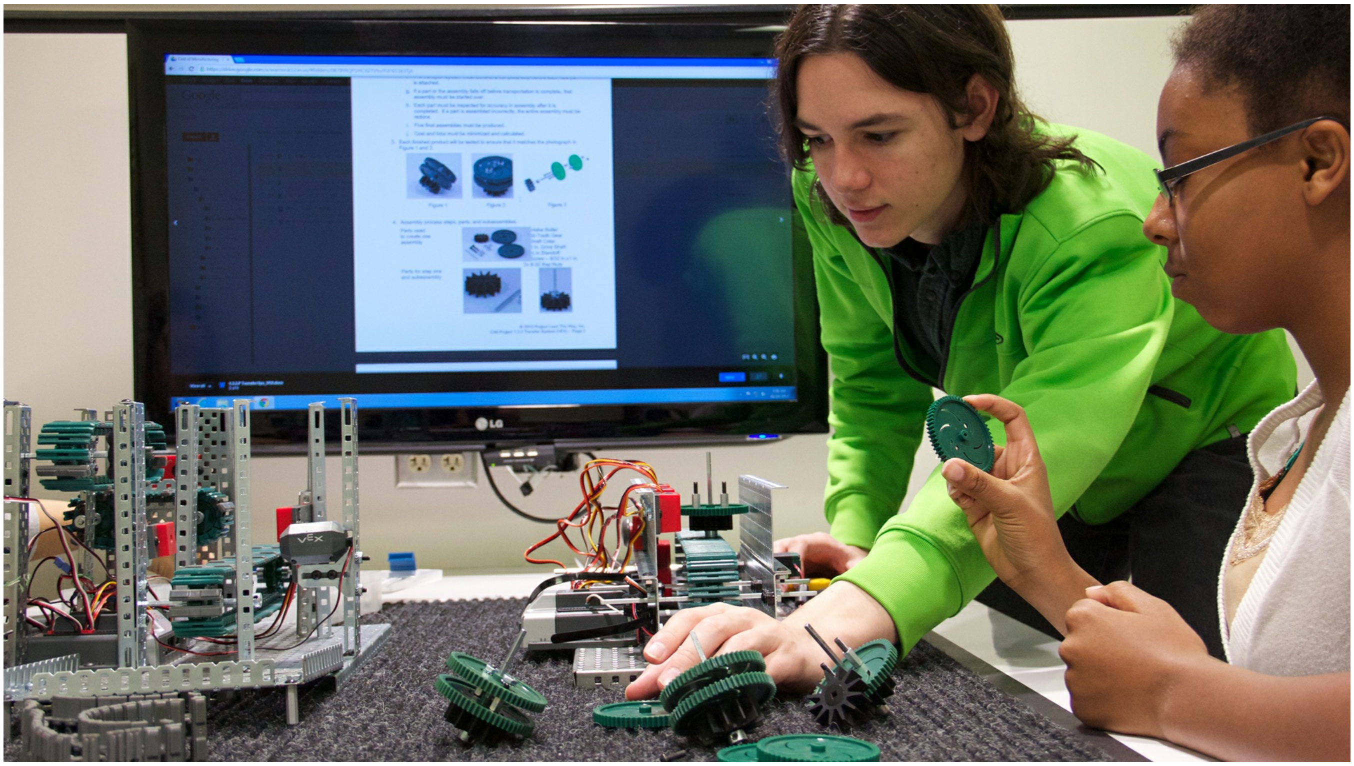
PowerPoint resources

Video resources

Table of Contents



Introduction to Engineering Design

General Student Resources

PLTW ENGINEERING NOTEBOOK, BINDER PORTFOLIO

Engineering Notebook Presentation

Engineering Notebook Sample Entries

Engineering Notebook Portfolio Binder Description

Isometric Graph Paper

Orthographic Graph Paper

Polar Graph Paper

Portfolios Presentation

ENGINEERING FORMULA SHEET

Engineering Abbreviations and Symbols

Engineering Formula Sheet

Engineering Formula Sheet Overview

DESIGN PROCESS

Decision Matrix Presentation

Decision Matrix Template

Design Modifications Chart

Design Process Graphic

Design Process Presentation

Dimensioing

Dimensioing Guidelines

ResEARCH

[Citations APA Style]

[Written Report Format]

[Written Report Template]

RUBRICS

[Decision Matrix Rubric]

[Design Problem Rubric]

[Peer Assessment Rubric]

[Presentation Rubric]

[Project Report Rubric]

[Written Report Rubric]

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Design Process Overview

Preface

In this unit you will learn an engineering design process (i.e., method to solve a problem or create a new product). You will also develop important skills such as concept sketching and setting up and maintaining an engineering notebook and portfolio.

Essential Questions

1. When solving an engineering problem, how can we be reasonably sure that we have created the best solution possible? What is the evidence?
2. How many alternate solutions are necessary to ensure a good final solution?
3. What engineering accomplishment of the 20th century has had the greatest impact on society? Justify your answer.
4. What will be the biggest impact that engineering will have on society and your life in the 21st century? Justify your answer.
5. Engineering tends to be a male-dominated profession. Why is that?

Activity 1.1

Instant Challenge: Cable Car

Introduction

There are many ways to solve a problem. Sometimes it is as simple as applying a piece of duct tape. Other times it takes months or years for a **product** to progress from an idea into full-scale production. Often **engineers** and **designers** use a specific set of steps (sometimes called a **design process**) to find the best solution to a problem. In this activity your team will quickly **design** the solution to a problem using a design process that progresses from **brainstorming** to presenting a final design.

Materials

- 1 sheet of cardstock
- 2 tongue depressors
- 2 paper clips
- 2 rubber bands
- 1 straw
- Toilet paper or paper towel roll
- 1 balloon: choice of either long and skinny (balloon animal) or round 9" diameter (or similar) balloon
- 12 in. of string
- 6 in. of masking tape
- Small figure (such as a LEGO® man or similar) or other small object to transport
- Scissors (tool only – cannot be consumed in design)

Procedure

In a team of three or four, using only the materials provided, design and build a device or vehicle to move a small figure (or other object) as far as possible across the room on the fishing line cable. A team member may initiate the motion of the vehicle or device but may not provide forward momentum.

Brainstorm (5 minutes): Assign a recorder for your group. As a team, brainstorm as many ideas for your device/vehicle as possible as the recorder documents your ideas. You may handle and inspect the materials, but you may not alter or connect any of the materials in any way during this phase. Select one of your sketched ideas to pursue.

Build (10 minutes): Build your device. Make changes to your original ideas as necessary.

Test (1 minute): Each team will have one minute to test their device on the fishing line cable.

Redesign (5 minutes): Make revisions to your device based on the results of your testing.

Present: Each team will take a turn attempting to send their vehicle across the room on the fishing line cable. The distance traveled will be recorded.

Scoring

Your team may receive points for the following.

- Creativity: Up to 20 points for creativity in the design and use of materials
- Teamwork: Up to 20 points for how well your team works together
- Performance: 1 point for each foot that the device moves along the fishing line cable

Conclusion Questions

1. Why do you think brainstorming is helpful when solving a problem?
2. How did testing improve your design?
3. With respect to designing the solution of a problem, what are some important characteristics of a successful team?

Activity 1.2

Instant Challenge: Aerodynamic Distance

Introduction

In this activity your team will quickly find a solution to an aerodynamics challenge – to **design** and build a vehicle from the provided materials that will fly as far as possible.

Equipment

- 2 sheets of paper
- 2 rubber bands
- 12-in. piece of string
- 3 straws
- 12 in. of masking tape
- 5 paper clips
- 1 plastic grocery bag
- 2 tongue depressors

Procedure

Using only the materials provided, design and build a device or vehicle to fly as far as possible. A team member may initiate the motion of the vehicle or device but must release the device or vehicle before the Start line.

Brainstorm (5 minutes): Assign a recorder for your group. As a team, brainstorm as many ideas for your device/vehicle as possible as the recorder documents your ideas. You may handle and inspect the materials, but you may not alter or connect any of the materials in any way during this phase. Select one of your sketched ideas to pursue.

Build, Test, and Redesign (12 minutes): Build your device or vehicle. Test the device as necessary and make changes to your original ideas as needed.

Present: Each team will take a turn attempting to fly their vehicle as far as possible. A team member may initiate the motion of the device but no part of the team member's body may cross the Start line when starting the motion. Each team will get two attempts. The longest distance traveled will be recorded.

Scoring

Your team may receive points for the following.

- Creativity: Up to 20 points for creativity in the design and use of materials
- Teamwork: Up to 20 points for how well your team works together
- Performance: 1 point for each foot that the vehicle flies from the starting point.

Conclusion Questions

1. How did your experience in the first Instant Challenge help you in solving this problem?
2. Did you make changes during your Design/Build/Test phase that resulted in your vehicle flying a shorter distance? If so, what were the changes?
3. Do you think it is more productive to continually test your **product** or to test at set time intervals? Why?

PLTW ENGINEERING

Activity 1.3

Concept Sketching

Introduction

You have heard the phrase, “a picture is worth a thousand words.” Visualization through images (as opposed to words) allows people to absorb large amounts of data quickly. Sketching is an important skill for **engineers** and **designers**. Sketches provide a means through which one can quickly and clearly communicate ideas. Representing existing objects and new ideas with sketches can make the **design process** more effective and efficient and greatly enhance the ability of others to understand your ideas.

One of the most important skills necessary to create an accurate sketch that realistically represents an object is the ability to make careful observations of the characteristics of that object. Paying close attention to the underlying basic shapes and the relative proportions of various features of the object will allow you to more accurately reflect the true shapes and proportions of the object in your sketch.

Another important key to success in sketching is practice. As is true with most activities (like playing lacrosse, solving Sudoku puzzles, and beating the system in Guitar Hero), the more experience you gain, the better you will perform. So consider carrying a pencil with you wherever you go. When you notice something interesting, something that can be improved, or something you would like to share, make a quick sketch instead of taking a picture. Your sketching skill will improve, you will impress your friends and family with your ability, and you will become a more competent designer.

In this activity you will sketch a variety of objects in your **engineering notebook**. The goal is to produce hand-drawn representations of real objects that closely resemble the actual objects and that appear three-dimensional. In this activity, you will focus on obtaining the correct shape and proportions of each object from a single “straight-on” or orthographic view and add shading to produce a more realistic three-dimensional effect. You will start with simple forms and progress to more complicated products. Some examples of student-produced sketches are provided.

Equipment

- Various objects to sketch (see below)

Resources

Engineering Notebook

Concept Sketching

Sketching Tips Guide

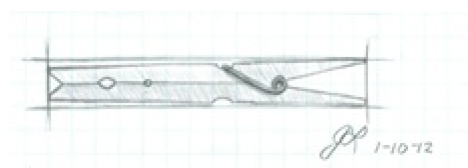
Activity 1.3 Concept Sketching Rubric

Orthographic Graph Paper

Procedure

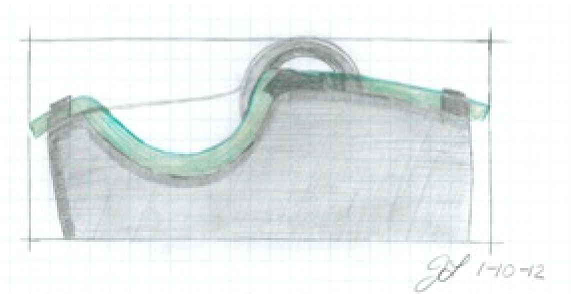
Create the following sketches in your engineering notebook as directed by your instructor. A front view refers to the view that typically shows the longest dimension and the most distinctive shape. For instance, in this context, the “front” view of a vehicle would actually be one of the side views (driver’s side or passenger side). Concentrate on boxing out the correct size and shape of the object and then refining the sketch based on careful observation. Insert a photographic image of the object represented adjacent to each sketch. Remember to title, initial, and date all sketches and inserted photographs.

1. Sketch a “front” view of at least two of the following objects:



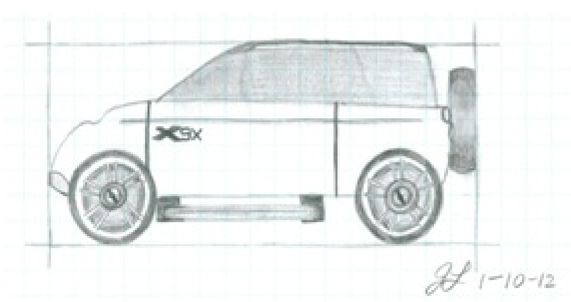
- Highlighter, Sharpie, pen, or pencil
- Toothbrush
- Clothespin
- Scissors
- Flash drive
- Coffee cup
- Glue bottle
- Flashlight
- Beverage can or bottle
- Other instructor-approved object

2. Sketch a “front” view of at least two of the following objects:



- Computer mouse
- Tape dispenser
- Stapler
- Contoured speaker
- Monitor
- Surge protector
- Cell phone
- Other instructor-approved object

3. Sketch a “front” view of an Automoblox vehicle.



4. Sketch a “front” view of two objects at home. Some suggestions follow:

- Spoon, fork, or knife
- Remote control device
- Cleaning product bottle
- Can opener
- Corkscrew
- Coffee maker
- Sink faucet
- Lamp
- Computer desk
- Chair
- Squirt gun
- Etc.

Conclusion Questions

1. Explain the concept of proportion. How does the concept of proportion relate to creating a realistic sketch?
2. Why would the ability to create realistic sketches make a person a more competent designer?
3. Give an example of a visual or graphic representation of information that has more impact than an explanation of the information in text.
4. In your opinion, what is the most important thing to know/do in order to create a realistic sketch of an object?

Engineering Notebook

Resources

Engineering Notebook Sample Entries

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Concept Sketching

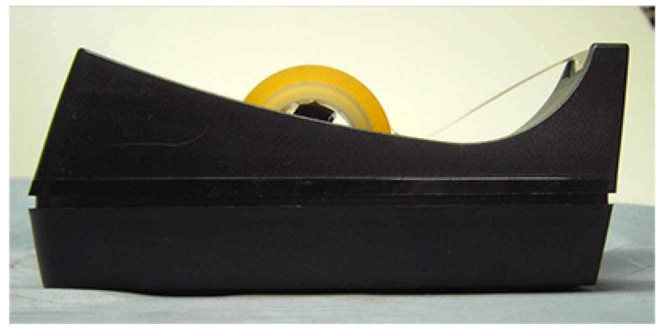
Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Sketching Tips Guide

[Download Sketching Tips Guide]

Sketching with Simple Shapes

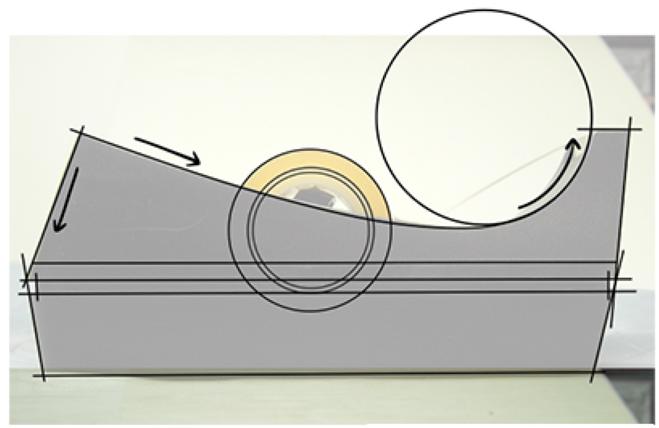
An object that seems complex at first can be broken down into easier-to-understand lines and shapes, such as rectangles and circles.



The tape dispenser to the right has complex curves and angles that can be broken down into simple straight lines and concentric circles.

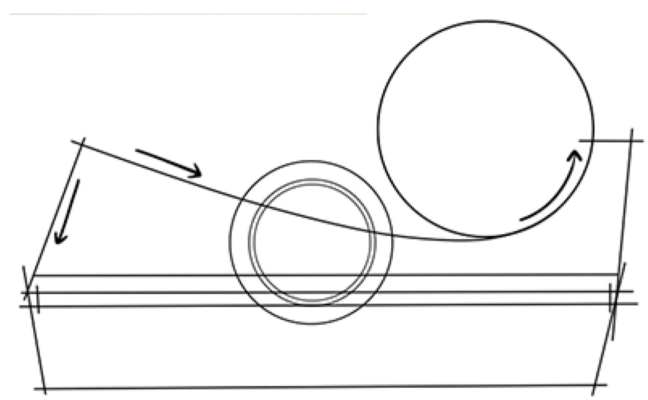
The sketch may appear messy at this point, but that's okay!

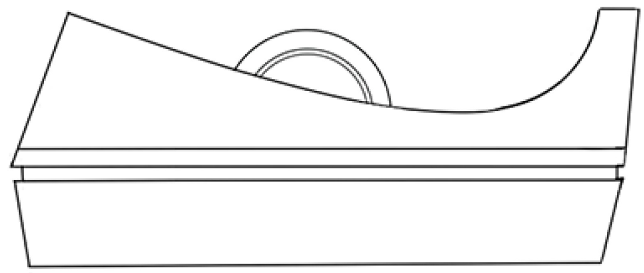
Note how the complex curve of the top of the dispenser can be broken down into two angled lines and part of a circle.

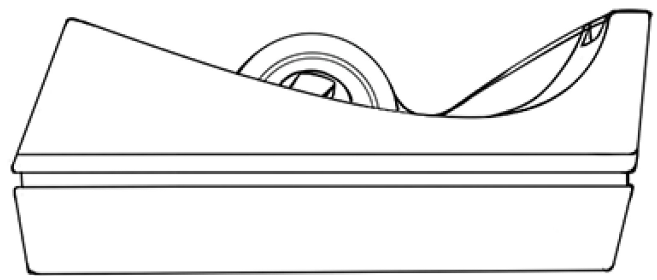


After you have the basic shape down, clean up the sketch by erasing outlying line endings.

You can start detailing the sketch by adding in rounded corners and smaller details where appropriate.



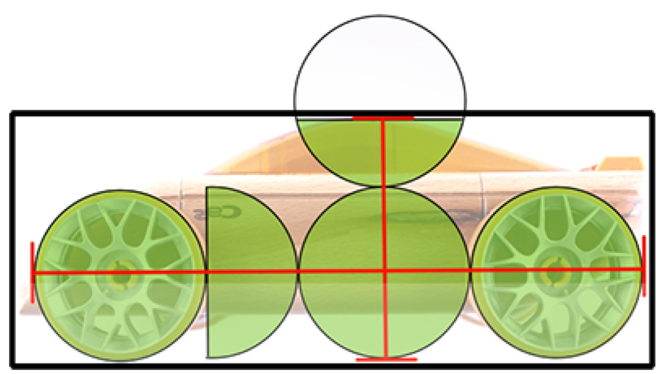




Sketching with proportions

A trick to drawing correct proportions is to break the object down using a simpler component of the object. In this case, we'll start with the wheel of the car.

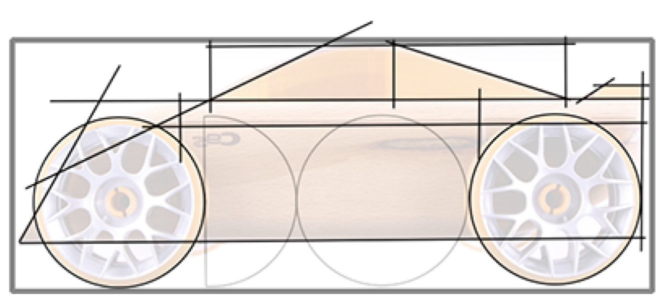
In terms of ‘wheels,’ the car is about 3.5 wheels wide and 1.4 wheels tall. We can use these rough proportions to box in the object's proportional guidelines. Hint: When drawing cars, it is easier to get the proportions right if you draw the placement of the two wheels first!

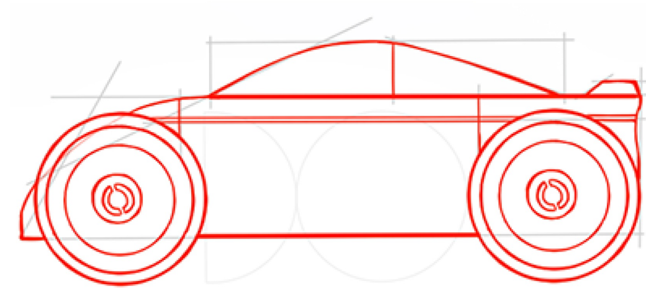


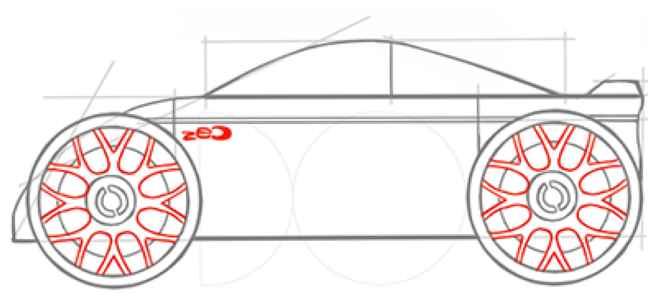
After breaking down the rough proportions, use simple lines to break the object down into simple shapes. (See: Sketching with Simple Shapes.)

After breaking the object down into simple shapes, you can start rounding out certain details such as curved surfaces.

Add in the rest of your details, and you're ready to shade in your sketch!







Sketching with Curved Objects

When drawing curved objects, using simple lines to break down a shape is not enough!

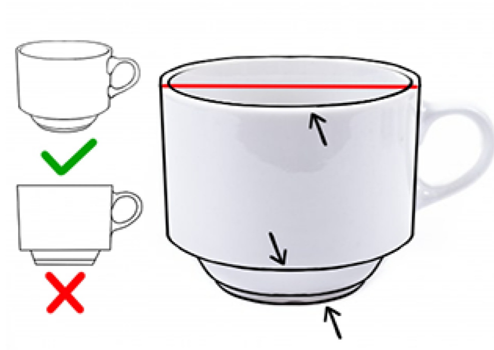
A curved object, such as this cup, will not appear to have straight top and bottom edges even when looked at directly at eye-level.

After using flat lines to box in the shape of the cup, you will need to curve the edges of a curved object to properly convey its shape.

Note the difference between the flat, red line, and the curvature of the top edge of the cup.

Remember to fill out the rounded edges of a curved object.

Don't just stop at the flat, boxed-in sketch!



Note how the curvature persists in the bottom edges of the cup as well.

Hint: The curved edge of an object changes depending on how you're looking at it. The further away the edge is from your eye-level, the more rounded it becomes.

Note how the top of and/or bottom of a hollow curved object forms an ellipse. This is risible at the top of the cup in the example above.

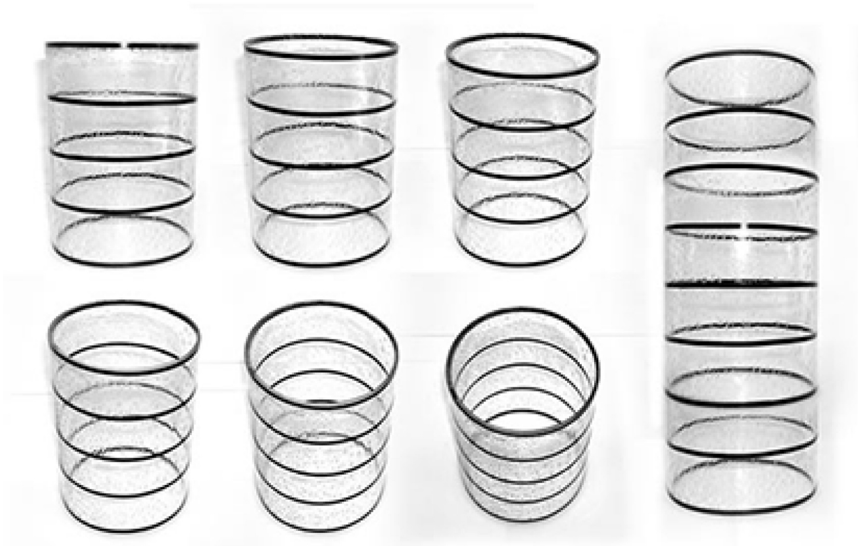


Image referenced from http://www.idsketching.com/ with permission.

Sketching with Shading

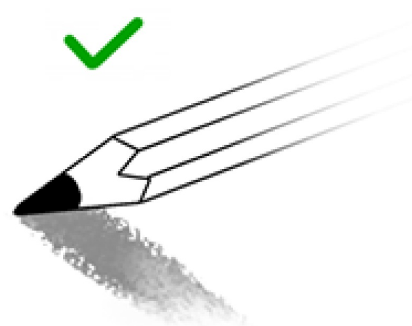
Tip: When shading with a pencil, try to avoid using the tip of your pencil's graphite and instead use the side of the graphite.

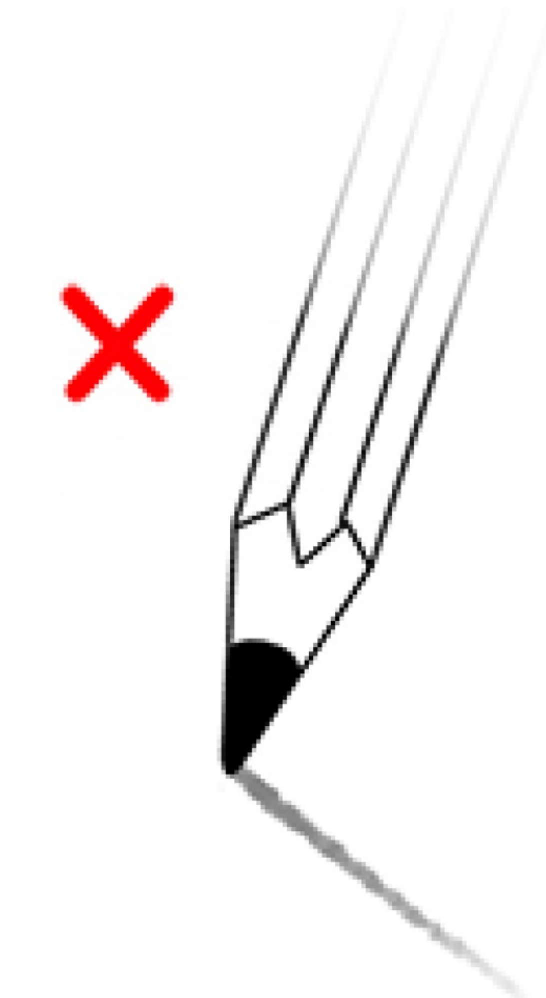
If you're using a mechanical pencil, try wearing down the tip of your lead to an angle to simulate this.

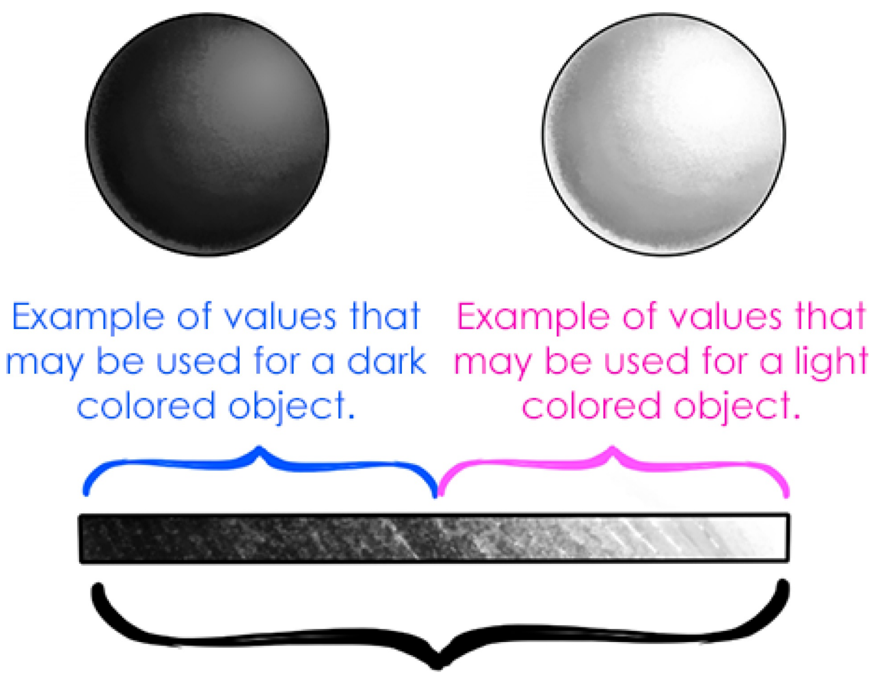
This covers areas easier and makes the shading smoother.

Don't be afraid to use a wide range of values to create contrast, but don't overdo it!

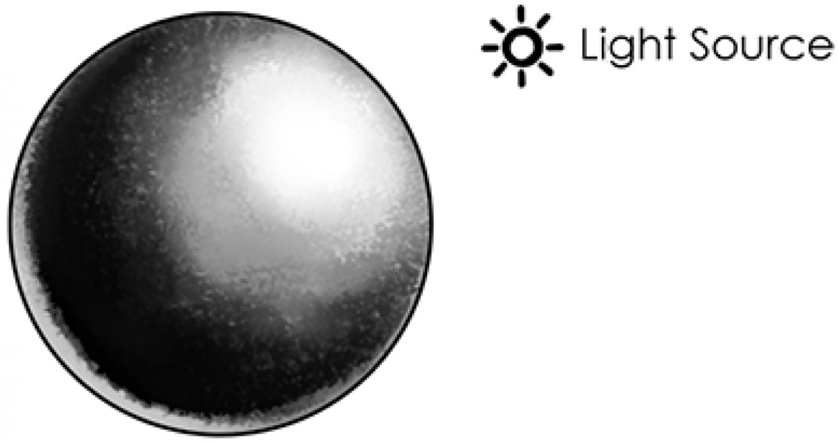
Not every object will use the full spectrum from white to black.



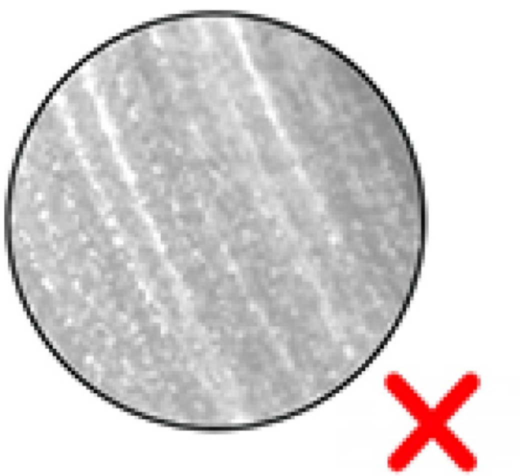




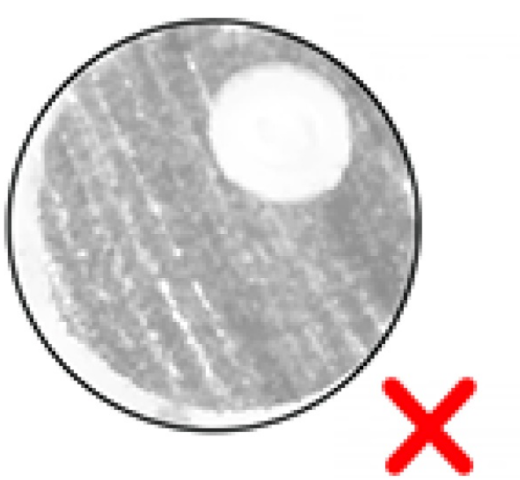
Very few items will use the full spectrum from white to black. Notably: metallic objects, dark-colored objects with extremely bright lighting, etc.



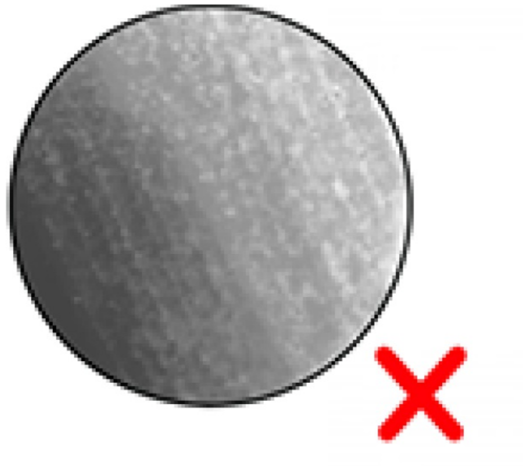
Sketching with Shading



Avoid coloring in objects with only one tone. Even flat objects have a range of values, even if it's a very small range.



Avoid harsh blocks of highlight and shadow. This is unrealistic and makes things look cartoony.



Avoid using flat gradients for shading curved objects. Note how for curved objects, the shading follows along the curve of the object and is not flat.

Activity 1.3 Concept Sketching Rubric

Resources

[Activity 1.3 Concept Sketching Rubric]

Elements	5 Points	4 Points	3 Points	2 Points	1–0 Points
Proportions	Proportions of the sketch mirror the size and shape of sketched object.	Proportions of the sketch closely resemble the size and shape of the sketched object but the sketch looks slightly distorted.	Proportions of the sketch somewhat resemble the size and shape of the sketched object. There are obvious indications that the sketcher created guidelines to attempt to establish proper proportions.	The sketch is disproportional to the object being sketched. Some indications that the sketcher attempted to provide guidelines to establish proper proportions.	No evidence that proper proportions were attempted
Attention to Detail	The sketch shows great attention to detail and is a realistic representation of the object.	The sketch contains many strong elements of detail but some details are missing.	The sketch shows detail that is reflective of the object but needs further refinement and fine-tuning to appear realistic.	The sketch is lacking detail. The detail included is not reflective of the object and is incomplete.	No evidence of detail in the sketch.
Shading	The sketch has strong, well-done shading that displays good use of value to represent the color(s) of the object and creates a realistic and three-dimensional appearance.	The sketch has strong, well-done shading that displays good use of value to represent color(s), but additional shading is necessary to show shadows and create a more realistic and three-dimensional appearance.	The sketch is shaded but does not represent the color(s) of the object nor the shadows that create a realistic three-dimensional appearance.	Minimal shading is incorporated in the sketch.	No evidence of shading in the sketch.
					Messy with

Neatness		Clean, neat pages with no smudges.	Neat work with some smudges.	Poor appearance.	food or other stains.

PLTW ENGINEERING

Activity 1.4

Product Improvement

Introduction

Hummers®, iPods®, cell phones, clothes, and video games are just a few **products** that are familiar to most people. What is it about any of these products that you like? What causes you to want to buy a cell phone or an iPod? Is it the commercials or the appearance of the product? Whatever the reason, **design** plays a vital role in the creation and marketing of any product.

Equipment

- Plain white coffee cup (1 per class) or alternate consumer product

ResourceS

Brainstorming Solutions

Procedure

This activity is designed to provide an introduction to design. As a team of two, you will **brainstorm** ways to enhance or change a plain white beverage container so that nearly every consumer would want to purchase it. Remember to apply the rules for brainstorming that were identified in the PowerPoint during this activity. The following list is available to guide your team through this activity:

- Assign a recorder and a speaker for your group.
- Brainstorm for five minutes with your team to identify enhancements or changes that you would make to the item. The recorder will make a list of all ideas mentioned in those five minutes. Changes or enhancements could be anything; you are not limited by cost.
- After five minutes, select ideas to enhance or change the item from the brainstorming list.
- For the next ten minutes, each member of the team should develop and sketch a potential change or enhancement to your product.
- Your team will take five additional minutes to develop a **justification** for each potential change to the item.
- Your team speaker will present your changes to the class.

Conclusion Questions

1. What factors must be considered when changing or enhancing a design?
2. Why is it important to document the brainstorming process?
3. What is the purpose of sketching your ideas?
4. What effective or ineffective techniques did the group speaker use to communicate your idea to the class?

Brainstorming Solutions

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

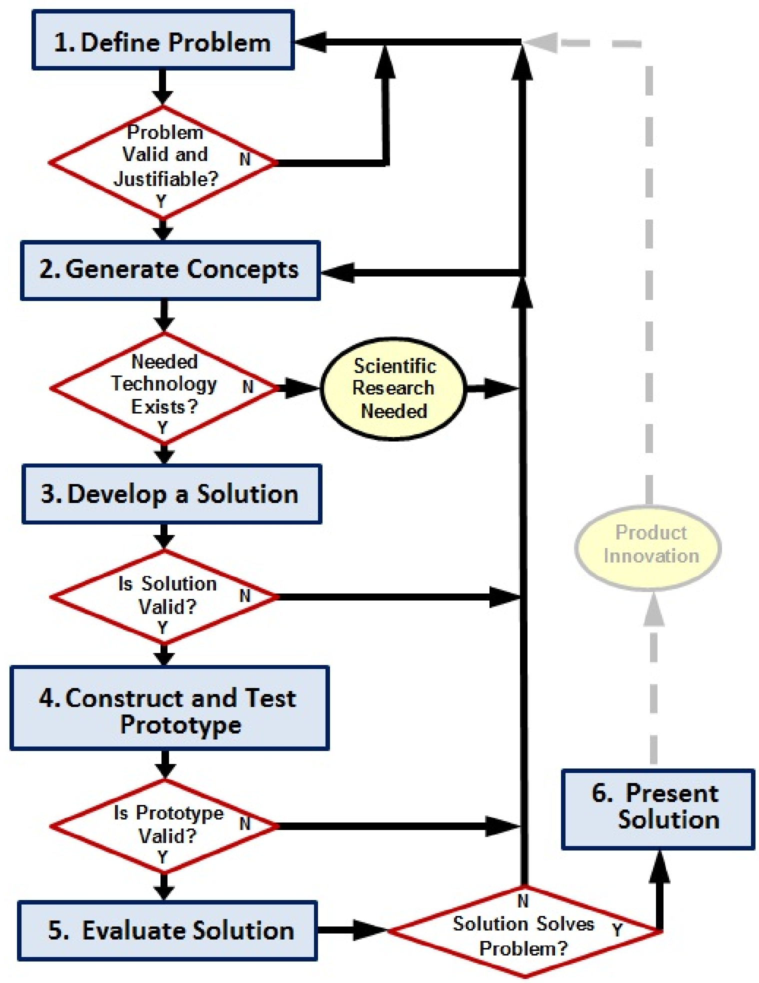
Activity 1.5

The Deep Dive

Introduction

How do professional **design** companies work through a **design process**? The video you are about to see chronicles the efforts of a world-renowned design firm, as they apply their process to the redesign of a common, everyday **product**.

One of the best-documented examples of the design process in action took place in Palo Alto, California, at an industrial design firm called IDEO. ABC News gave IDEO the challenge of redesigning the old and familiar shopping cart in just five days. *Nightline* chronicled the experience and aired the program on February 9, 1999.



This short documentary reinforces the idea that fantastic solutions can be produced under very difficult constraints when the **designers** have a commitment to the problem, a firm understanding of a design process, and a willingness to operate as a team.

In this activity you will watch the Deep Dive documentary and record information related to the design process used in the redesign of a shopping cart.

Equipment

- *The Deep Dive* video(s)

Resources

[Design Process](#)

[Writing a Design Brief](#)

[Deep Dive Guided Notes](#)

Procedure

In this activity you will watch a group of professionals work to solve a design problem in just five days. Complete the **Deep Dive Guided Notes** as you watch *The Deep Dive*. A class discussion will take place following the broadcast.

The Deep Dive - Part 1 of 3 First aired on 13th July 1999, this abcNEWS - Nightline clip features international design firm and shares some of the best practice in encouraging **innovation** at the workplace today.

Refer to your downloadable resources for this video.

The Deep Dive - Part 2 of 3 First aired on 13th July 1999, this abcNEWS - Nightline clip features international design firm and shares some of the best practice in encouraging innovation at the workplace today. Read more at http://go.innovatus.com.sg/bis

Refer to your downloadable resources for this video.

The Deep Dive - Part 3 of 3 First aired on 13th July 1999, this abcNEWS - Nightline clip features international design firm and shares some of the best practice in encouraging innovation at the workplace today. Read more at http://go.innovatus.com.sg/bis

Refer to your downloadable resources for this video.

1. "From the buildings in which we live and work, to the cars we drive, or the knives and forks with which we eat, everything we use was designed to create some sort of marriage between __________________ and __________________."
2. The folks at IDEO state that they are not experts in any given area. But they do claim to be experts on the _____________________, which they apply to the innovation of consumer products.
3. After the team of designers is brought together, introduced to the problem, and informed they have five days to "pull it off," what phase of the design process do they immediately engage in?
4. Give two examples of what the team members did during this phase.
    - ____

- ____

5. List five rules of thumb that IDEO employees follow when they share ideas during the brainstorming phase:

    - ____
    - ____
    - ____
    - ____
    - ____

6. Why should wild (and sometimes crazy) ideas be entertained during the brainstorming phase?

7. After the brainstorming phase was over, the team narrowed down the hundreds of ideas by _____________ for those ideas that were not only "cool" but also _________________ in a short period of time. Which phase of the design process includes brainstorming and narrowing ideas?

8. IDEO believes that the ideas and efforts of a ______________ will always be more successful than the planning of a lone genius.

9. Once the ideas were narrowed down and divided into categories, the group was split into four smaller teams. For which phase(s) of the design process was each of these groups responsible?

10. The leaders at IDEO believe that ________________ behavior and a ______________ environment are two important reasons why their employees are able to think quickly and creatively to produce innovative results.

11. Sometimes, people come up with great solutions that work by trying their ideas first and asking for _________________ later.

12. Design is often a process of going too far and having to take a few steps back. What phase(s) of the design process would the critique of the four mock-ups come under?

13. Upon critique of the four teams' models, it was obvious that none of the teams had developed an optimum solution. However, the people at IDEO believe that it is important to _____________ often in order to _____________ sooner.

14. What percentage of the entire week's time did it take to fabricate the final **prototype**?

15. Instead of showering his design team with a tremendous amount of praise, what did the boss require his employees to do with their new design?

16. Of all the things that we are surrounded by every day, what has not been placed through the design process?

Extend Your Understanding (Optional)

Engineers need to know what problems they are addressing. They must have an idea about the degree to which the solution should be carried out, along with what the solution should do to solve the problem. The engineer must also work within constraints, such as time and budget. A **design brief** is a tool that is used to concisely identify the problem, solution expectations, and project constraints. The engineer will often return to the design brief throughout a design process to **assess** the progress and **validity** of his or her creative work.

Imagine that you are part of that design team. The project leader has given you the responsibility of creating a **design brief** that defines the problem, states the expectations that the solution must meet, and identifies the project **criteria** and **constraints**. Your design brief will serve as a guide to the team as they work through the design process.

From your observations of the video, record your information in the design brief in your **engineering notebook**.

Shopping Cart Redesign Design Brief

Client
Who is the customer or client that is paying for the design service?

End User
Who is going to use the new product?

Designer(s)
Who was responsible for the design of the revised grocery cart?

Problem Statement
What was the problem that the design team was trying to solve? Write your answer as a complete sentence.

Design Statement
To what degree was the solution to be realized? Was the design team's intention to merely sketch an idea and be done? Was the intention to come up with an idea, build it, and stop there? Or, was it the design team's intention to design, build, and test an idea? What expectation(s) did the design have to meet before it would be considered a successful solution to the problem? In other words, what did the solution have to do?

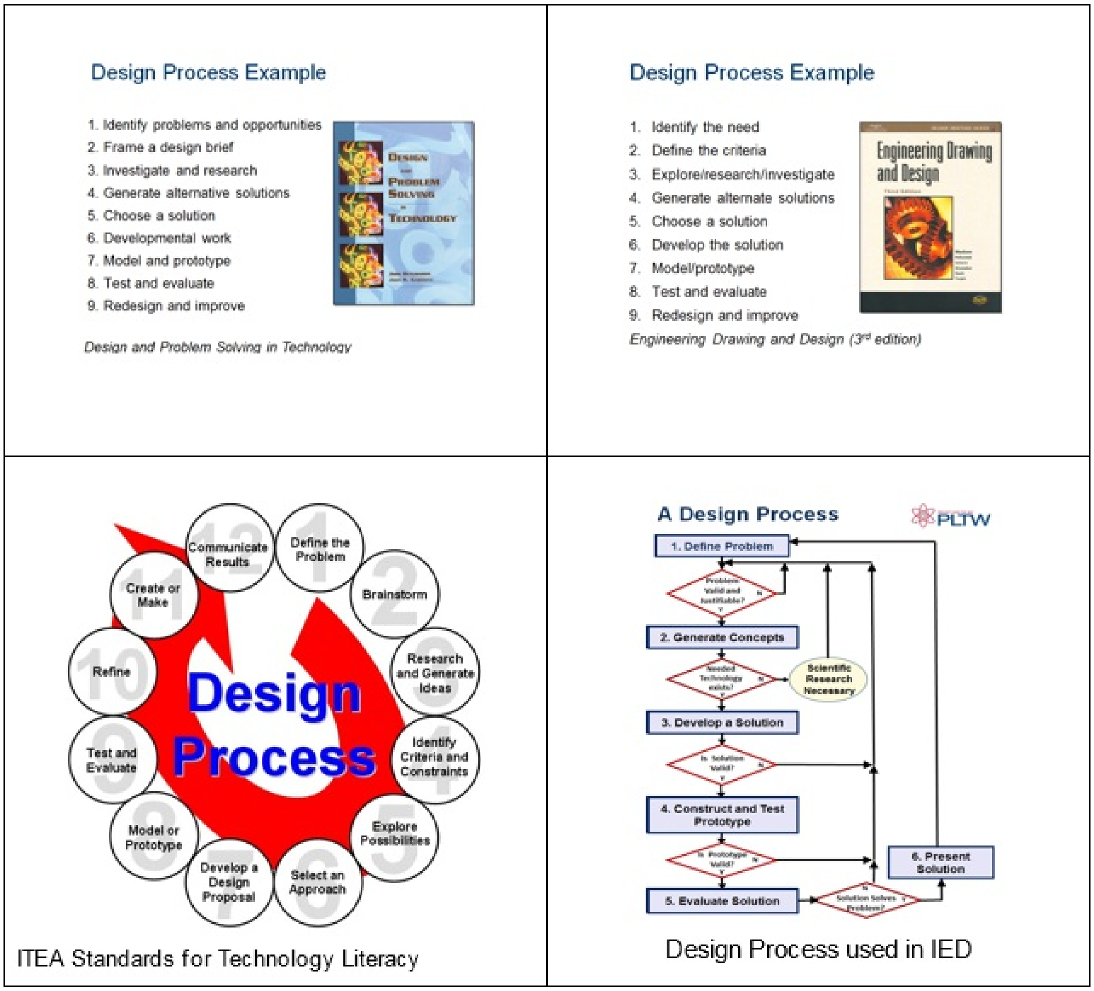
Criteria and Constraints
What criteria did the solution have to meet? What limitations did the design team have to work with? Was there a time constraint to get the project finished?

Conclusion Questions

1. What was the most impressive part of the team's effort?
2. What advantages are there to having a design team with members that have non-engineering backgrounds?
3. There was a point in the process where a self-appointed group of adults stepped up, stopped the ideas, and redirected the group to break up into teams. Why was this done?
4. At the end of the video, Dave Kelly states, "Look around. The only things that are not designed

are the things we find in nature.” Can you think of anything that would contradict this statement?

5. Consider the various versions of a design process (below) that were introduced in the Design Process presentation that you viewed. How are the processes similar? How are they different?



6. Do you think the tasks completed by the design team during the design challenge or the final solutions would have changed if the team had followed a different version of a design process? Explain.

Design Process

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Writing a Design Brief

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 1.5.a

Gossamer Condor Design Brief (Optional)

Introduction

What would you do if you had a teacher that expected you to complete an assignment, but refused to tell you what the assignment was? Imagine, too, that the result of this assignment was expected to be submitted in a specific format, which was also not explained to you. Oh yes, and there was a due date. But you were not told what that was either. How could a person be expected to accomplish anything under such conditions?

Engineers need to know what problems they are addressing. They must have an idea about the degree to which the solution should be carried out, along with what the solution should do to solve the problem. The engineer must also work within **constraints**, such as time and budget. A **design brief** is a tool that is used to concisely identify the problem, solution expectations, and project constraints. The engineer will often return to the design brief throughout a **design process** to **assess** the progress and **validity** of his or her creative work.

Design briefs will be used throughout the Introduction to Engineering Design course. Long term projects will be initiated with design briefs, and as you become a more proficient **designer**, you will be required to write your own. This activity is designed to guide you through the development of a design brief by observing a design project from start to finish. The information gained in this lesson will not only help you understand how to create a design brief, it will also allow you to observe the design process in action.

Equipment

- *The Flight of the Gossamer Condor* DVD
- Television or computer with projector and audio amplifier
- DVD player

Procedure

In this activity, you will witness the development of the first controlled, sustainable human-powered aircraft as chronicled in the Academy Award-winning documentary, *The Flight of the Gossamer Condor.*

Imagine that you have traveled back to the mid-1970s. You are part of a design team that is attempting to build a human-powered aircraft. The project leader has given you the responsibility of defining the problem, stating the expectations that the solution must meet, and identifying the project constraints. Your design brief will serve as a guide to the team as they work through the design process.

Read the following questions prior to viewing the film. From your observations of the film, answer the questions and record the information in the design brief on this page or in your **engineering notebook**, as instructed by your teacher. If you record information in the design brief on this page, you can capture an image of your responses, print it out and paste it into your notebook.

1. Who was responsible for the **design** of the Gossamer Condor? Write your answer next to the word Designer in the design brief.
2. What was the problem that the designer and his team were trying to solve? Be advised, the problem was not to design an aircraft. The design of an aircraft was part of the solution to the problem. Write your answer as a complete sentence(s) next to the words Problem Statement in the design brief.
3. To what degree was the solution to be realized? Was the designer's intention to merely sketch an idea and be done? Was the intention to come up with an idea, build it, and stop there? Or, was it the designer's intention to design, build, and test an idea?
4. What expectation(s) did the design have to meet before it would be considered a successful solution to the problem? In other words, what did the solution have to do? Combine your answer with the answer from question 3, and write it as a complete sentence(s) next to the words **Design Statement** in the design brief.
5. What limitations did the design team have to work with? What **criteria** did the solution have to meet?

Gossamer Condor Design Brief

Designer:	
Problem Statement:	
Design Statement:	
Constraints:	

Conclusion Questions

1. Aside from being the first to solve the problem, what was the major motivating factor for the designer of the Gossamer Condor?
2. Where did the idea for the Gossamer Condor come from, and what did it have to do with the power output of a bicyclist?

3. What was the major natural element that caused the most problems to the Gossamer Condor?
4. What were three major differences between the first generation design and the final generation design of the Gossamer Condor?
5. How long did it take the design team to accomplish their goal? Was this the amount of time that the design team expected?

Activity 1.6

Discover Engineering

Introduction

What is engineering? Many people have difficulty answering this question. In fact, engineering is a diverse field; there are many disciplines within engineering that can each involve the application of a very different body of knowledge and skills. Nearly everything that is not “natural” (i.e., created by Mother Nature) most likely was designed and created with input from **engineers**. The shampoo you used this morning to wash your hair, the technology that cleans the water you drink, the buildings in which you live, work, and attend school, and the iPhone you use to communicate all involved the expertise of engineers in the initial design, building and testing, and final production.

All engineers are problems solvers. The differences among the roles of engineers in varying disciplines are dependent on the types of problems that are solved. In general there are four major disciplines within the engineering field: chemical, civil, electrical, and mechanical. Many other engineering disciplines are derived as an extension of or a specialization within one of these major disciplines. For example, environmental engineering is a sub-discipline of civil engineering. Other engineering disciplines have resulted from the combination of aspects of two or more of the major disciplines. Mechatronics is a relatively new branch of engineering that incorporates both mechanical and electrical engineering principles.

In this activity you will investigate the four major disciplines of engineering and consider their impact on you and the world.

Equipment

- Computer with Internet access

Resources

Engineering Overview

Engineering Disciplines

Procedure

1. What is engineering? Based on your current perception, in a few sentences define the term “engineering” in your **engineering notebook**.

2. Now investigate the engineering profession. Some websites that may be helpful in your **research** include the following.

[Discover Engineering]

[Engineer Girl | National Academy of Engineering]

[Career Cornerstone Center]

[Try Engineering]

As you perform your research, record information that will help you respond to the following. Once you have gathered sufficient information, write your answers in your engineering notebook or as directed by your teacher.

3. Describe the four major disciplines of engineering and identify problems or projects that an engineer in each discipline might encounter.

    - Chemical engineering
    - Civil engineering
    - Electrical engineering
    - Mechanical engineering

4. Choose a discipline of engineering (other than chemical, civil, electrical, or mechanical) that is of interest to you. Describe this engineering field and explain how it is an extension of, specialization within, or combination of one or more of the four major engineering disciplines. (**Optional**—create a PowerPoint slide to describe your chosen engineering discipline.)

5. Visit the National Academy of Engineering website on the Greatest Engineering Achievements of the 20th Century. Choose one of the achievements listed and read the information provided about your selected achievement. Then, based on what you learn, respond to the following.

    - Describe your selected achievement in a few sentences.
    - Which major discipline of engineering do you think was most involved in the development of this achievement? Justify your answer.

[Greatest Engineering Achievements of the 20th Century | National Academy of Engineering]

Optional Video

The Greatest Engineering Achievements of the 20th Century Freelance project produced for the McCormick School of Engineering at Northwestern University

Refer to your downloadable resources for this video.

5. Review your choice of an engineering discipline in item 3 and consider how an engineer within this discipline could contribute to the solution of one or more of the grand challenges.
6. If you were an engineer within the discipline that you chose in item 3, which engineering grand challenge would you like to work on?
7. Describe your selected grand challenge.
8. Why is a solution to this challenge important to the world?
9. How could you, as an engineer in your chosen discipline, contribute to a solution to this challenge?

Conclusion Questions

1. What is it about engineering that is common to all disciplines of engineering? That is, what makes an engineer an engineer regardless of the work one does?
2. Why do you think engineering has been called the *stealth* profession? (Hint: there are many Internet resources that address this question.)
3. How is an engineer different from a scientist?
4. What interpersonal characteristics do you think are important to the success of an engineer of any discipline?

Engineering Overview

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Engineering Disciplines

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 1.6.b

Engineering and Related STEM Careers (Optional)

Introduction

Because of their technical training, critical thinking skills, and problem-solving capabilities, **engineers** have a wide range of career choices. Many employers value the technical knowledge gained and the ability to understand and create technical information built in the course of completing an engineering degree program. And although many engineers choose to perform **design** work, some choose other, less traditional or less well-known paths in which their technical abilities and critical thinking skills prove valuable.

In this activity you will **research** an engineering or STEM career and create a Career Poster or information sheet to display in your classroom.

Equipment

- Computer with Internet access

Procedure

1. Select (or receive an assignment) of a career related to engineering or STEM from the list below. The Bureau of Labor Statistics website may be a helpful resource.

   Bureau of Labor Statistics

2. Create a poster, brochure, single-page information sheet, or multimedia presentation (as directed by your instructor) that briefly provides the following information related to the career:

   - Brief job description
   - Required training—high school and post-secondary
   - Skills and characteristics of a person successful in this career

UNIT	Career
2	Drafter Mechanical Engineer Mechanical Engineering Technician
3	Statistician Logistician Industrial Production Manager
4	Mathematician Commercial and Industrial

- Typical wages
- Job outlook
- Professional associations
- A job listing for this career to company name/location, job description/responsibilities, educational requirements, preferred experience/skills

In addition to the information above, include the following in your poster, brochure, information sheet, or presentation:

- Appropriate visual interest with color, text, and images
- At least one graph or chart to present information

	Designer
5	CAD Technician Chemist and Materials Scientist
6	Technical Writer Materials Engineer
7	Industrial Engineer Industrial Engineering Technician Machinist/Tool and Die Makers
8	Sales Engineer Physicist Electro-Mechanical Technician
9	Engineering Manager Other engineering (or related career) of interest

3. During the unit for which your career is listed present your career to the class using your poster, brochure, or information sheet as a visual aid or show your multimedia presentation.

PLTW ENGINEERING

Activity 1.7

What Is It?

Introduction

Engineering and **design** require **creativity** and the ability to problem solve. You must be able to gather new information, continually learn, and apply what you know to new situations. **Engineers** try to think outside the box in order to solve new problems or find ways to improve current solutions. In this activity you will act as an engineer and provide an explanation and evaluation of a **product** that you have hypothetically designed.

Resources

Providing Peer Feedback

Activity 1.7 What Is It? Elevator Pitch Rubric

Activity 1.7 What Is It? Essay Rubric

Procedure

Assume that you are an engineer that has developed a preliminary design for an important problem. Write and present an explanation and evaluation of your design.

1. Choose one of the designs represented in the four images presented by your instructor (and reproduced as follows) as YOUR design.

Think about the object in the image and the 2.
problem that it may solve. Answer the following questions.

- What is it?
- What problem does it solve?
- What **criteria** were used to guide the design?
- What are the most important features of the design? What features allow it to perform its intended purpose?
- How does your product affect society and the environment?

3. Outline a five paragraph essay that explains your design and answers the questions above. A five-paragraph essay includes an introductory paragraph, a conclusion paragraph, and three paragraphs in the body. Use the format below to outline your essay. You must use at least one of the terms, **invention** or **innovation**, within your essay to describe your design.

Five Paragraph Essay Outline Format

Title: ____________________

1. Introduction
    - Introductory statement
    - Thesis statement: ____________________
2. Body
    - First Supporting Idea (Topic Sentence): ____________________
        - ____________________
        - ____________________

- ____________________

- Second Supporting Idea (Topic Sentence): ____________________

    - ____________________
    - ____________________
    - ____________________

- Third Supporting Idea (Topic Sentence): ____________________

    - ____________________
    - ____________________
    - ____________________

3. Conclusion

    - Closing statement
    - Restate thesis: ____________________

    About the Author (sixth paragraph)

The thesis statement should identify the object or design and describe the problem that the design solves, that is, the purpose of the design. The body paragraphs should provide support for your thesis statement by describing three features of the design and discussing how each feature helps solve the problem.

4. Using the outline you have created, write a five-paragraph essay that explains your design, the problem it solves, and its most important features.

5. Add a paragraph entitled *About the Author* to the end of your essay. In this additional paragraph, describe your discipline of engineering and how knowledge from that discipline helped you create your design and solve the problem.

6. Review and evaluate a classmate's essay using the Activity 1.7 What Is It? Essay Rubric.

7. Present a one minute elevator pitch to your class describing your design, the problem it solves, and its most important features. An elevator pitch is an expression describing a short presentation with the goal to communicate major ideas and generate interest in your subject. The length of the presentation should short enough to be completed in a typical elevator ride.

Conclusion Questions

1. Why is it important for engineers to be creative and think outside the box?
2. What other characteristics do you believe engineers should possess in order to be successful problem solvers?

Providing Peer Feedback

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 1.7 What Is It? Elevator Pitch Rubric

Resources

[What Is It? Elevator Pitch Rubric]

Elements	5 Points	4 Points	3 Points	2 Points	1–0 Points
Content	The information included is accurate and completely addresses each component of the assigned topic or research question.	The information included adequately addresses each component of the assigned topic or research question.	The information included inadequately addresses the assigned topic or research question. The information included is sometimes inaccurate.	The information included does not address the assigned topic or research.	There is no evidence of accurate content information.
Delivery	The presenter effectively and creatively delivers the information while staying on topic. The presenter appears relaxed and self-confident. Body language, voice modulation, and eye contact are effectively used.	The presenter adequately delivers the information while staying on topic. The presenter appears relaxed and self-confident. Body language, voice modulation, and eye contact are mostly appropriate.	The presenter delivers the information but does not stay on topic. The presenter appears tense or nervous. Body language, voice modulation, and eye contact are inappropriate or lacking.	The presenter omits important information and does not stay on topic. The presenter appears tense or nervous. Body language, voice modulation, and eye contact are inappropriate or lacking.	The presenter does not effectively deliver the necessary information.
Organization	The presentation content has been organized using a logical sequence. The	The presentation content has been mostly organized using a logical sequence, but some	The presentation content has been organized using a somewhat logical sequence.	The presentation content is disorganized, unclear, or confusing. The presentation	The presentation does not include evidence of organization.

	presentation is engaging and effective.	flaws exist. The presentation is adequate.	The presentation is sometimes confusing.	is not adequate.	
Preparation	Presentation indicates detailed preparation.	Presentation indicates adequate preparation.	Presentation indicates minimal preparation.	Presentation indicates a lack of preparation.	Presentation shows no evidence of preparation.
Visual Aids	Visual aids are of excellent quality, easy to read, and relevant to the presentation. Visuals of all required elements are present.	Visual aids are adequate, easy to read, and relevant to the presentation. Visuals of all required elements are present.	Visual aids are somewhat effective but may include vocabulary or spelling errors. Visuals of all required elements are present.	Visual aids lack effectiveness. Aids may lack appropriate content. Aids include multiple vocabulary or spelling errors. Visuals of all required elements are not present.	The presentation shows no evidence of visual aids.

Activity 1.7 What Is It? Essay Rubric

Resources

What Is It? Essay Rubric

Elements	5 Points	4 Points	3 Points	2 Points	1–0 Points
Thesis Statement	The thesis statement provides a succinct, accurate overview of the content of the report.	The thesis statement provides an accurate overview of the content of the report. The thesis statement may not be succinct.	The thesis statement does not provide a completely accurate overview of the content of the report. The thesis statement is wordy and confusing.	The thesis statement does not provide an overview of the content of the report.	Minimal effort or the thesis statement is not included in the report.
Content: Product Description	Clear and concise description of the product including target market. Clear and concise description of multiple key features. Thorough explanation of the purpose of each feature and why it is important to the product design. Features not obvious from the image but are important to the design intent are included.	Clear description of the product. Clear description of the some important features of the product and a good explanation as to the purpose of each feature and why it is important to the design.	Adequate description of the product and some important features of the product. Explanation as to the purpose of each feature and why it is important to the design may be lacking.	A brief description of the product is included that includes a description of one or more features of the product without explanations as to the purpose of each feature or why it is important	Minimal effort or product and features description missing.
	A clear/concise problem	A	A problem statement is included but		

Content: Problem Statement and Criteria	statement. A clear description of several appropriate criteria including some quantitative (numerical) constraints such that the criteria very clearly define characteristics necessary for the success of the design.	clear/concise problem statement. A clear description of several appropriate criteria such that it can be determined whether a design meets (or does not meet) each criteria.	somewhat unclear. A description of several design criteria is included although the criteria may not be clear or concise such that it is difficult to determine if a design meets the criteria.	A problem statement is included but is not clear. Only one or two design criteria are included.	Minimal effort or no evidence of a design problem description.
Content: Effect on Society and the Environment	In depth consideration of the positive and negative effects of the product on society and on the environment including detailed explanation and support of points.	Adequate consideration several of the potential effects of the product on society and the environment with some support of points. May consider only negative effects.	Some discussion of one or two potential effects of the product on society and the environment. May not include explanation or support of points.	Brief discussion of one or more potential effects of the product on society and the environment without explanation or support.	Minimal effort or no evidence of consideration of the effects of the product on society or the environment.
Conclusion	The conclusion paragraph clearly and concisely states all of the key points addressed in the report.	The conclusion paragraph clearly states most of the key points addressed in the report.	The conclusion paragraph states several of the key points addressed in the report but lacks some clarity.	The conclusion paragraph does not mention several key points addressed in the report. The paragraph is overly wordy or confusing.	Minimal effort or the conclusion is not included in the report.
Grammar	Punctuation, grammar, usage, and spelling are effectively used throughout the report.	Minor errors in punctuation, grammar, usage, and spelling are evident, but they do not interfere with the readability of the report.	Occasional errors in punctuation, grammar, usage, and spelling are evident and interfere with the readability of the report.	Major errors in punctuation, grammar, usage, and/or spelling interfere with the readability of the report.	The report contains significant errors in punctuation, grammar, usage, and spelling.

Organization	The report content has been organized using the appropriate method. The required information is easy to locate within the report.	The report content has been mostly organized using a logical sequence, but some flaws exist. The required information is generally easy to locate within the report.	The report content has been organized using a somewhat logical sequence. The presentation is sometimes confusing.	The report content is disorganized. The required information is difficult to locate within the report.	The report does not include evidence of organization.

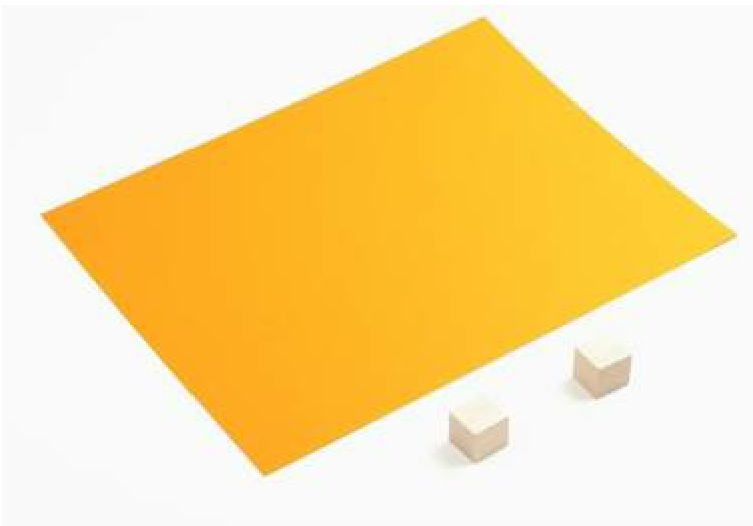
PLTW ENGINEERING

Activity 1.8

Instant Challenge: Paper Bridge

Introduction

Solving a problem is an amazingly creative process. **Creativity** can be messy. However, creativity can be channeled into a meaningful solution by using a structured **design process**. In this activity your team will **design** a solution to a problem using an engineering design process. You will document the process in your **engineering notebook**.



Equipment

- ¾-in. wooden blocks (2) or other objects of 3/4 in. to 1 in. in height
- 1 sheet of 8 ½ x 11 in. cardstock
- Assorted construction tools such as scissors

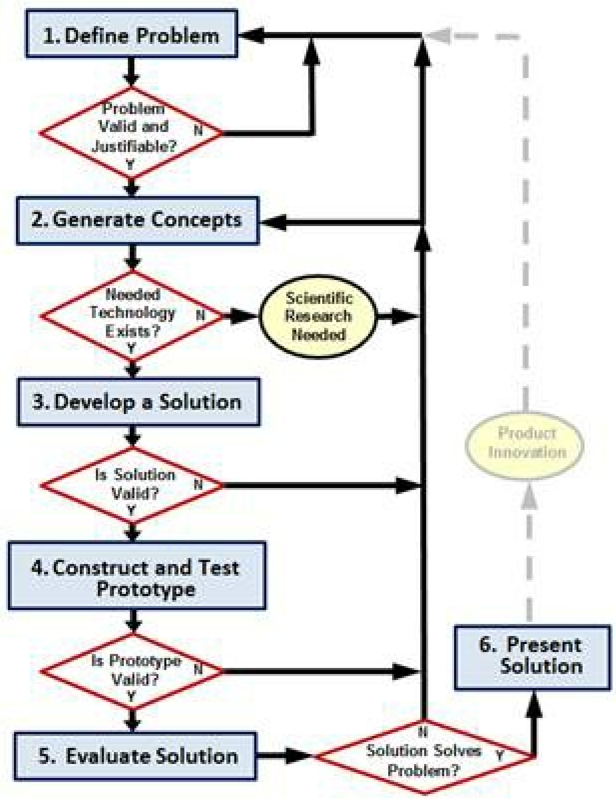
Resources

Instant Challenge: Paper Bridge

Design Process

Procedure

1. Follow the direction of the teacher while completing this activity.
2. Use the design process learned earlier in this lesson. Document each step in your engineering notebook.



3. Design and build a **product** that maximizes the distance between two blocks which are connected by a continuous route of paper. The product must meet the **constraints** below.
    - The paper must form a continuous chain of connectivity from one block to another without touching the tabletop.
    - Paper-to-paper linkage will be considered continuous.
    - The two wooden blocks are ¾-in. wooden blocks.
    - Both blocks are at table height.
    - Cardstock can be modified.
    - Additional material can be used during construction, but not on the final product.

4. The winning design meets the constraints above with the blocks farthest apart.

Conclusion Questions

1. Why do you think brainstorming is helpful when solving a problem?
2. How did testing improve your design?
3. With respect to designing the solution of a problem, what are some important characteristics of a successful team?

Instant Challenge: Paper Bridge

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Design Innovation

Introduction

Name a **product** or process that is truly an original **invention**. You possibly named an Xbox Kinect or an iPhone. These products are examples of high-quality consumer products; however, neither is an invention. Both are **innovations**: an improvement of an existing technological product, system, or method of doing something. The Kinect is an adaptation of existing technology using multiple cameras and facial and voice recognition to interact with a computer using gestures. An iPhone adapts mobile phone technology dating back to 1973.

An invention is a new product, system, or process that has never existed before, created by study and experimentation. An example of an invention is a nanobot. Robots of a size comparable to atoms had not been accomplished previously. The first wheel would be an invention. The modification to make the wheel out of aluminum alloy and cover it with a synthetic rubber tire is an innovation.

In this activity your team will **research** an original invention and show the timeline of subsequent innovations.

Equipment

- Computer with Internet access

Resources

Introduction to Research

Product Design Evolution

Activity 1.9 Design Innovation Rubric

Procedure

1. Form a two person team with the guidance of your teacher. Select an invention that your team will research. Examples are listed, though the possibilities are numerous.

Anti-lock Brakes	Multiplane Camera	3D Printer	Bulletproof Glass

Internet-based Social Network	Garbage Disposal	Tetracycline	Optical Fiber
Random Access Memory	Playable/Recordable Sound Media	Gaming Control Device	Bicycle
GPS	Crop Rotation	Hybrid Plant	Low-level Laser Therapy
Cataract Surgery	Teflon	Air Conditioner	Calculator
Eye Glasses	Kevlar	Coffee Maker	Elevator

Record the invention chosen by your team in this space or in your engineering notebook:

Teacher approval of invention:

2. Research the invention chosen by your team. Discover at least the information below and document in your **engineering notebook**.

    - When was the product invented?
    - What need did the product address?
    - Who invented the product?
    - List any existing patents.
    - What materials were originally used to make the product?
    - How was the product originally made?
    - What improvements have been made to the product?
    - Why were these improvements made?
    - Who uses the product?
    - What is the global impact on society of the invention and subsequent innovations?
    - If you had the ability to change this product in any way, what would you change?

3. Prepare to make a three- to five-minute presentation to your peers on the invention and innovation. Include a minimum of the information that follows:

    - Include your team member names, class, period, and selected invention.

- Explain the original invention and patents.
- List the discipline(s) of engineering most important to the development of the product and explain how these disciplines were essential.
- Provide a timeline drawn to scale showing the history of the invention and evolution.
- Identify major changes that have occurred in the **design** of the product.
- Address the global impact on society and the environment.
- Provide a reference page of at least four Internet sites and other sources used to gather your presentation information. Record all citations in APA style.

4. As a class combine research findings into a timeline drawn to scale. Each invention should be included on the timeline with a brief statement about the importance of the advancement or achievement. The timeline scale will show development pace including time lapse between achievements.

Conclusion Questions

1. Define and differentiate invention and innovation.
2. What were the major factors that contributed to past innovations of the invention that you researched?
3. How has the pace of development changed through the history of the design?
4. What future innovations to the chosen invention do you predict?

Introduction to Research

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Product Design Evolution

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 1.9 Design Innovation Rubric

Resources

Activity 1.9 Design Innovation Rubric

Elements	5 Points	4 Points	3 Points	2 Points	1–0 Points
Content	The information included is accurate and completely addresses each component of the assigned topic or research question.	The information included adequately addresses each component of the assigned topic or research question.	The information included inadequately addresses the assigned topic or research question. The information included is sometimes inaccurate.	The information included does not address the assigned topic or research.	There is no evidence of accurate content information.
Organization	The content has been organized using the appropriate method. The required information is easy to locate within the report.	The report content has been mostly organized using a logical sequence, but some flaws exist. The required information is generally easy to locate within the report.	The report content has been organized using a somewhat logical sequence. The presentation is sometimes confusing.	The report content is disorganized. The required information is difficult to locate within the report.	The report does not include evidence of organization.
Delivery	Effectively and creatively delivers the information while staying on topic and considering the audience. Excellent use of voice, posture, eye contact, gestures, and pace. Interesting	Good delivery of information while staying on topic and considering the audience. Speaks clearly and confidently although may not demand attention or inspire	Adequately delivers the information while staying on topic. Lack of confidence, appears nervous and fidgety. Marginal use of posture, eye contact, gestures, pace. Poor voice volume	Delivers the information but does not stay on topic. Little consideration of audience. Uses incomplete sentences. Speaker appears anxious. Difficult to	Little attempt is made to stay on topic. Does not consider audience. Presentation is difficult to follow and understand.

	and vivid to hear.	interest.	and intonation.	hear.	
Quality	Effective use of templates or designs which make the slides visually appealing. Excellent use of high-quality photographs, graphs, images, etc. that support and enhance the presentation.	Effective use of templates. Slides were somewhat appealing. Good use of photographs, graphs, and images, etc. that help to enhance the presentation.	Slides were somewhat appealing, but were not consistent. Some photographs, graphs, and images but may not enhance the presentation or support the content.	Ineffective use of templates. Few photographs, graphs, or images, or images are unrelated to content.	Slides were not effective or appealing. No use of pictures, graphs, or computer models.
Readability	All words and text are large, bold, and easy to read. Statements are brief and concise. No misspellings. Excellent grammar.	Most of the words and text are large, bold, and easy to read. Statements are brief and concise. One or two misspellings. Good grammar.	Some of the words and text are difficult to read. Statements are too long or are missing important elements. A few misspellings or grammatical mistakes.	Most of the words and text are difficult to read. Statements are too long. Presentation lacks detail. Several misspellings or poor grammar.	Text is insufficient to convey information in presentation. No detail. Consistent use of poor grammar or misspelled words.
Timing			Presentation lasted three to five minutes.	Presentation did not adhere to timeframe but lasted more than one minute.	Presentation lasted less than one minute.

PLTW ENGINEERING

Unit 2

Technical Sketching and Drawing Overview

Preface

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.

In this unit you will learn how to sketch isometric, oblique, perspective, and multiview sketches of various objects. You will also be introduced to accepted practices of technical drawing and the drawing standards that apply.

Essential Questions

1. How is technical drawing similar to and different from artistic drawing?
2. In what ways can technical drawings help or hinder the communication of problem solution in a global community?
3. Strong spatial-visualization skills have been linked to success in engineering. Why are spatial-visualization skills so important to engineering success?

Activity 2.1: Isometric Sketching

Activity 2.2: Perspective Sketching

Activity 2.3: Glass Box

Activity 2.4: Multiview Sketching

Activity 2.5: Sketching Practice

Activity 2.6: Instant Challenge: Choremaster

Activity 2.1

Isometric Sketching

Introduction

How do reading the face of a clock and **sketching** isometric pictorials relate to each other? Picture a cube in your mind. All of the surfaces of the cube form right angles with their adjacent faces. If you were to **draw** an isometric pictorial of the cube, you would see that the **edges** point toward 2 o'clock and 8 o'clock, 4 o'clock and 10 o'clock, and 6 o'clock and 12 o'clock. This idea helps when sketching isometric pictorials on writing surfaces that do not have isometric **grids**.

Isometrics are a common pictorial used both for concept sketches and to represent designs in technical drawings.

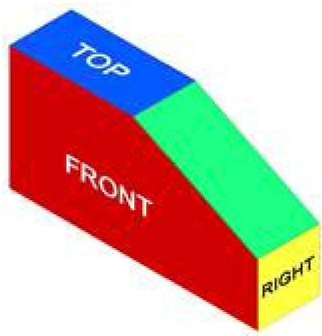
Resources

- **Line Conventions**
- **Isometric and Oblique Pictorials**
- **Sketching an Isometric Circle**
- **2.1.A Line Conventions Handout**
- **2.1.A Isometric Oblique Sketch Handout**
- **Isometric Grid Paper**

Procedure

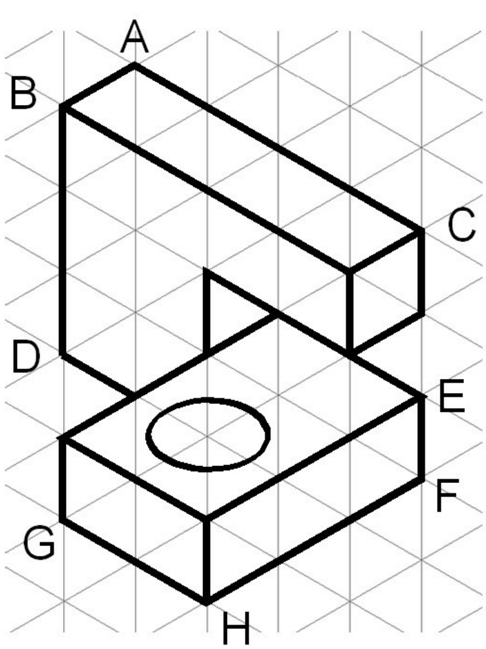
In this activity, you will develop your **isometric sketching** skills by first drawing isometric views of objects that are already given in an isometric orientation. You will apply your sketching skills in later exercises to sketch orthographic views of objects that are not given in isometric orientation and to represent your ideas and designs.

When referring to the orientation of an isometric view, the isometric view is labeled in the order of first face, second face, then third face. For example, the image on the left below shows a top, front, right-side isometric view. The same object is pictured again on the right but is shown in a top, left-side, front view orientation. We will almost exclusively use the top, front, right-side view in this course. In fact, the orientation of the isometric will dictate how you label and show the **orthographic projections** (or side views) of the object in later activities.



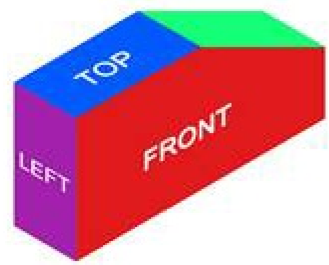
Top, Front, Right-Side View

Use points and construction lines to lay out the isometric sketches. Then delineate the visible edges of each sketch with heavy object lines to make them stand out. DO NOT ERASE YOUR POINTS AND CONSTRUCTION LINES. Add tonal **shading** to the sketches.



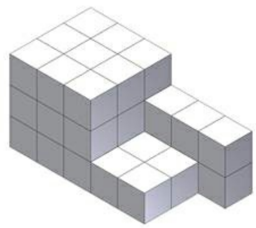
Reproduce the isometric view shown in the following sketch to the left on isometric grid paper (linked from Resources above). Start with **points** and **construction lines** to lay out the isometric sketches, as shown in the following image to the right. DO NOT ERASE YOUR POINTS AND CONSTRUCTION LINES.

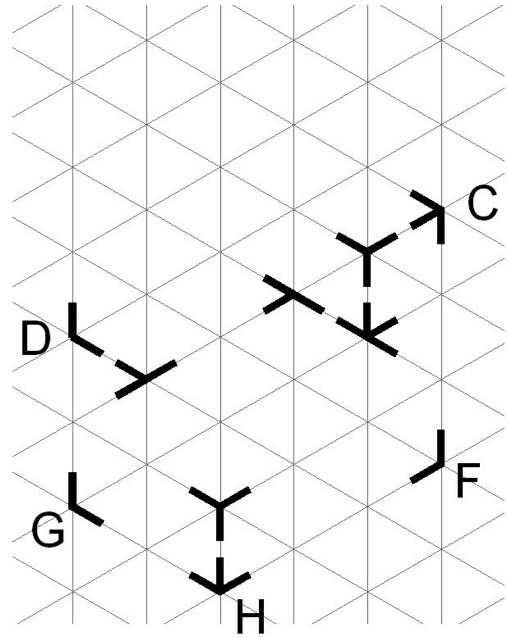
Make isometric sketches of the three objects pictured in the following diagrams. Sketch the objects on the back side of isometric grid paper using the same orientation in which they are pictured. Using the back side of the printed grid paper will allow more contrast between your **object lines** and the grid lines.



Top, Left-Side, Front View

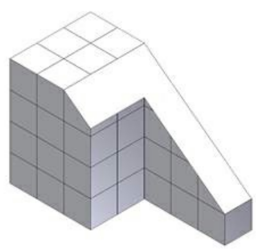
1.



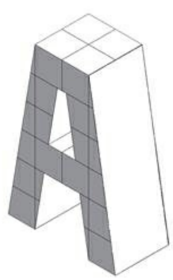


Top, Front, Right-Side View

2.

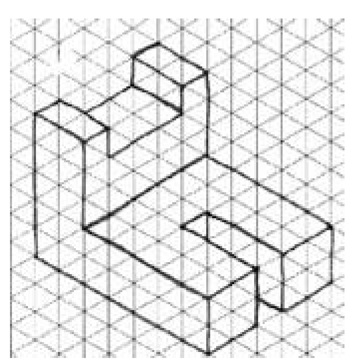


3.

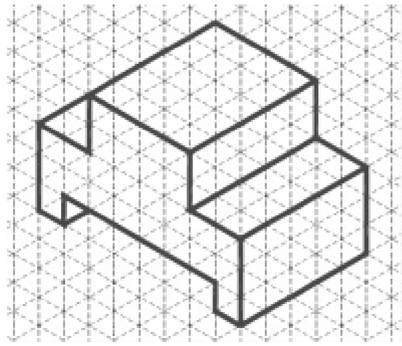


Study the isometric views that follow. Using the back side of grid paper, your engineering notebook, or graph paper (as indicated by your instructor) recreate the two isometric views for practice.

4.

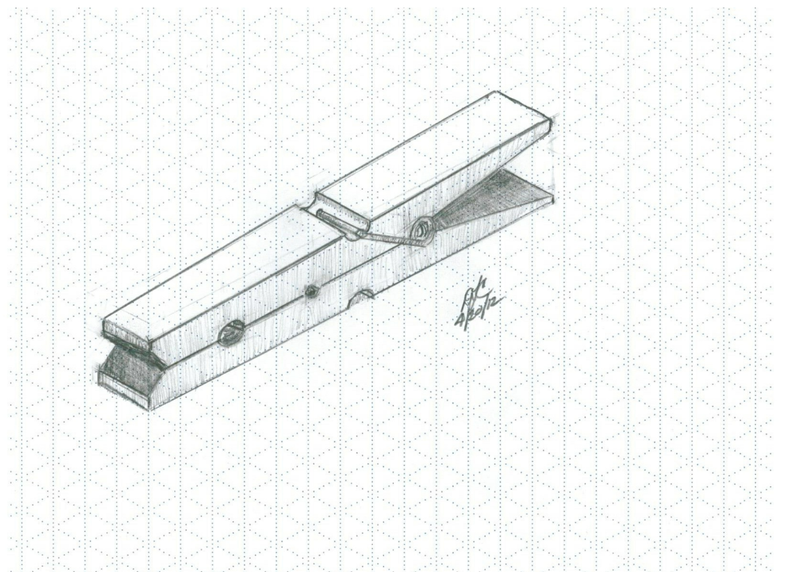


5.

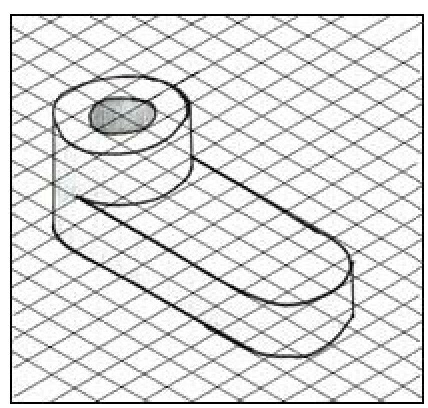


6. Create an isometric sketch of one of the following objects. You do not need to measure the object, but try to represent the object at an appropriate **scale** to fill a quarter of a sheet of graph paper using correct **proportions**.

    - Toothbrush
    - Clothespin
    - Flash drive
    - Flashlight
    - Monitor
    - Chair
    - Surge protector
    - Cell phone
    - Remote control device
    - Other instructor-approved object

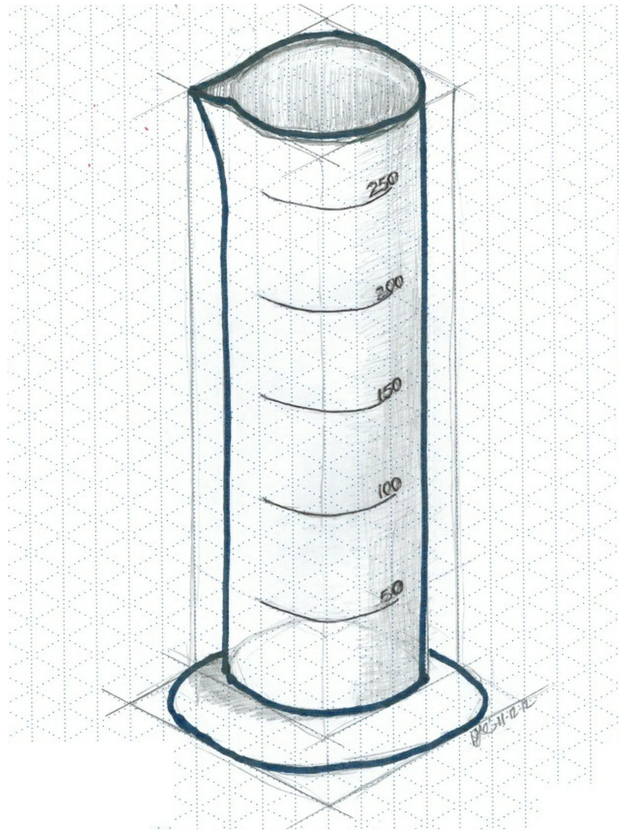


7. Study the isometric to the right. Using the back side of grid paper, your engineering notebook, or graph paper (as indicated by your instructor) recreate the isometric view for practice. Refer to the Sketching an Isometric Circle slideshow (linked in Resources above) to learn techniques for sketching isometric circles to represent the arcs and circles in this view.



8. Using the techniques you have learned for sketching isometric circles, create an isometric sketch of one of the following objects. You do not need to measure the object, but try to represent the object at an appropriate scale to fill a quarter of a sheet of graph paper using correct proportions.

- Coffee cup
- Flashlight
- Jar
- Highlighter, pen, or pencil
- Beverage can or bottle
- Graduated cylinder



Conclusion Questions

1. What are the advantages and disadvantages to using an isometric pictorial compared to using an oblique pictorial in technical drawings?
2. What is the difference between a two-dimensional sketch and an isometric sketch?
3. Why do designers use tonal shading?

Line Conventions

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Isometric and Oblique Pictorials

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Sketching an Isometric Circle

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 2.2

Perspective Sketching

Introduction

If you can stand on a straight road and look down the road, it appears as if the sides of the road eventually narrow to one **point**. The center of the road vanishes when the road meets the horizon. If the road is straight enough and long enough, the sides of the road not only look like they are converging to a single point, but the road seems to appear to vanish as it meets the horizon. A similar effect occurs if you stare upward from the base of a tall building. The vertical edges of the building will appear to angle in toward each other. This effect is called perspective.

The human eye sees the world in perspective. Objects that are further away from the eye appear smaller, and **edges** appear to recede into the distance. **Perspective sketches** depict objects in much the same way that the human eye sees the world.

There are three different types of perspective drawings: one-point, two-point, and three-point perspective. The different types of **sketches** are frequently used by architects, industrial designers, and illustrators when representing large-scale objects or environments in which the effect of distance must be taken into consideration.

In this activity, you will practice your sketching skills by generating perspective views based on provided isometric views of objects. You will also apply your skills by creating one-point and two-point perspective sketches of other imagined or real objects that you choose.

Equipment

- Various objects

Resources

Perspective Sketching

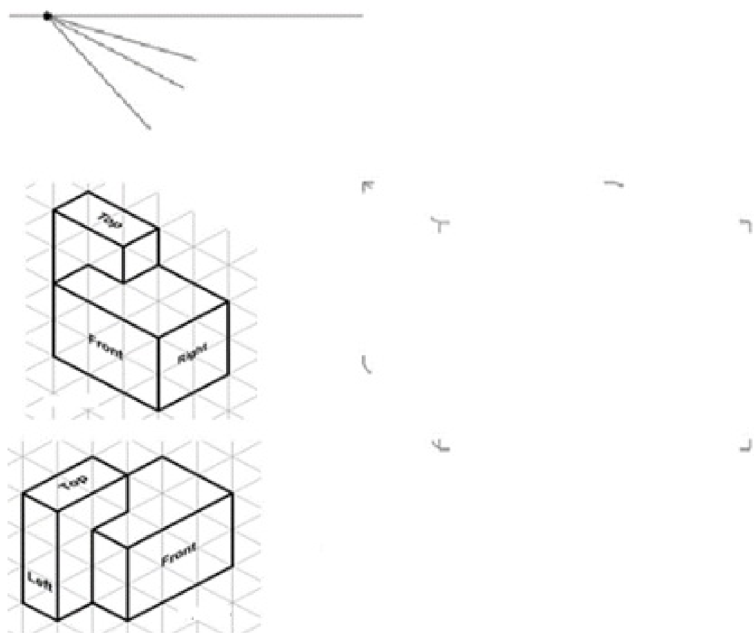
Orthographic grid paper

Procedure

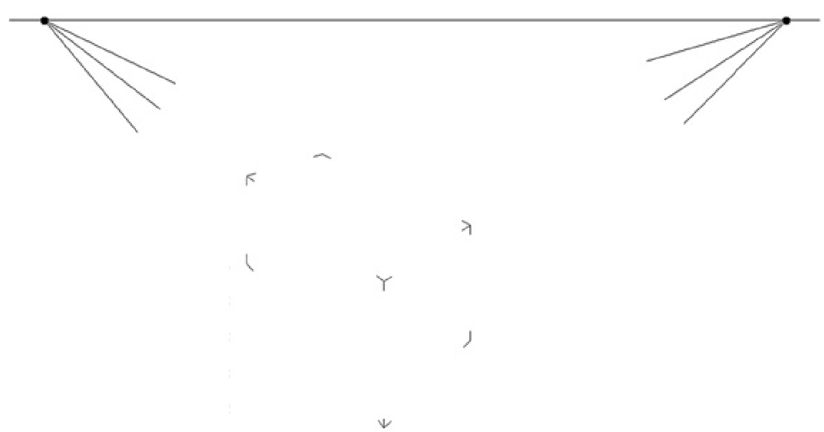
Create each of the following perspective sketches on the back of orthographic grid paper or in your PLTW Engineering Notebook, as instructed by your teacher.

1. Draw a one-point perspective sketch of the object shown in the two isometric views. Each

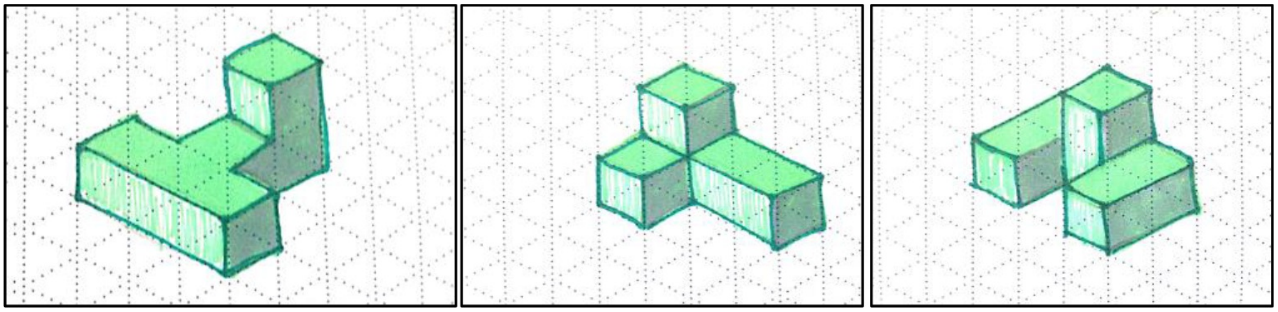
isometric view represents the object as viewed from a different line of sight. First sketch a **vanishing point** and a horizon line, as shown, to lay out light **construction lines**. **The perspective sketch must show the object in a top, left-side, front view orientation.** Delineate the visible edges of the sketch with heavy **object lines**. DO NOT ERASE YOUR CONSTRUCTION LINES. Add tonal **shading** to the sketch.



2. Draw a two-point perspective sketch of the object shown in item 1. First, lay out a horizon line, vanishing points, and construction lines. **The perspective sketch must show the object in a top, front, right-side view orientation.** Delineate the visible edges of the sketch with heavy object lines. DO NOT ERASE YOUR CONSTRUCTION LINES. Add tonal shading to the sketch.

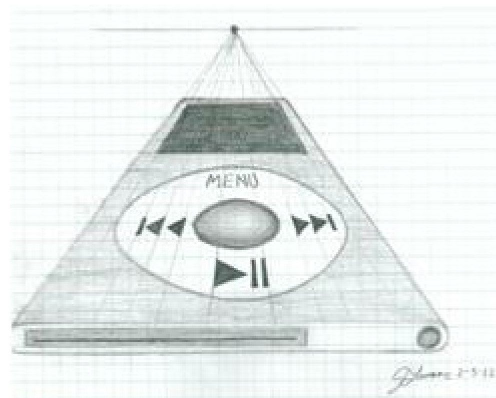


3. Three objects are shown in isometric view. Create a one-point perspective sketch of <u>at least one</u> of the objects. Use a pencil to create construction lines. Use ink to delineate the object lines. Add tonal shading.



4. Create a two-point perspective sketch of one of the objects shown in item 3 using pencil to create construction lines. Use ink to delineate the object lines. Add tonal shading.

5. Select one of the objects from the list and create a one-point **or** two-point perspective sketch. Shade the sketch.



- Highlighter, marker, etc.
- Clothespin
- Flash drive
- Flashlight
- Coffee cup
- Toothbrush
- Monitor
- Surge protector
- Cell phone, iPod, iPad, Kindle, or similar item
- Printer
- Remote control device
- Other object approved by your instructor

Conclusion Questions

1. What is a vanishing point?

2. Aside from the number of vanishing points, what is the difference between a one-point, two-point, and three-point perspective sketch?

3. How does a perspective drawing differ from an isometric drawing of the same object? When would you use a perspective view in lieu of an isometric drawing?

Perspective Sketching

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 2.3

Glass Box

Introduction

Rarely does a **pictorial sketch** provide enough information to produce an object accurately. Instead, multiview (or orthographic) drawings are used to provide a more accurate representation of an object and can be used to guide the creation of a physical object**. Multiview drawings** are used to show **views** of the faces of the object as if the viewer is looking directly at that face so that the line of sight is perpendicular to the face. This depicts the surface as the true size and **shape**.

The idea of **orthographic projections** can be demonstrated using a glass box. Place an object in a glass box so that the faces of the object are parallel to the sides of the box. The features of each surface of the object can be projected onto a side of the glass box by drawing lines to indicate the object **edges** on the glass box surfaces. Typically a multiview drawing will include a front, side and top orthographic projection as well as an isometric view.

In this activity you will design and build a "glass" box from a flat sheet of transparency film. You will then use your glass box to help you sketch orthographic projections of an object and create multiview drawings.

Equipment

- Transparency print of Glass Box Pattern
- Wet-erase markers
- Transparent tape
- Scissors
- Heavy paper or card stock

Resources

Glass Box Pattern

Multiview Sketching

Glass Box Assembly

A**ctivity 2.3 Glass Box Answer Sheet**

Orthographic Graph Paper

Procedure

1. A box net is a flat pattern that will fold into a box. Study the following patterns. Some of the following patterns are cube nets, that is, if cut along the exterior lines and folded on the interior lines, the flat pattern can be transformed into a box in the form of a cube. Which flat patterns that are cube nets? Click on each blue icon to reveal whether the flat pattern is a cube net.

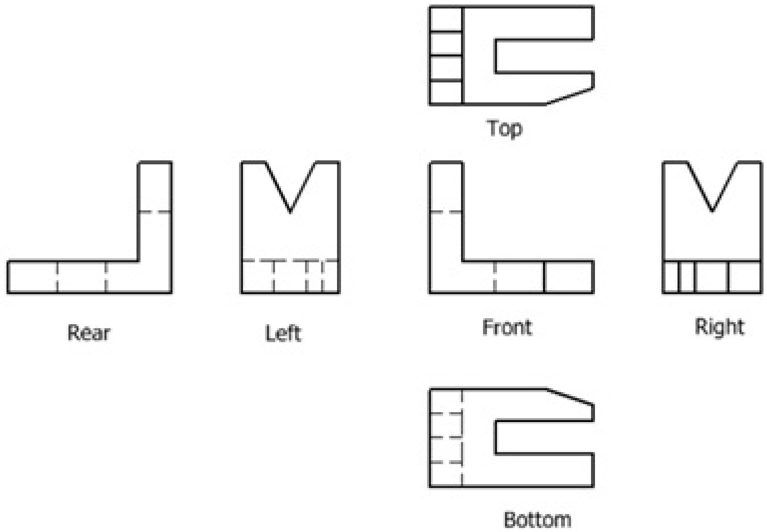
Flat Patterns

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

2. Brainstorm additional cube nets. Sketch as many additional cube nets as you can think of in your engineering notebook or on orthographic grid paper. Avoid nets that are rotations or reflections of those already identified.
3. Can you see a pattern to the nets that will fold into a box?
    - How many squares are included in a cube net? Why is this always the case?
    - What else is true about the arrangement of the squares in a cube net?
    - Put an X through your sketches that are not unique, that is, that are rotations or reflections of the nets you identified in step 1 or sketched previously in step 2.
    - There should be at least six unique cube nets. Sketch any cube nets missing in the step above.

You will use one of your cube nets to build a transparent "glass" box from transparency film. You will then place an object inside your glass box and sketch all six orthographic projections of the object on the box.

Remember that the orthographic projections of a multiview are carefully oriented with respect to the point of view shown by each. The principle multiview used in the United States (called third-angle projection) provides orthographic projections arranged and aligned as shown in the following drawings.

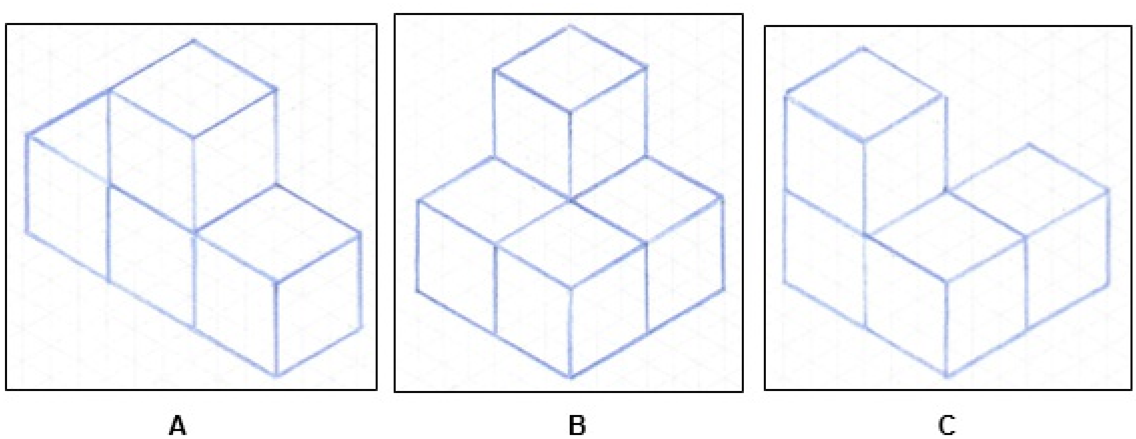


4. Review your cube nets and compare them to the multiview of orthographic projections shown previously. Choose the cube net that will provide proper orientation of views when you unfold your glass box. Circle your chosen net.

5. Obtain approval of your net from your instructor and obtain a copy of your chosen net printed on transparency film. Have your teacher initial your choice.

6. Assemble your glass box. Use transparent tape to secure adjacent sides together except do not secure the top side at this time. You will need to open the box to place objects inside.

7. Study the following **isometric sketches** of three objects. Your instructor will assign you to work with one of these objects.



Which object were you assigned? ☐ A ☐ B ☐ C

8. Sketch a flat pattern for your object in your PLTW Engineering Notebook or on orthographic grid paper. Assume that each cube shown in the sketches is a 3/4-inch cube. This will be much more complex than a cube net. Take your time. If it is helpful, you can cut out your net and test it by folding it.

9. Obtain approval of your flat pattern from your instructor.

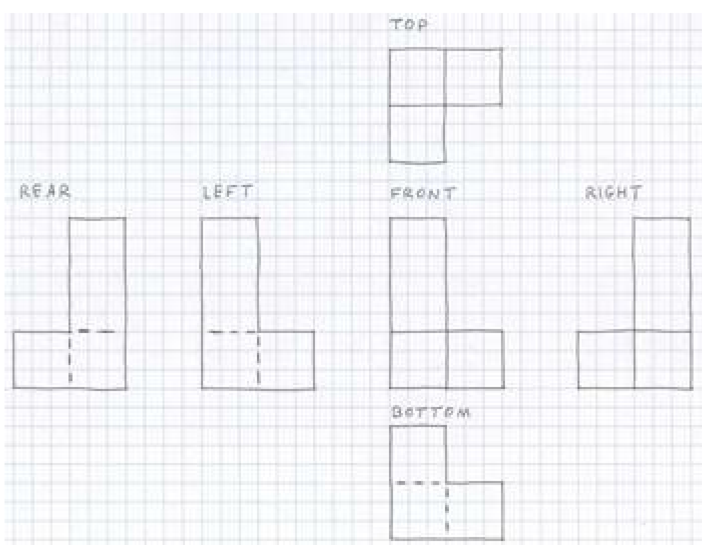
10. Transfer you flat pattern to heavy paper or card stock. Cut it out, and assemble your object.

11. Carefully choose the <u>best</u> front view for the object. Then tape your object to the bottom of the transparent box so that your chosen front view is oriented toward the front face of the glass box. Be sure to carefully align the object to the grid lines. Then secure the top side of the box with transparent tape.

12. Sketch orthographic projections on each face of the box until all six views are drawn on the box faces. Be sure to include **hidden lines** to represent hidden edges.

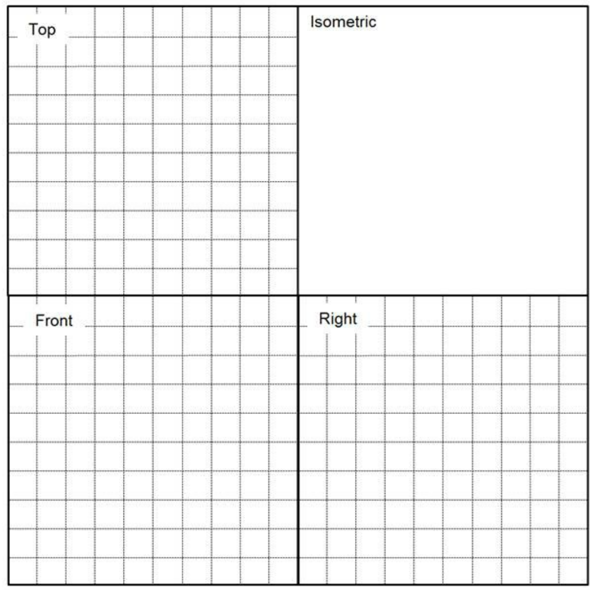
13. Remove the tape and flatten the transparency film.

14. Using your flattened transparent net, reproduce the six views on grid paper in the correct orientation. Include **construction lines** to demonstrate proper alignment between adjacent views and hidden lines where appropriate. Correctly label each view.



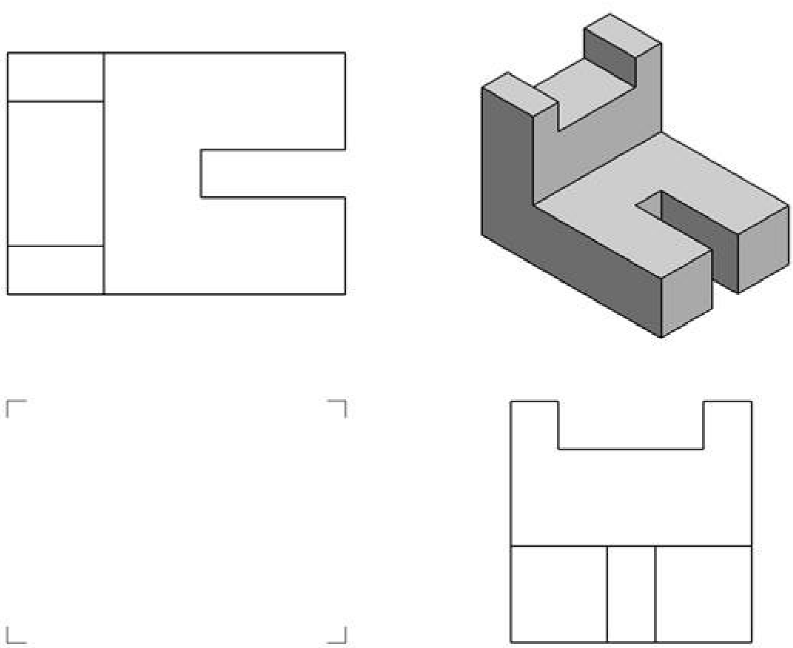
You may document your answers to the following items on the **Activity 2.3 Glass Box Answer Sheet.**

15. Exchange your object with another student. Carefully choose the front view for the new object. Then, using your glass box if necessary, sketch a three-view **drawing** (to include a front, top and right view) and the related isometric pictorial. Be sure to align your views correctly using the orientation shown below. Include hidden lines where applicable.

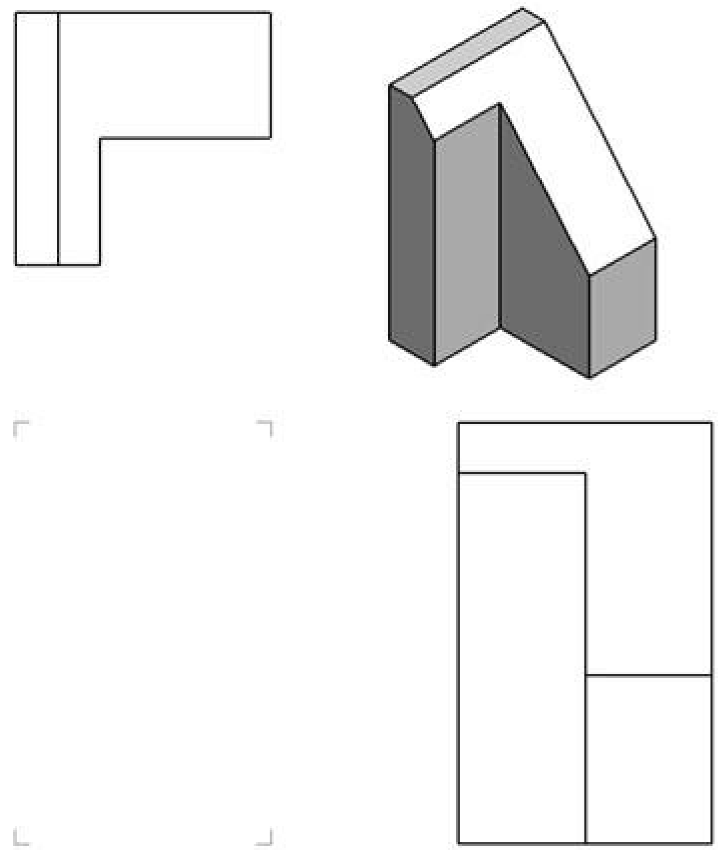


Study the images below. Imagine the object inside your glass box. Use **points**, construction lines, hidden lines, **center lines**, and **object lines** where applicable to sketch the missing view. Then add hidden lines and center lines to the other views, as applicable.

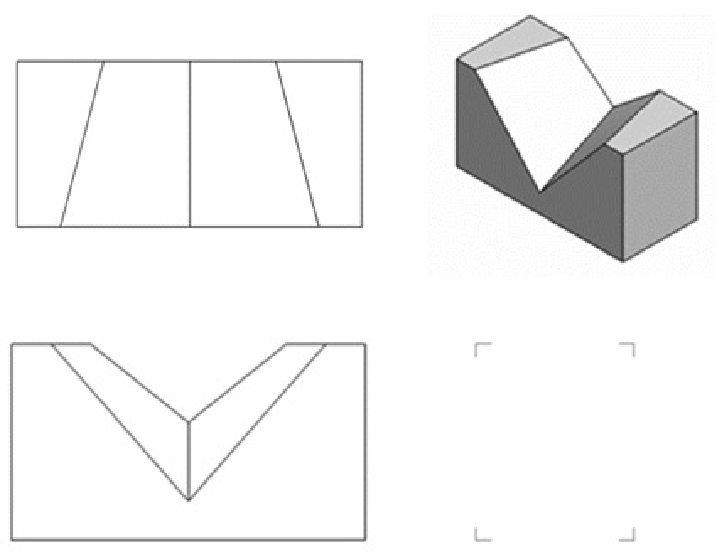
16. Draw the missing view.



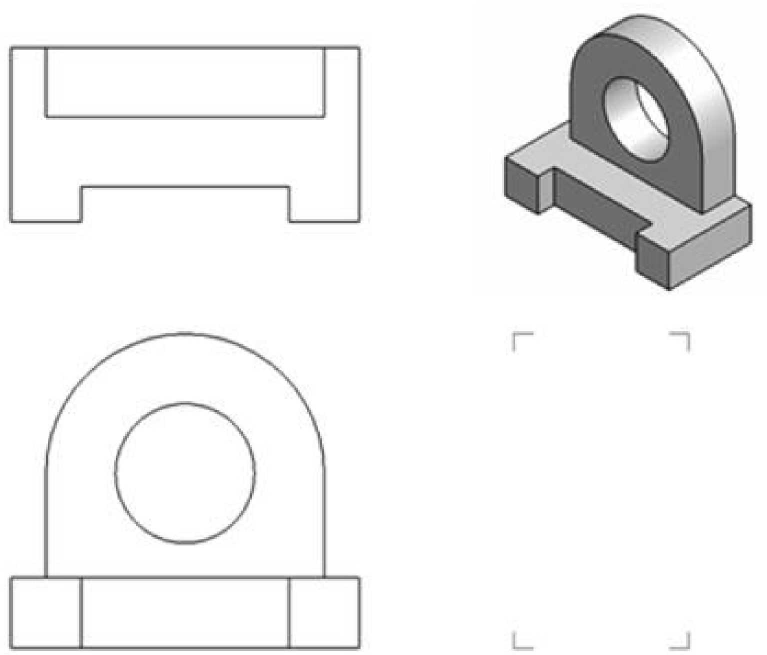
17. Draw the missing view.



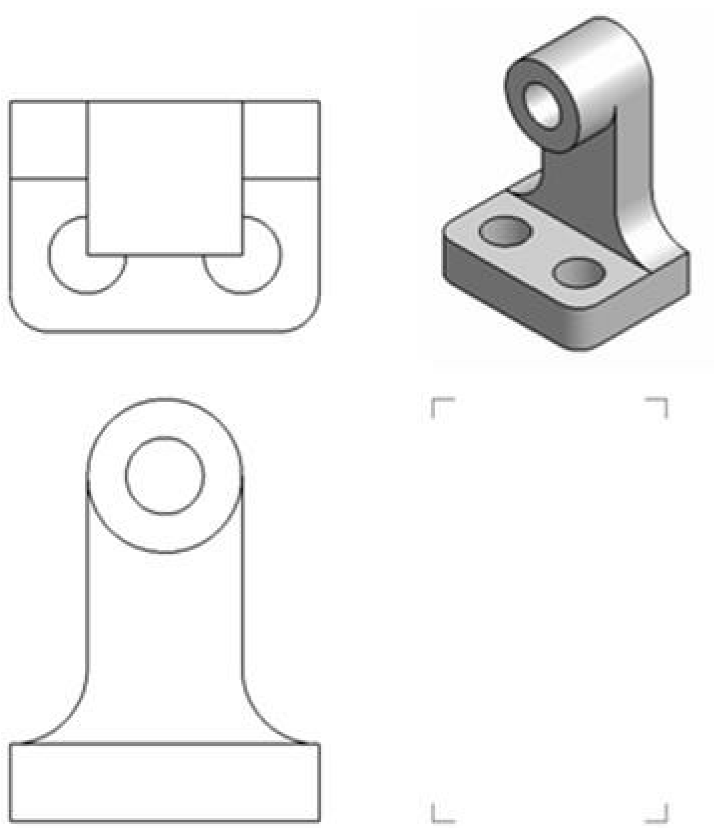
18. Draw the missing view.



19. Draw the missing view. Add the missing hidden lines and center lines to the views provided.



20. Draw the missing view. Add the missing hidden lines and center lines to the views provided.



Conclusion Questions

1. How do you determine the orientation of orthraphic projections in a multi-view drawing?
2. How would you describe the geometric relationship that exists between the adjacent views of a multiview drawing?
3. Why is it important to lay out a multiview sketch with points and construction lines before drawing object lines?

Multiview Sketching

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Glass Box Assembly

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 2.4

Multiview Sketching

Introduction

It's a very common occurrence to see a product advertisement and think, "I thought of an idea for something like that just a few months ago." People spend a lot of time in their various interest areas and envision ideas for making things work better. Spend some time with someone who has a permanent disability and see how many product ideas come to mind that would provide a degree of freedom to a person who has lost a physical capability. Coming up with wonderful ideas are only the first step in developing solutions to problems. At some **point**, ideas must be built.

You've practiced different techniques for sketching objects so that they appear to have a **three-dimensional** quality. These techniques are excellent for quickly communicating ideas to both technical and nontechnical people. Those who make their living building ideas require a different type of drawing format. A multiview sketch, also referred to as an **orthographic projection** sketch, is the standard sketch format used by engineers to communicate ideas to professionals in the building trades.

However, pictorials do not provide accurate information about the true size and **shape** of an object and all of its features. It is often the case that engineered objects have features and **edges** that are obscured by the standard surface views of a **multiview drawing**. These **views** require **hidden lines.** When engineers create **drawings** of cylindrical objects, or objects that have holes, they must represent their axes and axes points with centerlines.

Knowing how to **sketch** and interpret multiviews is an important skill for any engineer. In this activity, you will develop your ability to see and sketch objects as a series of related **two-dimensional** views. Understanding and using the different **line conventions**, discussed earlier in this lesson, will help when creating these views.

Resources

Activity 2.4 Multiview Sketching Answer Sheet

Procedure

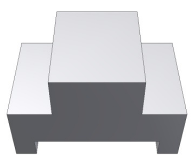
Use the Activity 2.4 Answer Sheet to respond to items, as appropriate.

1. Study the images that follow. The various surfaces of the object are identified by letters on the i**sometric drawing** and by numbers on the multiview drawing. Choose the number that corresponds with the lettered surface in each of the top, front, and right-side views. Click in the table to check your answer.

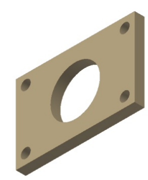
Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

2. For each of the six objects shown:

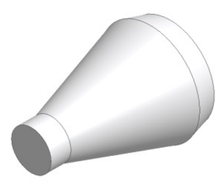
   - Select the face that would provide the best front view and create a quick sketch of the orthographic projection showing your selected view in approximate **proportions**.
   - Determine the minimum number of views required to adequately represent the object
   - List the views (in addition to the front view) that you would use to represent the object. For example, you might list Right Side and Top.



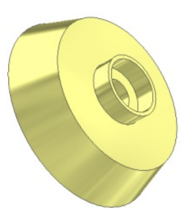
Object 1



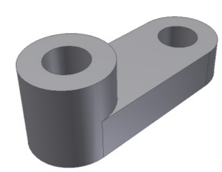
Object 2



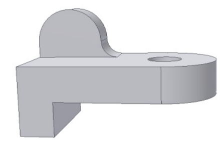
Object 3



Object 4



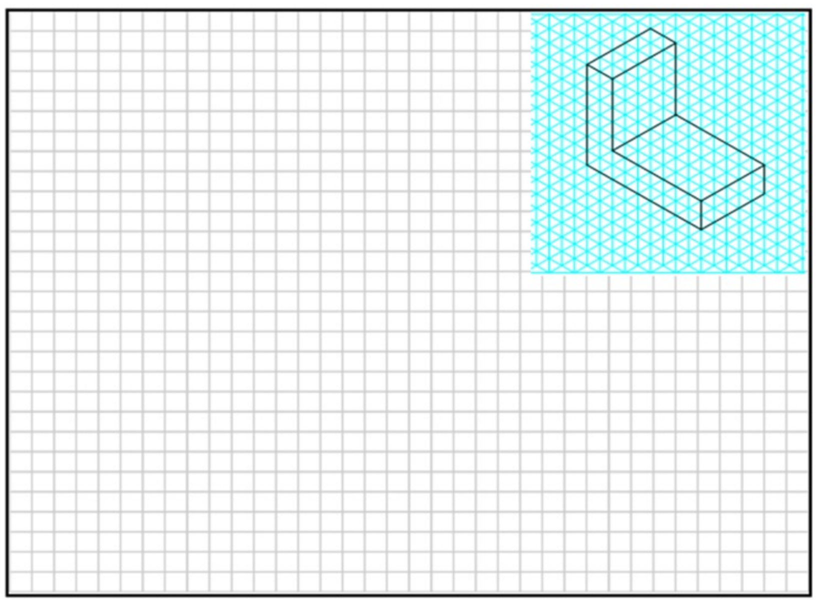
Object 5



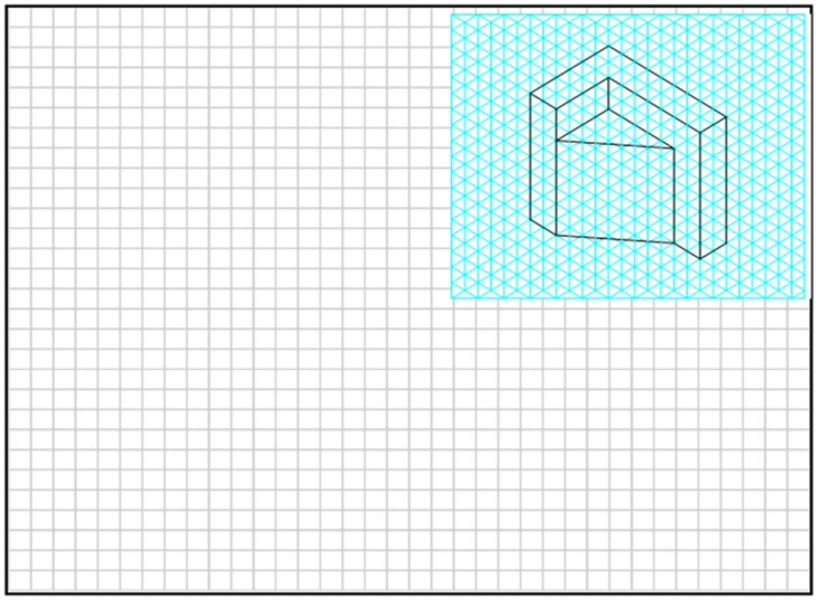
Object 6

Study the following isometric views. On grid paper, use points, hidden lines, **construction lines**, and **object lines** to sketch the three common views used to explain the object. The **scale** is 1:1, which means that each grid line on the isometric view represents a grid line on the orthographic grid. **DO NOT ERASE YOUR POINTS AND CONSTRUCTION LINES**.

3.



4.



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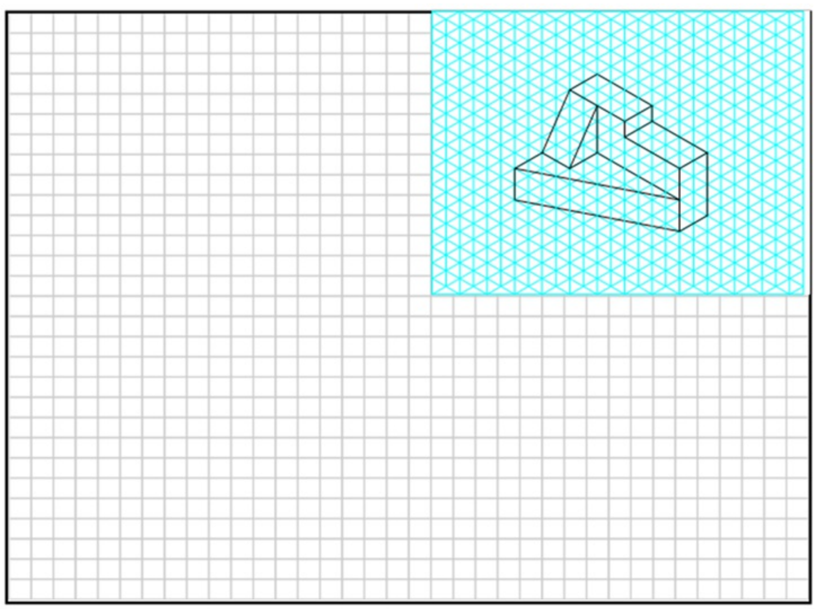
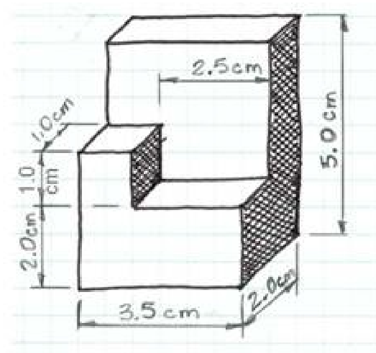


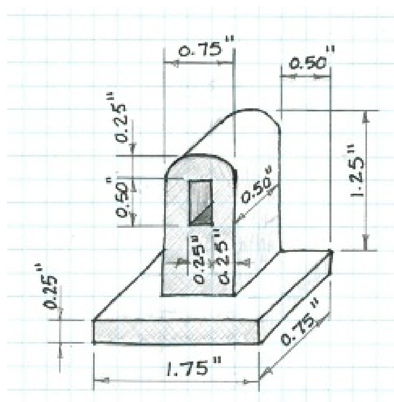
Extend Your Learning

For each of the following, create properly aligned orthographic projections on grid paper. Use the minimum number of orthographic projections necessary to fully describe the object shown. Include object lines, hidden lines, and **center lines** in all views, as appropriate. The sketches should be approximately proportional, but are not required to be drawn to scale.

6.



7.



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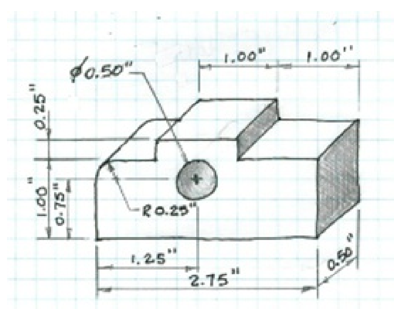


Conclusion Questions

1. What is the purpose of construction lines? Object lines?
2. What is the purpose of hidden lines and center lines?
3. What type of pictorial is shown in the first representation in item 2? How can you tell?
4. What type of pictorial view is shown in item 6? How can you tell?
5. Why would building professionals, such as machinists and contractors, prefer multiview drawings over pictorial drawings?

PLTW ENGINEERING

Activity 2.5

Sketching Practice

Introduction

Sketching is a valuable engineering skill that needs to be developed through practice. Through practice you will be able to communicate your vision of your idea.

In this activity you will apply the skills that you learned earlier in this lesson to more complex objects.

Resources

Activity 2.5 Sketching Practice Flat Patterns Student Resource

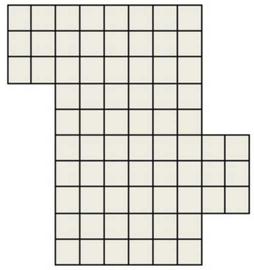
Isometric Grid Paper

Procedure

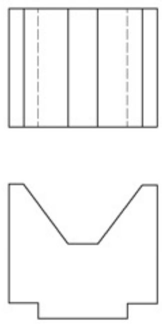
Each of the nets can be cut out and folded into a rectangular prism. Note that there may be more than one square on each face of the box once constructed. Sketch an isometric **pictorial sketch** for each of the boxes formed.

1.

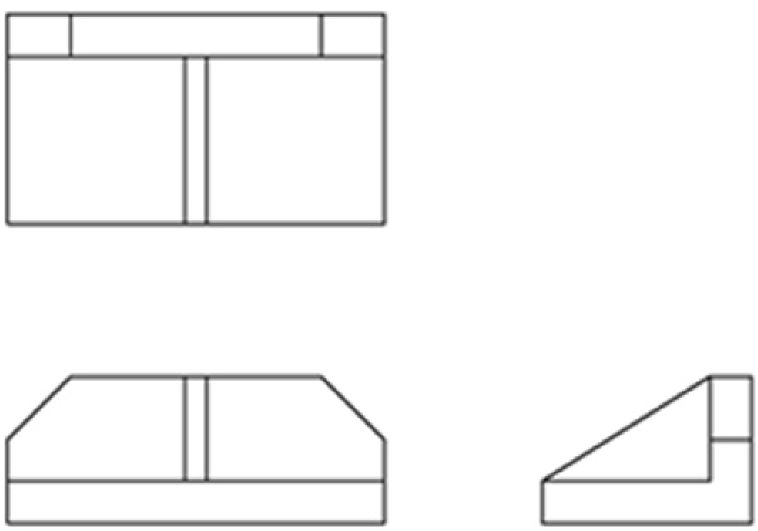
2.



3. Create a one-point perspective of the object represented by the **orthographic projections**. Apply tonal **shading**.

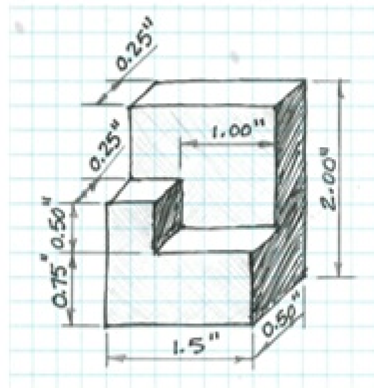


4. Create an isometric view of the object represented by the multiview. Apply tonal shading.

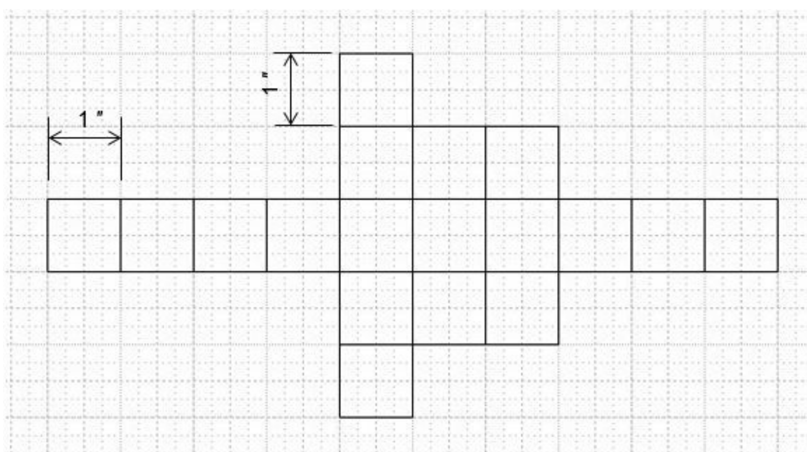


5. Sketch a two-point perspective view of the object represented by the sketch. Apply tonal

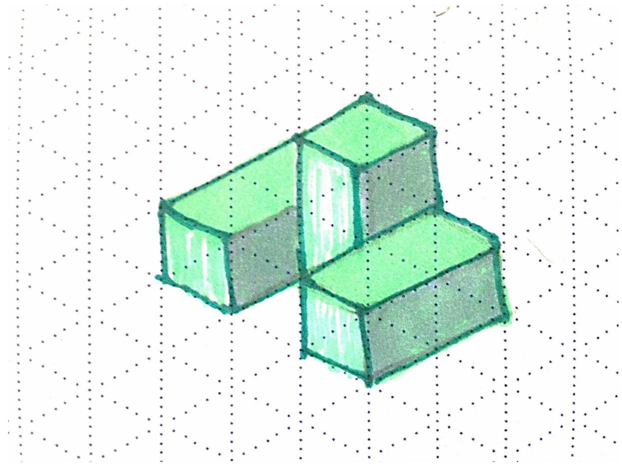
shading.



6. The flat pattern can be folded to create a hollow form. Each square on the pattern is 1 in. x 1 in. Sketch an isometric view of the form to **scale** on grid paper. Be sure to select the best front view and orient the sketch appropriately.



7. Produce a multiview sketch of the object represented by the isometric on grid paper using the minimum number of views necessary.



Conclusion Questions

1. What is a technical sketch? What is an artistic sketch? How are the two similar and how are they different?
2. How do you envision applying your sketching skills in other classes?
3. How do you envision applying your sketching skills in college?
4. How would you teach sketching to a student next year?

Instant Challenge: Choremaster

Introduction

There are many ways to solve a problem. Sometimes it is as simple as applying a piece of duct tape. Other times it takes months or years for a product to progress from an idea into full-scale production. In this activity your team will quickly design a product to perform a household chore using the available materials.

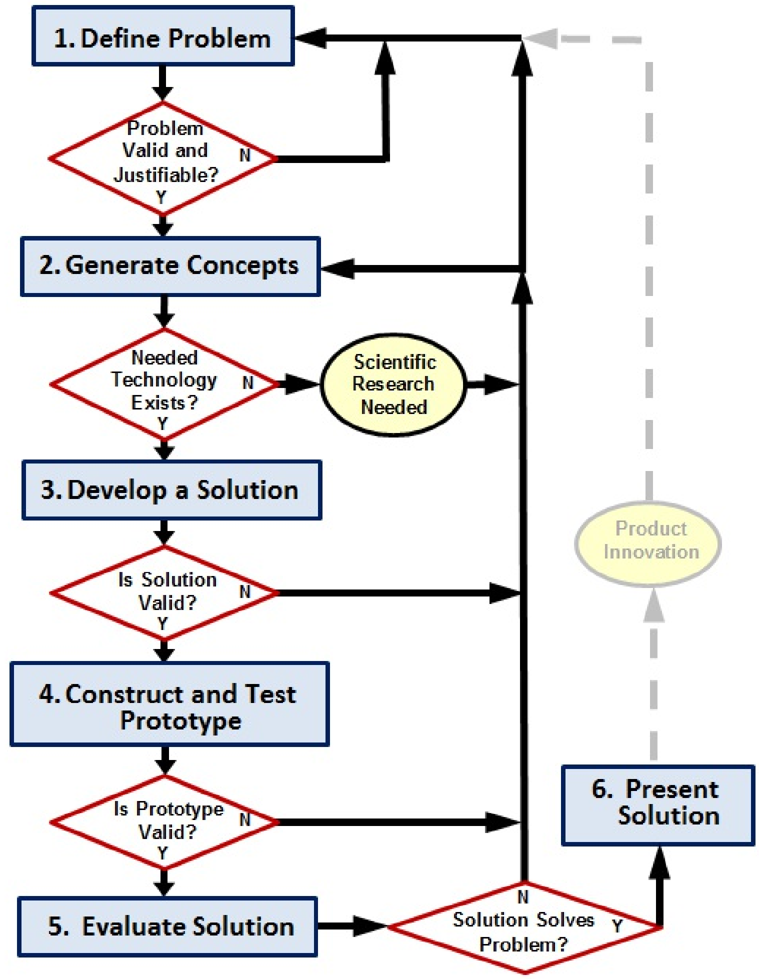
In this activity your team must think of a common household chore, then create a gadget to make that chore easier to perform. After the allotted time, your team will present a performance of your chore to the rest of the class.

Equipment

- Paper
- 12” foil
- 12” yarn
- 12” masking tape
- 5 cotton swabs
- 3 paper clips
- 3 paper plates
- 1 fabric square
- 1 sheet of newspaper
- 1 yard stick
- 1 shoe (supplied by the group)
- 1 sponge
- 1 paint brush

Procedure

1. Divide into teams with direction from your teacher.
2. Agree on a common household chore to create a product (2 minutes).
3. Define the problem, generate concepts, and develop a solution
(12 minutes).
4. Construct and test a prototype (12 minutes).
5. Present the solution to the class
(2 minutes).



Scoring

Your team may receive points for the following.

- Creativity: Up to 10 points for creativity in the design and use of materials.
- Teamwork: Up to 10 points for how well your team works together.
- Performance: Up to 10 points for how well the product completes the chore.

Conclusion

1. What were the major obstacles to selecting a solution?
2. How could you improve the effectiveness of your team?

PLTW ENGINEERING

Unit 3

Measurement and Statistics

Preface

The International System of Units (SI units) is accepted as the international standard for acquiring and communication measurements. Today, in the United States, we use both the U.S. customary system of units and the International System of Units.
In this unit, you will be introduced to measurement and precision of measurement using each of the common unit systems through the study of linear distance and angles. You will also learn to use statistics to organize, analyze, interpret and present measurement data.

Essential Questions

1. Can statistics be interpreted to justify conflicting viewpoints? Can this affect how we use statistics to inform, justify and validate a problem solution?
2. Why is error unavoidable when making a measurement?
3. What strategy would you use to teach another student how to use units and quantitative reasoning to solve a problem involving quantities?
4. What would happen if engineers did not follow accepted dimensioning standards and guidelines but, instead, used their own individual dimensioning methods?

Activity 3.1.a: Linear Measurements SI

Activity 3.1.b: Linear Measurements US

Activity 3.2: Unit Conversion

Activity 3.3: Making Linear Measurements

Activity 3.4: Linear Dimensions

Activity 3.5: Applied Statistics

Activity 3.6: Instant Challenge Fling Machine

Activity 3.7: Statistical Analysis with Excel

Activity 3.8: Precision Accuracy Measurement

Project 3.9: Manufacturing a Box

Optional Activity 3.10: Instant Challenge: Oil Spill

PLTW ENGINEERING

Activity 3.1.a

Linear Measurement with the International System of Units

Introduction

Modern civilization cannot exist without measurement systems. Measurements are everywhere, and you use them every day. Every time you buy gas, check the outside temperature, or step on a weight scale, measurements are used to represent a quantity. The abilities to conduct, record, and convert measurements are necessary to understand our technological world and to carry on the business of living. The fields of science, engineering, and mathematics use measurements extensively in the processes of discovery and design.

An interesting aspect of measurement is that a single quantity can be **measured** in different ways. I may describe the height of a horse in hands, feet, or meters. I can give the length of a property line in chains, miles, or meters. The **units** commonly used to measure a quantity can change with time and across borders. In the past it was not necessary to understand the system of measurement used by people outside of your local area, but today the world is a global marketplace.

The United States is the only developed country that has not fully adopted the **International System of Units**. In order to participate in the global market, we must be able to understand and communicate using various measurement systems. An object that is designed in the United States may end up being manufactured in another country. Due to the global nature of technology, engineered objects must often be communicated in SI (modern metric) units.

With respect to measurements within the science, engineering, and mathematical communities, **accuracy** and **precision** of measurements is extremely important. Often the correctness of a measurement is critical to the work of scientist, engineers, and mathematicians and must be carefully considered.

In this activity you will practice taking linear using SI measurements with a metric ruler and correctly recording the measurements to reflect the precision of the measurement.

Equipment

- Ruler – metric
- PLTW Engineering Formula Sheet

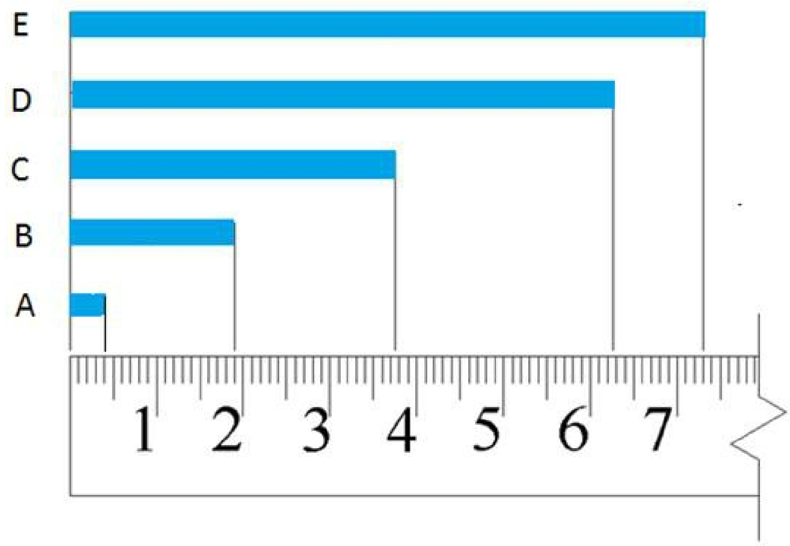
Resources

SI Measurement System

[Activity 3.1a Linear Measurements SI Answer Sheet](#)

Procedure

Record the length of the rectangles shown in the figure using SI units and the correct number of significant figures. Include the units in your answers.



	Distance	Measurement
1.	A	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.
2.	B	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.
3.	C	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.
4.	D	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

5.	E	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Calculate each of the following lengths and record the answer using appropriate **significant digits** and the correct units. Show all calculations.

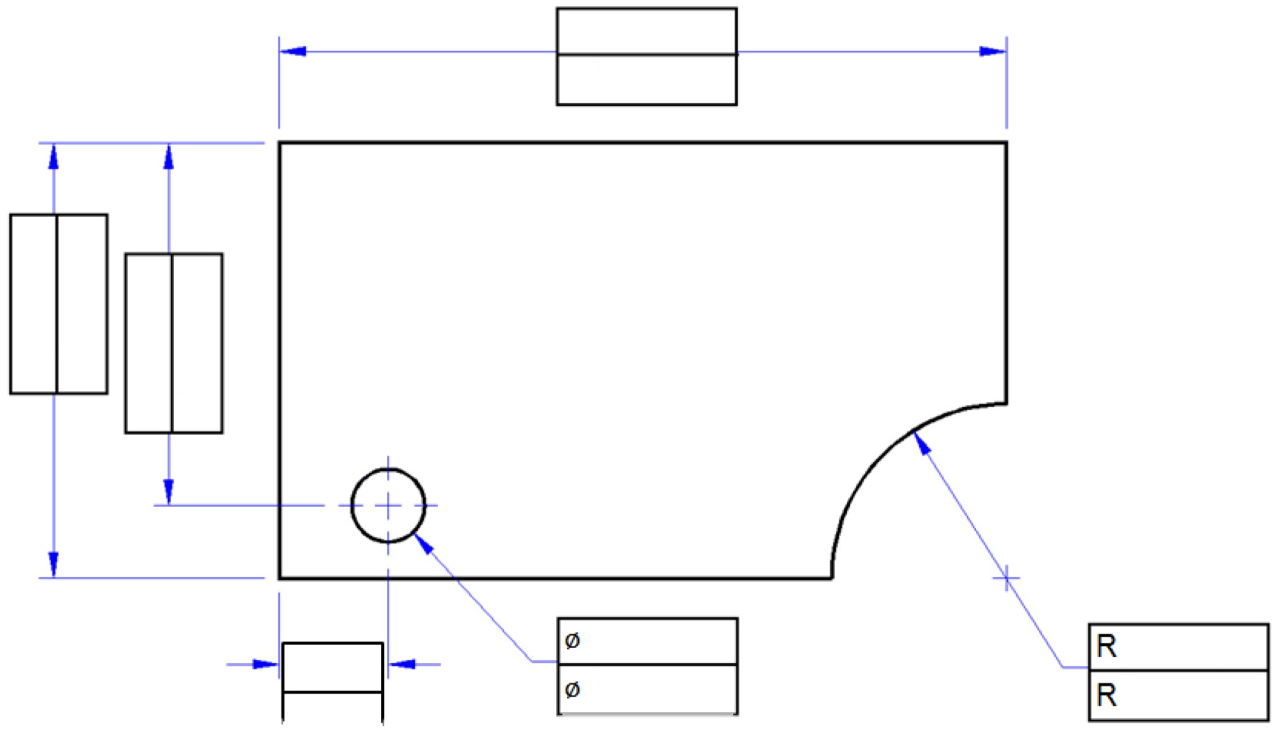
6. What is the difference in the length of rectangles A and C?

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

7. What is the difference in the length of rectangles B and E?

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

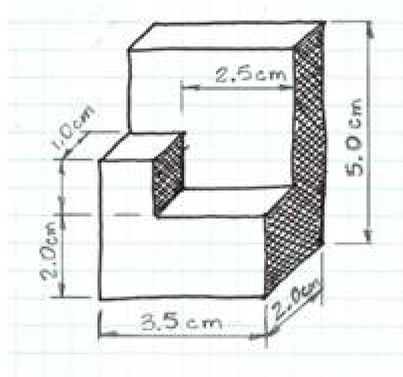
8. Using a metric ruler, measure the missing lengths in the figure **on the Activity 3.1a Answer Sheet** and enter the **dimensions** in the boxes on the answer sheet. Be sure to use the correct number of significant digits and include units.



9. Measure and record the linear measurement of items in your classroom using appropriate metric units as directed by your instructor. Be sure to include the appropriate number of significant digits.

Object	Description of measurement	Measurement units	Measurement
CD	Diameter	cm	
Lined paper	Distance between lines	mm	

10. In your engineering notebook, create a full scale isometric view of the object represented in the sketch using the dimensions shown. Use a metric ruler to obtain the correct dimensions on your sketch.



11. What type of pictorial is shown in number 10? How can you tell?

Conclusion

1. Explain the meaning of significant digits (or significant figures) in measurement.
2. Why is the metric system used instead of the US customary system, and vice versa, in various parts of the world?

SI Measurement System

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 3.1.b

Linear Measurement with US Customary Units

Introduction

The United States is the only developed country that does not use the **International System of Units**. The **U S Customary units** are the accepted **units** of **measure**. However, due to the global nature of the economy, SI units are also common. In order to participate in the global market, we must be able to understand and communicate using various measurement systems.

In this activity you will practice taking linear measurements using a standard ruler marked in US Customary units and correctly recording the measurements to reflect the **precision** of the measurement.

Equipment

- Ruler – U S Customary
- PLTW Engineering Formula Sheet

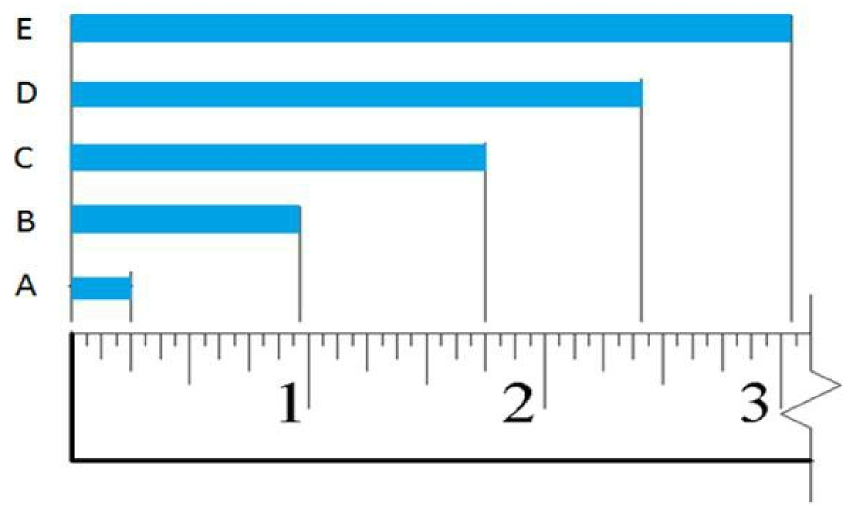
Resources

US Customary Measurement System

Activity 3.1b Linear Measurements US Answer Sheet

Procedure

Record the length of each rectangle in both fractional inch and decimal inch forms. Record fractional inches to the nearest 1/32 of an inch, and record decimal inches to the nearest hundredth of an inch.



	Distance	Measurement (Fraction)	Measurement (Decimal)
1.	A	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.
2.	B	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.
3.	C	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.
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5.	E		Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course. Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

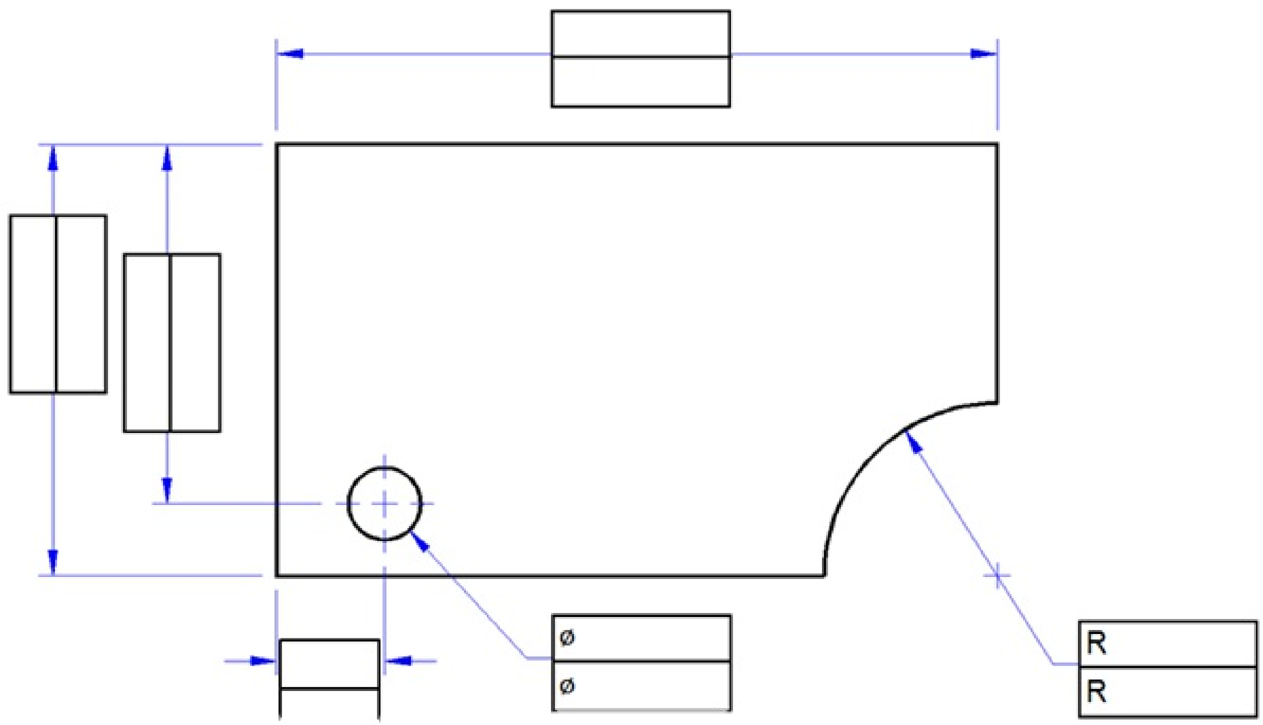
6. What is the difference in length between rectangles A and C?

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

7. What is the difference in length between rectangles B and E?

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

8. Using a ruler displaying U S Customary units, measure the missing lengths on the **Activity 3.1b Answer Sheet**. In the top half of each box, enter the **dimension** in fractional inches to appropriate precision (nearest 1/32″). Then **convert** the length to decimal inches and enter the result into the bottom half of the corresponding box to the nearest hundredth of an inch. Be sure to include units. Note that ø indicates a diameter, and R indicates a radius.



9. Measure the distance between two lines next to each other on a sheet of lined paper in US Customary units. Record the measurements using each of the following units.

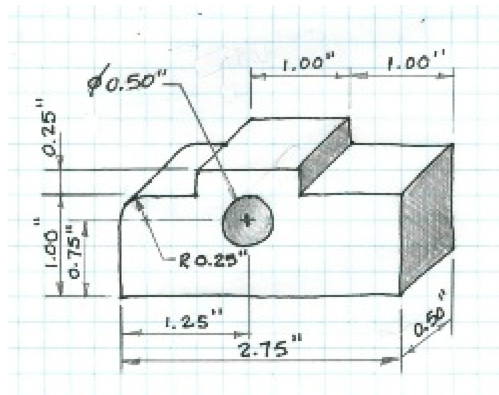
Fractional inches:

Decimal inches:

10. Measure and record the length of additional items in your classroom using appropriate measurement units as directed by your instructor. Record fractional inches to the nearest 1/32" and decimal inches to the nearest hundredth of an inch.

Object	Description of measurement	Measurement units	Measurement
CD	Diameter	cm	
Desk	Length and width	Decimal inches	

11. In your engineering notebook, create a full scale isometric view of the object represented in the following sketch using the dimensions shown. Use a ruler to obtain the correct dimensions on your sketch.



Conclusion

1. When you look at a drawing, how do you know if you are looking at U S Customary or SI measurements? Why is it important for an engineer to know this piece of information?

US Customary Measurement System

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 3.2

Unit Conversion

Introduction

Engineers of all disciplines are constantly required to work with measurements of a variety of quantities – length, area, volume, mass, force, time, temperature, electric current, etc. It is often necessary to be able to express those measurements in different units. For example, when designing a water distribution piping system, it is important to know how much water pressure is lost as the fluid flows through the pipe. The pressure loss depends on the length of the pipe which is often measured in *miles*. One formula that is sometimes used to calculate pressure loss requires that the pipe length be input in *feet*. Therefore, it is necessary to be able to **convert** miles to feet.

In other situations you may be forced to work between the SI and U S Customary measurement systems. Say, for example, that as a U S company, your product is manufactured and produced based on U S Customary units. However, a European company would like a proposal to incorporate your system into their existing assembly line, the characteristics of which are based on SI units. You must be able to convert between the two systems in order to provide a proposal for a design which includes your company's U S product.

In this activity you will convert measurements among units in both the U S Customary System and the SI system, and you will convert quantities between the two systems of measurement. You will also gain experience with converting units among units that are not specific to one measurement system (such as people and tanks of water) and use the skills you learn to solve everyday problems (such as calculating the cost of gas to travel a given distance).

Equipment

- Ruler – U S Customary and metric
- Tape measure
- PLTW Engineering Formula Sheet

Resource

Unit Conversion

3.2.h.A UnitConversionHomework.docx

Procedure

Complete each of the following. When a calculation is required, show your work.

1. Write an equation that shows the equivalency between meters and Gigameters.
2. What conversion factor should be used to convert from meters to Gigameters?
3. Convert each of the following quantities to the indicated units. Use the appropriate number of **significant figures** to express your answer unless directed otherwise.

    - 4.567 trillion (4,567,000,000,000) meters to Gigameters.
    - 14520 milliliters to liters. Report to the nearest hundredth of a liter.
    - 43 thousand microseconds to seconds. Report to the nearest thousandth of a second.
    - 6.30 yards to feet.
    - 0.55 feet to inches.
    - 9 ft – 2 ½ in. to inches. Report answer using fractional inches.
    - 3 ft – 5 inches to decimal feet. Report to the nearest hundredth of a foot.
    - 59.2 cm to inches.
    - 3.20 yards to inches.
    - 350.0 billion nanoliters to decaliters.

4. A village on a Caribbean island was devastated by a hurricane. The supply of fresh water was contaminated when the storm surge washed over the island, inundating the wells. Several tanks of fresh water were delivered to the village. Each tank contains 10.5 hectoliters of water.

    - How many liters of water does each tank contain?
    - On any given day, one person needs an average of 2.5 liters of water to survive. How many *people* will a tank supply for the day? Hint: Create a conversion factor to convert from liters to people.
    - If the village (which includes people and livestock) requires a total of 430 liters of water each day, approximately how long (in *days*) will one tank provide an adequate supply for the village? Give your answer to the nearest tenth of a day. Hint: Create a conversion factor to convert form liters to days.

      [Challenge] Convert the result to days and hours. Give your answer to the nearest hour.

5. It is 3.67 miles to your grandparents' home.

- If you can walk 4 miles in one hour, how long will it take for you to walk to your grandparents' home? Express your answer in decimal hours and then convert the time to minutes (to the nearest minute).

  Hours:

  Minutes:

- If your average stride length is 2.6 feet, how many strides will it take you to walk to your grandparents' home? Hint: You will need two conversion factors.
- If you ride your bike at an average speed of 15 mph, how long will it take you to ride to your grandparents' home? Express your answer in hours (to the nearest hundredth of an hour). Convert to minutes (to the nearest minute).
- If the circumference of each wheel on your bicycle is 82.6 inches, how many revolutions of a bicycle wheel will it take to get to your grandparents' home? Give your answer to the nearest revolution. Hint: You need to convert miles to inches and create a conversion factor to convert inches to revolutions of a wheel.

6. **Measure** the size of your desk (length, width, and height) using a tape measure. Record the measurement in feet and inches, and then convert the measurements to decimal feet and decimal inches.

Measurement	Feet-inches	Decimal feet	Decimal inches
width			
height			
depth			

7. Measure and record additional items in your classroom and then convert each measurement to an alternate **unit** as directed by your instructor.

Object	Description of Measurement	Original Measurement	Original Measurement Units	Converted Measurement	Converted Measurement Units
room	length x width	25'-6" x 30'-0"	ft-in.	7.77 x 9.15	m
CD	diameter	4 5/8	in.		cm

8. Many track and field events are measured in metric units.

    - In the long jump, if you can jump 5.92 meters, what is your jump length in feet? In yards?
    - How many yards must you run to complete a 100 meter dash?
    - The women's world record high jump is 6 feet, 10 ¼ inches. What is the record in meters? Record your answer to the nearest hundredth of a meter.
    - How many meters is equivalent to a mile? Give your answer to the nearest meter.
    - What is the length of a marathon (26.2 miles) in kilometers?

9. A European car manufacturer reports that the fuel **efficiency** of the new MicroCar is 28.5 km/L highway and 22.0 km/L city. What are the equivalent fuel efficiency rates in miles per gal?

    If gas costs $3.50 per gal, how much would it cost to drive 500 miles in the city in this car (assuming the fuel efficiency rating is accurate)?

Conclusion

1. Why would you have to know how to convert measurements when looking at a technical drawing?
2. How can you use units to help you solve a problem?

Unit Conversion

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 3.3

Making Linear Measurements

Purpose

How thick is one of the hairs on your head? Could it be measured accurately with a standard inch **scale**? If the smallest increment on an inch scale is 1/16 inch, then 20 average size human hairs could fit within the space of a 1/16 inch gap. The required degree of **accuracy** needed is dependent on the application. If you were to build a home, a standard inch scale is perfect for laying out walls and locating window openings. A dial **caliper** is a **precision** measurement tool that is often used in the design and manufacturing of consumer products and is, perhaps, the most common of all the precision measurement tools. Engineers, technicians, scientists, and machinists all use dial calipers to assist the processes of analysis, inspection, engineering design, reverse engineering, and manufacturing.

In this activity you will practice making measurements with a dial caliper.

Equipment

- Dial caliper
- Automoblox vehicle

Resources

[Dial Caliper]

[An Introduction to Section View]

[Activity 3.3 Making Linear Measurements Answer Sheet]

Procedure

You may use the Activity 3.3 Making Linear Measurements Answer Sheet to record measurements of the Automoblox vehicle.

Use dial calipers to make the following measurements. Remember that you can make four different types of measurements with dial calipers. Take careful measurements - you will use your measurements later when you model these parts in 3D solid modeling software.

Outside Measurement

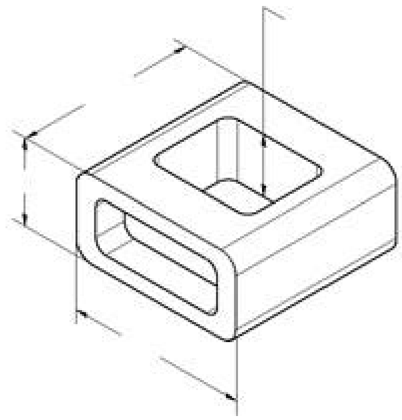
Inside Measurement

Depth Measurement

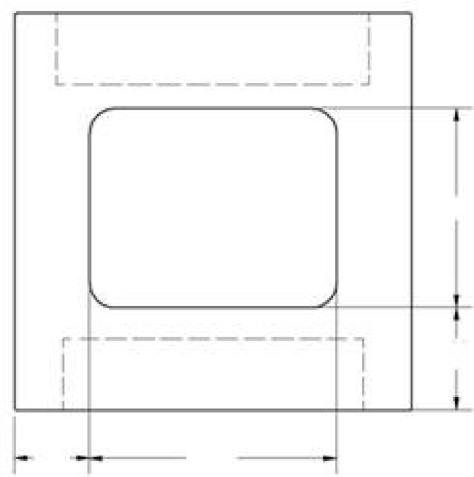
Step Measurement

1. Using dial calipers, measure and record dimensions of the Passenger Section of the Automoblox vehicle as indicated.

    - Measure the overall dimensions and the depth of the top opening. Be sure to measure the hole depth to the bottom of the hole, not the top of the plastic insert. Record the dimensions on the pictorial using appropriate **significant digits**.

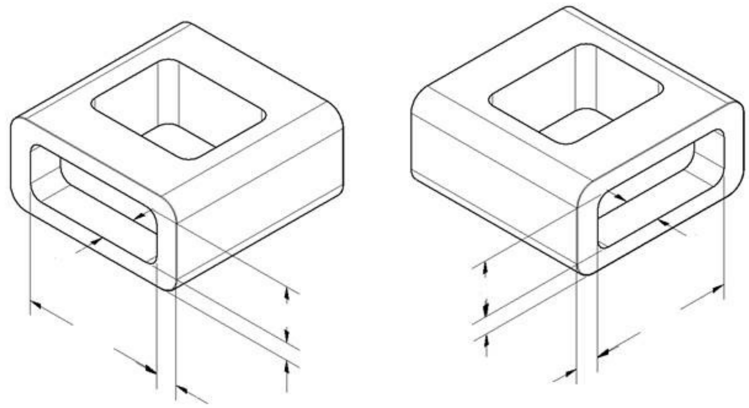


- Measure the location and size of the opening on the top of the part. Record your measurements on the top view to the appropriate number of significant digits.

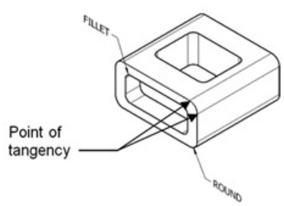


TOP VIEW

- Using the dial calipers, *carefully* measure the depths and locations of the holes on the front and back faces of the part where the connector insert is located. Be sure to measure to the bottom of the holes, not the face of the plastic inserts. Record the measurements to the appropriate number of significant digits on the pictorials.



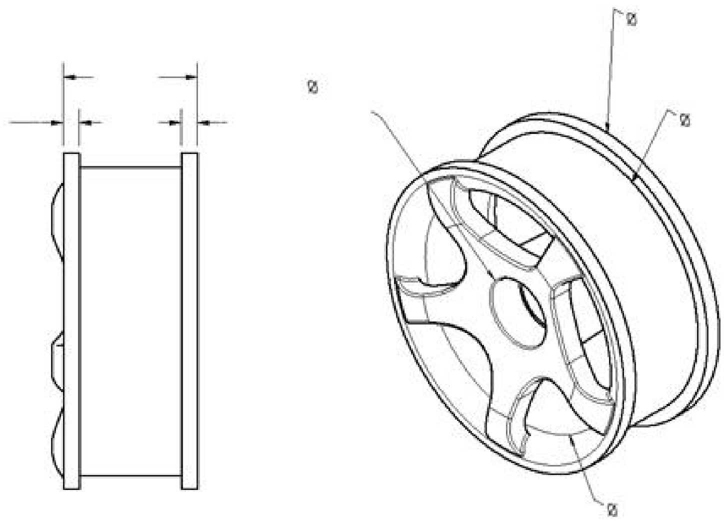
- A fillet is an inside radius between two intersecting planes. A round is a rounded exterior blend between two surfaces. Use the dial caliper to estimate the radii of the outside rounds and the fillets at the corner of the holes. You will have to estimate the points of tangency (where the curve transitions into the straight edge). Assume that all the rounds have the same radius and that all the fillets have the same radius. Record the radii to the appropriate number of significant figures.



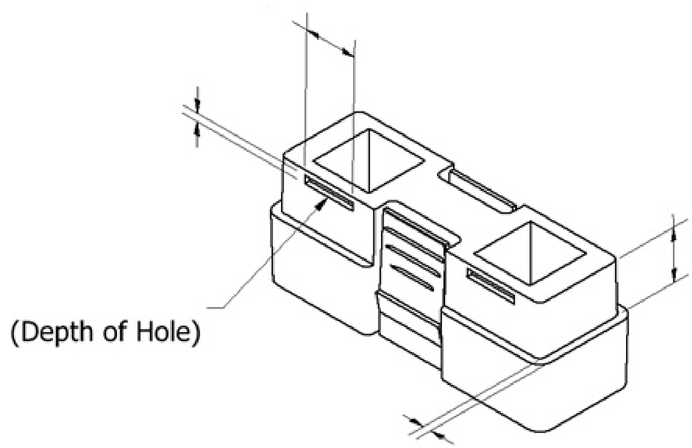
Estimated fillet radius:
____

Estimated round radius:
____

2. Using a dial caliper, Measure and record the missing dimensions of the Automoblox wheel indicated in the views shown. Note that you do not need to measure the details of the rim pattern. Record the dimensions using appropriate significant digits. Important: There is a small circular rib on the inside cylindrical surface that fits around the axle pin. Measure the smallest inside diameter of that rib when recording the inside diameter of the wheel.



3. Measure and record the dimensions for the connector piece missing on the pictorial. Next to each recorded measurement, list measurement type (outside diameter/part width, inside diameter/space width, hole/feature depth, and step distance) that you employed to measure the distance.



4. Compare your measurements of the Passenger Section with a teammate who measured the same part.

   - Are your measurements identical to your teammate's measurements? If no, describe the difference(s).
   - Why would your measurements differ from those of another student who measured the same object?

5. **(Optional)** As a group choose one of the following objects to measure. In your engineering

notebook, sketch the object and record dimensions necessary to completely describe the object.

  - Graduated cylinder
  - Soda can
  - Coffee cup
  - White board marker
  - Another object as directed by your instructor

Conclusion

1. What additional tools may have helped to measure these parts?
2. Revisit number 1 above. Measure at least five of the dimensions of your part using a standard ruler and record the measurements in brackets next to each caliper measurement. Which measuring device (the caliper or the ruler) provides the best measurements? Why?

Dial Caliper

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

An Introduction to Section View

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 3.4

Linear Dimensions

Purpose

If you were given the responsibility of going to a store and purchasing a throw rug that had to fit within a room in your home, how would you communicate the shape and size of the room to the salesperson?

Given the sketching skills that you've developed, you would probably sketch a top view of the room on a piece of paper. This would be useful, but a sketch alone only communicates shape information.

A shape has a size that must be communicated in order to make intelligent design decisions. Information about an object's size must be conveyed using **dimensions**. In manufacturing, a part must be dimensioned fully and correctly and to the proper **precision**. Otherwise, the part may not function properly or may not fit into an assembly as intended. Dimensioning errors can lead to a delay in production time, increased design and manufacturing costs, and a potentially unsafe product.

In this activity, you will apply your knowledge of dimensioning to identify dimensioning errors and provide missing dimensions on multi-view drawings. You will also fully dimension multi-view sketches according to dimensioning guidelines.

Equipment

- Inch scale or ruler

Resources

Introduction to Dimensioning

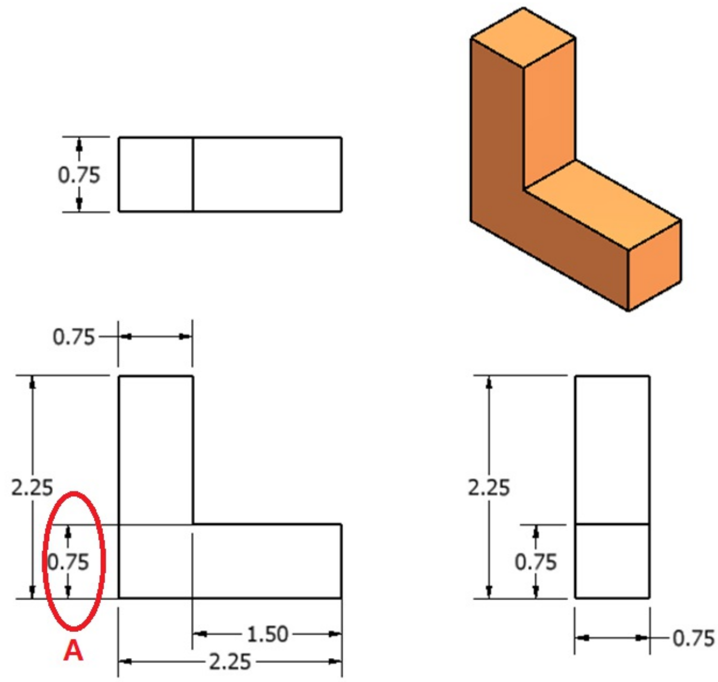
Dimensioning Guidelines

Procedure

Your teacher should provide you with a printed copy of this activity.

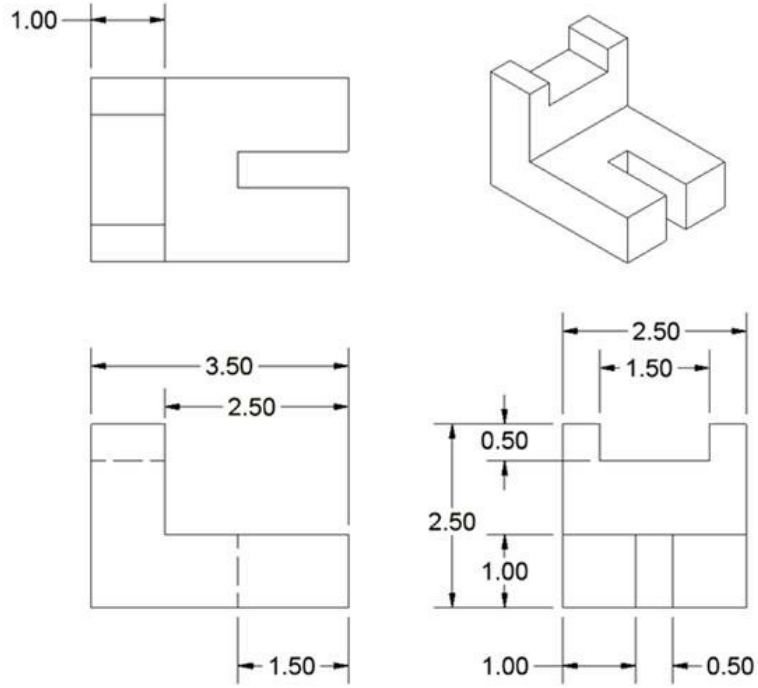
Identify dimensioning errors based on the Dimensioning Guidelines. Circle each error and place a letter, **A** through **P**, next to each error on the drawing. In the space provided below each drawing, next to the appropriate letter, give the reason for each correction and cite the dimensioning guideline that is misapplied.

1. Multi-view Drawing #1



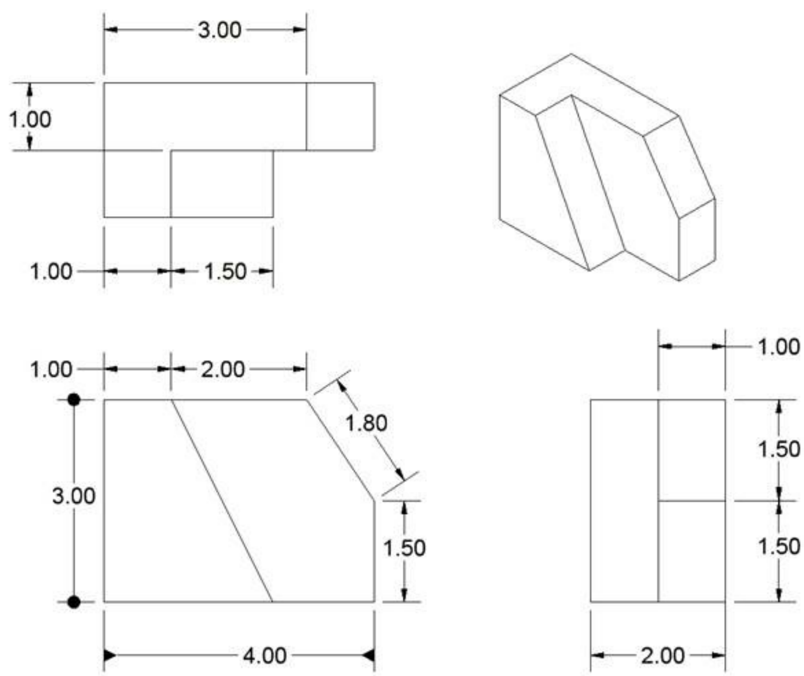
	Dim. Guide	Reason		Dim. Guide.	Reason
A.	**4a** **7**	**Double-dimension;** **wrong side**	**B.**		
C.			**D.**		

2. Multi-view Drawing #2



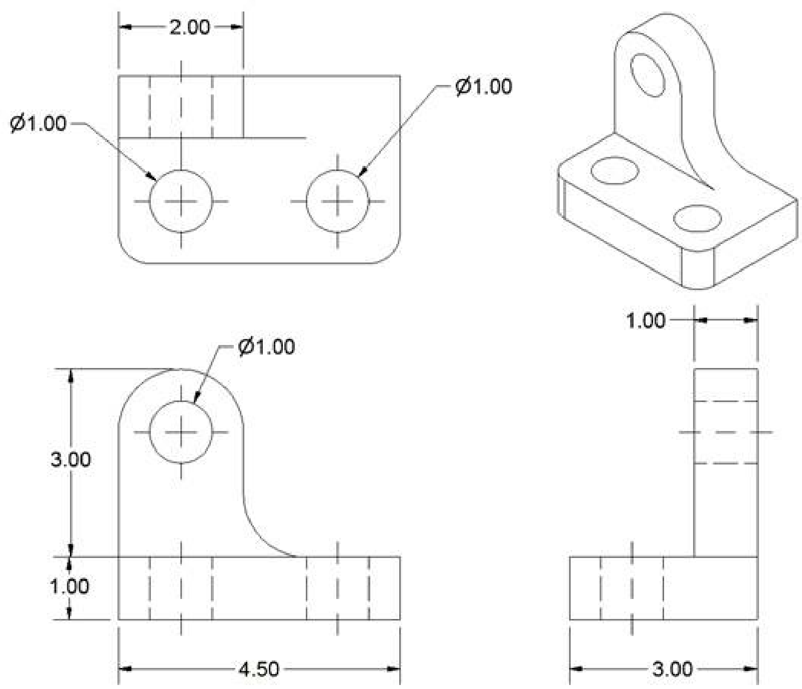
	Dim. Guide	Reason		Dim. Guide	Reason
E.			**F.**		
G.			**H.**		

3. Multi-view Drawing #3



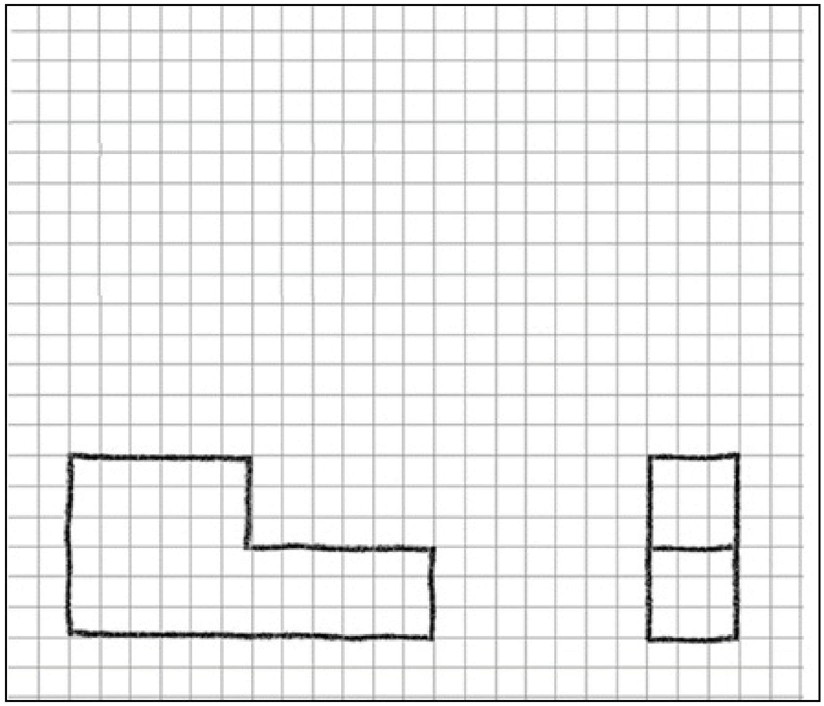
	Dim. Guide	Reason		Dim. Guide	Reason
I.			**J.**		
K.			**L.**		
M.			**N.**		
O.			**P.**		
Q.			**R.**		

4. Multi-view Drawing #4

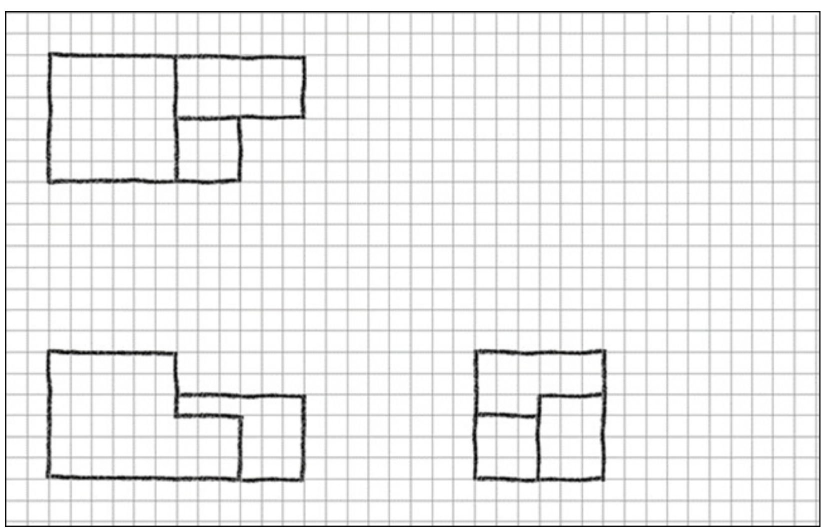


	Dim. Guide	Reason		Dim. Guide	Reason
S.			**T.**		
U.			**V.**		
W.			**X.**		
Y.			**Z.**		
AA			**BB.**		

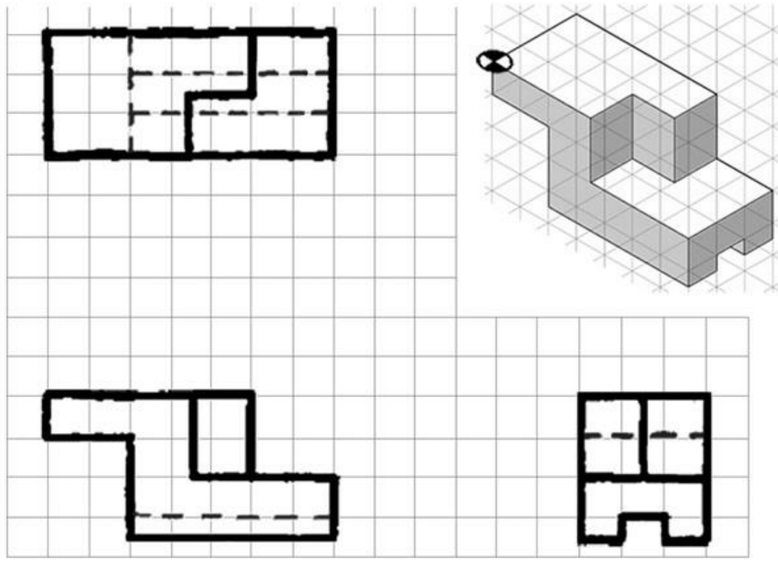
5. Sketch an isometric view of the object. Then dimension the orthographic projections. Line spacing on the grid equals 0.125 in.



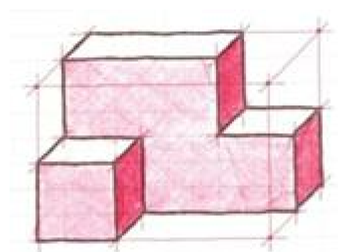
6. Sketch an isometric pictorial of the object. Then dimension the orthographic projections Line spacing on the grid equals 4 mm.



7. Fully dimension the following sketch. Each square on the grid equals one cm.



8. In your notebook, create a fully dimensioned multi-view drawing for the following object piece. Assume that the object is made up of six ¾ in. cubes.



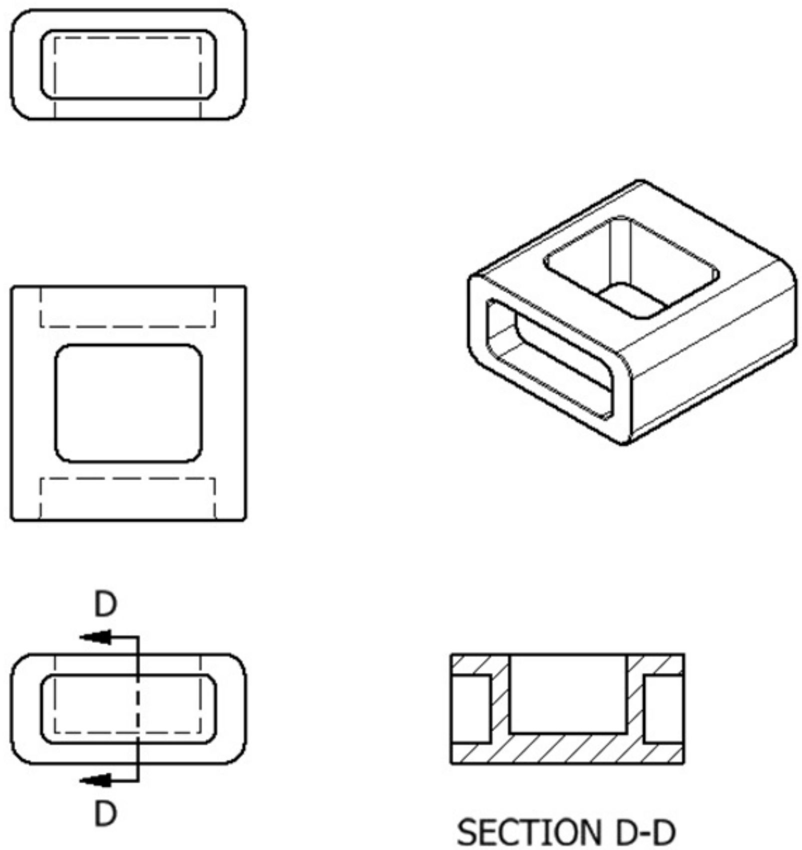
Reflection Question: What type of pictorial is used above to represent the object? How can you tell?

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

9. Review another student's fully dimensioned multi-view drawing completed for number 8. Identify any dimensioning errors (or errors in line work, view selection, or view orientation) and record the errors on a copy of the drawing or on a separate sheet of paper. Be sure to fully describe the error and cite the Dimensioning Guideline that was misapplied.

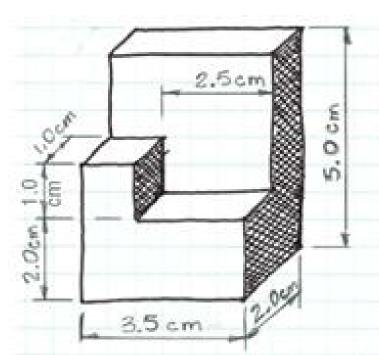
10. Fully dimension the multi-view drawing of the Automoblox Passenger Section using the measurements you recorded in Activity 3.3 Making Linear Measurements. We will discuss tolerances later, but for now assume that the part must be dimensioned to the thousandth of an inch in order to insure sufficient dimensional accuracy.

    Note that the right view is a section view and shows the holes using solid object lines instead of dashed hidden lines. This view is drawn as if the part was cut in half (at the D-D line in the front view) and you are looking at the cut surface. The hatched area indicates solid material. You will learn how to create section views later. For now, use the section view to dimension the depth of the holes. Connector inserts must fit into the holes in the part.



Extend Your Learning

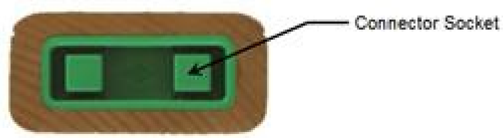
11. In your notebook create a fully dimensioned multi-view drawing for the part shown below. Note that you have already sketched orthographic projections in Activity 2.4 Multi-view Sketching.

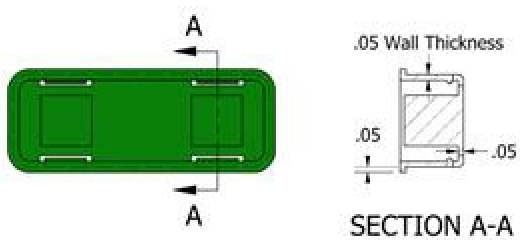


12. Go back to Activity 2.4 Multi-view Sketching. Fully dimension the multi-view sketches that you created in numbers 3 through 5. Use the following grid spacing.

    - For numbers 3 the grid line spacing is 0.5 cm.
    - For number 4 the grid line spacing is 2 mm.
    - For number 5, the grid line spacing is 0.25 in.

13. In your engineering notebook, create front, top and side orthographic projections of the connector socket that is inserted and affixed to the passenger section or the front section of your Automoblox vehicle. Typically a product would be completely disassembled in order to obtain true dimensions; however, we do not want to damage the Automoblox vehicle. Therefore, as carefully as possible, without damaging the vehicle, establish all necessary measurements and dimension your drawing accordingly. You may reproduce the section view shown in lieu of the right view. Assume that the square (or triangular, or oval, etc.) are solid plastic but that the wall thickness of the plastic is .05 inches as shown in the section view. Remember, a section view is drawn as if the part were cut in two (at the A-A line in the front view) and you are looking at the cut surface. The hatched area indicates solid material. You will learn how to create section views later.





Conclusion

1. Why is placement of your dimensions so important?
2. Why do designers need to fully dimension a part?
3. What does it mean when a sketch is over dimensioned?

Introduction to Dimensioning

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Dimensioning Guidelines

Resources

[Dimensioning Guidelines]

General Rules for Dimensioning

1. Dimensions should reflect the actual size of the object, not the scaled size.
2. Include overall dimensions in the three principle directions – height, width, and depth.
    - Overall dimensions should be placed the greatest distance away from the object so that intermediate dimensions can nest closer to the object to avoid crossing extension lines.
3. Include all dimensions necessary to produce or inspect the part.
    - Dimensions should be placed so that it is not necessary for the observer to calculate, scale or assume any measurement.
4. Do not include unnecessary dimensions.
    - Dimensions should NOT be duplicated, nor should the same information be given in two different ways.
    - Do not include chain dimensions that add up to a given overall dimension.

    Important: In the case of chain dimensions, in general, you do not need to know the measurement of every smaller dimension in a chain that contributes to an overall dimension if the overall dimension is given. At least one of the contributory dimensions should be omitted to avoid duplication. This omission does not require a calculation of the omitted dimension since the part can be produced without knowing the specific magnitude of that dimension. That magnitude is simply the distance remaining after the part is built according to the overall dimensions and the other contributory dimensions that are provided.

5. Dimensions should be attached to the view that best shows the contour of the feature to be dimensioned.

6. A dimension should be attached to only one view (i.e., extension lines should not connect two views).
7. Place dimensions between adjacent views whenever possible.
8. Avoid dimensioning to hidden lines.
9. Do not place dimensions on the object unless it is absolutely necessary.
10. Do not cross a dimension line with another dimension line or with an extension line.
11. Avoid crossing dimension or extension lines with leader lines.
12. Leader lines point toward the center of the feature at an angle and should never be placed horizontally or vertically.
13. Dimension numbers should be centered between arrowheads, except when using stacked dimensions where the numbers should be staggered.
14. In general, a circle is dimensioned by its diameter; an arc is dimensioned by its radius.
15. Holes should be located in the view that shows the feature as a circle.
16. Holes should be located by their center lines which may be extended and used as extension lines.

PLTW ENGINEERING

Activity 3.5

Applied Statistics

Introduction

Today's consumers are constantly trying to judge the quality of products. But what is quality? How and by whom is quality determined? Some would say the designer creates specifications, which in turn dictate the quality of a product. That quality is also based on the acceptable value of a part within a whole product. **Statistics** are commonly used in manufacturing processes to control and maintain quality. This activity will allow you to apply statistics in order to analyze and determine the quality of a set of wooded cubes.

In this activity you will collect **data** and then perform statistical analyses to determine **measures** of central tendency and **variation** of the data. You will also represent the data using a histogram.

Equipment

- Dial caliper

Resources

Introduction to Summary Statistics

Procedure

1. Part of the manufacturing **quality control** testing for a toy is to measure the depth of a connector piece that must fit into another part. The designed depth is 4.1 cm. Every tenth part produced on the production line is measured. The following data was collected during a two minute production period.

   4.1, 4.1, 4.0, 4.1, 3.9, 4.4, 3.9, 4.3, 4.0, 4.2, 4.0, 3.8

   - Calculate each of the following measures of central tendency. Show your work in your notebook.

     - Mean:
     - Median:

- Mode:

- Calculate each of the following measures of **variation** for the **data set**. Show your work in your notebook. Create a table similar to the one shown in your engineering notebook to help you calculate the **standard deviations**. In the table round values in the last two columns to four decimal places. Report the standard deviation statistics to four decimal places.

  - Range:

x	**x - μ**	**$(x - \mu)^2$**
	SUM	

  - Standard Deviation of this data:

- Create a **histogram** for the data in your engineering notebook. The horizontal axis should display each length measurement from the minimum to maximum recorded lengths. You may choose to begin with a **dot plot** and then fill in the bars. Be sure to label your axes.

  - What **class interval** is appropriate for the measurement values reported as 4.1 cm?

2. Gather measurement data taken by your teammates on Activity 3.3 Making Linear Measurements for the largest outside diameter of the wheel. You should collect at least 5 measurements. In your engineering notebook, list each measurement value recorded by your team (including yours) and show calculations for the **mean**, **median**, **mode**, range and standard deviation. Remember the rules for rounding in statistics. Show your work.

3. Compare your results to a teammate's calculations. Make corrections to your work as necessary.

Conclusion

1. How can statistics of a product's dimensions be used to assess the quality of the product?

2. In which phase(s) of a design process might statistics be most useful? Why?

Introduction to Summary Statistics

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 3.6

Instant Challenge: Fling Machine

Introduction

There are many ways to solve a problem. Sometimes it is as simple as applying a piece of duct tape. Other times it takes months or years for a product to progress from an idea into full-scale production. In this activity your team will quickly design and build a device that will send a cotton ball as far as possible through the air.

Equipment

- Scissors
- Timer

Materials (may vary)

- 2 cotton balls
- 1 balloon
- 2 corks
- 1 rubber band
- 2 paper clip
- 1 piece aluminum foil
- 2 coffee stir sticks
- 2 straws
- 2 pipe cleaners

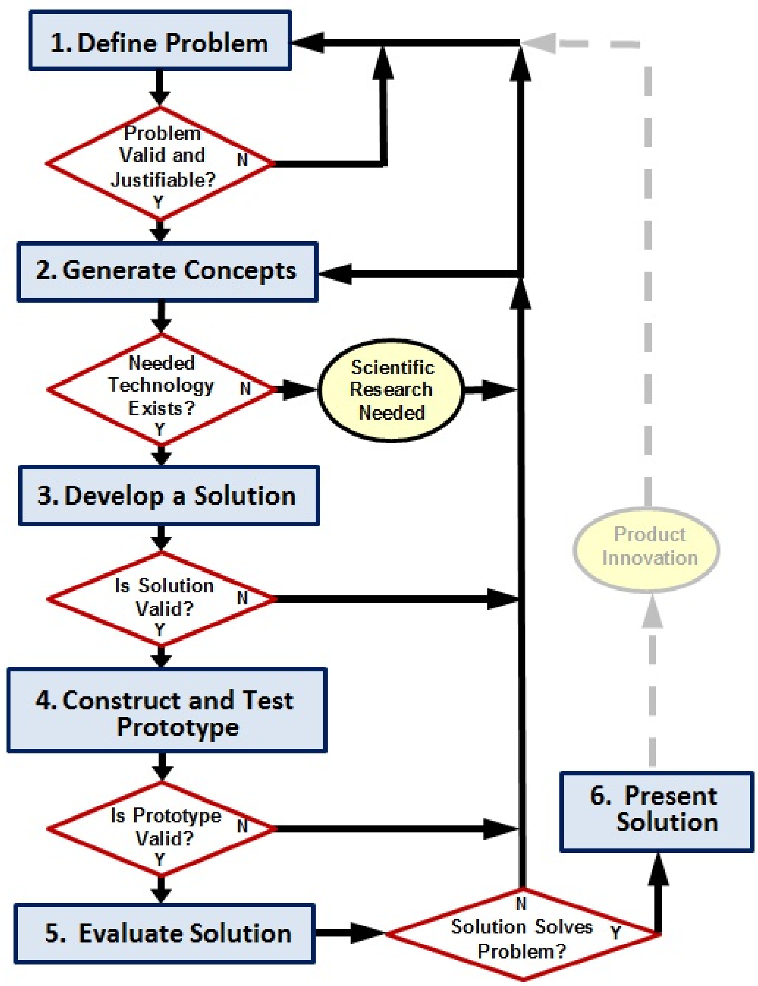
Resources

Inferential Statistics

Procedure

Using only the materials provided, design and build a device to launch a cotton ball and send it as far as possible.

1. Your team will have 15 minutes to devise a solution and document the solution both in writing and in graphical form with a drawing.
2. Your team will have 5 minutes to build your solution.
3. Your team will have 5 minutes to test your solution. Record the distance traveled by the cotton ball (to the nearest quarter inch) for at least ten attempts.
4. Finally, your team will have one attempt to demonstrate your solution.
5. Use the design process learned in Unit 1. Document each step in your engineering notebook as you complete this design challenge.



Scoring

Your team may receive points for the following.

- Creativity: Up to 10 points for creativity in the design and use of materials.
- Teamwork: Up to 10 points for how well your team works together.
- Performance: Using the landing point of the cotton ball that was propelled the furthest from the launch device, 2 points for each inch between the device and the point at which the cotton ball lands.

Conclusion

1. Analyze the cotton ball travel distance **data** that you collected.
    - Record the travel distances of the cotton ball that you measured during the testing phase below and create a **dot plot** of your data.
    - Create a **histogram** of your data using five **class intervals**.
    - Is the data **normally distributed**? Justify your answer.
    - Calculate the **mean**, **median**, range and **sample** **standard deviation** of the travel distances of the cotton ball.
    - Give a range of travel distances within which you would predict that 95% of all cotton balls launched with your device would fall. For example, you might predict that 95% of the cotton balls that you launch would travel between 2.25 ft and 3.00 ft. Justify your answer.
2. Do you feel that the statistical analysis results would be a better **measure** of performance when comparing alternate devices that the distance traveled by a cotton ball in a single attempt? Why or why not?
3. How would you recommend using the results of your statistical analysis of travel distances to assess device performance (rather than giving points for the distance of the single attempt allowed in the challenge)?
4. If you had the opportunity to optimize your design, how would you increase the distance that the cotton ball moves?
5. If you had the opportunity to optimize your design, how would reduce the amount of materials used?
6. How could you improve the **effectiveness** of your team?

Inferential Statistics

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 3.7

Statistical Analysis with Excel

Introduction

Engineers use various tools to make their jobs easier. Spreadsheets can greatly improve the **accuracy** and **efficiency** of repetitive and common calculations; therefore, engineers often employ spreadsheet applications in their work.

In this activity you will collect **data** and use Microsoft Excel to perform statistical analyses and create a statistical chart to display your data.

Equipment

- Completed Activity 3.5 Applied Statistics

Resources

Statistical Analysis with Excel

Analysis ToolPak Loading Instructions

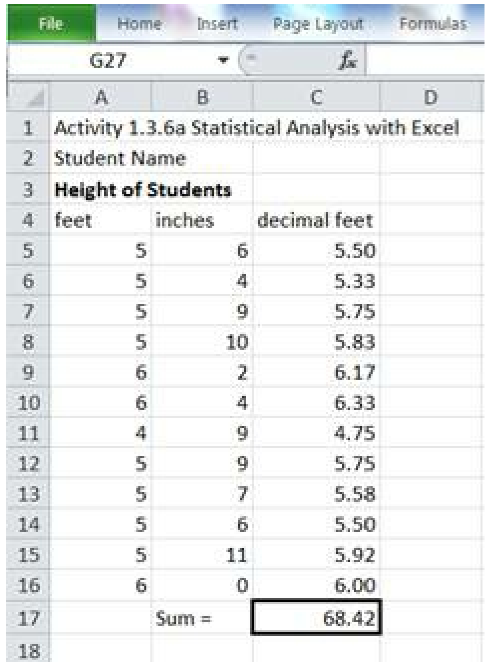
Procedure

Important: This activity requires the use of the Analysis ToolPak, which is an Add-in to Microsoft Excel that is not available by default in the program. To load the Analysis ToolPak follow the instructions of your instructor or read **Analysis ToolPak Loading Instructions.**

Part 1

Perform a statistical analysis in Excel of height measurements of students in your class.

1. Open an Excel workbook. On worksheet 1 type "Activity 3.5 Statistical Analysis with Excel" in cell A1. Type your name in cell A2.



	A	B	C	D
1	Activity 1.3.6a Statistical Analysis with Excel			
2	Student Name			
3	**Height of Students**			
4	feet	inches	decimal feet	
5	5	6	5.50	
6	5	4	5.33	
7	5	9	5.75	
8	5	10	5.83	
9	6	2	6.17	
10	6	4	6.33	
11	4	9	4.75	
12	5	9	5.75	
13	5	7	5.58	
14	5	6	5.50	
15	5	11	5.92	
16	6	0	6.00	
17		Sum =	68.42	
18				

2. In your notebook record the height of each student in your class in feet and inches to the nearest *quarter of an inch*.

3. Input the raw data into an Excel worksheet using a separate column (A) for feet and a separate column (B) for inches. Include appropriate data (column) headers.

4. Use a formula to convert each height to decimal feet and place the results in column C and include an appropriate column heading.

5. Format the height measurements in decimal feet to show two decimal places.

6. In the cell just below the column of heights in decimal feet, calculate the sum of the height measurements using the SUM function. Format the cell containing the sum to display a box around the number and add the text "Sum =" in the cell to the left of the sum cell. Note that the sum should display two decimal places.

7. Calculate the **statistics** indicated in the image to the right. Create the text labels in the appropriate cells. Be sure to calculate the ***population*** **standard deviation** (STDEV.P) as well as the appropriate Mode function (single or multimodal).

OPTIONAL: Use formulas to calculate the standard deviation of your height data.

If your data has more than one mode, use the MODE.MULT function. This function will create an answer in the form of an array. Before typing the function into a cell, highlight multiple cells (vertically), type in the function text, and select the range of values. Then depress **Ctrl/Shift/Enter** keys simultaneously to indicate that an array will be returned.

You can create a simple formula to calculate the range.

8. Create class intervals (value ranges) for a **histogram** at 0.250 feet intervals that will include **your** minimum and maximum recorded height.

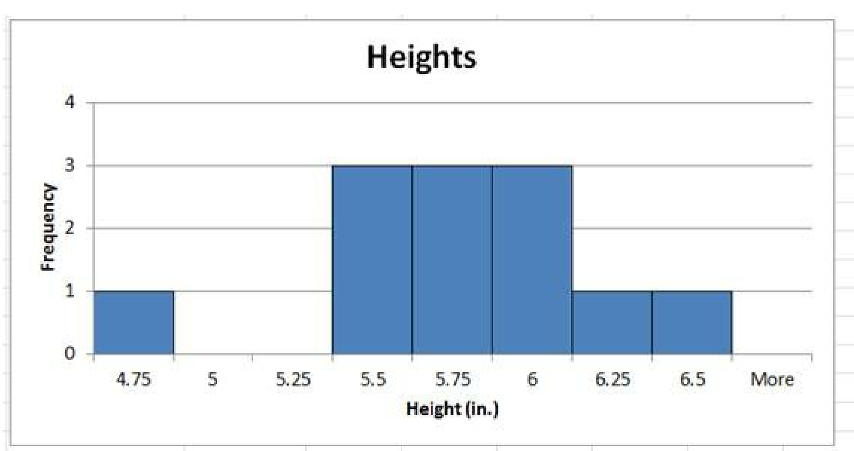
Bins
4.750
5.000
5.250
5.500
5.750
6.000
6.250
6.500

Mean	5.701
Mode	5.500
	5.750
Standard Deviation (P)	0.399
Mimum	4.750
Median	5.750
Maximum	6.333
Range	1.583

9. Create a frequency table using the Histogram tool choice in the Data Analysis Tool (Data tab, Analysis panel).

Bin	*Frequency*
4.750	1
5.000	0
5.250	0
5.500	3
5.750	3
6.000	3
6.250	1
6.500	1
More	0

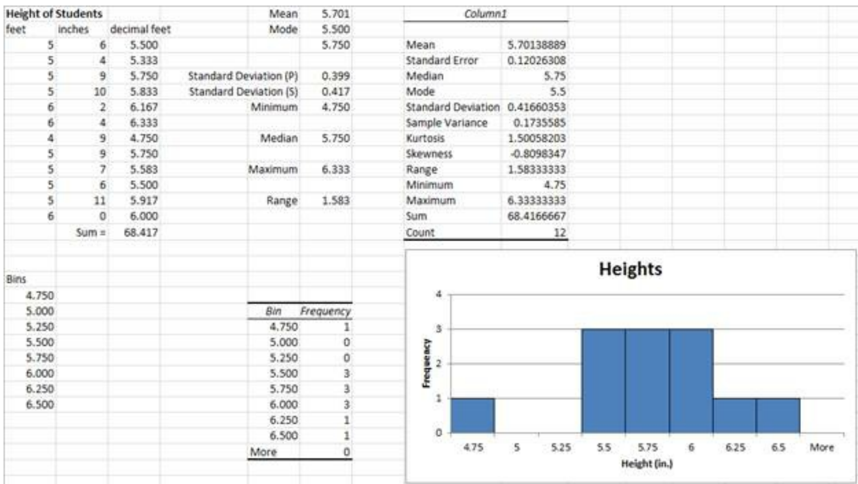
10. Create a histogram using the 2D chart tool. Format the chart as shown below.



11. Calculate the *sample* standard deviation using a function (STDEV.S) and display the output near the population standard deviation calculation.

12. Use the Data Analysis tool to calculate the Descriptive Statistics (Summary Statistics) and place the output data next to your calculated statistics.

13. Print your worksheet. Include all of the elements shown on the worksheet below.



Height of Students

feet	inches	decimal feet		
5	6	5.500	Mean	5.701
5	4	5.333	Mode	5.500
5	9	5.750		5.750
5	10	5.833	Standard Deviation (P)	0.399
6	2	6.167	Standard Deviation (S)	0.417
6	4	6.333	Minimum	4.750
4	9	4.750	Median	5.750
5	9	5.750	Maximum	6.333
5	7	5.583	Range	1.583
5	6	5.500		
5	11	5.917		
6	0	6.000		
	Sum =	68.417		

Column1	
Mean	5.70138889
Standard Error	0.12026308
Median	5.75
Mode	5.5
Standard Deviation	0.41660353
Sample Variance	0.1735585
Kurtosis	1.50058203
Skewness	-0.8098347
Range	1.58333333
Minimum	4.75
Maximum	6.33333333
Sum	68.4166667
Count	12

Bins
4.750
5.000
5.250
5.500
5.750
6.000
6.250
6.500

Bin	Frequency
4.750	1
5.000	0
5.250	0
5.500	3
5.750	3
6.000	3
6.250	1
6.500	1
More	0

14. Based on your histogram, does the data appear to be **normally distributed**? Explain your answer.

Part 2

Revisit Activity 3.5 Applied Statistics. Review the connector depth data (number 1) and the statistical analysis that you performed on the data. Then address each of the following.

15. Which value of mean did you use to indicate the central tendency of the data for the connector depth (population mean or sample mean) in Activity 3.5? Is there a difference in the numerical value between the population mean and the sample mean?

16. You used the population standard deviation to indicate the **variation** in the connector depth data. Which value of standard deviation (population or sample) should be used to estimate the variation of the connector depth among *all* connectors produced? Explain.

17. Calculate, by hand, the sample standard deviation of the connector depth data. You may use the data table that you create in Activity 3.5; however, show the sample standard deviation formula, your substitutions, and the result of your calculation to the appropriate number of decimal places.

18. Use formulas or functions in Excel to find the **mean**, **median**, **mode**, population standard deviation, and the sample standard deviation of the connector depth data. Your worksheet should contain entries similar to those shown below.

    Note that the data is multimodal, therefore you must use the MODE.MULT function in Excel. The MODE.MULT function will create an answer in the form of a vertical array (list of numbers). Before typing the function (MODE.MULT) into a cell, highlight multiple cells (vertically), type in the function, and select the range of data values. Then depress

Ctrl/Shift/Enter keys simultaneously to enter the formula and to indicate that an array will be returned.

Activity 3.6 Statistical Analysis with Excel				
	X	x-mean	(x-mean)^2	Mean =
	3.8			Standard Deviation (P) =
	3.9			Standard Deviation (S) =
	3.9			
	4.0			
	4.0			
	4.0			
	4.1			
	4.1			Median =
	4.1			Mode =
	4.2			
	4.3			
	4.4			
Sum	48.8		0.0000	

19. How do the statistics presented in Excel compare to the toy connector depth statistics that you calculated by hand**?**

20. Create a histogram using the 2D chart tool. Use the following bins.

Bins
3.8
3.9
4
4.1
4.2
4.3
4.4

21. Does the data appear to be normally distributed? Explain your answer.

22. Use the Data Analysis tool to calculate the Descriptive Statistics (Summary Statistics).

23. Print the results of your statistical analysis. Include the Descriptive Statistics and histogram in a format similar to that shown in Part 1 number 13 above.

Part 3 (Optional)

Revisit Activity 3.6 Instant Challenge: Fling Machine. Use Excel to verify your answers to Conclusion question number 1.

Conclusion

1. Describe the difference between population standard deviation and sample standard deviation. Describe a scenario in which you would use each.

2. Which type of standard deviation (population or sample) is displayed when the Data Analysis Tool is used within Excel?

3. How do the statistics that you calculated using Excel compare to the statistics that you calculated by hand for the connector depth data?

4. Other than the calculation of statistics, how could an engineer use a spreadsheet application to increase efficiency?

Statistical Analysis with Excel

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Analysis ToolPak Loading Instructions

Activity 3.7 Statistical Analysis with Excel requires the use of the Analysis ToolPak, which is an Add-in to Microsoft Excel that is not available by default in the program. To load the Analysis ToolPak follow the instructions listed below.

1. Click the **File** tab, and then click **Options**.
2. Click **Add-Ins**, and then in the **Manage** box, select **Excel Add-ins**.
3. Click **Go**.
4. In the **Add-Ins available** box, select the **Analysis ToolPak** check box, and then click **OK**.
5. **Tip:** If **Analysis ToolPak** is not listed in the **Add-Ins available** box, click **Browse** to locate it.
6. If you get prompted that the Analysis ToolPak is not currently installed on your computer, click **Yes** to install it.
7. After you load the Analysis ToolPak, the **Data Analysis** command is available in the **Analysis** group on the **Data** tab.

PLTW ENGINEERING

Activity 3.8

Precision and Accuracy of Measurement

Introduction

This concept of random and systematic errors is related to the **precision** and **accuracy** of measurements. Precision characterizes the system's probability of providing the same result every time a sample is **measured** (related to random error). Accuracy characterizes the system's ability to provide a **mean** close to the true value when a sample is measured many times (related to systematic error). We can determine the precision of a measurement instrument by making repeated measurements of the same sample and calculating the s**tandard deviation** of those measurements. However, we will not be able to correct any single measurement due to a low precision instrument. Simply stated, the effects of random uncertainties can be reduced by repeated measurement, but it is not possible to correct for random errors.

We can determine the accuracy of a measurement instrument by comparing the experimental mean of a large number of measurements of a sample for which we know the "true value" of the characteristic of the sample. A sample for which we know the "true value" would be our calibration standard. We may also need to characterize the accuracy of the measurement instrument by observing historical trends in the distribution of measured values for the calibration standard (this allows for determining the systematic error expected from environmental effects, etc.). The effects of systematic uncertainties cannot be reduced by repeated measurements. The cause of systematic errors may be known or unknown. If both the cause and the value of a systematic error are known, it can be corrected for by "subtracting" the known deviation. However, there will still remain a systematic uncertainty component associated with this correction.

Equipment

- Gauge Block
- Dial Caliper

Resources

Accuracy and Precision of Measurement

The Empirical Rule

Procedure

Optional Video

Video: Arthur Benjamin: Teach statistics before calculus! | TED

1. Two students are asked to measure the length of a credit card. The accepted value for the length of the credit card is 85.105 mm.

   Student A uses a plastic ruler. Student B uses a precision measurement tool called a micrometer. To ensure good estimates of length, each student measures the length of the same card four times and records the following measurements.

	Student A	Student B
	85.1 mm	85.301 mm
	85.0 mm	85.298 mm
	85.2 mm	85.299 mm
	85.1 mm	85.301 mm
Mean		
Standard Deviation		

   - Create a dot plot of each student's data. Use the same number line but different colors or indicators for each set of data.
   - Which student's data is more accurate? Explain.
   - Looking at the dot plot, which student's measurement instrument do you feel is more precise? Is this result expected given the measuring instruments used by each student? Explain.
   - Find the mean of each set of measurements and enter each value in the appropriate cell in the table. Then answer the following questions.
     - What is the error of Student A's measurements? Show your work.
     - What is the error of Student B's measurements? Show your work.
     - How do these error calculations support or refute your answers to parts *a* and/or *b* above?
   - Find the sample standard deviation of each set of measurement data (by hand, using a graphing calculator, or using Excel) and enter each value in the last row of the table.

- View The Empirical Rule presentation. Then answer each of the following.

    - Use the standard deviation to make a statement about the actual length of the credit card at the 68% confidence level using Student A's data. Give your answer in both plus/minus notation and using a compound inequality.

    - Use the standard deviation to make a statement about the true length of the credit card at the 95% confidence level using Student A's data. Give your answer in both plus/minus notation and using a compound inequality.

    - Use the standard deviation to indicate the precision of Student B's measurement data at the 68% and 95% confidence levels.

    - How do the standard deviation values calculated for each student's data support or refute your answers to parts *a* and/or *b* above?

2. Your instructor will choose two dial **calipers**. One caliper should be labeled #1 and the other #2. Each student in the class will measure a gauge block with each of the two dial calipers and record the measurements to the appropriate number of **significant figures** independently (without looking at another student's recorded measurements). Be sure to record your measurement using each dial caliper separately.

    - Record all data for each dial caliper in a separate table. An example of a table format is shown below.

DIAL CALIPER 1

	Measurement	Initials
1		
2		
3		
4		
25		

DIAL CALIPER 2

	Measurement	Initials
1		
2		
3		
4		
25		

- Find the mean and sample standard deviation of each set of data.

- Compare the accuracy of the two dial calipers. Your discussion should include the mean of each **data set**.

- Make a statement regarding the precision of Dial Caliper 1 at the 95% confidence level.

- Make a statement regarding the precision of Dial Caliper 2 at the 95% confidence level.

- Based on the accepted value of the length and the accepted value of the width, which dial caliper is more precise? Explain.

While classmates are measuring the gauge block, complete the following exercises.

3. In a group of six, obtain two different metric rulers. Place a piece of masking tape on each ruler. Write “Length” on the masking tape on one ruler and “Width” on the masking tape on the second ruler.

    - Each person should measure and record the length of the same sheet of copy paper using the “Length” ruler. Then each person should measure and record the width of the same sheet of paper using the “Width” ruler. Each person should initial his/her measurements in a table similar to that shown below. Be sure to use the appropriate number of significant digits.

	Length (cm)	Width (cm)	Initials
Mean			
Standard Deviation			

    Assume that the sheet of paper that you just measured actually measures 27.92 cm x 21.36 cm.

    - Compare the accuracy of the measurements for the two rulers. Your discussion should include the mean of each data set.
    - Give a statement indicating the precision of each ruler at the 95% confidence level.
    - Based on the accepted value of the length and the accepted value of the width, which ruler is more precise? Explain.

Conclusion

1. Why is it important to know the accuracy and precision of a measuring device?

2. Do you think that the dial caliper manufacturer's claim that the "accuracy" of the instrument is ±.001 is appropriate? Why or why not?

3. Do you think that either of the dial calipers needs to be adjusted in order to accurately display measurements? Explain.

Accuracy and Precision of Measurement

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

The Empirical Rule

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Project 3.9

Manufacturing a Box

Introduction

In the past, artisans who produced one item at a time built most products. Today, industry uses **mass production** to build many of the same items more efficiently. *Assembly lines* can benefit mass production. An assembly line is an arrangement of machines, tools, and workers that build a product in steps. Each station of the line is equipped to perform a specific task. Assembly-line production can usually manufacture a product in less time and at lower cost. Mass production can also improve the **quality** of the product.

What is quality? How is quality determined? Some would say that the product designer determines quality. The designer creates specifications. Those specifications dictate the quality of the product. However, poor manufacturing processes may also affect the quality of a final product. The use of inferior materials or components can also reduce quality.

Quality control, or QC, is a system used to verify the quality of a product. By testing important product features and comparing the resulting **data** to the previously established specifications, you can identify product defects. *Quality assurance*, QA, attempts to adjust the manufacturing process to improve and stabilize the quality of the product. We use **statistics** to help us determine and control quality. This is often the responsibility of quality control engineers.

In this project, you will work in teams to design, test, and improve a manufacturing process to build boxes. Collectively you will build a box for each student in your class. As part of the process, you will test the quality of the boxes using statistics. Note that your box will become part of your design for Problem 8.2 Automata Design Challenge. Quality matters!

Equipment

- Sand Paper (180 grit)
- Student Box Kit
- Quick-dry Tacky Glue
- Computer with spreadsheet capabilities
- Protractor
- Ruler or Dial Caliper
- Stopwatch
- Miter Box (Optional)
- Saw (Optional)

- MDF (Optional)
- Student Resource 3.9.SR Testing Trueness Squareness

Resources

Introduction to Manufacturing Processes

Testing Trueness and Squareness

Project 3.9 Manufacturing a Box Checklists and Rubric

Procedure

1. In your PLTW Engineering Notebook, hand sketch a scaled multiview drawing of an open box that is 4 in. x 4 1/2 in. x 5 in. (outside **dimensions**). The box drawing should show individual parts for assembly from the provided materials. That is, use a separate part for each side of the box and detail the connections at the corners. Use the thickness of the box material provided by your teacher. Remember that dimensions are nominal. That means that you can vary slightly the actual height, width, OR length dimension of the physical product from the nominal dimensions shown on the drawing, if using slightly different dimensions improves efficiency.

2. As a team, come to consensus on the specifications that you will use for your manufacturing process. That is, select a technical drawing created by a team member, or create a new technical drawing, which you will use when you manufacture boxes. You will compare the boxes you produce to this specification to determine the effectiveness of the manufacturing process.

3. As a class, develop two quality control standards that can be **measured** using a dial **caliper**, ruler, or protractor. Consider features that are most important to the aesthetics, function, and/or structural integrity of the box. Think about quality standards related to the box having square corners and being the correct size. Each standard may apply during an intermediate step of the process or to the final boxes. Refer to 3.9 SR TestingTruenessSquareness. Document these quality control standards in your PLTW Engineering Notebook.

4. As a team, design a manufacturing process flow diagram that details steps in your assembly line to produce one box for each student on your team. Document each step of the design process for your manufacturing process flow in your notebook.

5. Work with your team to estimate the cost of goods to make a single box. Use a Cost of Goods (COG) chart similar to the chart shown, and document calculations in your notebook. Remember to consider the number of boxes your assembly line will construct and pay close attention to **units**.

   Cost of Goods (COG)

Material or Service	Unit Cost	Quantity	Total

			Cost
Box Kit - 1 piece 1/4" × 4" × 4 1/2" wood - 2 pieces 1/4" × 4" × 5" wood - 2 pieces 1/4" × 4" × 4" wood	$4.25		
Student Time (research your state minimum wage per hour and write in)	State minimum wage: $________ /hour		
Teacher Consultation Time	$0.65/minute		
Testing Time	$0.12/second		
Fine for misrepresenting COG	Amount over real COG x 150%		

- What is your estimated COG for a single box?
- Based on the estimated COG, what revisions can be made to your manufacturing process flow to reduce the cost by reducing time or materials?

6. Have your teacher approve your manufacturing process flow before you move on to the next step. Your teacher should initial and date your process flow chart in your notebook.
7. Set up the assembly line to build one prototype box.
8. When all supplies and team members are ready, start the stopwatch and construct one box through the assembly-line process. Members of the team should document the test in their PLTW Engineering Notebooks, and when not directly involved in the manufacturing process, they should note flaws and mistakes. Include suggestions for process improvement. Stop the clock when the box is complete. Record the time it took to construct one box in your notebook. Be sure to specifically describe the quantity that you are recording. "Time to manufacture ONE box per the above process flow = ______."

   Estimate the time required to construct all the boxes. Remember that multiple workers can each work on separate boxes while the assembly line is running. Justify your estimate in a few sentences in your notebook.
9. As a team, assess the quality of the prototype based on the quality control standards you developed in step 3. Identify, discuss, and record (in your notebooks) the steps in the assembly line that resulted in an inefficient use of time or poor quality construction.
10. Devise and document in your notebook a plan to improve the process to address each inefficiency or quality issue.
11. Update your manufacturing process flow to reflect your planned improvements to the assembly line. Have your teacher approve and initial your revised process flow before you move on to the next step.
12. Set up the assembly line for mass production. After all supplies and team members are set up,

start the stopwatch and manufacture all the boxes. Stop the clock when the last box is complete. Record the time in your notebook.

13. Using your quality control standards determined in step 3, perform a quality inspection of all the assembled boxes. Document your results in your PLTW Engineering Notebook. As a class, compare and contrast manufacturing processes. What worked well? What needed improvement? Document your thoughts in your notebook.

14. Using a dial caliper, measure and record the length, width, and height of the boxes that your group produced. Collect this data for all the boxes constructed in your class.

15. Using a spreadsheet application, analyze one dimension (length, width, or height) of the class data by performing a statistical analysis of the data to determine each of the following:

    - Mean
    - Median
    - Mode
    - Range
    - Sample Standard Deviation

    Insert your data and analysis into your engineering notebook.

16. Create a **histogram** to represent the data. Use five to seven **class intervals** (bin values). Be sure to label your axes and define units, where appropriate. Insert your histogram into your engineering notebook.

17. Does your data appear to be **normally distributed**? Answer the question and justify your answer in your engineering notebook.

18. Compare your class data for the measurement under investigation to data from another class section for the same measurement (provided by your teacher). Describe any differences you see in the shape, center, and the spread of the distributions in your engineering notebook.

19. Share your data analysis and your assessment of the quality related to the measurement under investigation with your class. Based on the statistical analysis of each of the three dimensions (length, width, and height), is one dimension more difficult to maintain in the manufacturing process than the others? Justify your answer. Why do you think this is true?

20. (Optional) Use the data to calculate the lower-quartile median and upper-quartile median for each class **data set.** Create a box plot for each data set. What conclusions can you draw by comparing the box plots?

21. Revise your manufacturing process flow, as appropriate, to reflect recent findings. Create a final manufacturing process flow in your engineering notebook.

Conclusion Questions

1. Did you meet your estimated time to complete all the boxes? Why or why not?
2. List two advantages and two disadvantages of assembly-line manufacturing.
3. How does quality control and quality assurance fit into the design process of the product?
4. How can statistics of a product's dimensions be used to assess the quality of the product?
5. Did you class produce boxes more accurately than the comparison class? Explain your answer.
6. Did you class produce boxes that are more precise than the comparison class? Explain your answer.

Introduction to Manufacturing Processes

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Project 3.9 Testing Trueness and Squareness of Manufactured Box

1. **Scope**

   1.1 This test method covers locations for measuring trueness and squareness of boxes manufactured for the Automata Mechanism in Introduction to Engineering Design.

   1.2 This standard does not claim to address all safety concerns associated with its use. It is the responsibility of the tester to take appropriate precautions to protect the tester and the product from injury or damage.

2. **Key Terms**

   2.1 squareness – the lack of deviation from a right angle.

   2.2 trueness – the lack of deviation from straightness or flatness.

3. **Measuring Apparatus**

   3.1 Straightedge, minimum length of 6 inches (or maximum dimension of the box being measured).

   3.2 Rigid ruler, graduated to 1.0 mm or finer

   3.3 Square, with sides at least as long as the longest side of the box

   3.4 Flat surface, large enough to accommodate the box in its full width and depth dimensions

4. **Test Specimen**

   4.1 The number of test specimens shall be determined by the number of specimens produced during a production run. Every box produced shall be tested.

5. **Procedure**

   5.1 *Front Squareness*

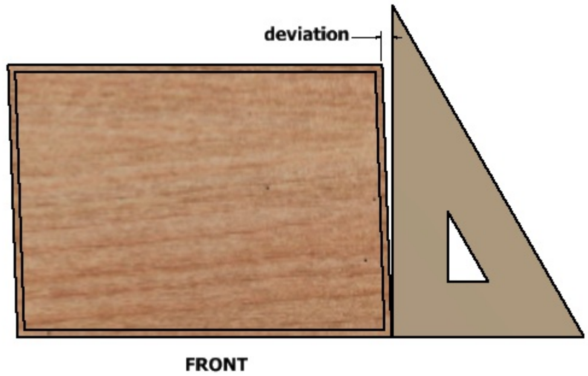


Figure 1

5.1.1 For front squareness, place the box on the flat surface such that the deviation from square is apparent with a line of sight to the front view as in Figure 1.

5.1.2 With the square resting on the flat surface, determine the deviation from square to the nearest 1.0 mm on the two sides at the point of maximum deviation. [That is, slide the square along each side until the maximum deviation is observed.]

5.2 *Side Squareness*

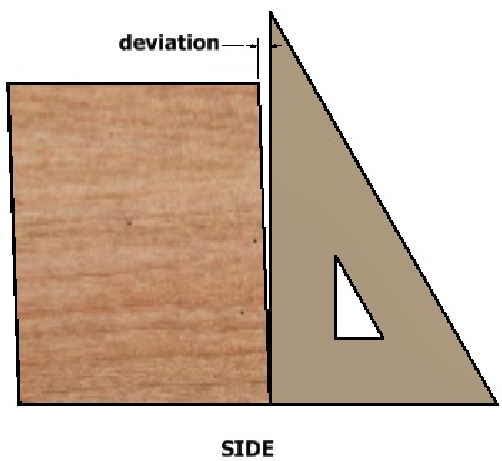


Figure 2

5.2.1 For side squareness, place the box on the flat surface such that the deviation from square is apparent with a line of sight to the side view as in Figure 2.

5.2.2 With the square resting on the flat surface, determine the deviation from square to the nearest 1.0 mm on the front face and the back face at the point of maximum deviation. [That is, slide the square along each side until the maximum deviation is observed.]

5.3 *Top Squareness*

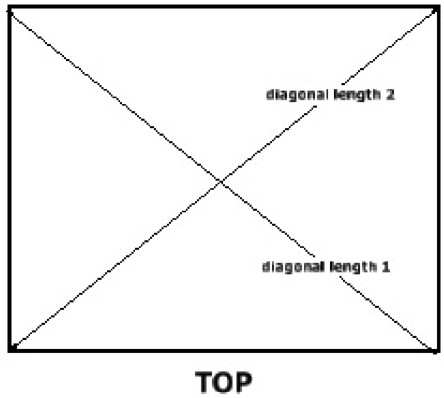


Figure 3

5.3.1 For top squareness, place the box on the flat surface and measure the diagonal lengths (as shown in Figure 3) to the nearest 1.0 mm.

5.3.2 The top squareness is the difference between the lengths of the diagonals.

5.4 *Bottom Face Trueness*

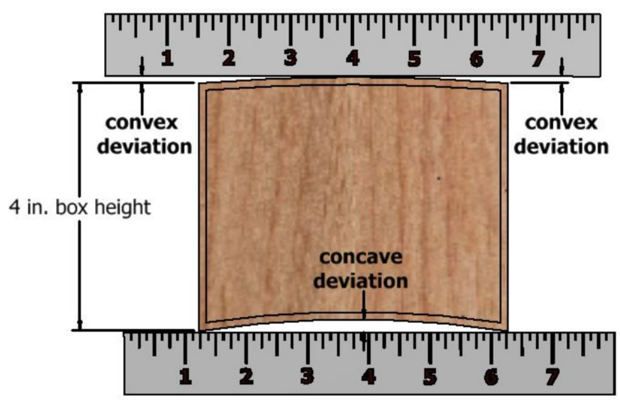


Figure 4

5.4.1 For bottom face trueness, place the box on the flat surface with the back face down as in Figure 4.

5.4.2 With the straightedge next to the **bottom** of the box on the flat surface, determine the concave deviation from true at the point of maximum deviation (see Figure 4).

5.4.3 For convex deviation from true, measure the deviation by equalizing the distance between the straightedge and the box at both corners of the box (see Figure 4).

6. **Report**

6.1 Report the following information:

- 6.1.1 Nominal dimensions of box
- 6.1.2 Manufacturer and date of manufacture
- 6.1.3 Date of testing

6.2 *Squareness*:

- 6.2.1 Maximum deviation from front squareness in millimeters
- 6.2.2 Maximum deviation from side squareness in millimeters
- 6.2.3 Maximum deviation from top squareness in millimeters

6.3 *Trueness*:

- 6.2.4 Maximum deviation from **bottom face** flatness in millimeters

Project 3.9 Manufacturing a Box Checklists and Rubric

Resources

3.9.P RU Manufacturing a Box_Checklists and Rubric.docx

Interim Reviews and Assessment Checklists

Review Content	Needs Revision	Reviewer name, date	Reviewer Comments	Approved
Design Process – Manufacturing Process Flow • All steps of the design process are followed. • Each step of the design process is verified by appropriate documentation and outcomes (i.e. design brief, decision matrix, test report, and/or project recommendations) • The manufacturing process flow provides clear, detailed, easy to read, step-by-step description of the product creation that can be replicated without additional information.				
Engineering Calculations – Mathematical Modeling • Correct materials and/or services (as determined from Cost of Goods table in Project document) are used in calculations. • Calculations are documented step-by-step so that a person unfamiliar with the work can understand the solution process. • Calculations and results are mathematically correct. • Appropriate units and unit conversion factors (when necessary) are documented throughout the				

calculations and in results.				
Technical Sketching • Box drawings have the necessary size and location dimensions present and properly located. • Drawings provide dimensions according to dimensioning guidelines. (See dimensioning guidelines.)				

Peer Review Rubric – The following criteria will be assessed when you review your peer's work.

Criteria	Basic	Proficient	Advanced
Peer Review and Feedback LO: Analyze and evaluate the work of others to provide helpful and effective feedback.	Expends little effort to provide helpful feedback. Provides feedback that is often inaccurate or not specific, or is not actionable. Sometimes shares feedback in a professional manner.	Carefully and thoughtfully assesses a peer's work. Provides effective and accurate feedback that is specific and actionable. Usually provides feedback in a professional manner.	Carefully and thoughtfully assesses a peer's work and asks for clarification from the peer to fully understand thinking and process, when appropriate. Provides effective feedback that is specific and actionable, and refers to a learning objective or goal. Amount of detail of feedback is user friendly – not overwhelming and not too technical, but substantial enough to provide specific guidance for significant improvement. Always provides feedback in a professional manner.

Through Project Performance - The following criteria will be assessed at any time and/or at multiple stages of the design process.

Criteria	Basic	Proficient	Advanced
Engineering Mindset LO: Persevere to solve a problem or achieve a goal. LO: Demonstrate independent	Frequently off task. Requires direct instructions before working on the project. Inflexible and resists making	Often uses time wisely. Often demonstrates self-direction with little direct oversight. Usually demonstrates flexibility and is adaptable to change.	Plans and uses time to best advantage. Always demonstrates independent thinking and self-direction to accomplish a goal. Always demonstrates flexibility and adaptability to change. Can explain the benefits to changing

thinking and self-direction in pursuit of accomplishing a goal. LO: Demonstrate flexibility and adaptability to change.	changes. Gives up easily. Does not consider or rejects effective feedback from peers or teacher without justification.	Usually perseveres to solve a problem, but sometimes requires intervention. Often uses effective feedback from others to inform performance.	direction in the design process. Perseveres to solve problems or achieve the goal until the problem is solved. Critically analyzes feedback and strategically implements feedback that will improve work. Provides appropriate justification when feedback is not implemented.

Project Submittal - The following criteria will be assessed through the project submittals.

Criteria	Basic	Proficient	Advanced
Collaboration Lo: Facilitate an effective team environment to promote successful goal attainment. LO: Contribute individually to overall collaborative efforts.	Team members' strengths are sometimes used. Workload is not shared equally. The student does not always effectively listen to team members nor show respect for varying opinions. The student does not always communicate ideas and opinions nor engage in compromise.	Excellent teamwork. An effective team environment is present. Team members' strengths are well used. Workload is shared equally. The student generally listens to team members, respects varying opinions, communicates ideas and opinions effectively, and engages in compromise. Student contributes an appropriate level of effort and productivity to the overall effort.	Model team. Team members' strengths are fully used. Workload is shared equally. The student consistently listens to all team members, respects varying opinions, communicates ideas and opinions effectively, and engages in compromise.
Data Analysis – Data Collection LO: Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose.	Data collected is inaccurate to assess each quantitative control standard and one size dimension of the product. Measurements and precision are incorrect for the purpose. Data observations are not evident.	Most necessary data is collected to assess each quantitative control standard and one size dimension of the product. Measurements are generally accurate and recorded to an appropriate level of precision for the purpose. Data observations are appropriate but no detail is provided.	All necessary data is collected to assess each quantitative control standard and one size dimension of the product. Measurements are accurate and recorded to an appropriate level of precision for the purpose. Data observations are appropriate and detailed.

Data Analysis - Analysis LO: Use a spreadsheet application to help identify and/or solve a problem.	Analysis of data is not consistently logical nor clear. Minimal appropriate statistical analysis results are evident, but presentation is not clear. Possible errors and suggestions for improvement are vague.	Analysis of data is logical and clear. Appropriate statistical analysis results are evident, but presentation is not clear. Possible errors and suggestions for improvement have been made.	Analysis of data is logical and clear. Appropriate statistical analysis results are clearly presented. Possible errors are explained and relevant suggestions for improvement have been made.
Quality Control Standards LO: Create quality control standards to assess the quality of a part or product.	The specifications include numeric properties that are impossible to accurately measure. It is impossible to determine whether the goal has been met.	The specifications include numeric properties, but they may be difficult to accurately measure. It is difficult to determine whether the goal has been met.	The specifications include quantitative properties that are easy to measure and of appropriate magnitude and precision. It is easy to determine whether the goal has been met. A sufficient number of specifications is included to ensure a quality product.
Tool/Machine Use LO: Construct physical objects using hand tools and shop tools.	Team members require some prompting to use tools and machines safely and as instructed.	Team members use tools and machines safely and as instructed most of the time.	Team members always use tools and machines safely and as instructed.

Activity 3.10

Instant Challenge: Oil Spill

Introduction

There are many ways to solve a problem. Sometimes it is as simple as applying a piece of duct tape. Other times it takes months or years for a product to progress from an idea into full-scale production. In this activity your team will quickly design a solution to a problem sometimes encountered by environmental engineers when an oil spill endangers the environment.

Equipment

- Clock or timer
- Scissors
- Large bucket or sink for testing
- “Oil” (1/2 cup vegetable oil mixed with cocoa powder works well)

Materials (may vary)

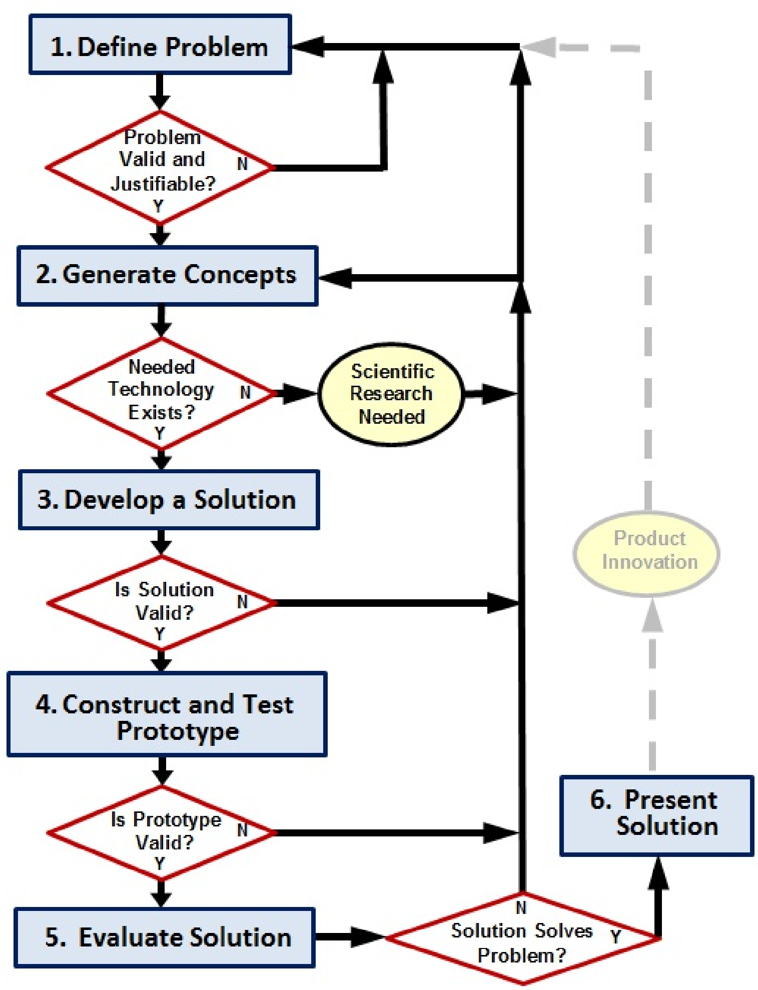
- 4 Rubber bands
- 12 inches of string
- 2 tongue depressors
- 2 paper clips
- 1 sheet of newspaper
- 2 balloons
- 2 paper towels
- 1 straw
- Cooked rice
- Grass
- 6 inches of masking tape
- 6 cotton balls

- Plastic spoon
- Plastic wrap
- Other materials as desired (toothpicks, plastic wrap, wood mulch, wooden cubes, cotton swabs, syringe, shredded paper, etc.)

Procedure

Using only the materials provided, design and build a device, system, or process to “clean up” an oil spill. The oil spill will consist of ½ cup of vegetable oil poured into a bucket or sink full of water. The clean-up should first contain the spill and then remove the oil.

1. Your team will have 15 minutes to devise a solution and document the solution both in writing and in graphical form with a drawing. Next you will have 5 minutes to demonstrate your solution. The clean-up process will be timed and the **effectiveness** of your solution scored.
2. Use the design process learned in Unit 1. Document each step in your engineering notebook as you complete this design challenge.



Scoring

Your team may receive points for the following.

- Creativity: Up to 10 points for creativity in the design and use of materials.
- Teamwork: Up to 10 points for how well your team works together.
- Time: Your team will receive 15 points from which one point will be subtracted for each 20 second period required to complete the clean-up. After five minutes your team will receive zero points for time, the test will end and your performance will be evaluated.
- Performance:
    - Your team will receive points according to the following level of containment.
        - 10 points – the oil was completely contained within a 12 $in.^2$ area
        - 8 points – the oil was completely contained within a 30 $in.^2$ area
        - 6 points – the oil was completely contained within a 50 $in.^2$ area
        - 4 points – the oil was completely contained within a 80 $in.^2$ area
        - 0 points – the oil was not contained within an 80 $in.^2$ area
    - Your team will receive points according to the following level of oil removal
        - 10 point – water is completely clear of all oil
        - 8 points – about a quarter of the oil remains
        - 6 points – about half of the oil remains
        - 4 points – about three quarters of the oil remains
        - 0 points – no oil was removed.

Conclusion

1. What property of oil dictates that most types of oil float on water? Be specific.
2. Other than physically removing the oil, what other methods might be used to eliminate an oil slick? (This may require research.)

3. If you had the opportunity to optimize your design, how would reduce the amount of materials used?
4. If you had the opportunity to optimize your design, how would you reduce the time required for clean-up?
5. How could you improve the effectiveness of your team?

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Unit 4

Modeling Skills Overview

Preface

The word *model* can have many meanings. In the context of engineering design a *model* is a representation of an idea or a design. Many different forms of models are used in engineering design - conceptual, graphical, mathematical, computer, physical. Which type of model and the needed complexity of the model depends on the problem at hand. This unit will introduce the use of models in engineering. You will create models to address different needs and to inform design decisions. You will continue to use a variety of models during the remainder of this course to represent, analyze, test and document your ideas and design solutions.

Essential Questions

1. 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?
2. Why do engineers use models?
3. How reliable is a model?

Introduction to Modeling

Activity 4.1: Software Modeling Introduction

Activity 4.2: Model Creation

Activity 4.3: Motion in One Direction

Activity 4.4: Mathematical Modeling

Activity 4.5: Cams in Motion

Activity 4.6: Design a Cam

Introduction to Modeling

Introduction

The following video provides a preview to Problem 8.2 Automata Design Challenge. The learning experiences included in this unit of study will introduce you to knowledge and skills that you will use later when you design and build your own **automata**. As you view the *Introduction to Modeling* slideshow and work through the activities in this unit, consider how each type of model can be effectively applied during the process of designing your automata.

Resources

Introduction to Modeling

Video: Introduction to Automata

Refer to your downloadable resources for this video.

Introduction to Modeling

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

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Activity 4.1

Software Modeling Introduction (2016)

Introduction

3D computer modeling is a powerful tool for engineers. It allows an idea to be translated into a **model** that can communicate the concept and adapt to changes. The 3D computer model can even be used to create a **physical model** with devices such as a 3D printer or a mill.

In this activity you will learn the basic Autodesk® Inventor® software interface and file management. This orientation is important to allow efficient modeling of your own ideas.

Equipment

- Computer with 3D computer-aided design (CAD) software (such as Autodesk® Inventor®)
- Autodesk® Inventor® videos
    - UI Navigation 1
    - UI Navigation 2
    - Navigation Control
    - Project Files
    - Part Browser
    - Geometric Constraints
    - Dimensional Constraints

Procedure

1. View the Autodesk® Inventor® Tutorials, UI Navitaton 1 and UI Navigation 2.

Video: Autodesk Inventor Tutorial - UI Navigaton 1

Refer to your downloadable resources for this video.

Video: Autodesk Inventor Tutorial - UI Navigation 2

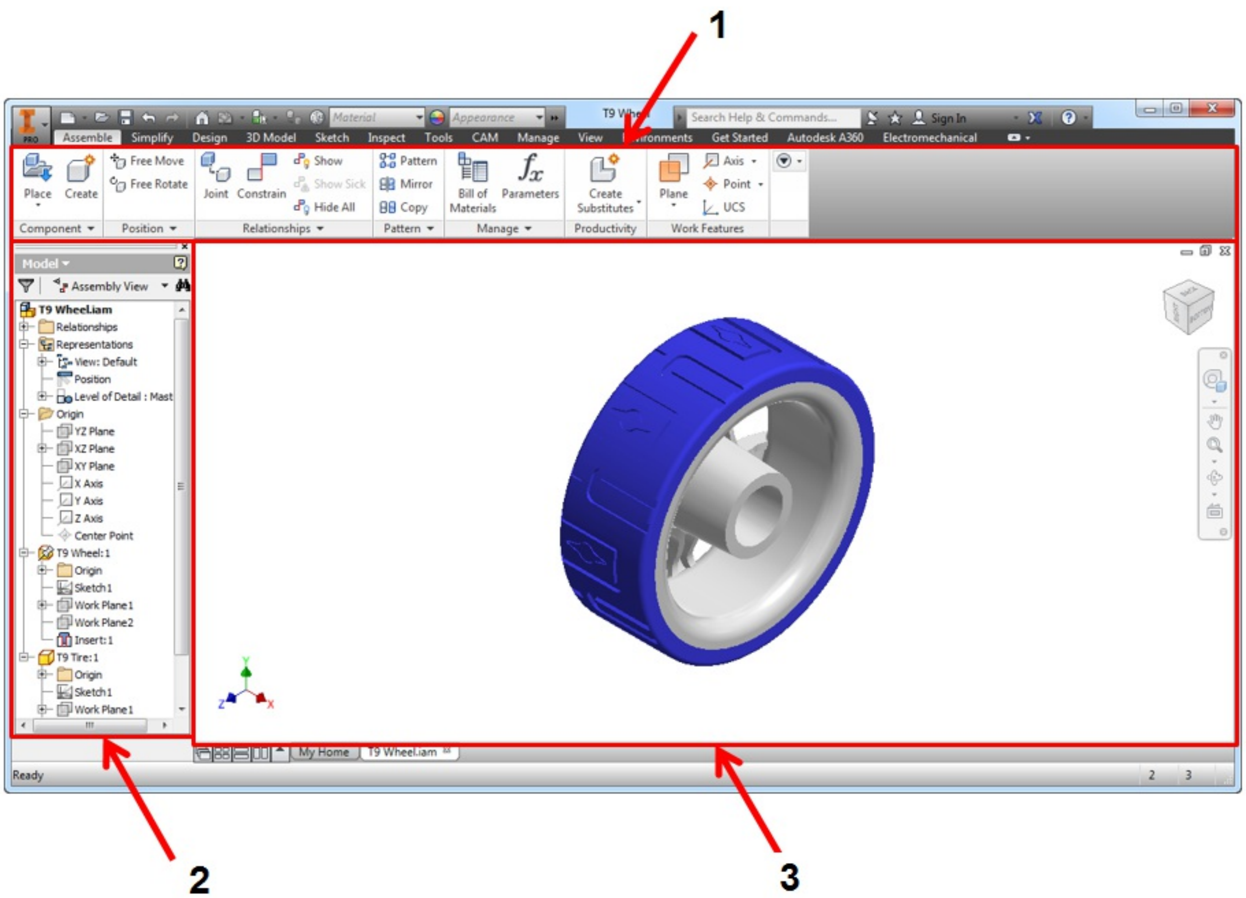
Refer to your downloadable resources for this video.

2. Open Autodesk® Inventor®. To explore the three Inventor templates represented on the opening screen, hover over each icon.

3. Complete the table with a description of the template and the file extension used for each file type.

Inventor Environment	File extension	Description
Part		
Assembly		
Drawing		

4. Identify the features of the user interface numbered in the image.

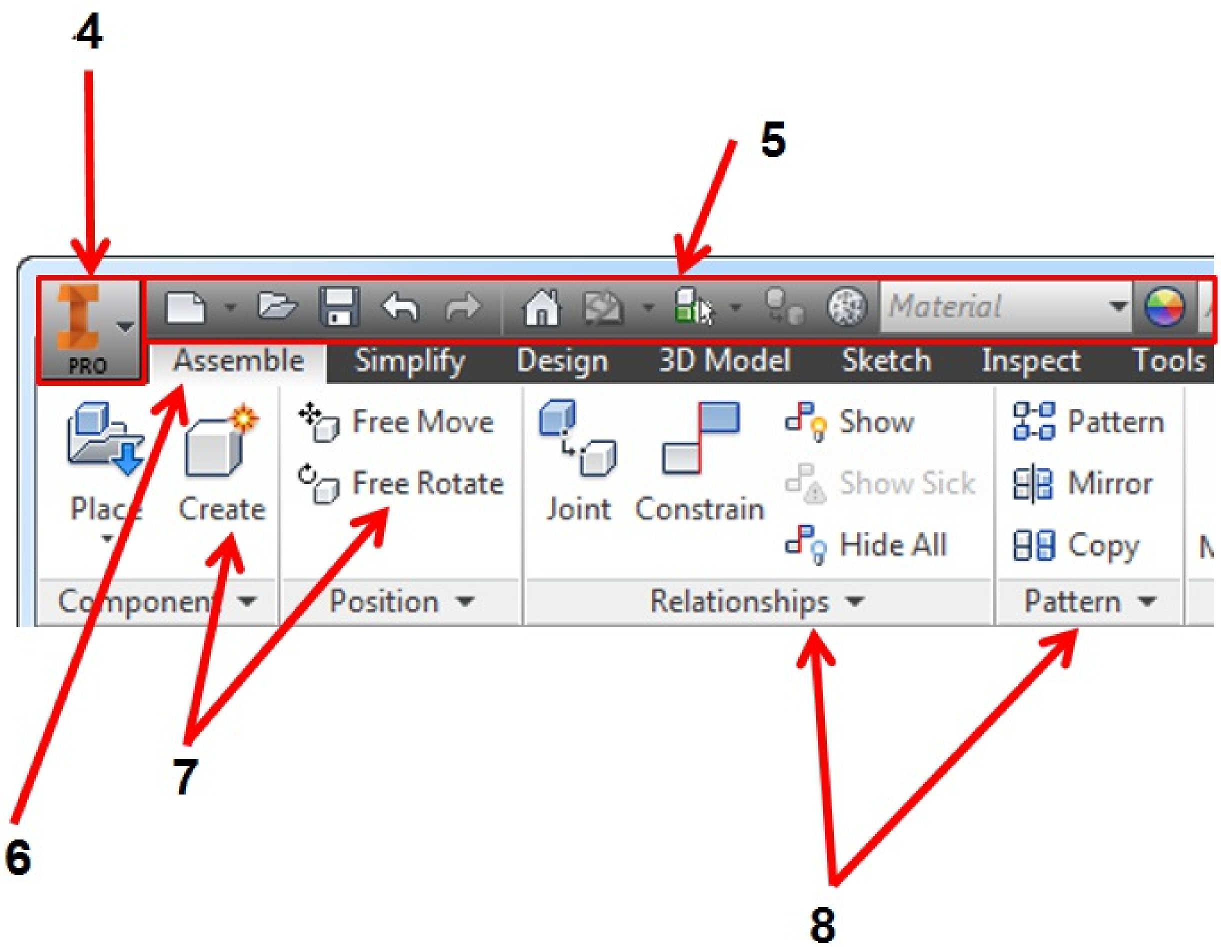


1

2

3

5. Identify the features of the user interface numbered in the image.



4

5

6

7

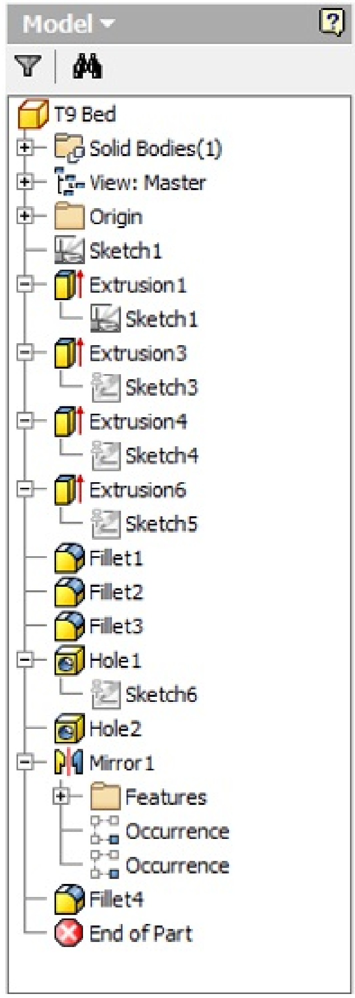
8

6. How do you restore the browser if lost?

7. View the Inventor tutorial Part Browser. Use the part browser displayed to answer the questions.

Video: Autodesk Inventor Tutorial - Part Browser

Refer to your downloadable resources for this video.

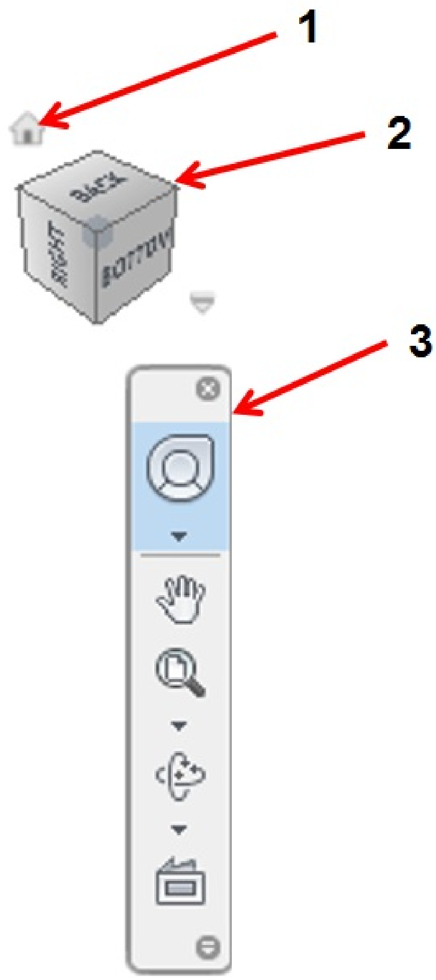


- Which feature was likely created first, Hole 1 or Extrusion 3? Explain your answer.
- How do you share a sketch in an Inventor part file?
- Which sketch is shared in the part file? Explain your answer.

8. View the Inventor tutorial Navigation Controls. Label the navigation controls in the image.

Video: Autodesk Inventor Tutorial - Navigation Control

Refer to your downloadable resources for this video.



1

2

3

9. Describe the **functions** available with each of the function keys.

- F2
- F3
- F4
- F5
- F6

10. View the Inventor Tutorial video Project Files. Then address the following items.

Autodesk Inventor Tutorial - Project Files

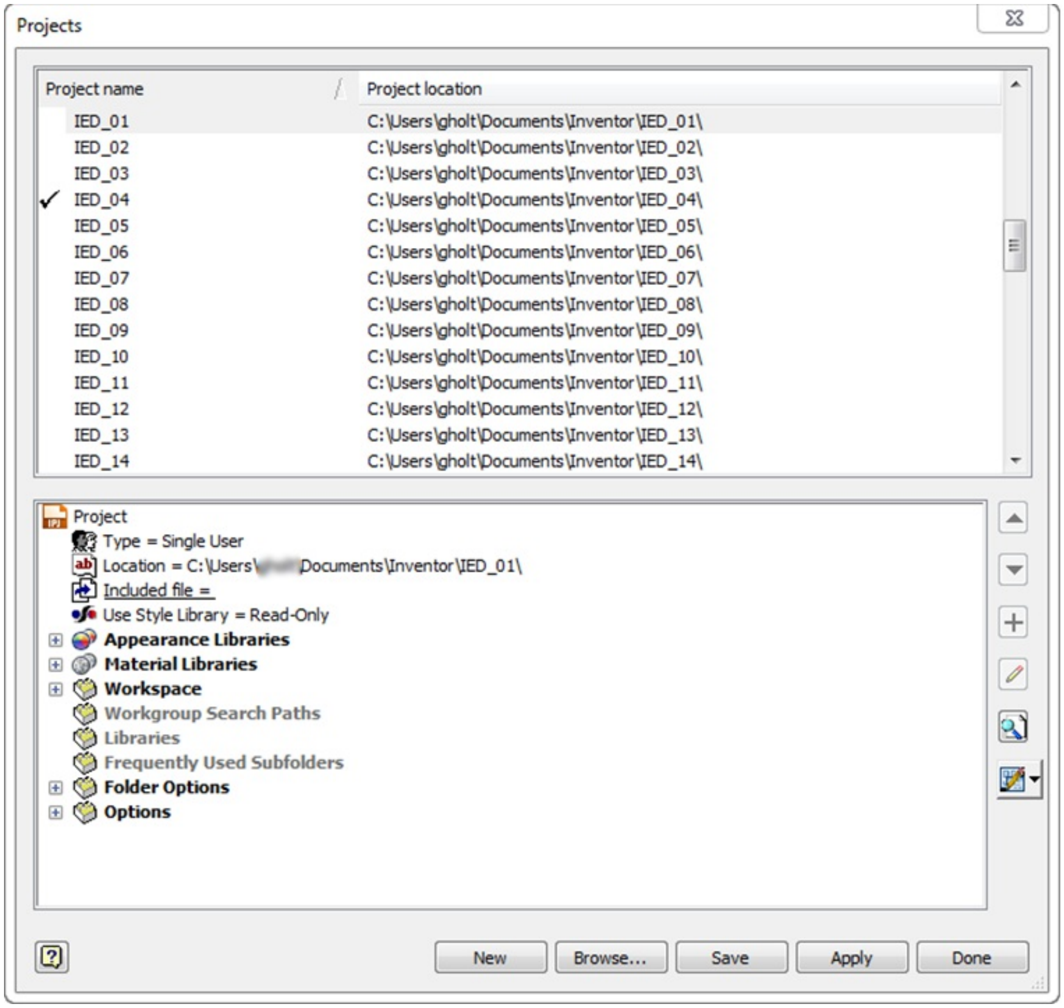
Refer to your downloadable resources for this video.

- See if you can follow the correct sequence of steps to set up a project without Libraries. Click on each blue icon in the correct order.

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

- What is the active project in the following image?



- How could IED_01 be made the active project?

Conclusion

1. Why is using the vocabulary presented in the tutorials important?
2. Why is it important to properly select the project each time a model is created?

Activity 4.2

Model Creation

Introduction

To effectively use a **CAD** program to create 3D **models** of a part, a designer must be familiar with the basic strategies of additive and subtractive modeling methods. This activity will help you understand the sketching tools and **extrusion** features that are common to most CAD programs, plan an efficient method of simple model creation, and gain experience creating simple 3D models.

Equipment

- Computer with 3D CAD solid modeling program

Resources

Model Creation

Procedure

Watch the two Autodesk Inventor tutorials related to constraints - Geometric Constraints and Dimensional Constraints. These tutorials will help you build the computer models required for this activity.

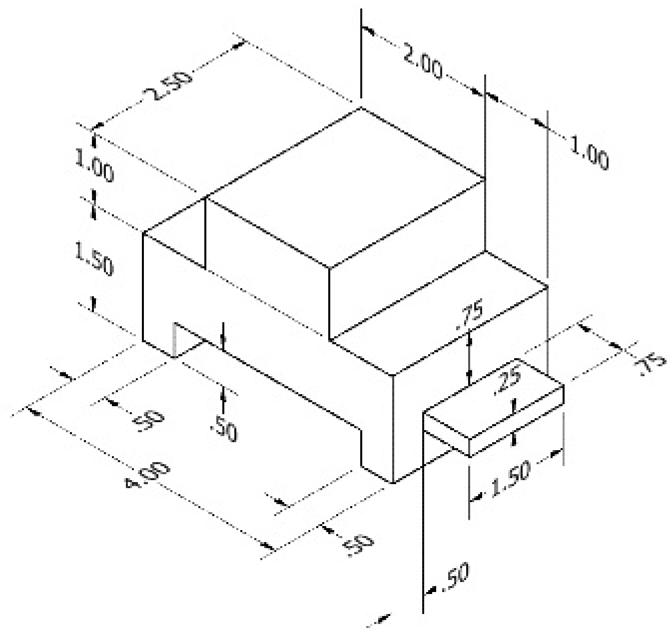
Video: Autodesk Inventor Tutorial - Gometric Constraints

Refer to your downloadable resources for this video.

Video: Autodesk Inventor Tutorial - Dimensional Constraints

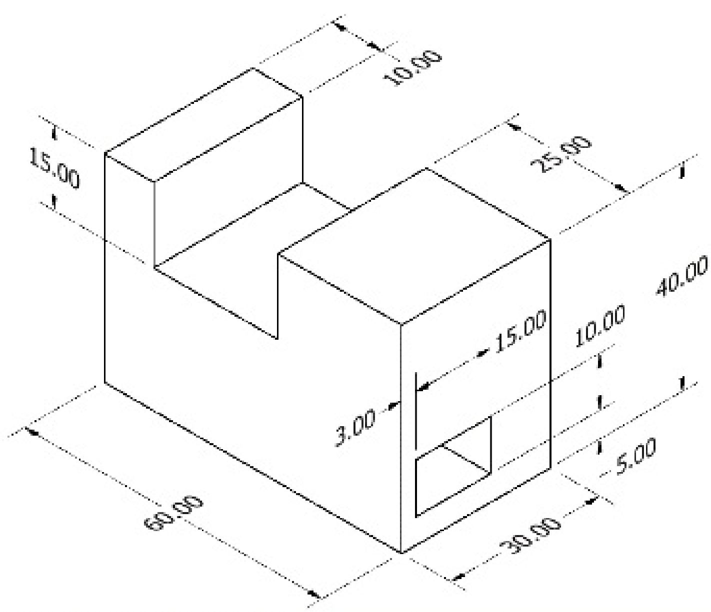
Refer to your downloadable resources for this video.

Follow the instructions to create 3D **solid** models of each of the following objects using the specified method(s) and respond to the prompts.



1. **All dimensions are in inches.**

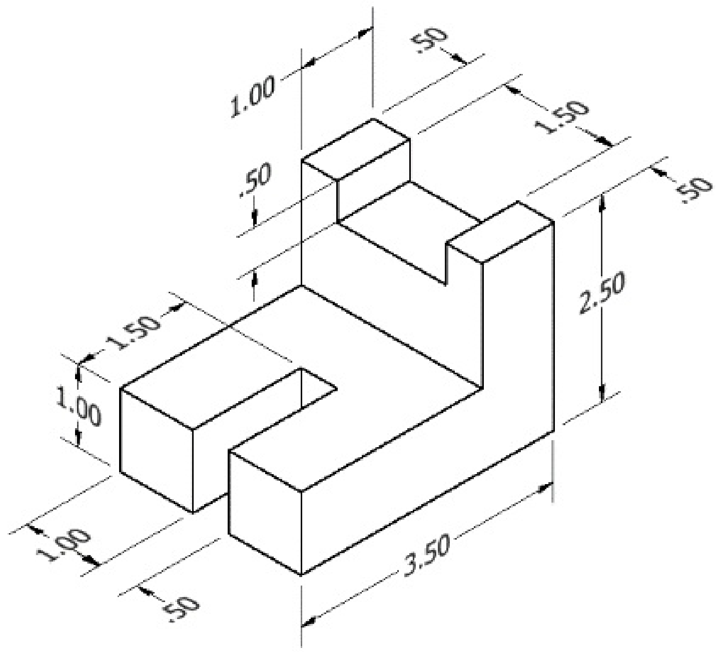
- Create a 3D solid model of the object above using the most efficient method
- Which method (additive, subtractive, or a combination of additive and subtractive) did you use? Why do you feel it was most efficient?



2. **All dimensions are in mm.**

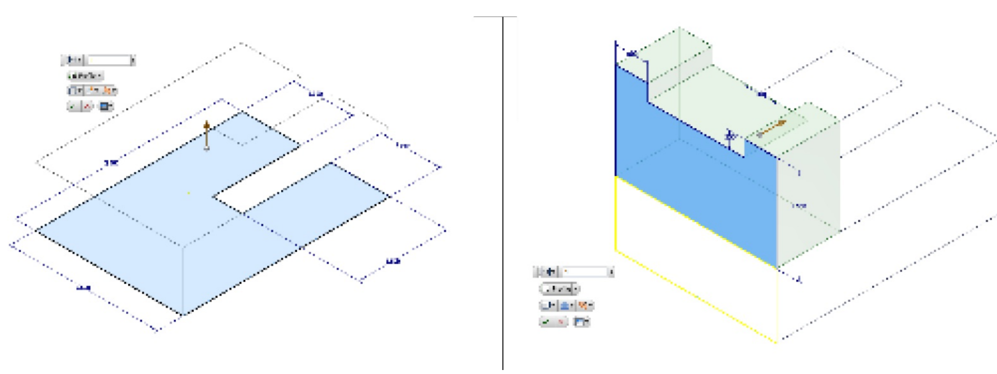
- Create a 3D solid model of the object above using the most efficient method possible.

- Describe the method you used to model the object. Why do you feel it was most efficient?

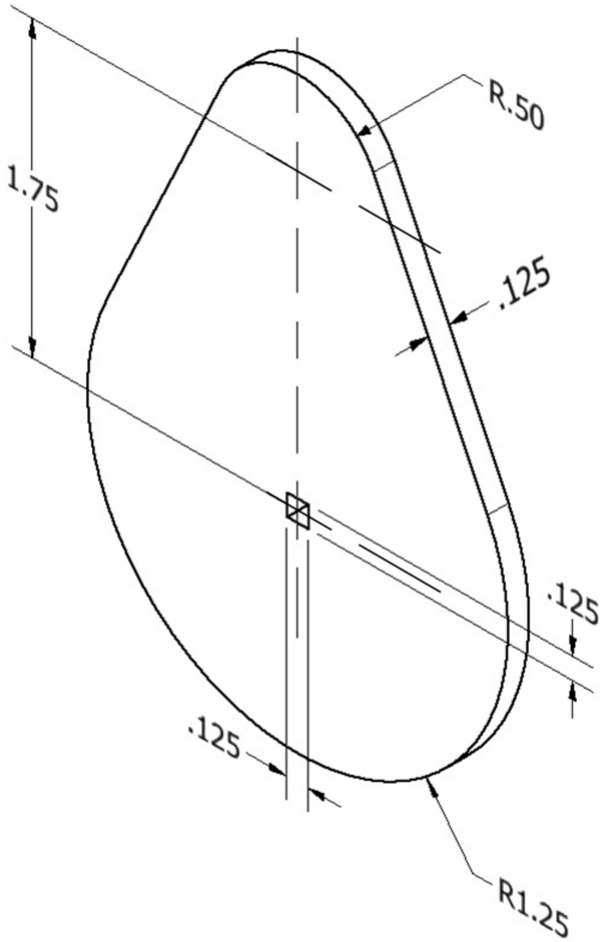


3. **All dimensions are in inches.**

- Create a 3D solid model of the object above using only additive procedures.
- Create a 3D solid model of the object above using only subtractive procedures.
- Which method (additive, subtractive, or a combination of additive and subtractive) do you feel would be the most efficient method for creating the object? Why?

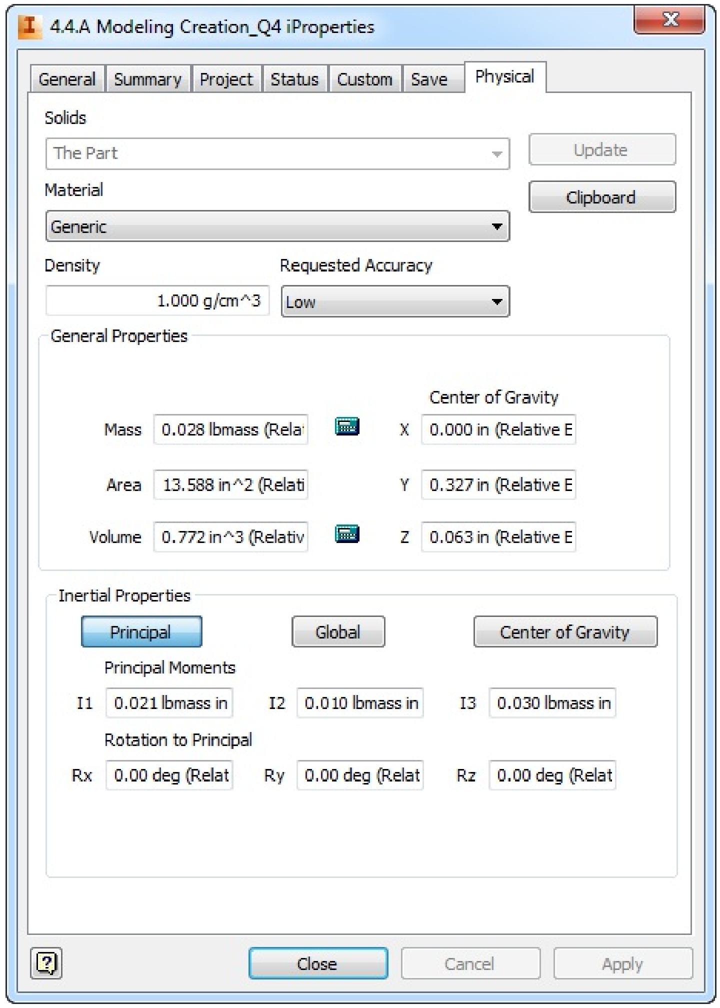


4.



All dimensions are in inches.

- Create a 3D solid model of the cam shown in the pictorial.



Hint: Use geometric constraints to properly constrain the cam sketch profile. For example, a tangent constraint is required between each arc and the contiguous straight edges of the profile. Also, to make later assembly easier, it is advisable to *vertically* align the center points of the arcs.

- Describe the method you used to create the object.
- Explain the most efficient procedure using a single extrusion to create this 3D solid model.

Conclusion

1. Why is it important to consider efficiency when planning your method of creation before you begin to model an object in CAD?
2. How can the information provided in the browser of the CAD software help you compare the efficiency of two different methods of modeling the same object?

Model Creation

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

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Activity 4.3

Motion in One Direction

Introduction

Motion is a change in position over time. We describe motion using terms such as **distance**, **displacement**, speed and **velocity**. Kinematics is the science of describing the motion of objects using words, diagrams, numbers, graphs, and equations.

In this activity you will interpret words and diagrams describing motion in order to graphically **model** the motion using a motion graph. You will also represent the motion using numbers (and direction, when applicable) to indicate the magnitude of distance, displacement, speed and velocity. Inversely you will interpret a graphical model of motion and describe the motion represented in words.

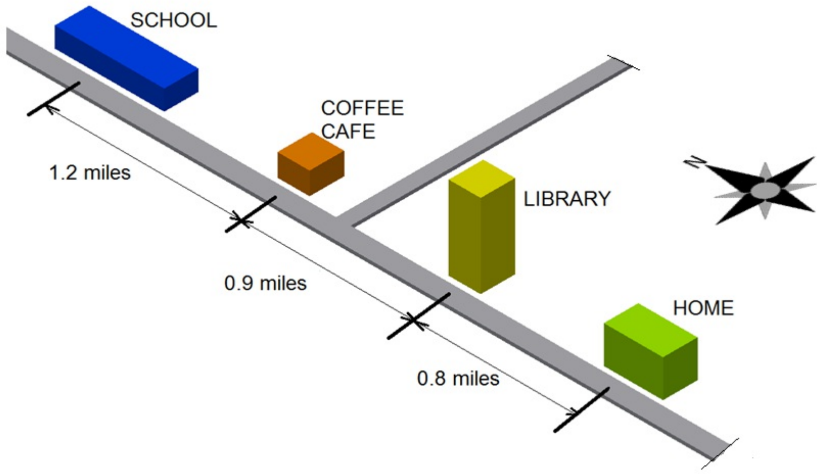
Equipment

- Computer with spreadsheet application

Procedure

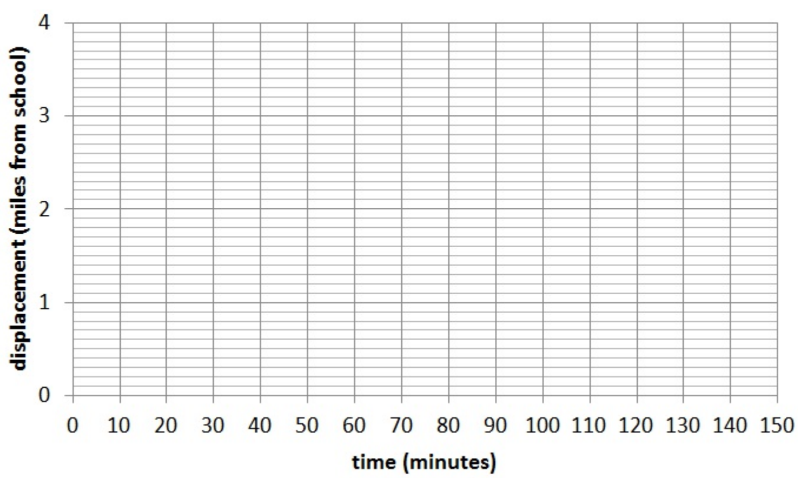
First, watch the **Describing Motion** tutorial video to learn about motion and motion graphs.

After school, a student jogged from school to the library. It took the student 35 minutes to get to the library, where he spent 10 minutes browsing and checking out a book. He then walked to the coffee shop, on the same street, in 15 minutes. He spent 40 minutes sitting at a table in the coffee shop and reading the book before heading home. He walked home in 25 minutes and remained there until the next morning.



1. Use the distances shown in the diagram above to draw a motion graph of the student along the street, in which he begins walking from school to the library at t = 0 minutes. Show 2.5 hours of time after he left school. Be sure to include axis labels, scales, and units.

   Assume that a positive displacement is from school toward home.

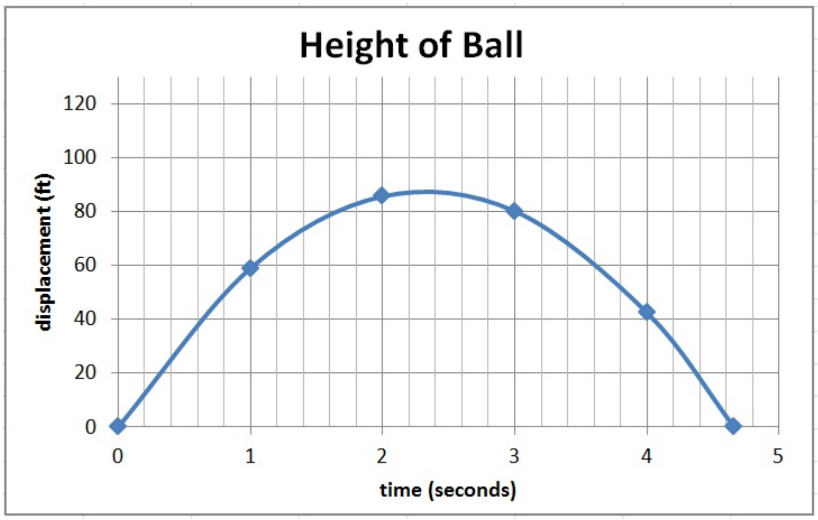


2. Using your motion graph, answer each of the following.

   - What is the student's displacement after 1.5 hours? Plot a point on your graph to correspond to this position and label it "Point A".
   - What is the total distance the student had walked after an hour and a half?
   - What was the student's displacement at 1 hour and 50 minutes? Plot a point on your graph to correspond to this position and label it "Point C".

- What is the total distance the student had walked when he arrived home?
- At what speed (in miles per hour) was the student walking 20 minutes after he left school?
- If home is due South of school, what is the velocity of the student at t = 50 minutes? Give the magnitude of velocity in miles per hour.
- What is the student's speed at t = 1 hour?

3. The following graph represents the vertical motion of a ball thrown straight up into the air.



Using the motion graph, answer the following. Show your work or explain your answer.

- What is the displacement of the ball at t = 4 seconds?
- What is the total distance the ball has traveled at t = 3 seconds?
- What is the **average speed** of the ball between t = 0 and t = 2 seconds?
- What is the average velocity of the ball between t =3 and t = 4 seconds?
- How long did it take before the ball returned to its original height?

4. Create a motion graph on orthographic grid paper, but do not define the units or scales for the graph. Exchange your motion graph with a classmate.

- Write a story or a description of a scenario that might be represented by your partner's graph.
- Label the axes, show scales and units for the graph.

Conclusion

1. How many different ways can you represent the motion of the student described in number 1?
2. What advantages does a motion graph have over the other ways to represent the motion of an object?

Mathematical Modeling

Introduction

In this activity you will collect and analyze data in order to make predictions based on that data. You will use both manual and computer methods to record, manipulate, and analyze the data in order to determine mathematical relationships between quantities. These mathematical relationships can be represented graphically and by equations, also known as **mathematical models**. You will then use the mathematical models to make predictions related to the quantities.

Equipment

Resources

Mathematical Modeling

Procedure

Part 1

Determine a mathematical model for the amount of rain water that runs off of the ground into surrounding waterways with respect to the amount of rain that falls on the ground given the following data.

Gaging Station	Estimated mean annual rainfall over area (inches)	Average annual runoff from area (in.)
Middle Fork Cottonwood Creek near Ono	40	14.1
Red Bank Creek near Red Bluff	24	6.4
Elder Creek at Gerber	30	9.6
Thomes Creek at Paskenta	45	21.2
Grindstone Creek near Elk		

Creek	47	16.8
Stone Corral Creek near Sites	21	2.2
Bear Creek near Rumsey	27	6

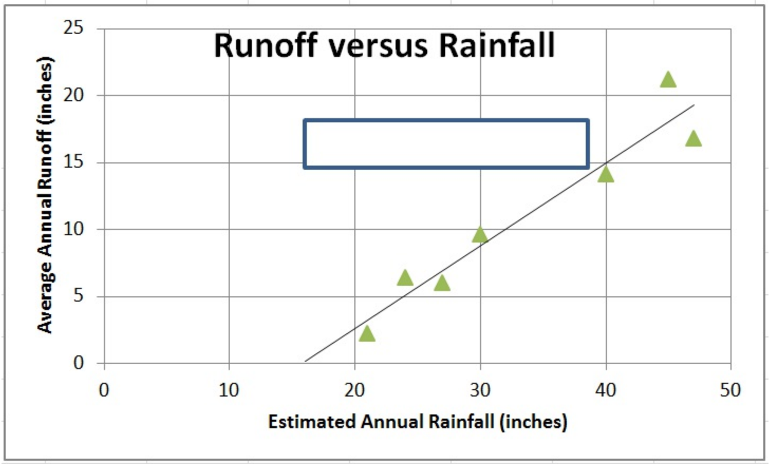
1. Use Excel to create a scatter plot of your data and find a trend line.

    - Input the data in tabular form. Be sure to include column headings. You do not need to include the piece color column.

	A	B	E
2	Water Quality and Supply on Cortina Rancheria, Colusa County, California		
4	Gaging Station	Estimated mean annual rainfall (inches)	average annual runoff per unit area (in.)
5	Middle Fork Cottonwood Creek near Ono	40	14.1
6	Red Bank Creek near Red Bluff	24	6.4
7	Elder Creek at Gerber	30	9.6
8	Thomes Creek at Paskenta	45	21.2
9	Grindstone Creek near Elk Creek	47	16.8
10	Stone Corral Creek near Sites	21	2.2
11	Bear Creek near Rumsey	27	6

    - Create a scatterplot of the data. Format the axes, label the axes, and title the chart as shown below.

    - Add a linear trend line and include the equation on the graph. Format the trend line to forecast backward 5 units.



- Print your graphical model showing the trendline and equation (mathematical model).
- Would you describe the relationship between Average Annual Runoff and Estimated Annual Runoff as a strong correlation, a weak correlation or neither? Provide evidence.

2. Use the mathematical model (trendline) to respond to items a - f.

- Rewrite the equation of the trend line using function notation where R(w) represents the annual Runoff and w represents the annual Rainfall.
- What is the **domain** of the **function**? That is, what values of *w* make sense?
- What is the **range** of the function?
- What is the slope of your trend line? Explain the interpretation of the slope in words.
- Estimate the annual runoff amount if the annual rainfall amount is 54 inches. Show your work.
  - Mark this point on your graph and label the point, Point E.
- If the annual runoff amount from an area was measured to be 11.5 inches, estimate the annual rainfall amount that fell on that area? Show your work.
  - Mark this point on your graph and label the point, POINT F.

Part 2

Find a mathematical model to represent the minimum jump height of a BMX bike as a function of the bike weight. Then use the mathematical model to make predictions.

The following data was collected for minimum jump heights achieved by an experienced rider for bikes of different weights.

Bike Weight (lb)	Minimum Jump Height (in.)
19	83.5
19.5	82.0
20	79.2
20.5	77.1
21	74.9
22	73.3
22.5	71.0
23	68.1
23.5	65.8
24	64.2

Use this data to complete each of the following.

3. Create a scatterplot and find a trend line for the data using Excel. Print a copy of your worksheet that includes the following:

    - Table of data
    - Scatterplot with properly formatted axes, axes labels and units, and an appropriate chart title
    - Trend line and its equation displayed on the scatterplot

4. Use the equation of the trend line to respond to items a - g.

    - Write the equation relating Bike Weight to Minimum Jump Height in function notation. Be sure to define your variable.

- What is the domain of the function? Explain.
- What is the range of the function?
- What is the slope of the line (include units). Is the slope positive or negative? Explain the interpretation of the slope in words.
- If the engineer designed a bike that weighs 18 pounds, predict the minimum jump height. Give your answer in inches (to the nearest hundredth of an inch) and feet and inches (to the nearest inch). Show your work.
- If the engineer designed a bike that weighs 1 pound, predict the minimum jump height. Give your answer in inches to the nearest hundredth of an inch and feet and inches to the nearest inch. Show your work.
    - Does the predicted height for a one pound bike make sense? Is this function a good predictor for minimum jump heights at all bike weights? Explain.
- If a minimum jump height of 89.7 inches is recorded, predict the estimated weight of the bike. Show your work.
    - Based on the correlation coefficient, how confident are you that your predictions are accurate?

Conclusion

1. What is the advantage of using Excel for data analysis?
2. What precautions should you take to make accurate predictions?
3. What is a function? Explain why the mathematical models that you found in this activity are functions.
4. Are all lines functions? Explain.

Mathematical Modeling

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 4.5

Cams in Motion

Introduction

A **cam** is a mechanism that moves in order to change the direction or rhythm of movement of other parts. A cam usually causes linear movement of another part when an axle rotates it. Cams are used to create motion in many engineering applications, such as clock mechanisms, sewing machines, toys, recording instruments, and engines.

In this activity, you will create a 3D **solid model** of a cam. You will place the 3D model in an assembly model, simulate the **rotation** of the cam, and study the resulting motion of another part called a **follower**. You will then collect data and create a motion graph to represent motion of the follower. By comparing your motion graph to those created by teammates, your team will develop a **mathematical model** for the vertical **displacement** of a follower resulting from the rotation of different sized cams of similar shape.

Later, you can use this computer model, and the mathematical models collected by classmates, to help you select an appropriate cam for your Automata design.

Equipment

- Computer with spreadsheet program

Resources

Creating Drawings CAD

Assembly Constraints

Cam Dimension Drawings

Polar Graph Paper

Automata Simulation Folder (of Inventor files)

Procedure

Part 1 – Create a motion graph

Watch the Cams in Motion video

Video: Cams in Motion

Refer to your downloadable resources for this video.

1. In a team of four, each team member will choose a different nominal diameter from the following list: 1.5 in., 2 in., 2.5 in., or 3 in.

   The *nominal diameter* is a dimension used to describe the cam but is not necessarily the actual diameter of the cam. In this case, you will use the nominal diameter to calculate the actual dimensions of the cam according to the Cam Dimension Drawings.

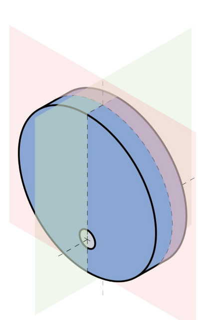
2. Your teacher will assign a cam shape to your team: eccentric, pear-shaped, regular hexagon, or snail. Create a 3D computer model of a cam using your nominal diameter and assigned cam shape per the Cam Dimension Drawings.

3. Create a fully dimensioned part drawing of your cam. Use a 1/4” square hole (to match a ¼ in. square axle) or match the axle dimension your teacher provides.

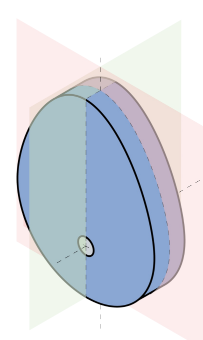
4. Watch the Placing Work Features in Your Cam 3D Model video. Add the listed work features to your cam 3D solid model. These work features will later help you properly constrain your cam in an assembly:

   - a midplane work **plane** centered between the flat surfaces of the cam
   - a work axis through the center of the hole
   - a work plane that includes the center axis of the cam hole and, if the cam is symmetrical, represents the plane of symmetry of the cam. Rename this work plane *Angle of Rotation Cam.*

   Note that a snail cam will not have a plane of symmetry. In this case, place a work plane parallel to the flat edge of the outside surface of the cam as shown below.

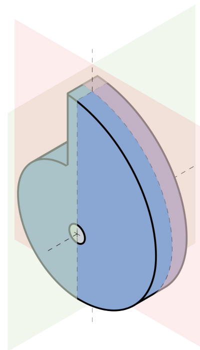


Eccentric Cam

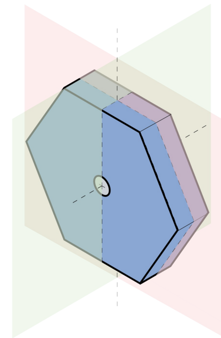


Pear Cam

Video: Placing Work Features within your Cam 3D



Snail Cam



Hexagon Cam

Model

Refer to your downloadable resources for this video.

5. Watch the Simulating **automata** Motion video. Simulate the motion of a cam assembly using your 3D cam model using the following instructions.

   - Download the AutomataSimulation.zip file and extract the files.
   - Open the AutomataSimulation.iam file. Place your cam model into the assembly file.
   - Add assembly constraints as follows.
     - Mate the midplane work plane of the cam to the work plane that passes through the centerline of the follower rod.
     - Mate the center axis of the hole in your cam with the center axis of the axle.
     - Mate the plane of symmetry of your cam to the work plane through the center axis of the axle.
   - Test the assembly by rotating the handle attached to the axle. The cam should rotate with the axle. Ignore any interference between the cam and the follower.
   - Place a transitional constraint between the outside edge surface of your cam and the curved surface of the bottom of the follower.
   - Test the assembly by rotating the handle attached to the axle. The follower should move up and down as the cam rotates. You may wish to turn off the visibility of the box for now to better observe the mechanical motion.
   - Insert an angle constraint to help you measure the angle of rotation.

- Rotate your cam and orient it such that the follower is in its lowest position.
- Turn **on** the visibility of the *Angle of Rotation* Work Plane associated with the follower part. [Note: you can toggle visibility of a feature on and off by right-clicking the feature in the browser and selecting Visibility.]
- Turn **off** the visibility of the *Mate with Midplane* work plane associated with the follower.
- Turn **off** the visibility of the midplane work plane of your cam.
- Place a directed angle constraint with a value of zero degrees between the *Cam Angle of Rotation* work plane and the *Angle of Rotation* work plane associated with follower.

- To test the constraint, try to rotate the axle. The axle should **not** move.
- Edit the angle constraint and set the angle to 45 degrees. The axle should rotate 45 degrees, but once the constraint is applied, the axle and cam should remain in the same position despite your attempts to rotate the part in the assembly file.

Video: Simulating Automata Motion

Refer to your downloadable resources for this video.

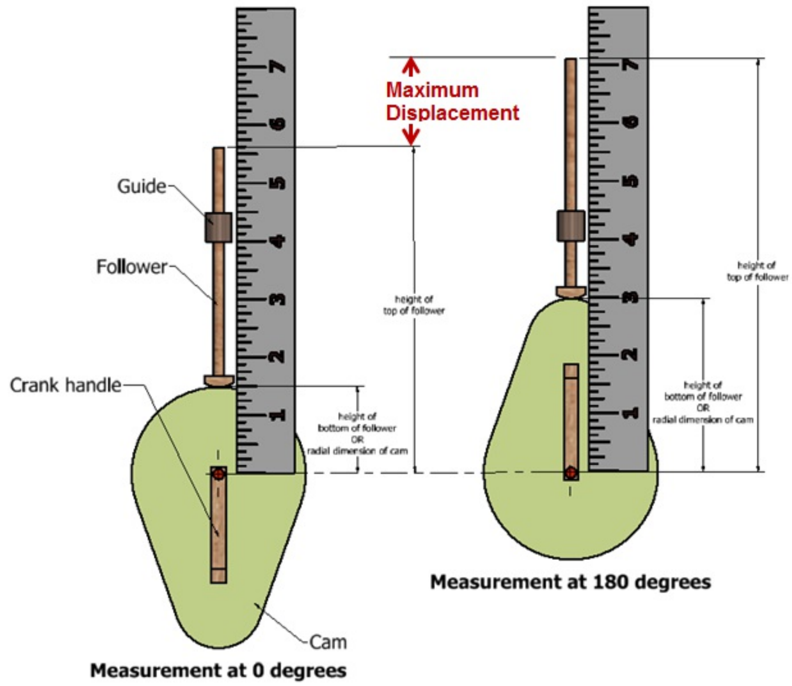
Note that you can *suppress* the angle constraint (or any assembly constraint) at any time by right-clicking on the constraint in the browser and selecting **Suppress**. Suppressing a constraint removes the constraint between the parts but does not delete the constraint. You can reapply the constraint using the same procedure to clear **Suppress**.

6. Collect and record data related to the motion of the follower. Record the height data at every 45-degree interval. Note that you can change the angle of rotation by editing the angle constraint just applied.

- Measure and record the height of the top of the follower rod above the center of the axle with respect to the angle of rotation of the axle.

  Note that you may use the Distance tool in lieu of using the ruler provided in the assembly to measure the **distance**. Be sure to select the appropriate axis and surface to obtain the correct orthogonal distance.

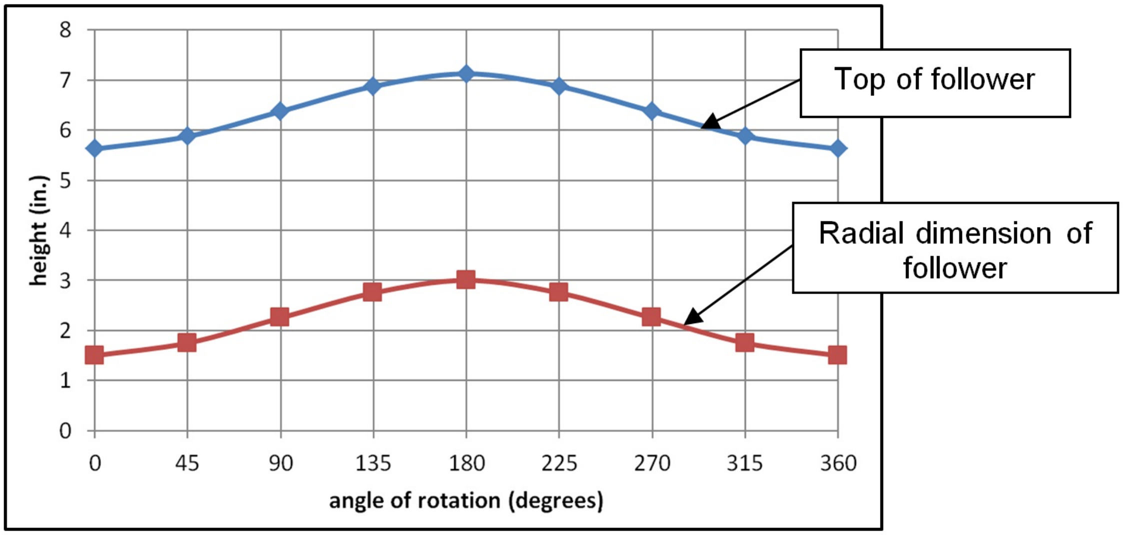
- Measure and record the radial dimension of the cam as the distance between the center of the axle and the point of contact between the bottom of the follower and the cam.



Angle of rotation (degrees)	0										
Height of top of follower (in.)											
Radial dimension of cam (in.) OR height of the bottom of the follower											

7. Create a motion graph.

   - To graphically model the vertical motion of the ***top*** of the follower rod, create a scatter plot with smooth lines in Excel. Format the axes, label the axes, and title the chart. Note that you can choose a scatterplot with smooth lines or straight lines in the Scatter menu (**Insert** tab > **Charts** panel > **Scatter** tool).
   - Graphically model the motion of the bottom of the follower (which is also the **radial dimension** of the cam) on the same axes.
   - Print a copy of your scatterplot. An example is shown.



- Add a line that represents the length of the follower (from bottom of the follower surface to the top of the rod) on your graph. Note that the length of the follower does not vary and is constant for all rotation angles.
- Compare the motion graphs for the top of the follower and the bottom of the follower. Describe the difference(s). How does this align to the length of the follower?

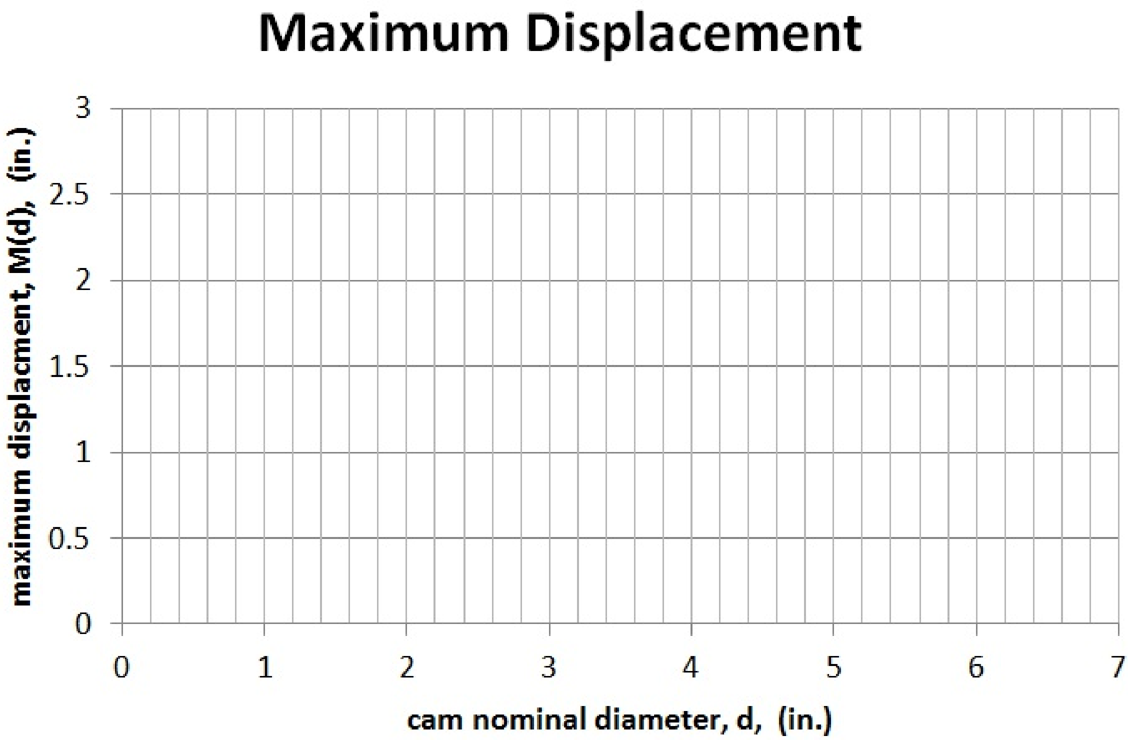
Part 2 – Generalize the motion graph

8. Compare your motion graph with the motion graphs of your teammates. For each cam, record the nominal diameter of the cam and the resulting ***maximum displacement*** of the follower.

Nominal diameter of cam (in.)	**1.5**	**2**	**2.5**	**3**
Maximum displacement (in.)				

9. Mathematically model the relationship between nominal diameter and maximum displacement.

- Create a scatter plot of your maximum displacement versus nominal diameter data. Use the format shown.



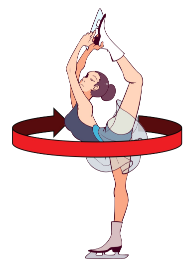
- Find a **function** to represent the maximum displacement with respect to the nominal diameter of the cam, where M(d) = maximum displacment and d = nominal diameter.
- Print a copy of your graphical and mathematical model.
- Explain the interpretation of the y-intercept of this equation in words.
- Explain the interpretation of the slope of this equation in words.

Extend Your Learning

10. Research simple automata designs that use cams. Respond to each of the following.
    - Describe one interesting automata design (that incorporates at least one cam) and the motion that results when the cam is rotated.
    - Represent the motion of the follower created by the cam with a simple motion graph. If more than one cam is included into the design, choose the motion resulting from **one** of the cams. Represent one complete **revolution** of the cam.

11. Create a sketch to illustrate how a cam and follower might be oriented to cause the follower to twist about its own axis (for example, like an ice skater performing a spin or helicopter blades spinning around the drive shaft).

12. Create a sketch to represent a cam mechanism in which a single follower is moved by two different cams, and describe the resulting motion in words.



Conclusion

1. Create a motion graph of the top of the follower for a mechanism that has a 5-inch nominal diameter and a 3-inch follower.
2. Create a motion graph of the bottom of the follower for a mechanism that has a 3.75-inch nominal diameter and a 3-inch follower.

Creating Drawings CAD

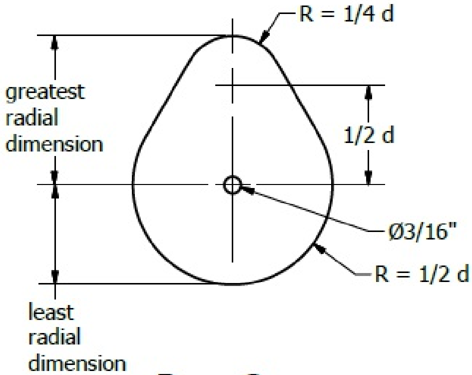
Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Assembly Constraints

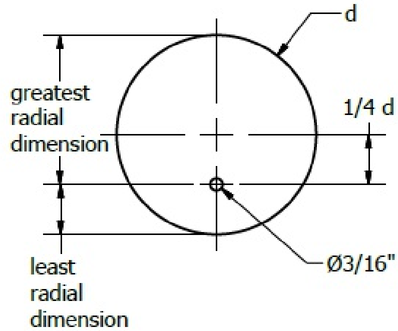
Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Cam Dimension Drawings

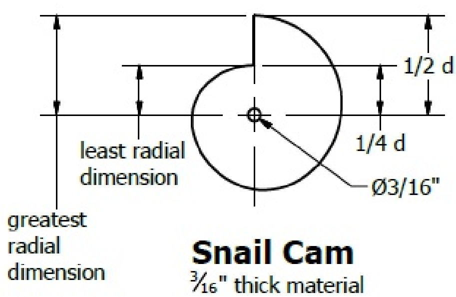
General Notes:
1. Not to scale.
2. All dimensions in inches.
3. Material varies
4. d = nominal diameter of cam



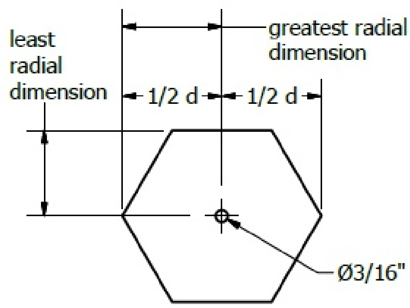
Pear Cam
3⁄16" thick material



Eccentric Cam
3⁄16" thick material



Snail Cam
3⁄16" thick material



Regular Hexagon Cam
3⁄16" thick material

Activity 4.6

Design a Cam

Introduction

Often engineers must design a mechanism to replicate a specific motion. In this project, you will design a **cam** to provide a specified motion. You will then create a **physical model** and test your design to compare the results against the desired outcome.

Equipment

- Foam board, balsa or bass wood, corrugated plastic, 3D printer, or other prototyping material
- Manufactured box
- 3/16”-diameter dowel
- 3/16”-square dowel

Resources

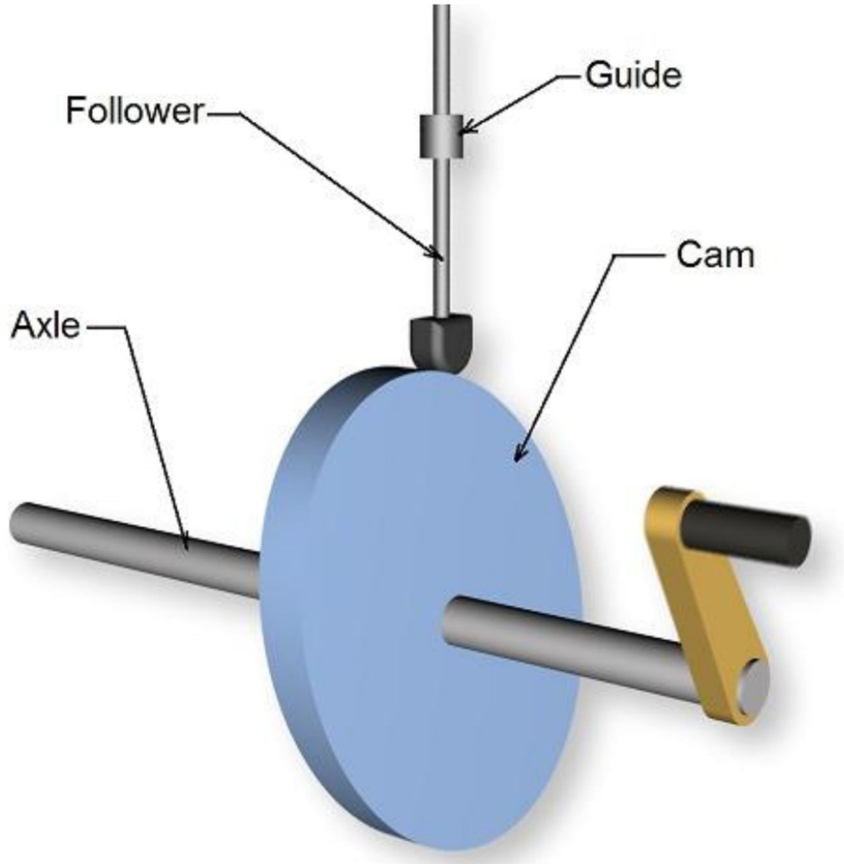
Polar Graph Paper

Procedure

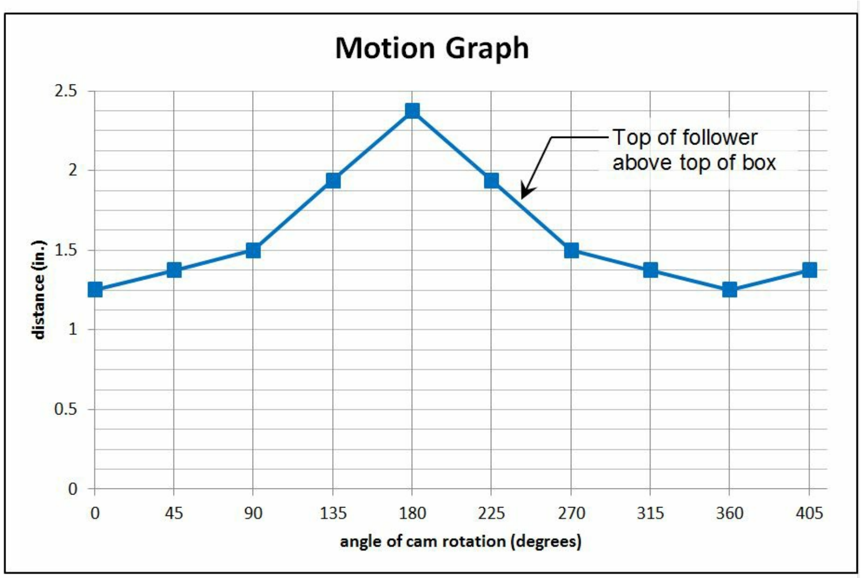
Watch the *Design a Cam Tutorial* video to learn how to use a motion graph to design a cam.

Design a Cam Tutorial

Study the cam assembly shown below.



The motion graph represents the vertical **follower** motion created by a cam in an assembly similar to this assembly. Note that the cam shown is for illustration only and will not produce the motion displayed in the motion graph.



1. Assume that the minimum radial dimension of the cam is 1/2 inch. Replicate the motion graph

of the position of the top of the follower above the box. Then draw a motion graph (on the same grid) to represent the radial dimension of the cam. This will require you to **translate** the follower motion graph down, such that the radial dimension at an angle of **rotation** of 0 degrees is 1/2 inch. Label your **function** "radial dimension of cam".

2. On a polar grid, sketch the profile of a cam that will create the vertical follower motion represented by the motion graph in the cam assembly. Note that your cam will have a different profile than the cam illustrated above.
3. Calculate the length of follower needed to produce the motion graph shown in step 1, using the box manufactured in Project 3.9 Manufacture a Box. Show your work.
4. Sketch a multi-view drawing of your follower design.
5. Create a physical model of your cam and follower.
6. Test your cam assembly. Record your test data in a table and represent the test results using a motion graph.
7. Evaluate your solution with respect to each of the following. Explain each assessment.
    - Does the cam and follower design provide a smooth follower motion when the cam is rotated?
    - Is the cam/axle connection sufficient to ensure that the cam rotates with the axle without slippage?
    - Does the motion of the follower replicate the motion represented by the top of follower motion?

Conclusion

1. What real phenomenon might produce a motion that could be replicated by a cam of the shape you produced? Explain.
2. How would you improve your cam assembly design?
3. Based on your experience with this cam assembly, what considerations might be important in the selection of a linear motion and the resulting cam design that could affect the design of your **automata**?
4. You have developed several types of models to represent cam designs -- graphical models, computer models, and physical models. Evaluate the merits and limitations of each type of model in the process of designing a cam as part of a system (for instance an automata) to cause a desired linear motion.

Unit 5

Geometry of Design Overview

Preface

Geometric shapes are found everywhere. A strong understanding of shapes and other geometric relationships is necessary to effectively and efficiently develop computer and graphic representations. Today's software that employs parametric design functionality requires an understanding of plane and solid geometry as well as geometric relationships (such as perpendicular, parallel, and tangent). In this unit you will be introduced to geometric concepts and transfer your knowledge of geometry to parametric computer modeling. You will also learn how the geometry of objects affect the physical properties of those objects. and and as well as an understanding of the physical properties.

Essential Questions

1. 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?
2. Which high school math topic/course, Algebra or Geometry, is more closely related to engineering? Justify your answer.
3. How does the material chosen for a product impact the design of the product?

Activity 5.1: Calculating Properties of Shapes

Activity 5.2.a: Geometric Constraints

Activity 5.2b: Introduction to CAD Modeling Skills

Activity 5.3: Determining Density

Activity 5.4: Calculating Properties Solids

Activity 5.5.a: CAD Model Features Part 1

Activity 5.5.b: CAD Modeling Features Part 2

Activity 5.6: Physical Property Analysis

Activity 5.7: Force Stability

Project 5.8: Reindeer Games

Optional Activity 5.9: Instant Challenge: Popcorn Package

PLTW ENGINEERING

Activity 5.1

Calculating Properties of Shapes

Introduction

If you were given the responsibility of painting a room, how would you know how much paint to purchase for the job? If you were told to purchase enough carpet to cover all the bedroom floors in your home, how would you communicate the amount of carpet needed to the salesperson? If you had to place an order for new shingles for the roof of your home, how would you determine the number of shingles needed? Aside from the fact that each of these questions deals with home improvement issues, they all center on the concept of **area**.

Area describes the measure of a two-dimensional surface. One example of how area is used in engineering is the calculation of stress that develops in an object that is subjected to an external load. If you have ever stretched a rubber band to the point that it breaks, then you have applied an external load to an object that has a constant cross-sectional area. In doing so, you caused stress to build up inside the rubber band until it broke. Another example of how area is used in engineering is the calculation of beam deflection. If you have ever walked across a fallen tree in an effort to cross a creek, then you have experienced the concept of deflection. If the tree had a small diameter, then the amount of deflection would be significant and noticeable. If the tree had a large trunk, then the amount of deflection was probably too small to feel or notice.

Resources

Geometric Shapes and Areas

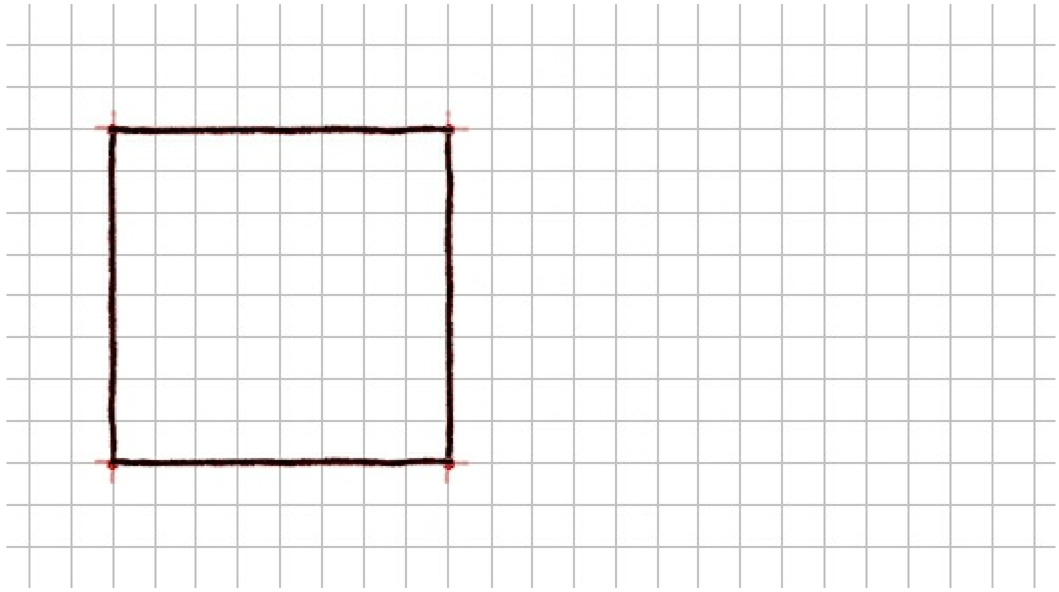
Attend to Precision

Procedure

Your teacher should provide you with a printed version of this activity.

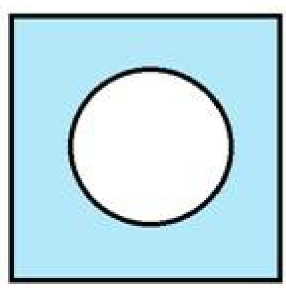
In this activity you will broaden your knowledge of shapes and your ability to sketch them. You will also learn how to calculate the dimensions and area of a shape. Use points, construction lines, and object lines to sketch the shapes described in the first seven word problems. Use the notes contained in your engineering notebook to help you perform the necessary calculations. Calculator use is encouraged, but you must show all of your work.

1. Use the sketch to calculate the area of the square. Add all linear dimensions to the sketch that were used in the calculations. Note: Each grid unit = 1 inch.



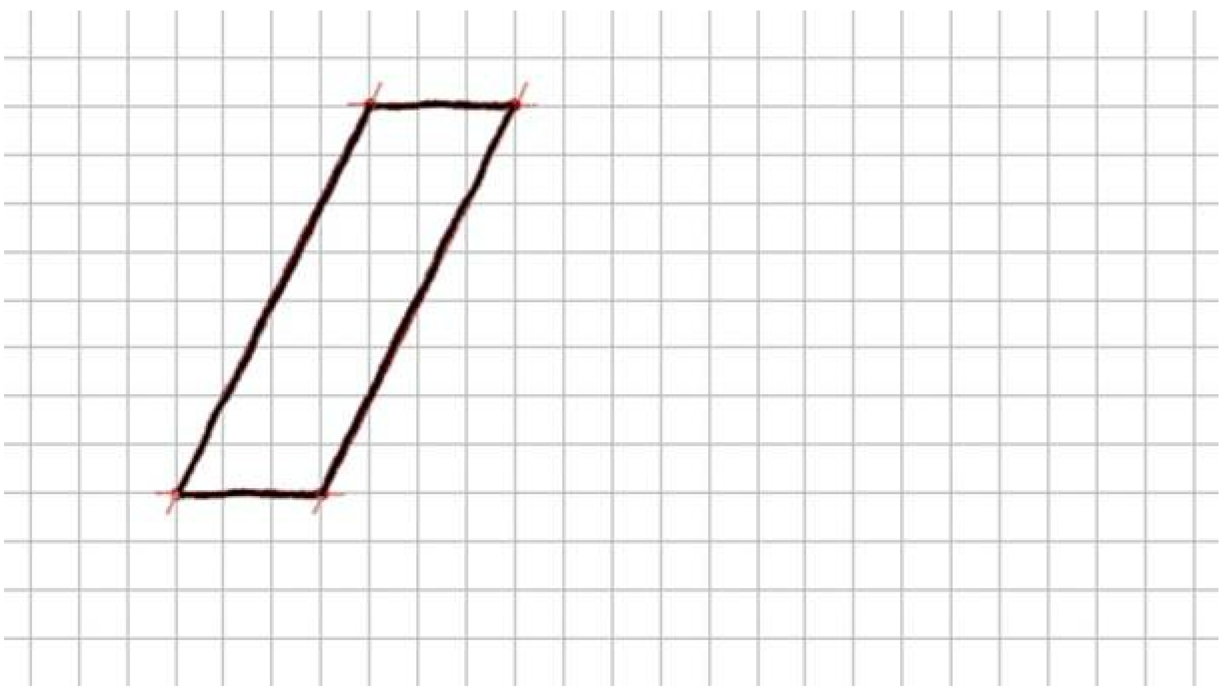
2. The area of the square represented in item 1 is revised to be 90.0 in.^{2}. Note that the original grid spacing no longer applies.

   - What is the side length of the square? Justify your answer.
   - Using this length, what would be the corresponding grid spacing for the sketch above? Justify your answer.
   - What size **circle** would you cut out of the square in order to have a remaining area of 66.5 in.^{2}? Justify your answer.
   - Apply all necessary annotations and dimensions to size the shapes and locate the circle in the center of the square.

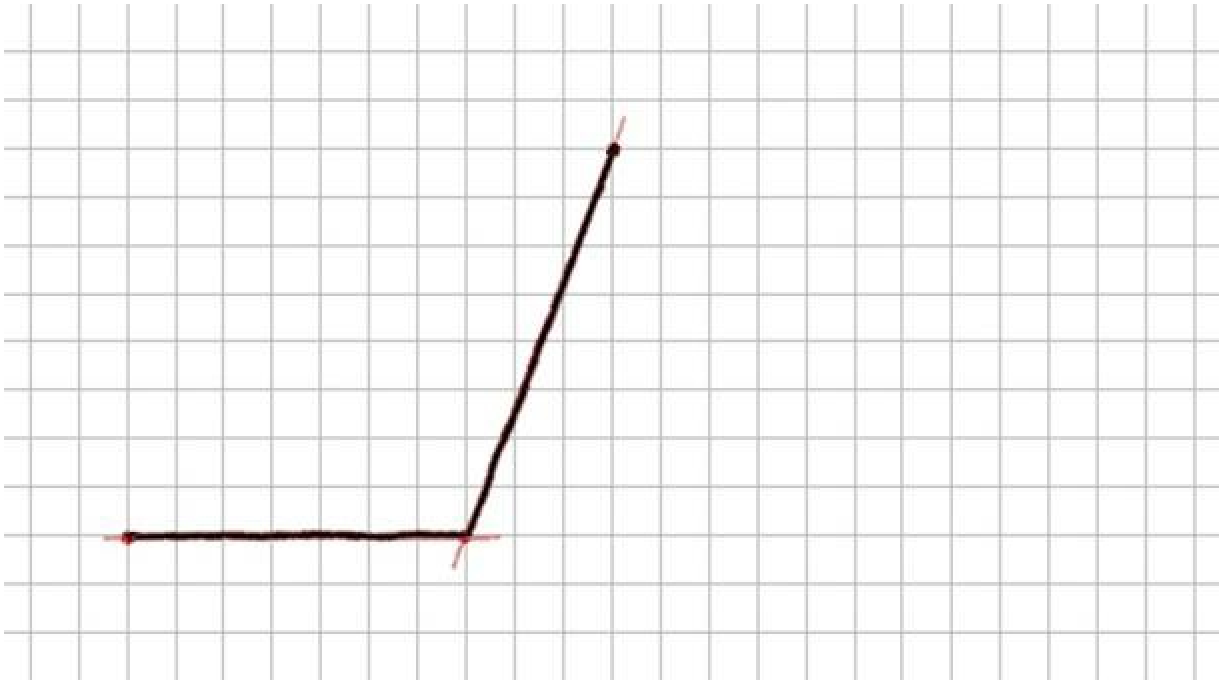


3. Complete the sketch of the **rectangle**. It must have an area of 2.25 in.^{2} Prove the enclosed area by dimensioning the sketch and showing the area calculation. Show only those dimensions needed for the area calculation. Note: Each grid unit = 0.25 inch.

4. Use the sketch to calculate the area of the rhomboid. Add linear dimensions to the sketch that were used in the area calculation. Note: Each grid unit = 1 inch.

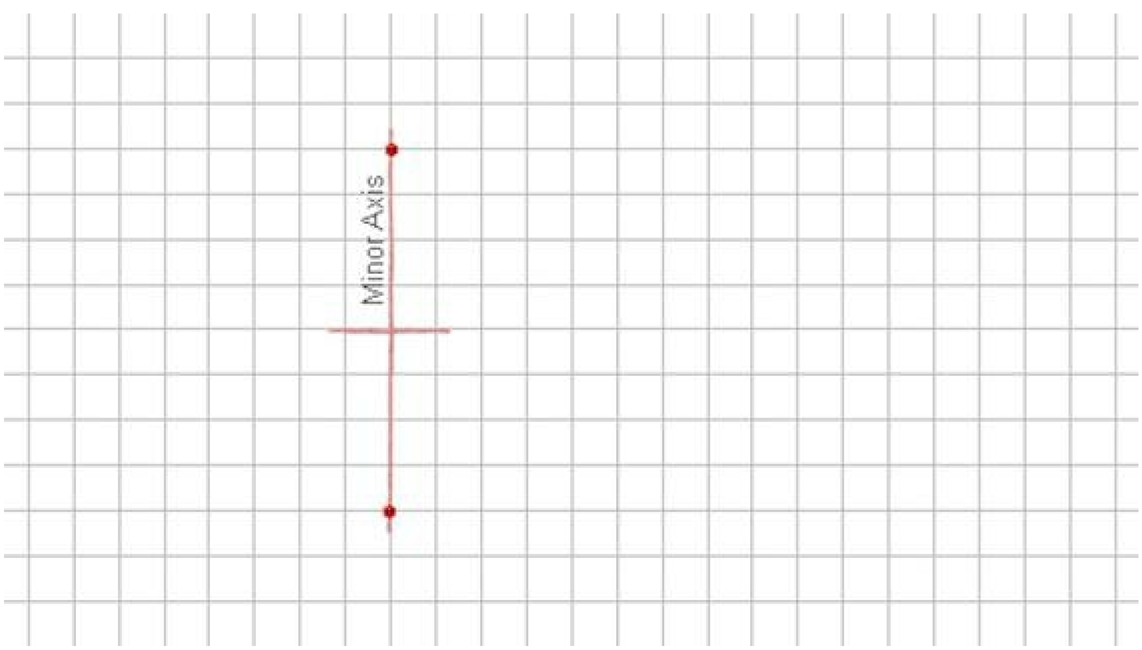


5. Complete the sketch of the **obtuse triangle**. It must have an area of 1.75 in.^{2}. Prove the geometry by dimensioning the sketch and showing the area calculation. Show only those dimensions needed for the area calculation. Note: Each grid unit = 0.25 inch.

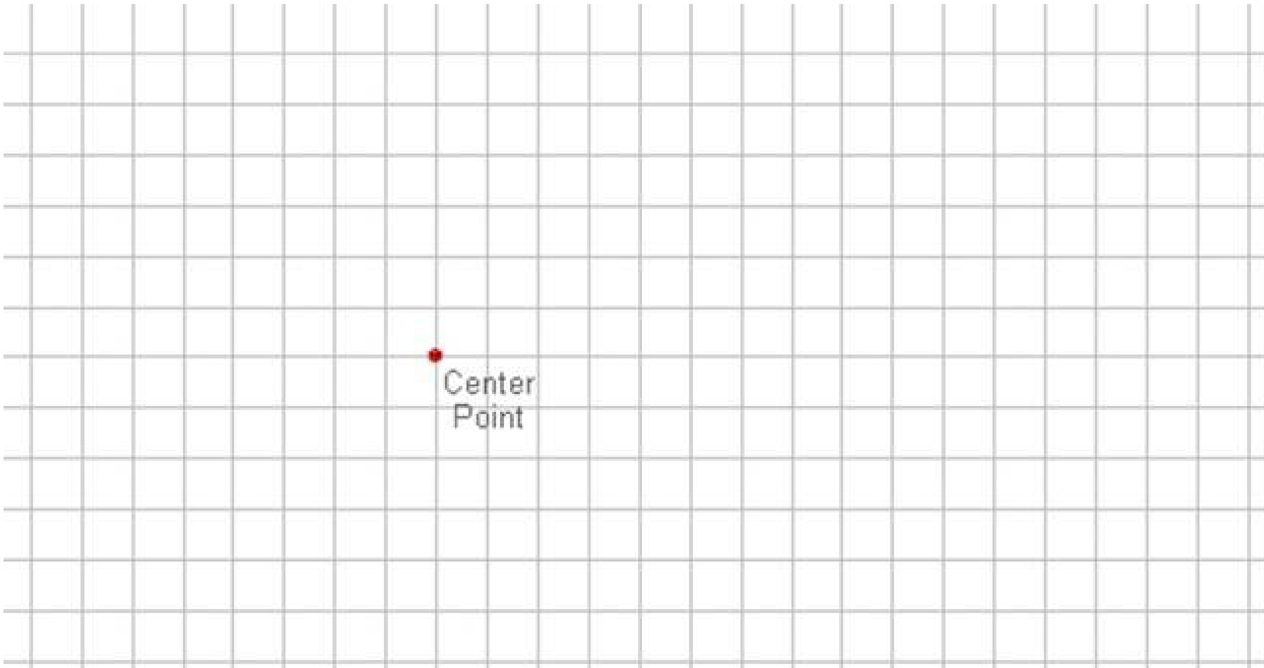


6. You are given a sheet of cardboard that is 8.0 in. x 11.0 in. How many full circles with a diameter of 3.0 inches can you cut from the cardboard? What is the percentage of waste if the excess cardboard (outside the circles) is thrown away?

7. An **ellipse** has an area of 4.71 $in.^2$ and a minor **axis** that is 2.00 in. long. Solve for the major axis, and then sketch the ellipse using that dimension. Show only those dimensions needed for the area calculation. Note: Each grid unit = 0.25 inch.

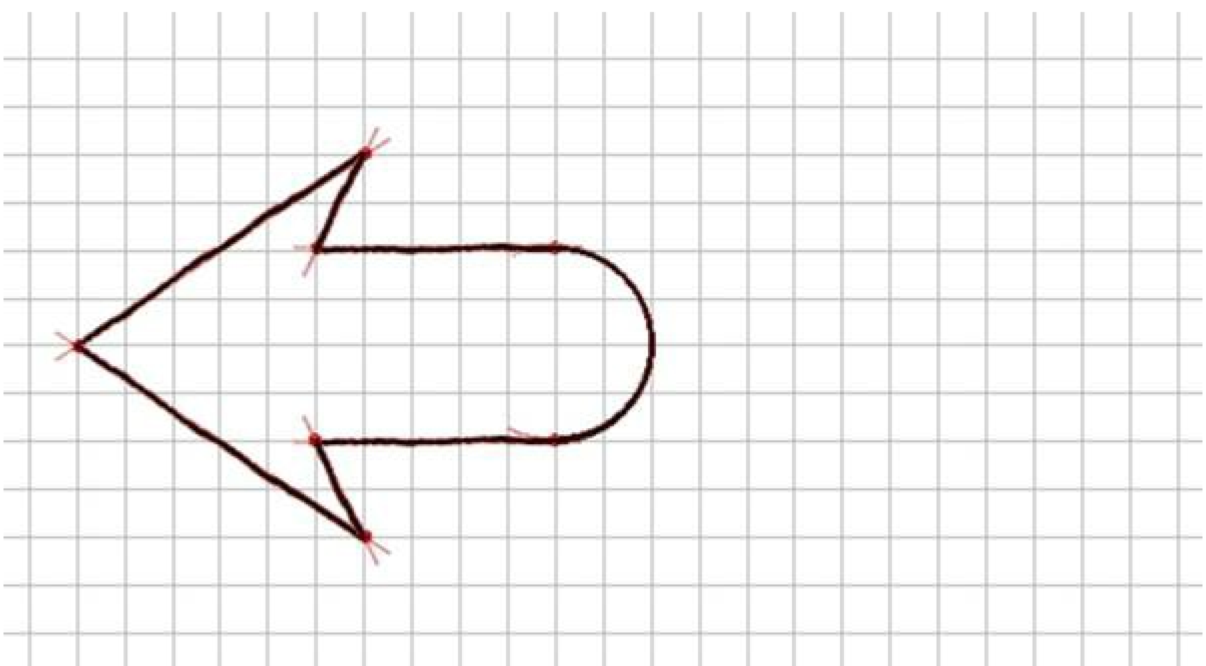


8. What side length would you specify if you were required to create a regular hexagonal plate that was comprised of 33 cm^2 of sheet metal? Sketch the hexagon, dimension the side length on the sketch to 0.1 cm, and indicate your grid spacing. Justify your dimension.



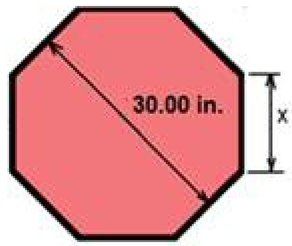
Extend Your Learning

9. The sketch shown represents the profile of a commercial sign. It was drawn to 1/10 of its true size. What is the surface area of the front of the actual sign? Prove your answer by showing all calculations. Note that the sign was not drawn to scale but was drawn on a grid in which the grid spacing unit is 1 inch.



More Challenging

10. A standard stop sign measures 30.00 inches from flat to flat. What is the side length, x, of the stop sign (to the nearest 0.01 in.)? Justify your answer.



Conclusion

1. What is the difference between a circle and an ellipse?
2. What is the difference between an inscribed and a circumscribed shape?
3. Why is it impossible for a triangle to contain a 180° angle?
4. How is a rhombus similar to a square?
5. What is the difference between a right, acute, and obtuse triangle?

Geometric Shapes and Areas

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Attend to Precision

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

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Activity 5.2a

Geometric Constraints

Introduction

There are several types of constraints that can be applied within a 3D solid modeling program to control the geometry associated with a solid model: geometric constraints, dimension constraints, and assembly constraints. We will talk about dimension constraints and assembly constraints later in this lesson. In this activity we will explore geometric constraints.

Geometric constraints are applied in CAD programs to control geometry within sketches and enforce relationships between lines, arcs, **circles**, and other geometry. Examples of geometric constraints include parallel, perpendicular, concentric, and equal.

Constraints are often automatically applied by the software as you create a sketch in a CAD program. Sometimes you don't even realize the constraints are being applied. For instance, to ensure that a **rectangle** always remains a rectangle in a sketch, a CAD program will automatically apply constraints when you create a rectangle using the rectangle tool.

However, you can also manually apply geometric constraints to a sketch to force the geometry to behave in a way that you intend.

In this activity you will investigate the effect that constraints have on the behavior of a sketch and try to replicate that behavior in a CAD sketch by applying appropriate constraints.

Equipment

- Computer with 3D modeling software

Resources

Work Points, Work Axes, Work Planes

Procedure

Watch the Autodesk® Inventor® Tutorial: Geometric Constraints.

Video: Autodesk® Inventor® Tutorial: Geometric Constraints

Refer to your downloadable resources for this video.

1. Open a new Inventor® part file in Inventor®. Create a sketch and experiment with each geometric constraint so that you become familiar with how the constraints affect the sketch behavior. Be sure to show the applied constraints so that you may understand how Inventor® indicates the application of each constraints.

2. Reproduce the following table in your PLTW Engineering Notebook. Be sure to leave enough space to add sketches.
View each of the videos posted at the end of this activity. In the appropriate column, draw a representation of the Inventor® sketch presented in each video in its initial form. On each sketch indicate the geometric constraints that you think are applied to the geometry in each case.

Video	Sketch geometry with geometric constraints	Teacher initials
1		
2		
3		
4		
5		

3. In Inventor® , create each sketch and apply the appropriate constraints to enforce the same sketch behavior as is demonstrated in each video. Demonstrate the behavior of each sketch to your teacher to get approval.

Geometric Constraint Video 1

Refer to your downloadable resources for this video.

Geometric Constraint Video 2

Refer to your downloadable resources for this video.

Geometric Constraint Video 3

Refer to your downloadable resources for this video.

Geometric Constraint Video 4

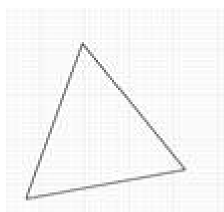
Refer to your downloadable resources for this video.

Geometric Constraint Video 5

Refer to your downloadable resources for this video.

Conclusion

1. Why is it important to use constraints when sketching with your 3D modeling program?
2. Why are some constraints automatically applied by the software, but you must manually apply others?
3. Study the shape shown below.

		
Original figure	Box A	Box B

- Create a table similar to the one shown and reproduce the original triangle. Consider which geometric constraint you would apply to the **triangle** to change it to a **right triangle**. Sketch the resulting right triangle in Box A and show the icons for the constraint(s) as they would appear if applied in Inventor.
- Consider which geometric constraint you would apply to the right triangle to change it to a right isosceles triangle. Sketch the resulting triangle in Box B and show the icons for the constraint(s) as they would appear if applied in Inventor.

Work Points, Work Axes, Work Planes

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 5.2b

Introduction to CAD Modeling Skills

Introduction

The capability of computers and software is astounding in some respects. For instance, computers can generate a solid computer model using a 3D scanner to analyze an existing object or space. Likewise, internal body organs and tissue can be “seen” using technology such as Magnetic Resonance Imaging (MRI). Unfortunately, commercially available computer systems have not advanced to the extent that they can document ideas and mental images from the human brain. For now engineers must continue to express ideas as sketches – hand drawn and computer generated.

A CAD model can quickly display an engineer’s ideas in a realistic way. And once an engineer has developed a model in CAD representing an idea, the idea can be shared much more easily with a wider audience. As is the case with technical sketching, CAD models must begin as sketches of points, lines, and shapes. However, a computer model can be much more accurate and precise than a freehand sketch. The lines of a CAD sketch can be drawn perfectly straight (or perfectly circular), with start and end points that occur in exact locations in space. A line may also be given precise length through the use of dimensions. If more than one line is being sketched, they can be made perfectly parallel or perpendicular or shown at a precise **angle**. CAD programs give designers the ability to sketch any kind of geometry and provide the ability to dimension, extend, rotate, mirror, copy and paste, pattern, move, and trim (to name a few tools) that geometry. Whereas hand-drawn representations are made to appear three dimensional by the strategic placement of additional points, lines, and shapes, CAD sketches can be transformed into 3D models using features that appear to add and manipulate material. As a result, within the software designers can extrude, revolve, or sweep a sketch such that the two dimensional sketch appears to become a solid form that can be electronically manipulated and viewed from any angle. Once a 3D model is created, the solid form can be hollowed out or the edges can be rounded.

The ability to realize CAD models through sequentially developing geometric sketches and generating 3D forms is a critical skill that designers in multiple engineering disciplines use in the process of converting mental images into money-making products. To effectively use a CAD program as a design tool, a designer must be familiar with the use of the available tools and features within the software. This activity will help you to understand and use the most frequently used sketching and feature tools that are common to most CAD programs.

Equipment

- Computer with 3D CAD solid modeling program

Resources

Automoblox® T9 Dimensioned Drawings

[**Automoblox® T9 Dimensioned Drawings (2016 or later)**]

[**Automoblox® To Dimensioned Drawing (original model)**]

Procedure

The exercises contained in this activity require the creation of new CAD files in which you will reproduce sketches and forms represented in the displayed mages. Most of the CAD files created in this activity will be Automoblox® part files.

Before beginning this activity, create an electronic Automoblox project folder in which you will save all files associated with your Automoblox vehicle. Create a second electronic folder named "Practice" to store non-Automoblox part files. As you finish each exercise, save the associated CAD file in the appropriate folder. It is important that you save all Automoblox parts to a single project folder for later use.

Automoblox® Body

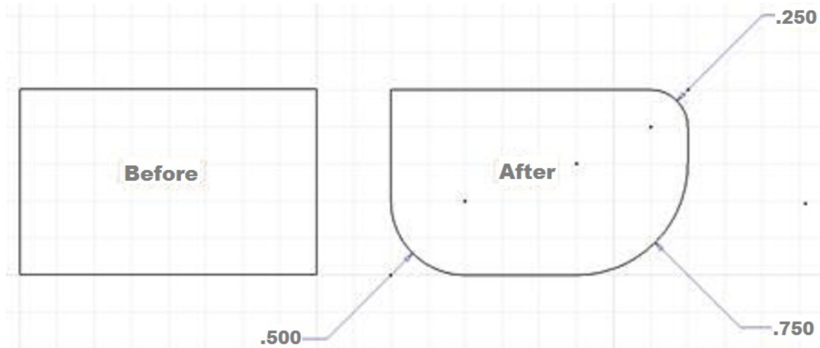
Sketch Tools – These are suggested tools for this activity:

- **Rectangle Tool**
- **Fillet**
- General Dimensioning (Numeric Constraints) Size and Location
- Adding new sketches to same part
- **Text**

Feature Tools – These are suggested tools for this activity:

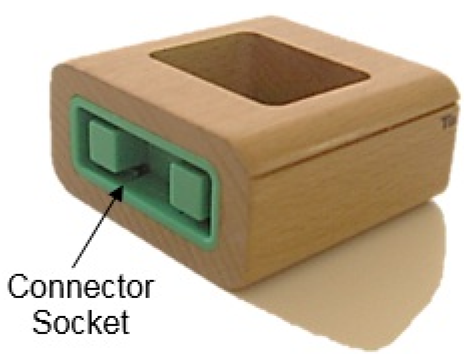
- **Extrude** (Add/join and Cut)
- Properties (Face Appearance)

1. Reproduce the sketch below in a part file. The **Fillet** sketch tool creates a **round** where two lines meet at a corner. The size of the round is identified as a radius value. Create a new CAD file and draw a **rectangle** that is approximately 2 inches wide by 1.25 inches tall. Use the **Fillet** sketch tool to round off the top right to 0.25 inch **radius**. Then round the bottom right corner with a .75 inch radius. Lastly, round off the bottom left-hand corner with a 0.5 inch radius. Save the file to your Practice project folder.

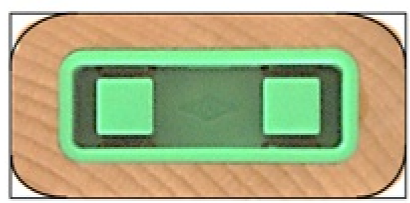


2. Create a 3D model of the passenger section of the body of your Automoblox vehicle (use the measurements you recorded or the Automoblox T9 Dimensioned Drawings).

    - Begin by sketching a rectangle and then filleting the corners before extruding.
    - Next select the top of the body part, create a new sketch, and then draw and locate a rectangle with filleted corners to represent the hole, based on the appropriate measurements.
    - Extrude a cut of the shape to the appropriate distance.
    - In the same way, make appropriate extrude-cuts in the two opposing faces of the body to allow for the connector socket parts.
    - Save the file as PassengerSection*YourInitials*.ipt in your Automoblox project folder.



BODY



Begin by sketching a rectangle and then filleting the corners.

Automoblox Windshield

<u>Sketch Tools</u> – These are suggested tools for this activity:

- **Line**

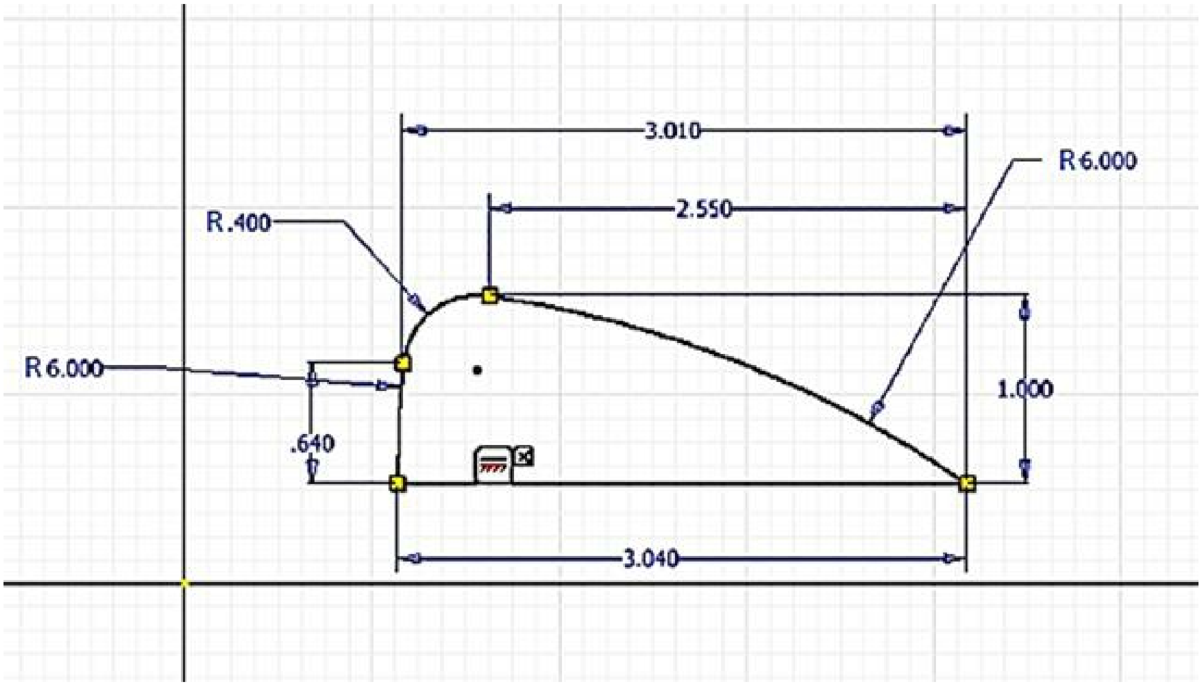
- **Arc** (Three Point)
- General Dimensioning (Numeric Constraints) Size and Location
- Geometric Constraints (Manually placed/auto-placement)
- Show (F8) and Hide (F9) Constraints
- **Project Geometry**
- Edit Sketch
- Construction Line

<u>**Feature Tools**</u> – These are suggested tools for this activity:

- **Extrude** (Add)
- **Fillet** (placed feature)
- View Control (View Cube or Orbit)
- **Shell**
- **Offset Workplane** with Sketch
- **Extrude** (to next)

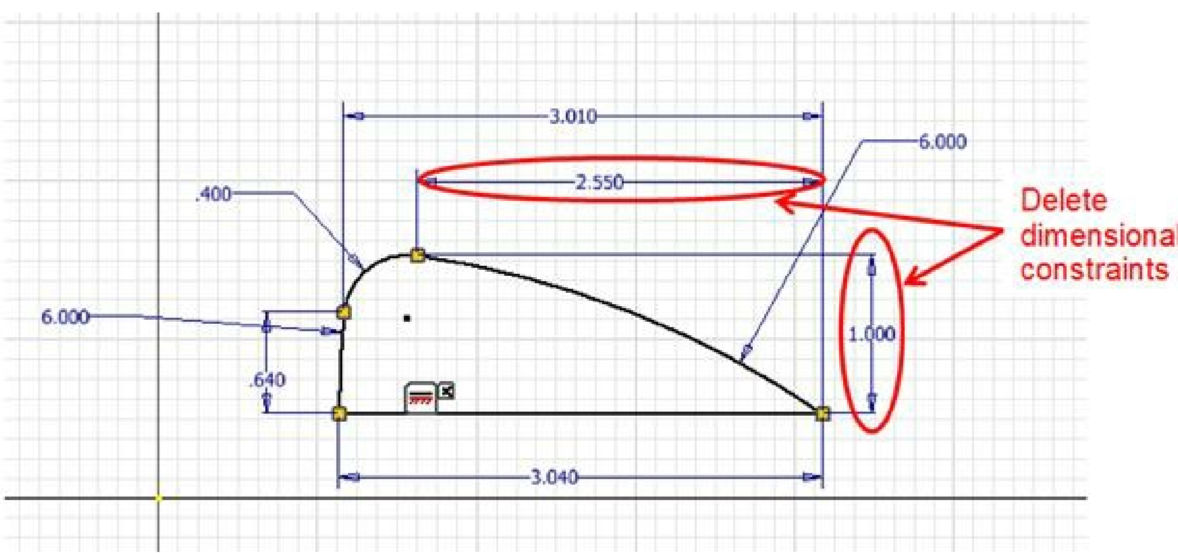
3. Begin to create a 3D solid model of the windshield of the Automoblox® vehicle.

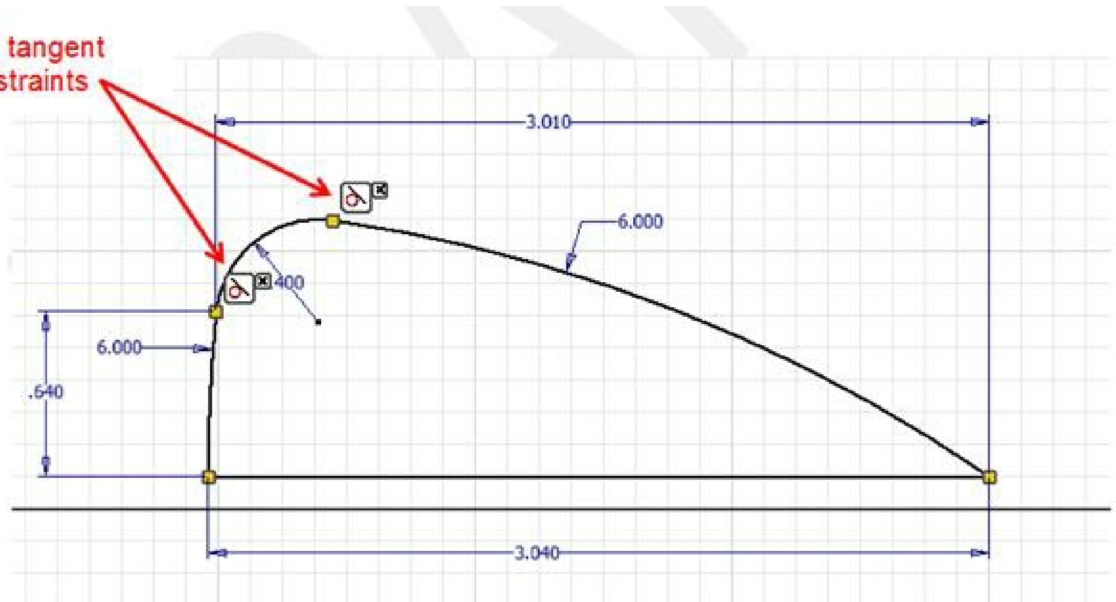
    - First create a sketch using the **Line** and **Arc** tools. Dimensions for the sketch of the T9 Automoblox® windshield are given below.



Hint: The top of the windshield is sketched using a series of three arcs. Place the horizontal line first. You may now find it easier to (1) sketch the two arcs with the 6-in. radius (using a three point arc to an approximate size), (2) locate each endpoint with vertical and horizontal dimensions, and (3) dimension the radii of those two arcs. Place and dimension the .4-in. arc last.

- Edit the sketch to remove the dimensional constraints on the upper coincident point between the two arcs and add geometric tangent constraints between each pair of adjacent arcs as shown below. Note that if these arcs are not **tangent**, you will not be able to later fillet the edge.





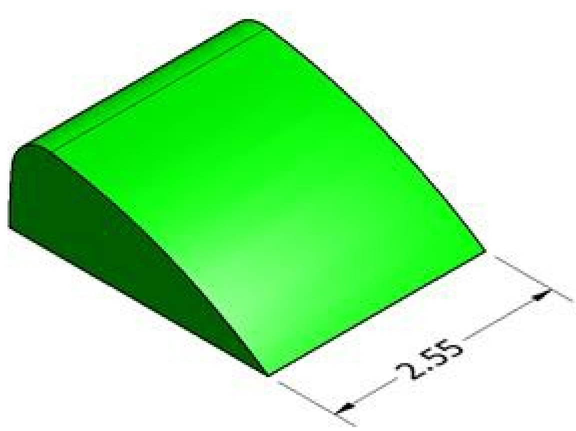
Helpful Hint: To remove a constraint, display the constraint in the sketch (press F8), select the constraint to remove, and then depress the Delete key (or right-click and select Delete).

The *Automoblox® Windshield Modeling Sketch Creation* video may provide helpful guidance as you model the windshield part.

Video: Automoblox® Windshield Modeling Sketch Creation

Refer to your downloadable resources for this video.

- Extrude the part the measured width of the enclosure or according to the pictorial drawing. You will have a “blockish” representation of the top portion of the enclosure as shown below. You will complete the model later in this activity.

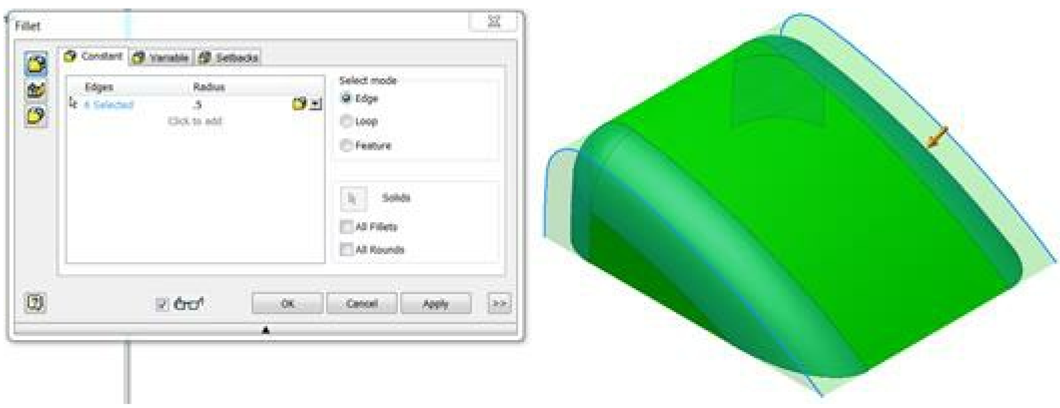


Completed “blockish” extrusion of windshield

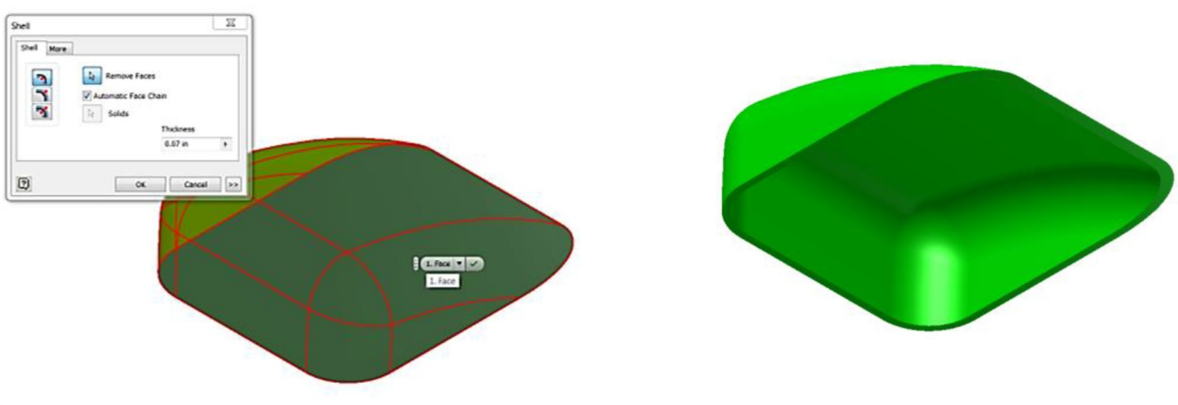
- Save the file to your Automoblox® project folder as Windshield*YourInitials*.ipt.

4. Complete the Automoblox® windshield 3D model.

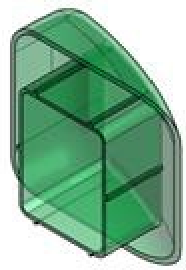
   - Continue working with the file that you created earlier in this activity. Fillet the exterior edges of the windshield to a radius of 0.5 inch.



   - Rotate the part to view the underside. Shell the enclosure to the measured thickness.



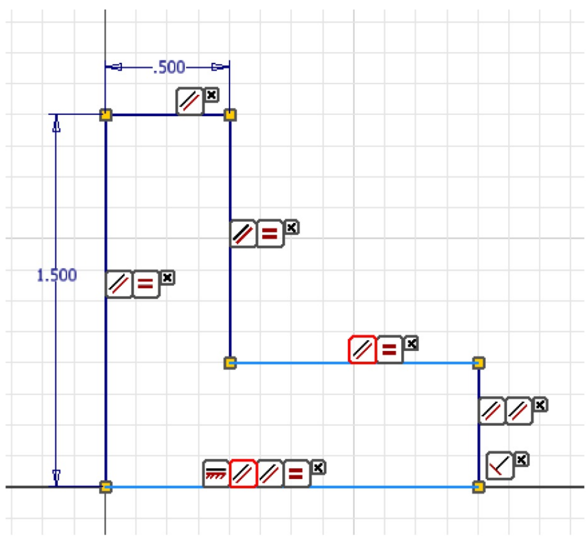
   - Using your measurements or the Automoblox® T9 Dimensioned Drawings, create the interior wall of the enclosure that will fit into the vehicle body. You may want to consider the use of an offset work plane and the Shell tool.

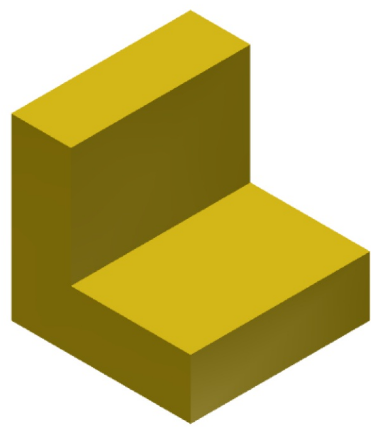


- Save the completed part file to your Automoblox® project folder.

5. Generate a structural angle part as described below.

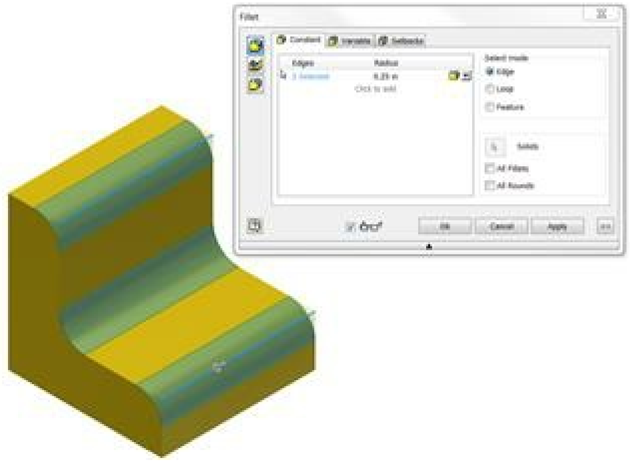
    - Reproduce the sketch shown below. Apply the dimensions and constraints as shown in the image and then extrude the sketch to a depth of 1.5 inches.





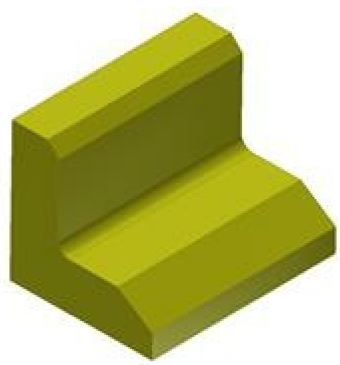
- Fillet and round the edges. Select the **Fillet** feature tool from the modeling ribbon. The image below illustrates that both inside (fillet) and outside (round) edges can be selected together or separately. Be sure to enter the value of .25 inch and select the OK button to apply the feature.

Note: The **Fillet** feature is a placed feature, because it does not require a sketch. It is different from the **Fillet** sketch tool used earlier in this activity which simply rounded corners in a *sketch*. The **Fillet** feature is a function that allows the user to create a rounded blend where two *surfaces* meet to form an edge. It should be noted that on an exterior corner, the resulting feature is known as a round. On an interior corner, the resulting feature is known as a fillet.

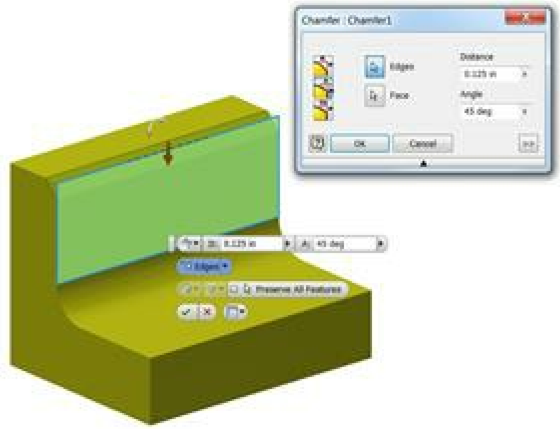


Chamfer

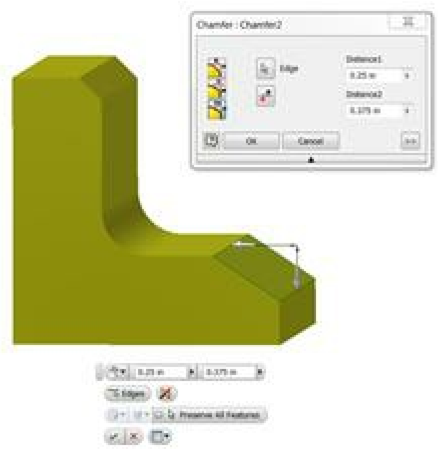
6. Edit the part created in the last exercise to modify the edge treatments. The outside corners will be changed to chamfers and the fillet radius will be changed on the inside corner.



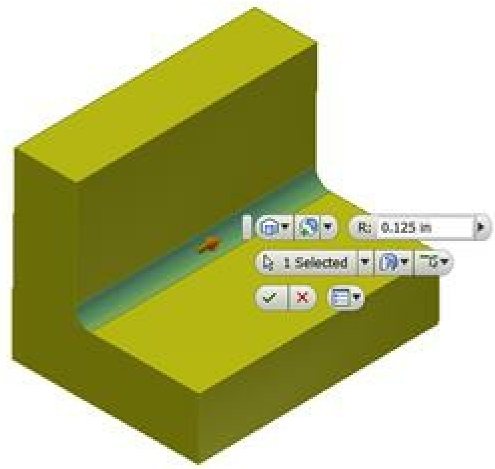
- Open the FilletAngle.ipt part file and save it as ChamferAngle.ipt.
- Change the rounds on the outside edges to chamfers.
    - In the Project Browser, right-click on Fillet1 and Edit Feature. This will open the Fillet dialog box. Deselect the outside edges by holding down the Ctrl key and selecting each edge. When selected, the edge should turn from blue to red. Then select the OK button.
    - Next activate the **Chamfer** tool in the Modify panel. On the top outside edge, apply a 45-degree chamfer with a distance of 0.125 inch.



- In a similar manner, apply a chamfer with two different distances – 0.25 inch vertically and 0.375 inch horizontally.

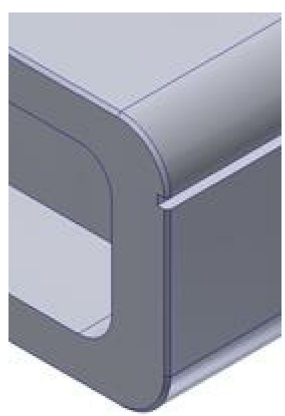


- Next, edit the fillet radius on the insider corner to a 0.125 radius.



- Save the file.

7. If appropriate for your vehicle, apply edge treatments to appropriate outside edges on the Automoblox body Passenger Section. Look closely at the part. Determine the type of edge treatment (round or chamfer) applied to the outside edges (that are not filleted) and approximate the size of the treatment. Modify the PassengerSection*YourInitials*.ipt file to include the edge treatments. Note that the color of the part was changed to improve the visual identification of the edge treatment.



Automoblox® Passenger Base

Sketch Tools – These are suggested tools for this activity:

- **Rectangle**
- **Fillet**

- **Geometric Constraints** – Vert. /Hor. /Equal
- General Dimensioning (Numeric Constraints) Size and Location
- **Polygon** – **Inscribed**/**circumscribed**
- View (F8) and Hide (F9) Constraints
- **Circle**
- **Trim / Extend**

Feature Tools – These are suggested tools for this activity:

- **Extrude** (Add)
- **Fillet** (placed feature)
- View Control (View Cube or Orbit)
- **Shell**

8. Model the Automoblox Passenger Base part.

    - Model the passenger base according to the measurements you recorded or the Automoblox® T9 Dimensioned Drawings. There are two versions of the drawings. Choose the version that represents the model of your Automoblox vehicle.
    - Shell the part to an appropriate thickness (0.01 inch in this example). The **Shell** function allows the user to remove unnecessary **mass** from a feature. The resulting geometry will have a wall thickness that is specified by the user. **Hint:** Be sure to place the necessary fillets on edges before you use the **Shell** Feature. This way, the fillets will be included in the final shelled part and the thickness will be consistent through the edges.
    - Save the part file as PassengerBase*YourInitials*.ipt into your Automoblox® project folder.

Automoblox® Wheel (Simplified Version)

Note: This model will not replicate the Automoblox® wheel exactly. Once you have gained more familiarity with 3D solid modeling tools and features, you may want to try to more closely mimic the contours of the wheel. Suggested steps to creating a basic wheel form are given below. You will have an opportunity redesign the Automoblox® wheel in Unit 8.

Sketch Tools – These are suggested tools for this activity:

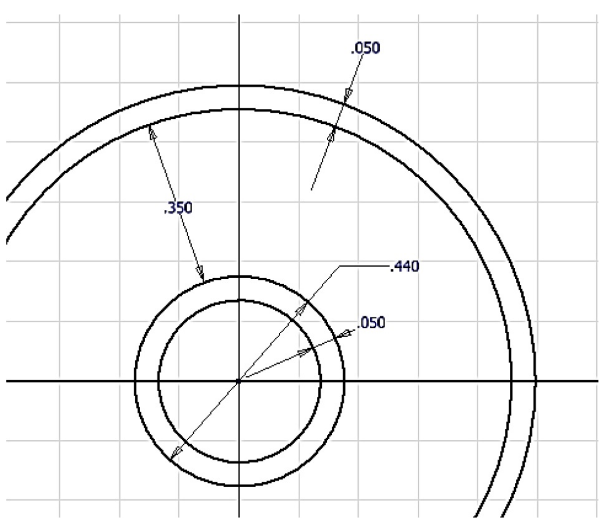
- **Circle**
- **Offset**
- Geometric Constraints (Manually placed/auto-placement)
- General Dimensioning (Numeric Constraints) Size and Location
- **New Sketch** (**2D**)
- **Project Geometry**
- **Trim / Extend**
- **Circular Pattern**

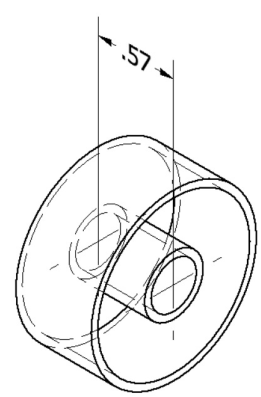
Feature Tools – These are suggested tools for this activity

- **Extrude** (Add / Cut)

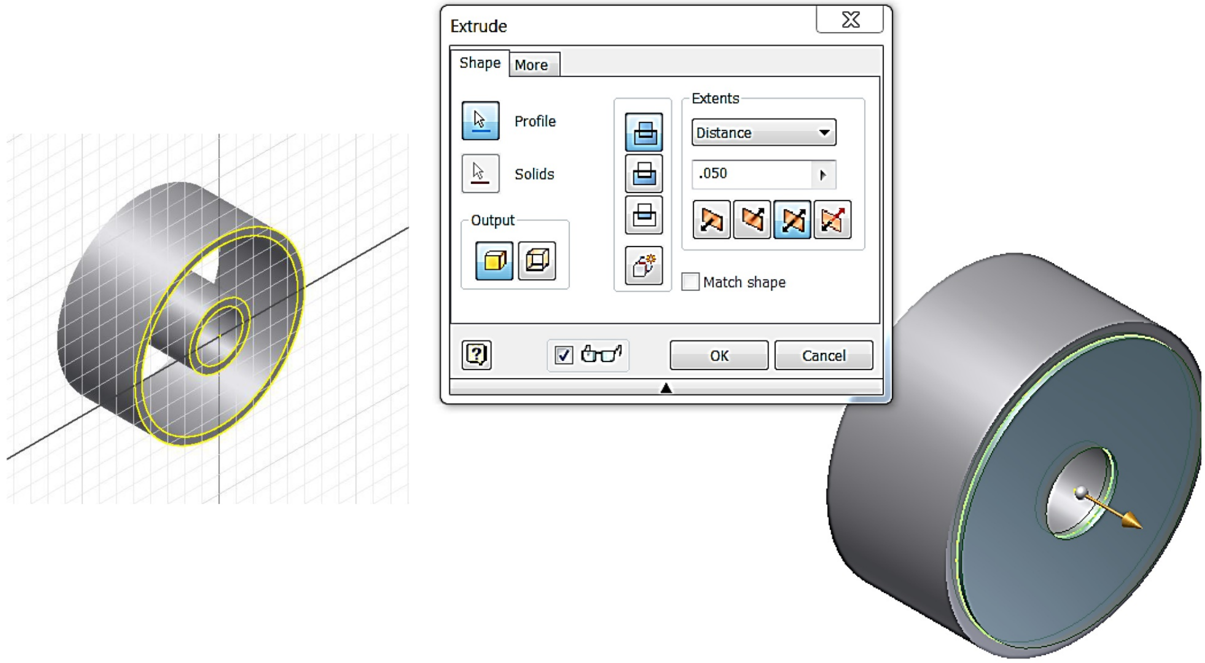
9. Create a *simplified* 3D model of the wheel for the Automoblox vehicle.

    - Create the inner and outer walls. Use **Offset Circles** (2 pair) to create the inner and outer walls per the measurements shown (or use your own measurements of the wheel).

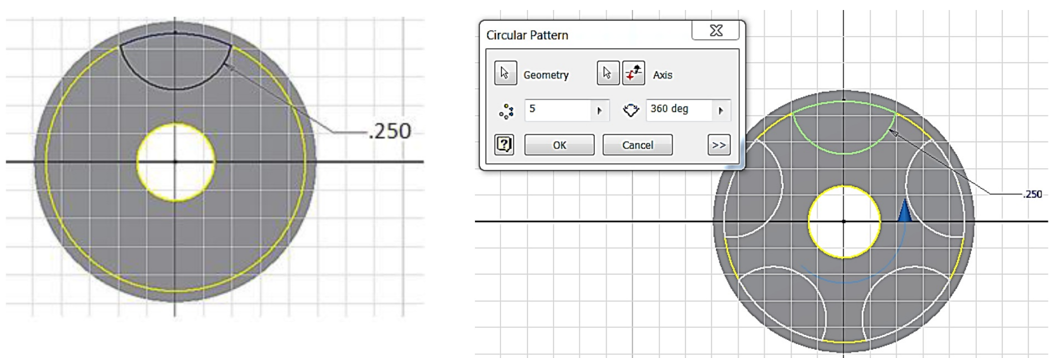




    - Create the wheel. **Extrude** both the outer and inner rings of the sketch to the depth shown in the isometric view. Create a new sketch on a flat face and use the **Project Geometry** sketch tool to transfer the geometry of the inner and outer walls to the sketch plane. Use a **Mid-plane Extrusion** to extrude the ring a distance of .050 inch to create the face of the wheel. Note that you need to include the **area** of the inner ring (the hub) in the extrusion.

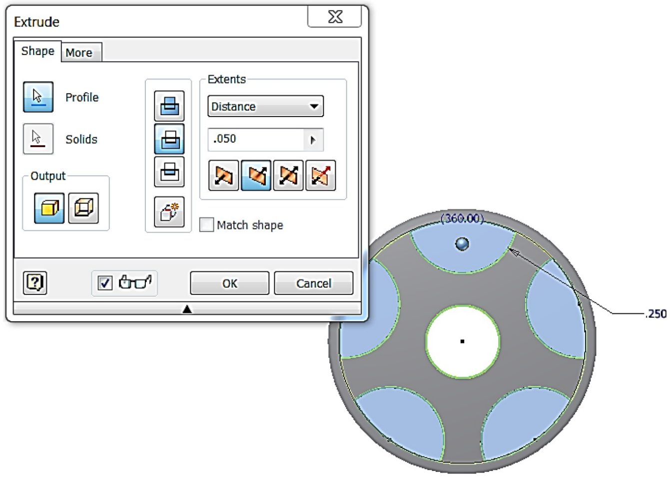


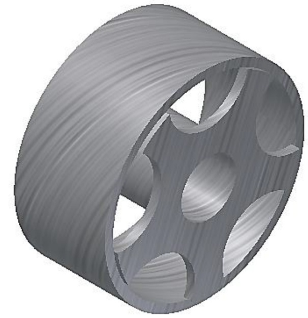
- Create the face pattern. Place a new sketch on the exterior face of the wheel and sketch a **closed loop** to mimic the semicircular cutout shape of one opeing in the wheel face. Use your measurements or the dimensions shown below for the T9 wheel. You may use the **Circle** and **Trim** tools to create this shape.



- Pattern the sketch. Use a **circular pattern** to create the remaining openings in the wheel face.

- Cut the face pattern. **Extrude – Cut** the semicircular shapes to create the face pattern.





Finished (simplified) Model

- Save the file as Wheel*YourInitials*.ipt.

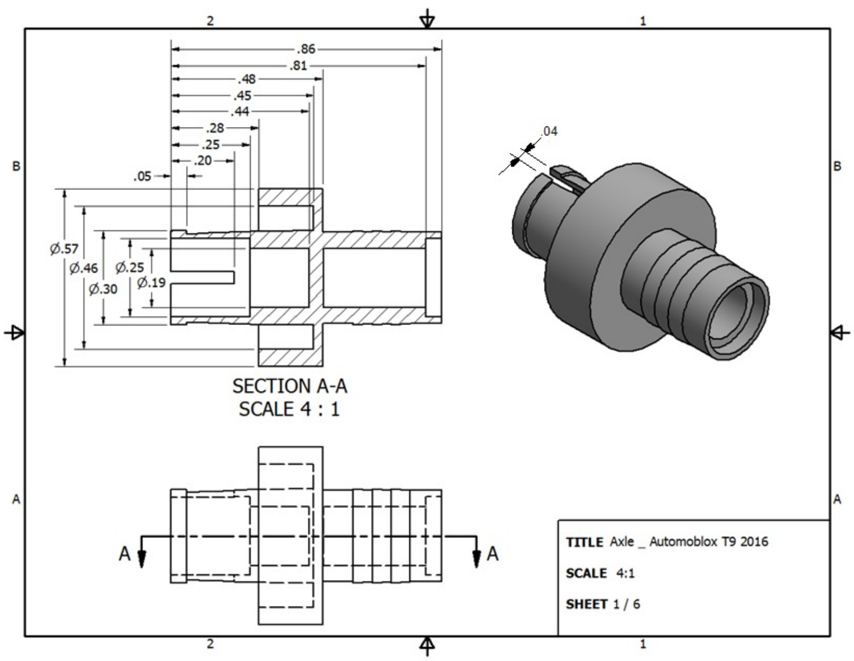
Conclusion

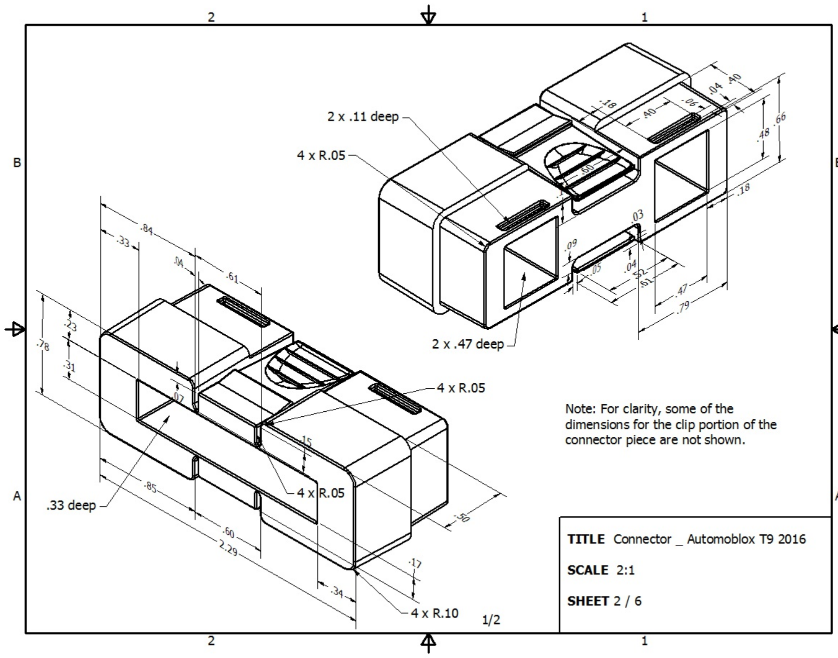
1. What advantages do CAD sketches have over freehand sketches?
2. What disadvantages do CAD sketches have when compared to freehand sketches?
3. What types of numeric constraints may be applied to sketches?
4. Explain the difference between the **Fillet** sketch tool and the **Fillet** placed feature.
5. The **Fillet** placed feature is used to create both a “fillet” and a “round”. Describe the difference between the two results.
6. Could the **Shell** feature be used to create the opening in the Automoblox body passenger section (as in number 2 above)? Explain your answer.

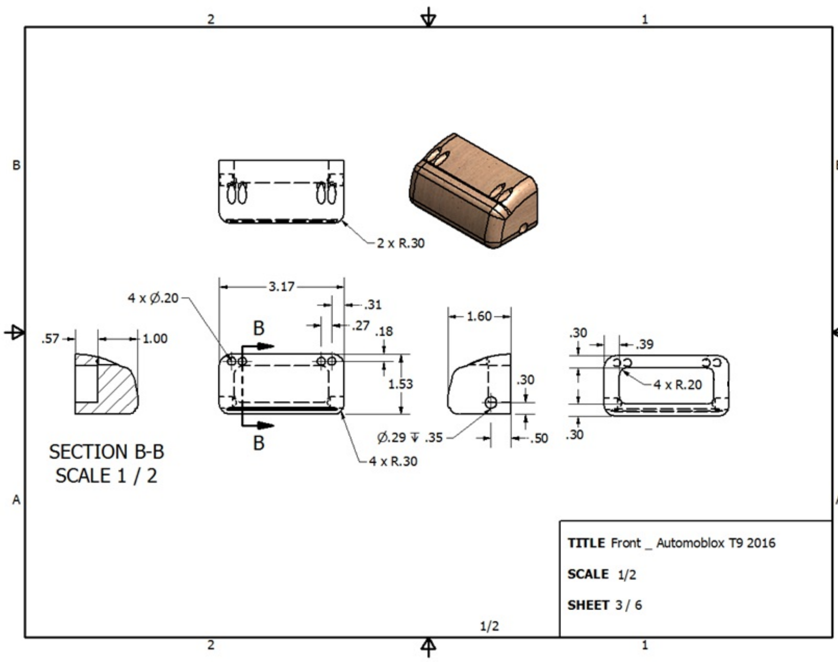
Unit 5 Automoblox T9 Dimensioned Drawings (2016 Model)

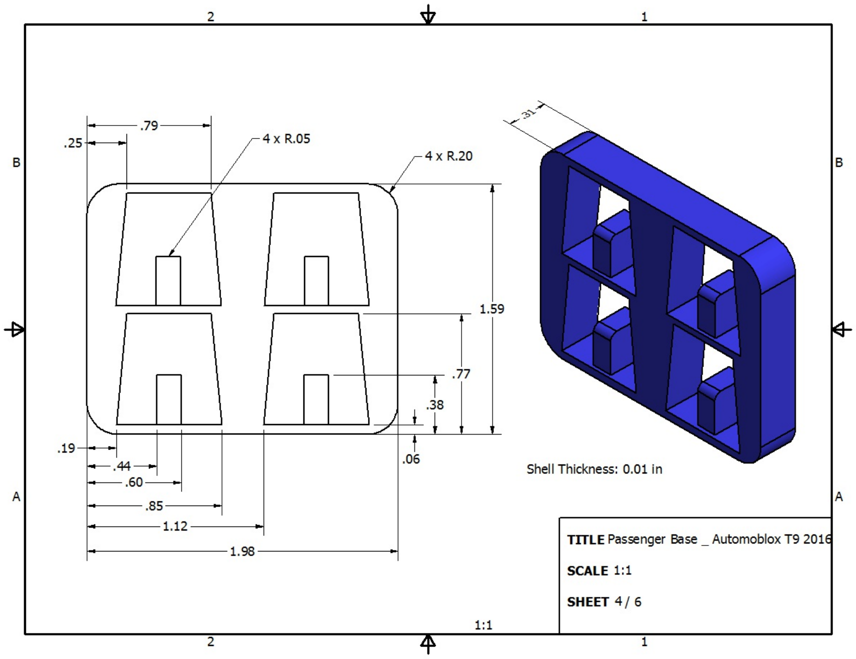
Note: the drawings provided here represent the 2016 Automoblox vehicle model. If you are working with an original Automoblox vehicle model, please download the Dimensioned Drawings for the original models from the Resources section of the activity.

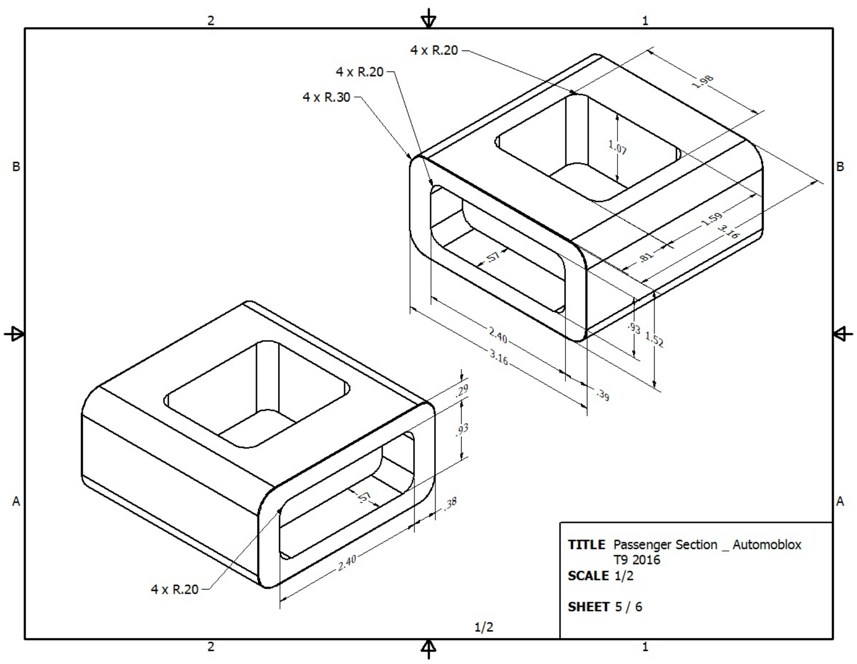
The following drawings are provided for information only, to be used with Activity 5.2 Making Sketches in CAD and Activity 5.5 CAD Model Features and are not intended to provide complete details. Only partial dimensions for some of the T9 Automoblox® model components are given to provide the measurements necessary to complete Activities 5.2 and 5.5 when the physical models are not available.

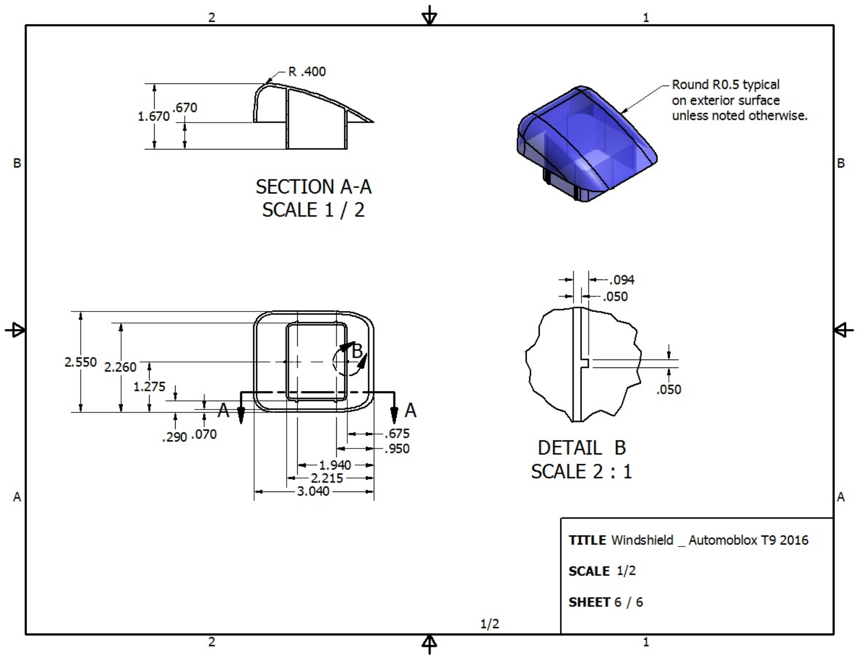



2 x .11 deep
4 x R.05
2 x .47 deep
4 x R.05
4 x R.05
.33 deep
4 x R.10
Note: For clarity, some of the dimensions for the clip portion of the connector piece are not shown.
TITLE Connector _ Automoblox T9 2016
SCALE 2:1
SHEET 2 / 6
1/2


2 x R.30
4 x Ø.20
3.17
.31
.27
.18
1.53
.57
1.00
SECTION B-B
SCALE 1 / 2
1.60
.30
Ø.29 ↧ .35
.50
4 x R.30
.30
.39
4 x R.20
.30
TITLE Front _ Automoblox T9 2016
SCALE 1/2
SHEET 3 / 6
1/2


.79
.25
4 x R.05
4 x R.20
1.59
.77
.38
.06
.19
.44
.60
.85
1.12
1.98
.31
Shell Thickness: 0.01 in
TITLE Passenger Base _ Automoblox T9 2016
SCALE 1:1
SHEET 4 / 6
1:1


4 x R.20
4 x R.20
4 x R.30
1.98
1.07
1.59
.57
.81
2.40
3.16
.93
1.52
.39
.29
.93
.57
.38
2.40
4 x R.20
TITLE Passenger Section _ Automoblox T9 2016
SCALE 1/2
SHEET 5 / 6
1/2



R .400
1.670
.670
SECTION A-A
SCALE 1 / 2
Round R0.5 typical
on exterior surface
unless noted otherwise.
2.550
2.260
1.275
.290
.070
A
B
A
.675
.950
1.940
2.215
3.040
.094
.050
.050
DETAIL B
SCALE 2 : 1
TITLE Windshield _ Automoblox T9 2016
SCALE 1/2
SHEET 6 / 6
1/2

PLTW ENGINEERING

Activity 5.3

Determining Density

Introduction

How full is the bag that you take to each of your classes? Can you put any more stuff into it? What happens to the size of the bag? What happens to the mass of the bag? The size of the bag likely stays the same, though the bag itself is probably about to burst open. When the **volume** of something stays the same while the mass increases, then the **density** increases.

In this activity, you will measure volume and mass to determine the density of several objects.

Equipment

- Triple beam balance or scale
- Graduated cylinder
- Dial calipers
- Automoblox® brake parts and wheels
- Crafts sticks (or other wood samples)
- Steel spheres
- Delrin spheres
- Paper clips
- (Optional) Aluminum ruler

Resources

Determining Density

Density and Uses of Common Materials Chart

Common Metals and Plastics

5.3.A.SR Determining Density Delrin Ball McMaster Carr0.pdf

5.3.A.SR Determining Density Delrin Ball McMaster Carr01.pdf

5.3.A.SR Determining Density Delrin Ball McMaster Carr02.pdf

[5.3.A.SR Determining Density Steel Ball McMaster Carr02.pdf]

[5.3.A.SR Determining Density Titanium McMaster Carr01.pdf]

[5.3.A.SR Determining Density Wood Densities.pdf]

Procedure

Part I. Determining Density of a Material

1. Measure the mass or weight of the Delrin, steel, and wood samples as directed by your instructor. For improved accuracy, measure ten samples of each material and calculate the average mass or average weight. Record values including units to the appropriate precision based on the precision of the scale. **Note that you need only measure either mass in SI units or weight in U.S. units, not both**.

	Delrin		**Steel**		**Wood**	
Mass/weight of 10 samples (include units)	**Mass (SI)**	**Weight (US)**	**Mass (SI)**	**Weight (US)**	**Mass (SI)**	**Weight (US)**
Average mass/weight of a single sample (include units)	**Mass (SI)**	**Weight (US)**	**Mass (SI)**	**Weight (US)**	**Mass (SI)**	**Weight (US)**

2. Calculate the volume of the Delrin, steel, and wood samples. For improved accuracy, measure three samples of each material and calculate the average volume. Record and calculate values to the appropriate precision including units. When adding or multiplying measurements, record the sum or product to the precision of the least precise number involved in the calculation.

	Delrin (diameter)	Steel (diameter)	Wood		
Volume formula (sphere, cylinder and/or rectangular prism, as appropriate)					
			W	D	H
Measurement 1					

Calculate volume (Show all steps including units)			
Measurement 2			W | D | H
Calculate volume (Show all steps including units)			
Measurement 3			W | D | H
Calculate volume (Show all steps including units)			
Calculate average of three volume measurements (Show all steps including units)			

3. Calculate the density of the Delrin, steel, and wood samples. Show units for each measurement or quantity.

	Delrin	Steel	Wood
Average of a single sample			
Average of three volume measurements			
Formula for density			
Calculate density (Show all steps including units)			
Formula to convert from SI to US system or from US to SI system			
Convert density from SI to US system or from US to SI System (Show all steps including units)			

4. Do your results correspond to published values for the density of steel, Delrin and wood? If not, why do you think your density value(s) vary from the published values?

5. (Optional) Create an Excel Spreadsheet to perform calculations and present the data calculated in Step 3 above. Format the information in a table similar to that shown. Print your table.

	Delrin		Steel		Wood	
	Value	Units	Value	Units	Value	Units
Mass of 3 samples						
Mass Average						
Volume of sample						
Density (SI)						
Density (US)						

6. Consider how you might determine the material from which an object is made. If you are given a sample of a metal (which you know is either steel or aluminum), a graduated cylinder, and a balance or scale, how could you determine from which metal the object is made?

Part II. Determining the Plastic Materials used in Automoblox Vehicles

Obtain an Automoblox vehicle from your teacher. Study the Automoblox brake parts and the wheels.

7. (2016 or later vehicle) Are the Automoblox circular brake parts made of the same material as the Automoblox wheels? Why do you think so? How might you test your hypothesis?

   (prior to 2016 vehicle) Are the Automoblox people made of the same material as the Automoblox wheel? Why do you think so? How might you test your hypothesis?

8. You will determine the density of the plastic used to manufacture the circular Automoblox brake parts (or people) and the Automoblox wheels. Measure the **mass** of the brake parts (or people) and wheels. For improved accuracy, measure the eight brake parts (or four people) together and then measure the four wheels together. Record values, including units, to the appropriate number of significant digits.

	Automoblox Brakes (or People)	Automoblox Wheels

	 OR 	
Total mass/weight of all sample(s) (include units)		

9. Measure the volume of the eight circular brake parts (or four people) and then measure the volume of the four wheels. Because of the irregular form of each object, the volume is more easily measured using a graduated cylinder.

    - Add water to the graduated cylinder until it is approximately 2/3 full.
    - Record the water level.
    - Carefully add samples.
    - Record the new water level.

	Automoblox Brakes (or People)	Automoblox Wheels
Water level without samples (Include units)		
Water level with samples (Include units)		
Water volume displaced = volume of sample(s)		

(Show calculations)		

10. Calculate the density (by hand or using Excel) of the eight brakes (or four people) and four wheel samples. Complete the table below or attach a print of your Excel worksheet. Be sure to **include units** with all measurements and quantities.

	Automoblox Brakes (or People)	Automoblox Wheels
Total mass/weight of sample(s)		
Volume of sample(s)		
Formula for density		
Density (SI)		
Density (US)		

11. Does your data support or refute your hypothesis (from Step 1 above)? Explain.

12. Refer to the Common Materials Density and Uses Chart. Use your results to make an educated guess as to the material used in the manufacture of the Automoblox brakes and wheels. What other tests might further substantiate your guess?

Extend Your Learning

13. Measure the mass of the aluminum ruler and paper clip samples. Choose the appropriate number of samples of each, if an average is needed for improved accuracy. Record values including units.

	Aluminum Ruler	Paper Clips
Total mass of sample(s)		

14. Measure or calculate the volume of the aluminum ruler and paper clip samples. [Note that you can calculate the volume of the ruler without submerging it in water.] Show all measurements, if using the indirect measurement. Sketch the object, if using the calculation method.

15. Calculate the density of the aluminum ruler and paper clip samples by hand or using Excel.

Complete the table below or include a print of your Excel worksheet. Be sure to use the mass and volume based on the same number of objects. **Show units** for all measurements and calculated quantities.

	Aluminum Ruler	Paper Clips
Mass of sample(s)		
Volume of sample(s)		
Formula for density		
Density (SI units)		
Density (US units)		

16. Do your results support the manufacturer's claim that the ruler is made of aluminum? Justify your answer. (Refer to the Common Materials Density and Uses chart.)

17. Are the paper clips made from the same material as the ruler? How do you know?

Conclusion

1. How can you use density to identify a material?

2. What are limitations of the calculated and indirect volume measurement?

3. Explain the difference between weight and mass.

Determining Density

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 5.3 Density and Uses of Common Materials Chart

Ferrous Metals

Material	**Density (g/cm^3)**	**Uses**
Cast Iron	7.2	Heavy equipment, machine frames.
Carbon Steel 1000,4000,5000 series	7.85	Fasteners like rivets, nails, wire, chains and machine parts. Medium carbon steel is used for gears, shafts, tool shanks. High carbon steel is used for screwdrivers, cutting tools, blades, drills, springs, bearings and knives.
Stainless Steel	7.9	Sinks, cutlery, kitchen utensils, surgical tools.

Nonferrous Metals

Material	**Density (g/cm^3)**	**Uses**
Aluminum	2.71	Used in chemical and food processing, fasteners, structural members, aircraft structural components, hardware, car and truck wheels, decorative trim, awnings, siding, storage tanks, boats, missiles, truck and trailer assemblies.
Copper	8.79	Water pipes, electrical circuit boards, electrical wire, roofing.
Brass	8.48	Jewelry, water valves, boats, fittings, hardware, electrical sockets, bullet casings, ornaments.
Bronze	7.4 – 8.9	Pipe fitting, statues, coins, and bearings.

Plastics

Material	**Density (g/cm^3)**	**Uses**

Acrylonitrile-Butadiene-Styrene (ABS)	1.0	Kitchenware, food processors, mixers, camera cases, appliances and tool housings, instrument panels, luggage, sporting goods, safety helmets, telephones, battery cases.
Polyethylene Terephthalate (PET)	1.39	Soft drink and water bottles, salad dressing and peanut butter containers, salad domes, surf boards.
Cellulose Acetate (CA)	1.3	Photo films, magnetic recording films, handles and knobs, sheet packaging for products, brushes, combs, textiles.
Polyamide (PA) and Nylon	1.15	Bearings, gears, casings for power tools, packaging for foods such as bacon and cheese. Textiles, fishing lines, carpet, rollers and bearings.
Polycarbonate (PC)	1.2	Electrical components (due to heat resistance and insulation properties) glazing, eyewear lenses, CDs, bullet-proof glass, theft-proof packaging.
High Density Polyethylene (HDPE)	0.95	Food and liquid containers, squeeze-type bottles, toys, garbage cans, milk crates, buckets, bowls, rigid agricultural pipes, flower pots, toys
Polypropylene (PP)	0.90	Medical equipment, syringes, containers with hinges, automobile ducts and trim, outdoor carpet, string, rope, nets, crates, and kitchenware, chip bags, straws, microwave dishes, ice scrapers, lawn mower wheels.
Polymethyl Methacrylate Acrylic (PMMA)	1.2	Models, automobile taillights, aircraft canopies, windows, furniture, illuminated signs.
Polystyrene (PS)	1.05	Model kits, blister packaging, lenses, CD cases, disposable plates, cups, utensils, sound and heat insulation, marine applications, low cost brittle toys, envelope windows, license plate holders.
Polyvinyl Chloride (PVC)	1.16 – 1.45	Film for meat packaging, pipes, gutters, bottles, soles of shoes, cosmetic containers, electrical conduit, blister packs, floor mats, hoses.
Styrene-Butadiene (SBR) - Rubber	1.52	Sealants, adhesives, vibration mounting materials, footwear, tires, hoses, and latex paint.
Polyester Resins	1.4	Gears, pump impellers, lawn sprinklers, boat and car bumpers, shell chairs, and containers.

Hardwoods

Material	Density (g/cm^3)	Uses
Ash	0.65 – 0.85	Tool handles, ladders, laminating, and sports equipment.
Balsa	0.16	Commercial model making especially aero modeling industry, sandwich construction in aircraft and boats.
Basswood	0.3 – 0.6	Commercial model making, carving and pattern making.
Beech	0.7 – 0.9	Chairs, toys, tool handles, turnings, steam bending
Cherry		Solid wood for furniture.
Elm, American	0.57	General furniture construction, garden furniture, and turned items.
Maple		Solid wood for furniture.
Oak	0.6 – 0.9	General furniture construction and veneer plywood. Boat building, garden furniture, and posts.
Poplar	0.35 – 0.5	General furniture construction and model construction.
Walnut, American Black	0.63	Veneer and solid wood for furniture, handles such as gun stocks.
Mahogany	0.5 -0.85	Solid wood for furniture.

Softwoods

Material	Density (g/cm^3)	Uses
Cedar, western red	0.38	Outdoor furniture and siding, posts.
Fir/Hemlock	0.50	Residential construction.

Pine	0.35 – 0.50	Finish construction work, trim, furniture.

Note: Material densities can vary widely. These densities are provided for reference only.

Material uses charts can be found in Chapter Eleven of the text listed below.

Hutchinson, J. & Karsnitz, J.R. (1997). *Design and problem solving in technology*. Glencoe McGraw-Hill.

Activity 5.3 Density and Uses of Common Metals and Plastics

Ferrous Metals

Material	Density (g/cm^3)	Uses
Cast Iron	7.21	Heavy equipment, machine frames.
Carbon Steel 1000,4000,5000 series	7.85	Fasteners like rivets, nails, wire, chains and machine parts. Medium carbon steel is used for gears, shafts, tool shanks. High carbon steel is used for screwdrivers, cutting tools, blades, drills, springs, bearings and knives.
Stainless Steel	7.9	Sinks, cutlery, kitchen utensils, surgical tools.

Nonferrous Metals

Material	Density (g/cm^3)	Uses
Aluminum	2.6	Used in chemical and food processing, fasteners, structural members, aircraft structural components, hardware, car and truck wheels, decorative trim, awnings, siding, storage tanks, boats, missiles, truck and trailer assemblies.
Copper	8.9	Water pipes, electrical circuit boards, electrical wire, roofing.
Brass	8.4 – 8.85	Jewelry, water valves, boats, fittings, hardware, electrical sockets, bullet casings, ornaments.
Bronze	8.8	Pipe fitting, statues, coins, and bearings.

Plastics

Material	Density (g/cm^3)	Uses

Acrylonitrile-Butadiene-Styrene (ABS)	0.99 – 1.10	Kitchenware, food processors, mixers, camera cases, appliances and tool housings, instrument panels, luggage, sporting goods, safety helmets, telephones, battery cases.
Polyethylene Terephthalate (PET)	1.38 – 1.39	Soft drink and water bottles, salad dressing and peanut butter containers, salad domes, surf boards.
Cellulose Acetate (CA)	1.3	Photo films, magnetic recording films, handles and knobs, sheet packaging for products, brushes, combs, textiles.
Polyamide (PA) and Nylon	1.15	Bearings, gears, casings for power tools, packaging for foods such as bacon and cheese. Textiles, fishing lines, carpet, rollers and bearings.
Polycarbonate (PC)	1.2	Electrical components (due to heat resistance and insulation properties) glazing, eyewear lenses, CDs, bullet-proof glass, theft-proof packaging.
High Density Polyethylene (HDPE)	0.95 – 0.97	Food and liquid containers, squeeze-type bottles, toys, garbage cans, milk crates, buckets, bowls, rigid agricultural pipes, flower pots, toys
Polypropylene (PP)	0.90 – 0.91	Medical equipment, syringes, containers with hinges, automobile ducts and trim, outdoor carpet, string, rope, nets, crates, and kitchenware, chip bags, straws, microwave dishes, ice scrapers, lawn mower wheels.
Polymethyl Methacrylate Acrylic (PMMA)	1.2	Models, automobile taillights, aircraft canopies, windows, furniture, illuminated signs.
Polystyrene (PS)	1.04 – 1.09	Model kits, blister packaging, lenses, CD cases, disposable plates, cups, utensils, sound and heat insulation, marine applications, low cost brittle toys, envelope windows, license plate holders.
Polyvinyl Chloride (PVC)	1.16 – 1.45	Film for meat packaging, pipes, gutters, bottles, soles of shoes, cosmetic containers, electrical conduit, blister packs, floor mats, hoses.
Styrene-Butadiene - Rubber	1.52	Sealants, adhesives, vibration mounting materials, footwear, tires, hoses, and latex paint.
Polyester Resins	1.4	Gears, pump impellers, lawn sprinklers, boat and car bumpers, shell chairs, and containers.
Urea-	1.5 –	Appliance parts such as pot handles and knobs.

Formaldehyde	2.0	

- Material uses charts can be found in Chapter Eleven of the text listed below.
- Hutchinson, J. & Karsnitz, J.R. (1997). *Design and problem solving in technology*. Glencoe McGraw-Hill.

PLTW ENGINEERING

Activity 5.4

Calculating Properties of Solids

Introduction

Have you ever stopped to think why it is that you are able to float in water? The reason has to do with the concept of buoyancy, described by the Archimedes principle. The **volume** of water that your body displaces has weight. The weight of the displaced water pushes upward on you, while the weight of your body pushes down. If the weight of the displaced water pushing upward is less than your weight, then you will sink into the water to a point where equilibrium has been achieved. Equilibrium is reached when the weight of your body is equal to the weight of the volume of water that your body is displacing. At that point you are floating.

Another way to explain this is to look at **density**. If your average weight density, or the average amount of weight per unit volume of your body, is less than the weight density of the water, then you will float. The word *average* is used because skin, bone, hair, and muscle tissue all have different weight densities. If you were to drop a coin in the water, you would notice that it sinks. The weight density of metal is higher than the weight density of water; therefore, the volume of water that is displaced by the coin cannot weigh as much as the coin itself.

Engineers design vessels to travel on and under the surface of the water. Typically, these vessels are comprised mostly of metal. How is it that these vessels do not sink straight to the bottom of the sea floor? The answer again deals with weight, average density, and volume. If you were to fill a glass with water and place it in a tub full of water, the glass would sink. Like metal, glass has a weight density that is greater than water. If you were to place the same glass in a tub full of water, but with no liquid in the glass, it would float. In this case, the majority of the volume of the space that is taken up by the glass is the air on the inside of the glass, which is significantly less dense than water. Therefore, the average weight density of the glass/air is less than the weight density of water. This is the reason why ships are able to float. The majority of the volume enclosed by a ship is air. This example is only one engineering application of physics and the mathematics associated with the properties of solids.

Resources

Properties of Geometric Solids

Procedure

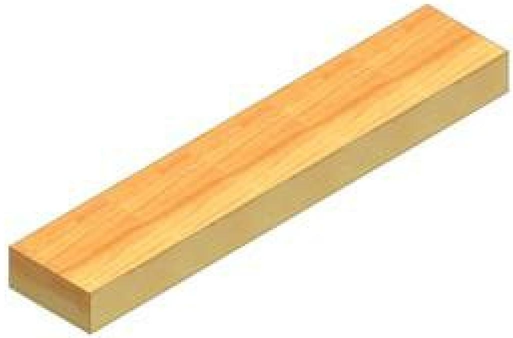
In this activity you will learn how to hand calculate the volume, weight, and **surface area** of common solids. You will then apply your knowledge by calculating these properties for each of your puzzle piece solutions.

For each item, show your work, specify units, and record your answer with a degree of precision appropriate for the problem context, unless noted otherwise for intermediate calculations.

1. A cast iron **cylinder** serves as a counterbalance that is used in a window manufacturer's double-hung window design. The cylinder has a height of 5.25 inches and a **diameter** of 1.75 inches. The weight density of cast iron is 0.259 lb/in.^{3}. Use this information to answer the following questions.

   - What is the volume of the cylinder? Precision = 0.00
   - What is the surface area of the cylinder? Precision = 0.00
   - What is the weight of the cylinder? Precision = 0.00
   - If one quart of cleaning solution will clean 7,200 square inches of surface, how many quarts will be required to clean 1,500 cylinders?
   - What will the total cost be to ship 200 of the cylinders if the shipping rate is $4.25 per pound?
   - If a cylinder for a larger window is cut from the same stock (a rod of the same diameter) and must have a weight of 4.25 lb in order for the window to operate properly, how long must the counterweight cylinder be?
   - If the original window frame is redesigned such that the space provided for the counterweight requires that the height of the counterweight be reduced to 4.5 in. with the original weight, what is the diameter of the new counterweight design?

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 in. x 17.0 in. x 1.5 in., respectively. The board is made from southern yellow pine, which has an air dry weight density of .021 lb/in.^{3}.



- What is the volume of the wood board? Precision = 0.00
- What is the surface area of the wood board? Precision = 0.00
- What is the weight of the wood board? Precision = 0.00
- 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?
- 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?
- If a 2 x 6 (which means the actual dimensions of the board are 1.5 in. x 5.5 in.) milled from the same wood (and therefore has the same density) weighs 3.2 lb, how long is the board?

3. Record the properties of your manufactured box (from Project 3.9 Manufacture a Box).

   - Create a table similar to the table shown. Record your box **mass**, surface area and volume measurements as Sample 1 in the first row (but do not include density). Note that the volume is the solid volume of the box material (and does not include the empty interior space). The surface area includes all surfaces (both interior and exterior). Be sure to use SI units, and add appropriate units in the Density header.

Sample number	Mass (g)	Surface area (cm^2)	Volume (cm^3)	Density
1				
2				
3				
4				

5				

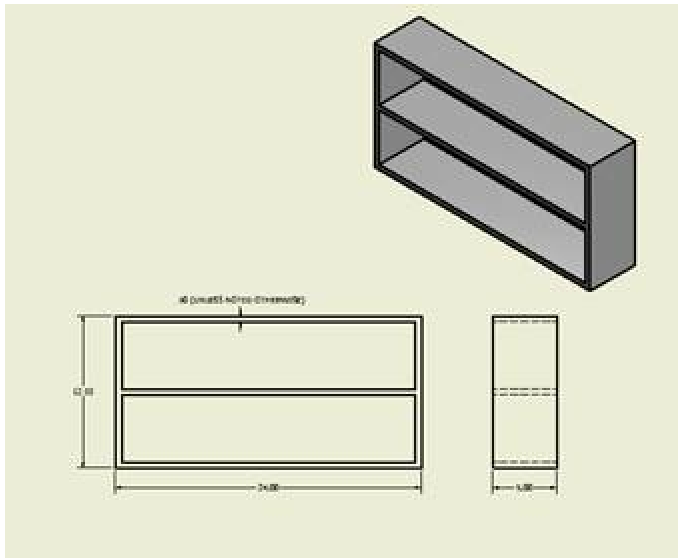
Note that you can measure your box with a metric ruler or use a solid modeling tool to determine the properties.

Reflection Question: If you used a solid modeling tool to determine your box properties, is the box material density displayed in the software accurate for your box?

> Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

- Add the properties of four other student's boxes to the table. Be sure to indicate appropriate units. Calculate the density of material for each box and record the value in the table.
- Create a **scatterplot** in Excel displaying mass and volume as the variables.
    - Which variable (mass or volume) should you use as the independent variable (which will be plotted on the horizontal axis) in order to best represent the density? Why?
    - Since a zero volume would result in zero mass, to what value should you set the y-intercept?
    - How can you use the trendline of the scatterplot to provide information about the density of the box material? Explain.
- Find a trendline for your mass/volume data. Print a copy of the scatterplot with the trendline and mathematical model equation displayed.
    - Rewrite the equation of the trendline in function notation such that M(v) = mass and v = volume.
    - What is the slope of the trendline (include units)?
    - How does this compare to your calculated value of density above? Explain any difference.
- Convert the (mass) density indicated by the equation of your trendline to (weight) density in pounds per cubic inch. Show your work including all conversion factors.
- Convert the mass of your box to weight in pounds. Show your work.
- Convert the mass of your box to weight in ounces. Note that 1 lb = 16 oz. Show your work.

- If WeShipIt offers a flat rate of \$7.95 to ship a parcel up to ten pounds (as long as it fits within a 22 cm x 22 cm x 22 cm box), how many of your manufactured boxes can be shipped in this box for \$7.95? Be sure to check both the size and the weight constraints. Ignore the weight of the shipping box.
- If the same wood is used to build a CD storage unit according to the drawing below, what is the weight of the shelving unit? All dimensions in the drawing are in inches.



4. A jar made of 3/16 inch thick glass has an inside **radius** of 3.00 inches and total height of 6.00 inches (including the bottom thickness of glass). The glass has a density of 165 lb/ft^3. The jar is placed in water with a density of 62.5 lb/ft^3.

- Assume the jar sits upright in the water without tipping over. How far will the empty jar sink into the water?
    - What is the volume of the glass shell of the jar? Precision 0.00
    - What is the weight of the jar? Precision 0.00

- What is the weight of water the empty jar will displace? Precision 0.00
- What is the volume of water the empty jar will displace? Precision 0.00
- How far will the empty jar sink?

Extend Your Learning

5. If the jar is half filled (inside height) with honey, which has a density 1.4 times the density of water, how far will the jar sink into the water?

    - What is the volume of the honey? Precision 0.00
    - What is the weight of the honey? Precision 0.00
    - How far will the jar halfway filled with honey sink?

6. What would happen if the jar was three-quarters of the way filled with honey?

Conclusion

1. What is the difference between area and volume?
2. What is density?
3. What is a “physical” property? Give examples of physical properties.

Properties of Geometric Solids

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 5.5a

CAD Model Features Part 1

Introduction

To use CAD effectively as a design tool, the designer must have the skills necessary to create, edit, and manipulate a 3D model of a part to create a realistic representation of an imagined object. In this activity you will build on the CAD skills that you learned in Activity 5.2b Introduction to CAD Skills. You will learn about and use additional tools and features available in most CAD programs and apply your new CAD skills to the creation of more complex parts.

As you work through the exercises in this activity, pay particular attention to the environment in which you are working. Several CAD tools can be used as sketch tools or features tools, and it is important to understand the difference. For instance, sketch components (such as points or shapes) can be patterned within a sketch. But pattern tools are also available outside of the sketch environment to create patterns of features (such as holes or protrusions).

Equipment

- Computer with 3D CAD modeling software

Resources

Creating a Custom Drawing Sheet

Procedure

The exercises contained in this activity require the creation of new CAD files in which you will reproduce sketches and forms represented in the displayed images. You have already created an Automoblox project folder and a Practice project folder (per Activity 5.2b).

As you complete each exercise in this activity, save the associated CAD file in the appropriate folder. It is important that you save all Automoblox parts to a single project folder.

Revolve

Sketch Tools – These are suggested tools for this activity:

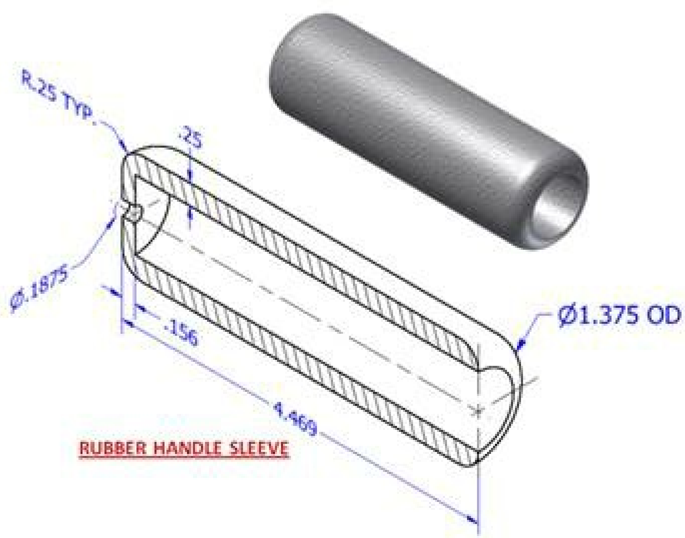
- **Construction Line**

- Basic Geometric Constraints

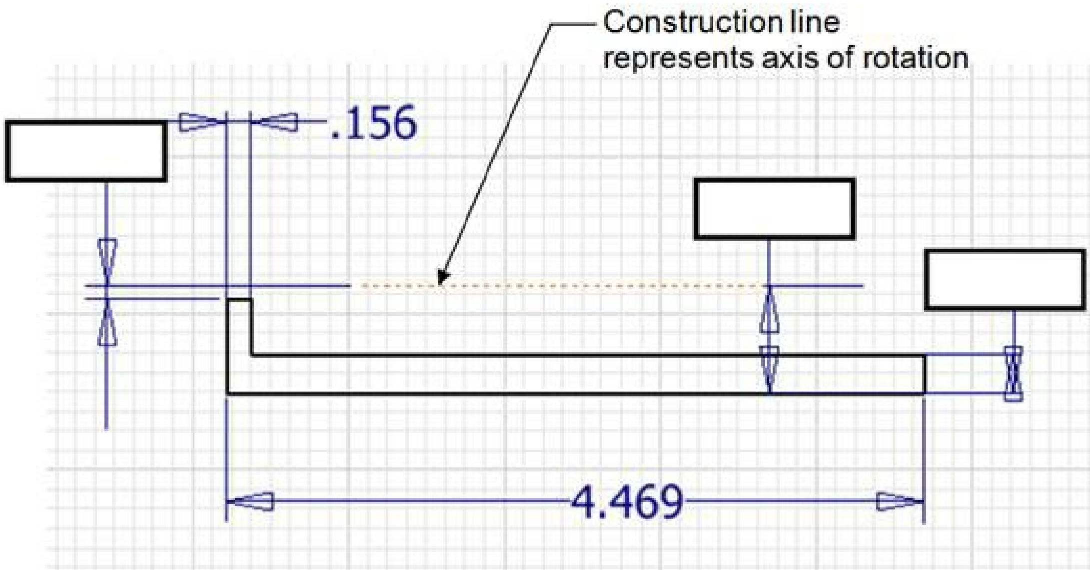
**Feature Tools – ** These are suggested tools for this activity:

- **Revolve**
- **Fillet**
- **Work Axis**
- **Work Plane**

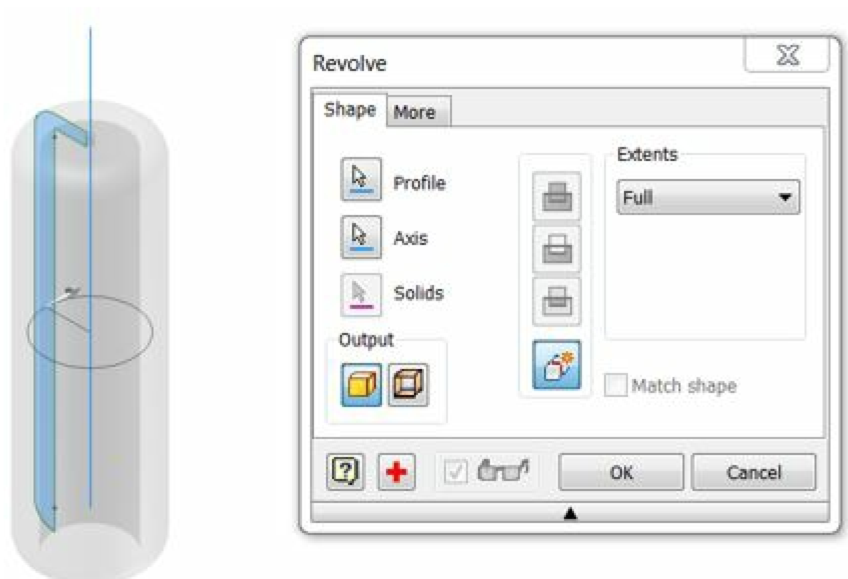
1. Use the **Revolve** function to create the Rubber Handle Sleeve part for a button maker.



   - Create a sketch according to the dimensioned drawing above. First, use the sketch below to determine the missing dimensions and write the appropriate values in the boxes, and then create the appropriate geometry. Be sure to include a line to represent the axis of revolution at the center of the part. Note that you may toggle between construction lines and sketch lines using the Construction switch in the Format panel of the Sketch tab.

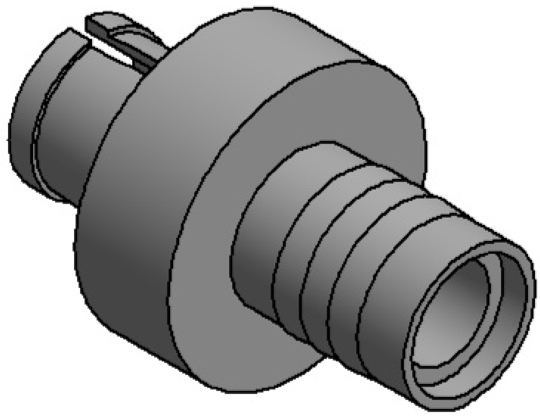


- Revolve the sketch a full 360 degrees.
- **Round** the outside edges. The fillets for this part can be applied as Placed Features once the Revolve is completed (see the dimensioned isometric for the fillet values).



- Save the file as RubberHandleSleeve*YourInitials*.ipt in your Practice project folder.

2. Create a 3D solid model of an axle for the Automoblox vehicle using the **Revolve** tool. Use your measurements or the Automoblox dimensioned drawings provided in Activity 5.2b. Then model the cut(s) in the end of the axle. [If you want to jump ahead, you could create just one cut and then use the **Circular Pattern** tool or **Mirror** tool to create the second cut.] Save the file as Axle*YourInitials*.ipt to your Automoblox project folder.



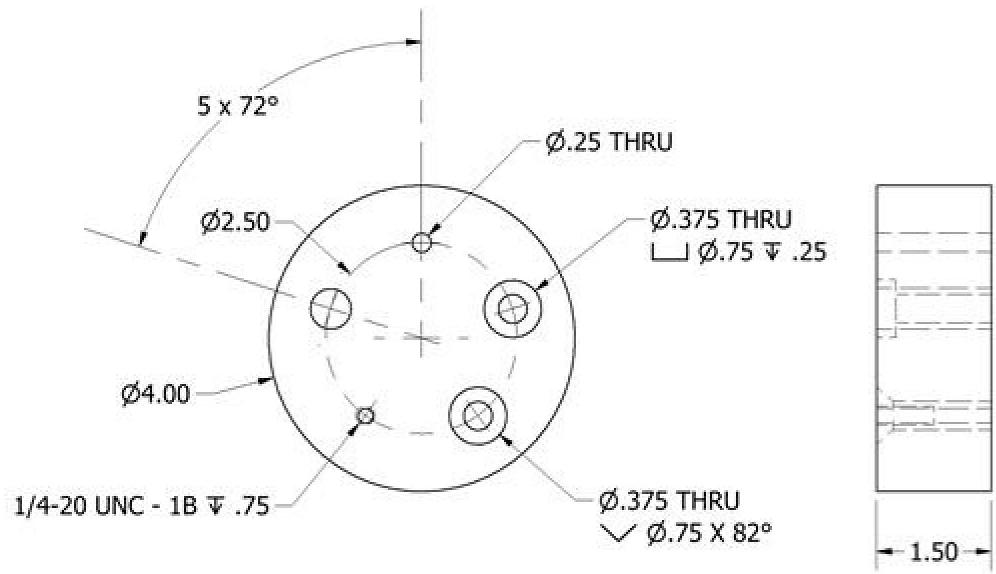
Holes

Sketch Tools **–** These are suggested tools for this activity:

- **Circle**
- Point
- Circular Pattern
- Browser Editing
- Share Sketch

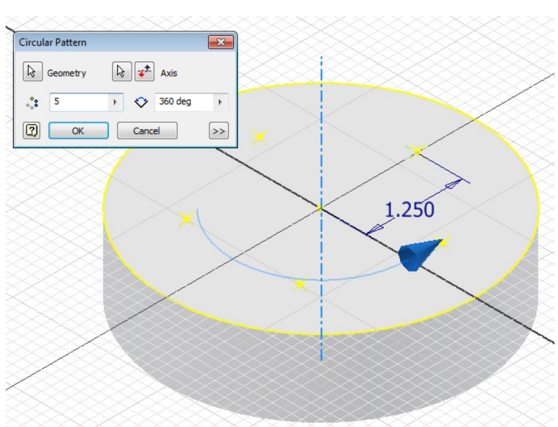
Feature Tools **–** These are suggested tools for this activity:

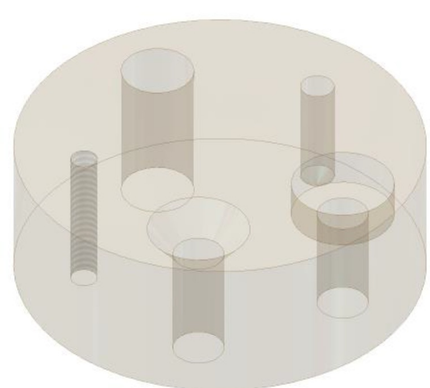
- Extrude (Add/Join)
- Hole Tool (5 styles)



3. Create a model of the circular plate with holes as shown above.

  - Create a new *Standard.ipt* file. Sketch a circle and **Extrude** the profile using the appropriate dimensions.
  - The **Hole** function requires a hole center for each instance. Place the first hole center by placing a new sketch on the surface of the disc as shown in the image above. Then place one point to represent a single hole center. Note that you many want to change the point switch (in the Format panel) to the center point before placing the point. A sketch point will appear as a small dot in the sketch; a center point (which is automatically selected for hole center points) will appear as a dashed cross.





  - Select the **Circular Pattern** tool from the sketch ribbon bar. Select the point (geometry) that you just placed, then select the Axis button and select the origin of the sketch as your rotation axis, and enter the number of hole centers needed in the occurrence window. Note that you used the circular pattern tool within a sketch. In a later exercise, you will create a circular pattern of a 3D feature outside of a sketch.

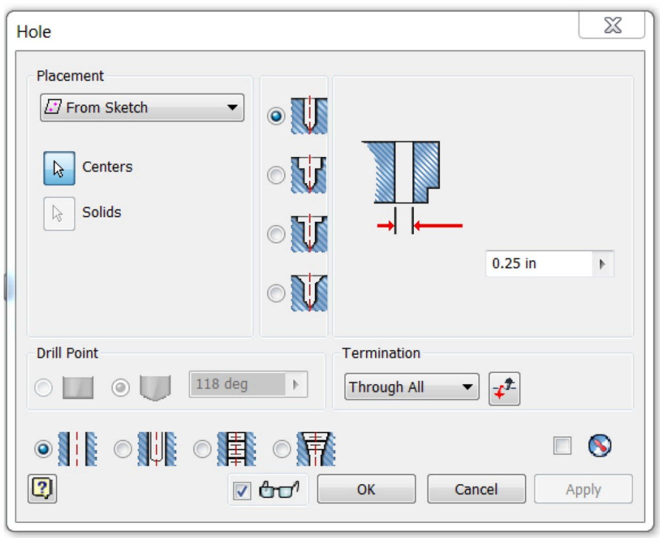
- Select the **Hole** tool from the Modify panel. (If you used center points to represent the hole centers, all points in a sketch will be auto-selected by the software when the **Hole** command is initiated. You will have to hold down the Shift key to deselect the hole centers that you do not want—be sure the Centers button is depressed). Create the first hole. Note that Function windows that are associated with creating a Through hole, Counterbore hole, Countersink hole, Tapped hole, and Clearance hole follow these instructions and may help if you are unsure about feature choices.

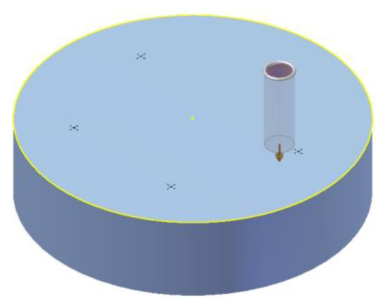
- Once the first hole has been placed, your sketch with the 5 points will have been consumed by the feature. To proceed, you must go to the Browser to “share” the sketch. Click the plus sign to the left of Hole 1 in the browser to expand the model tree. Once you see Sketch 2 in grey, right-click on it and select Share Sketch.

- To create the remaining holes, initiate the **Hole** function, select the appropriate hole center, and enter the information necessary to identify the type of hole feature that is needed. The information for each hole is found on pages 6–8.

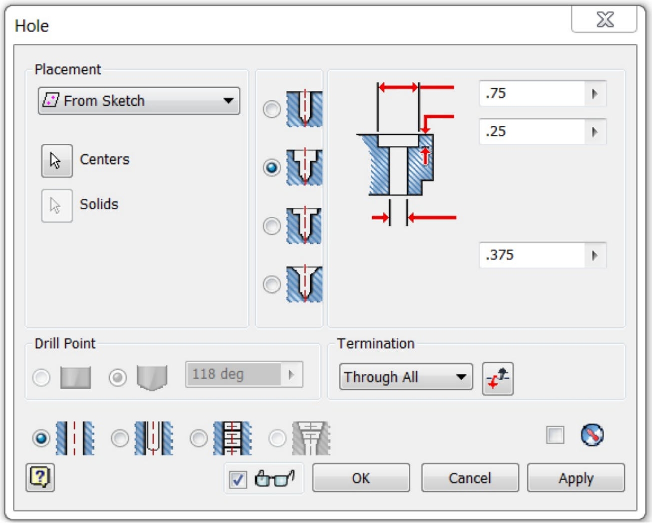
- Save the file *HolePracticeYour Initials.ipt* in your Practice project folder.

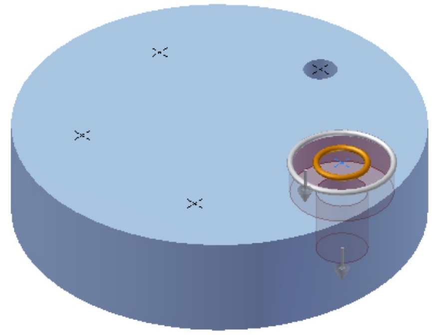
Through (THRU) Hole



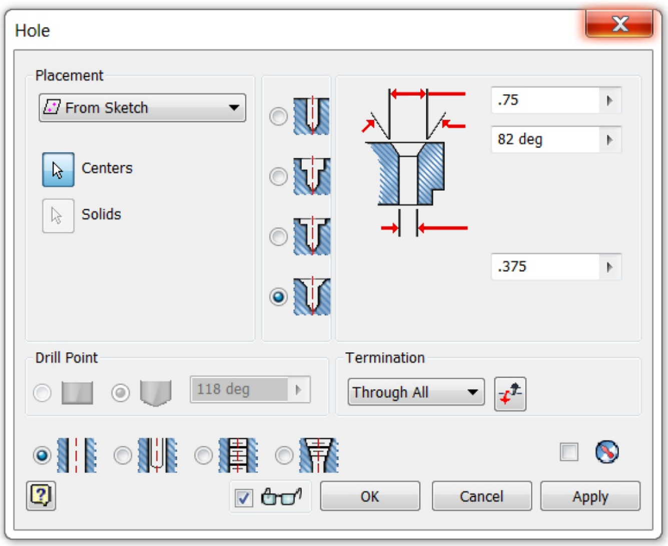


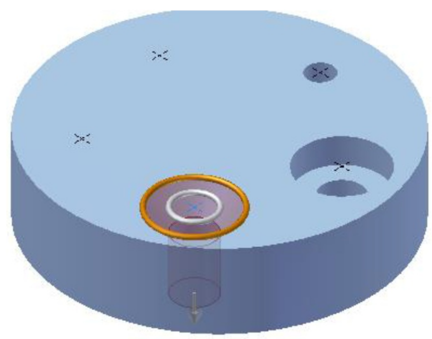
Counterbore



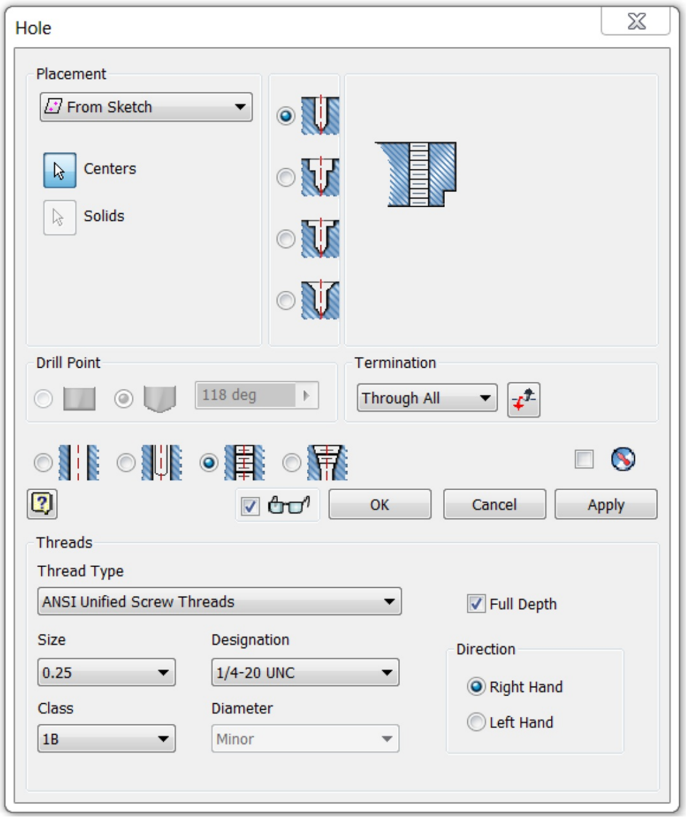


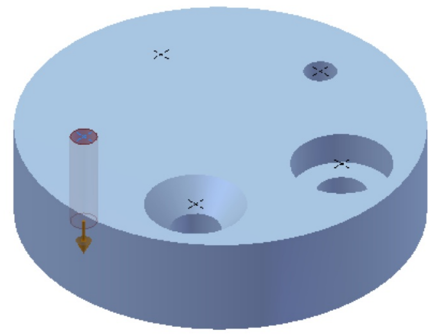
Countersink



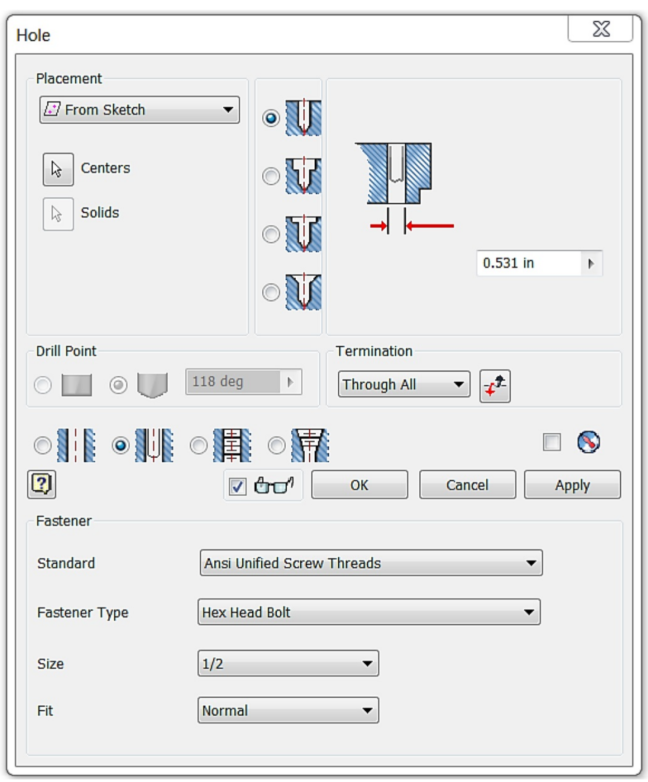


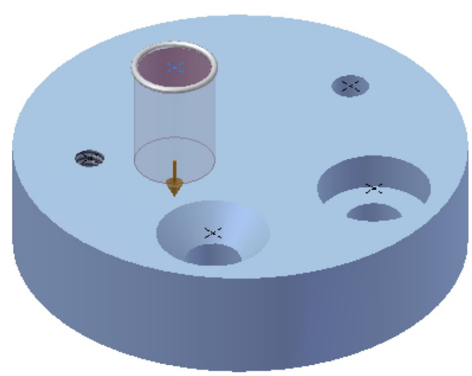
Tapped Hole





Clearance Hole





Circular Pattern (Feature)

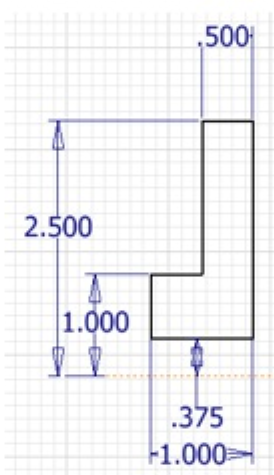
Sketch Tools – These are suggested tools for this activity:

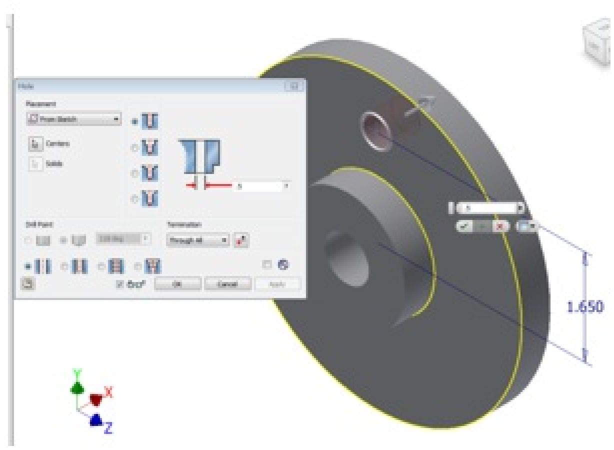
- **Construction Line**
- **Point**
- **Constraint** – Vertical (point to point alignment)
- **Share Sketch**
- **Trim**

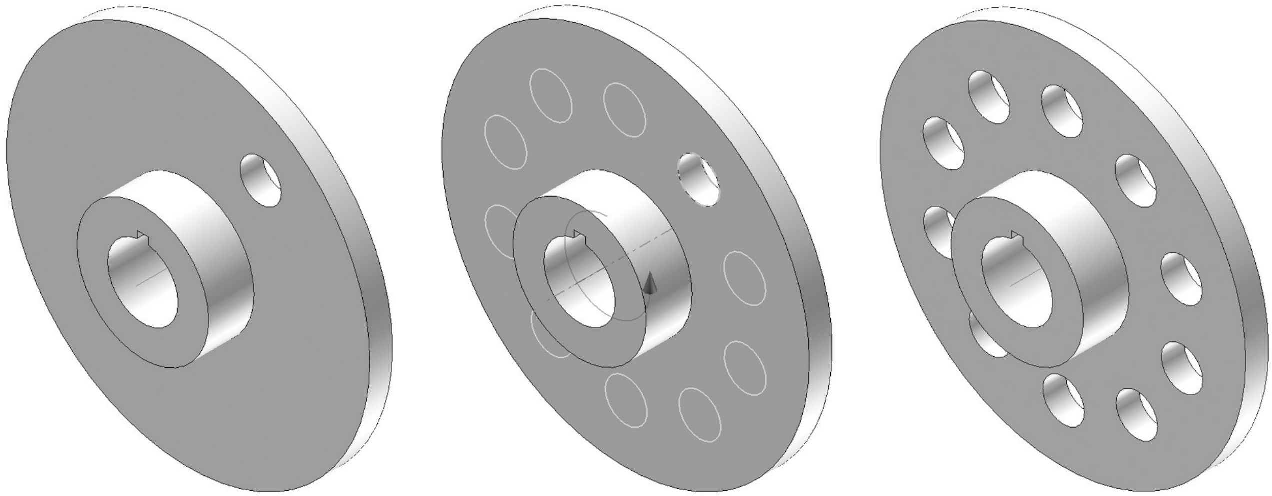
<u>Feature Tools</u> – These are suggested tools for this activity:

- **Revolve**
- **Hole**
- **Circular Pattern**
- **Extrusion** (Mid-plane/symmetric)

4. Model the following flange plate part.



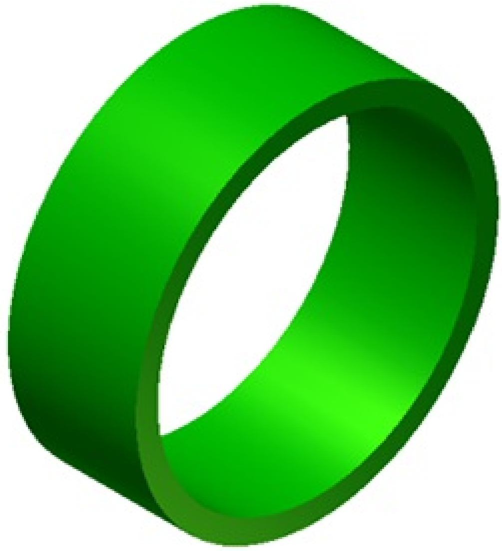




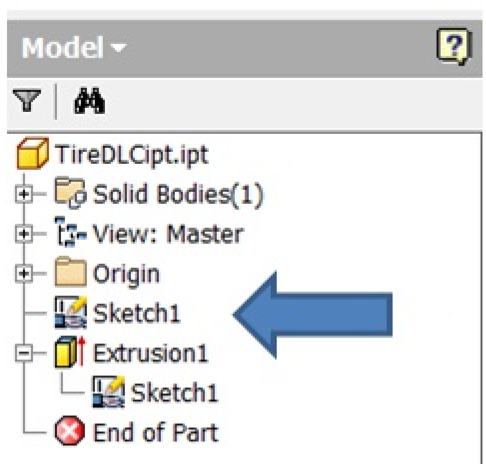
- Create a sketch based on the image above. Finish the sketch and use the Revolve command to create the part.
- Apply a sketch and place a **Point** that is vertically aligned with the sketch origin and located the appropriate distance from the part center point. Use the **Hole** Feature to place a Ø0.5 THRU hole located on that point.
- The pattern function allows the user to make multiple copies of an existing ***feature***, such as a hole (as opposed to a sketch component as you discovered in the previous exercise in this activity), in one of three ways. A circular pattern is often used to array a hole around a center axis. An edge on an existing feature can also serve as the center axis. Use the **Circular Pattern** function to pattern the hole on the flange plate such that 10 holes (including the first hole) are modeled around the part centerline.
- Save the file to your Practice project folder as *CircularPattern.ipt*.

5. Create a 3D solid model of an Automoblox tire. Use your measurements or the dimensioned pictorials. The dimensions shown in the images below are for reference only.

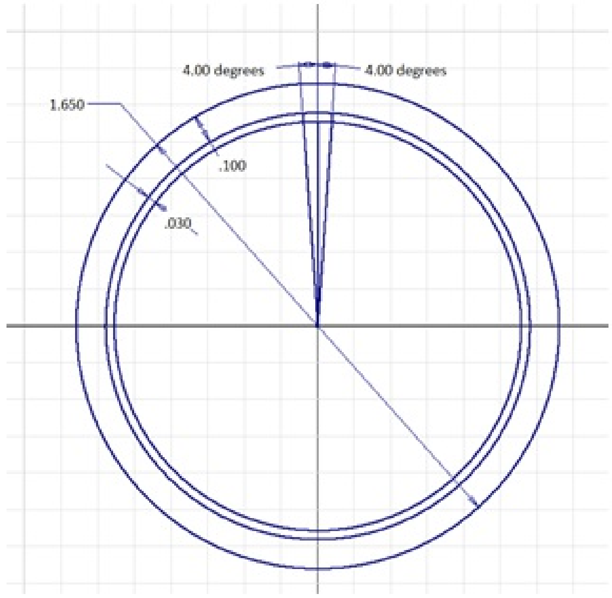
   - Sketch concentric circles and use a **Midplane** (or Symmetric) extrusion to create the rubber ring. The part does not need to be created to exact dimensions, as it is a visual representation used to develop skills sets.

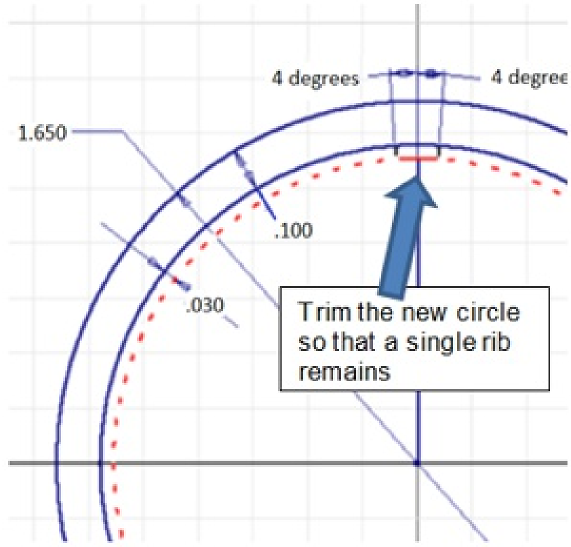


- Share the sketch by right-clicking on the sketch in the Project Browser (under Extrusion1 parent) and choosing Share Sketch. An unconsumed copy of the Sketch will appear in the browser.

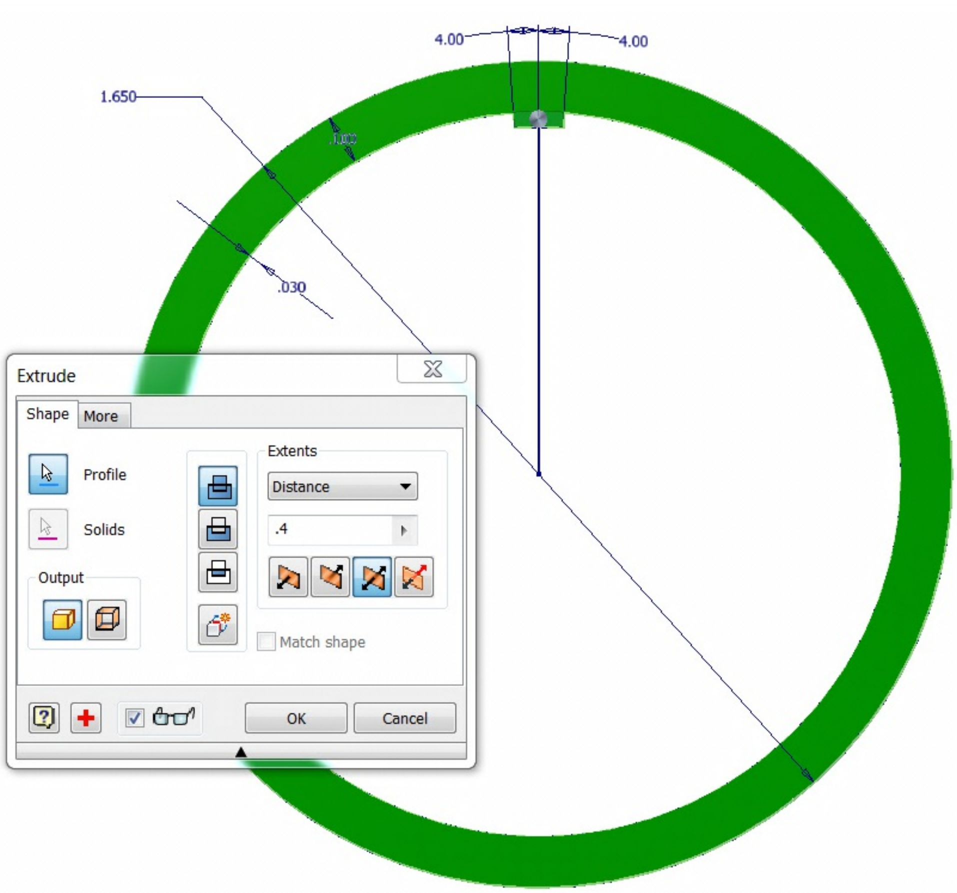


- Edit the sketch to create the geometry for one internal rib using a concentric circle, lines, and the **Trim** tool.

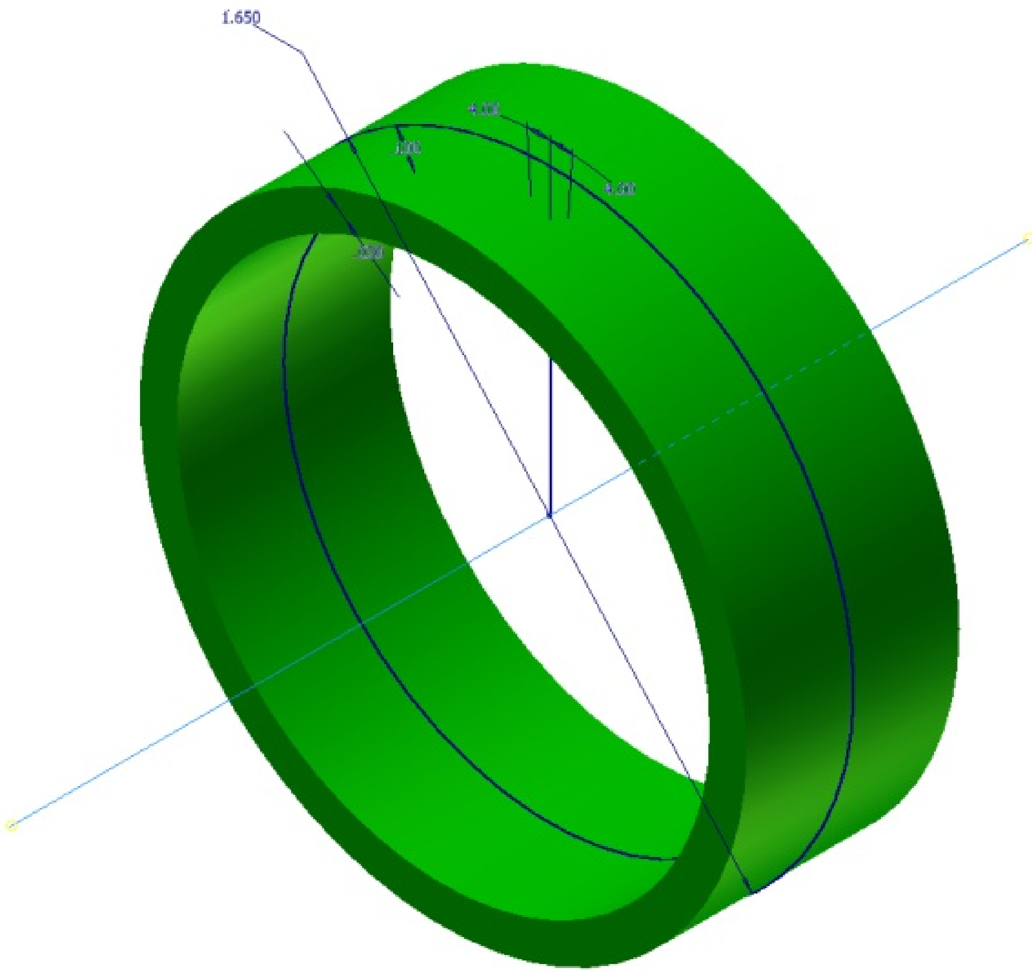




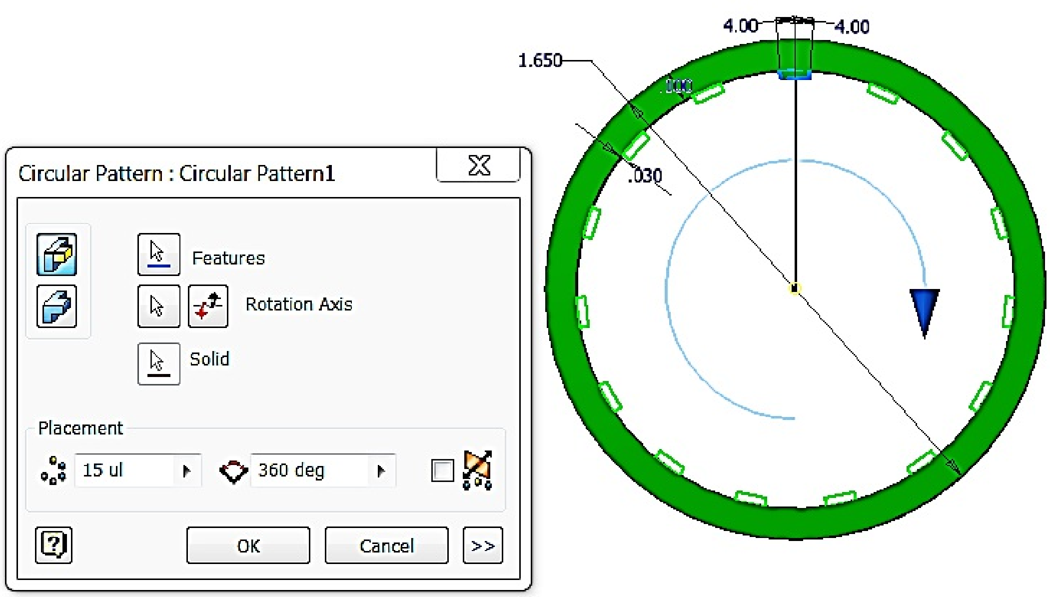
- Use another **Midplane** (or Symmetric) extrusion to create a single rib.



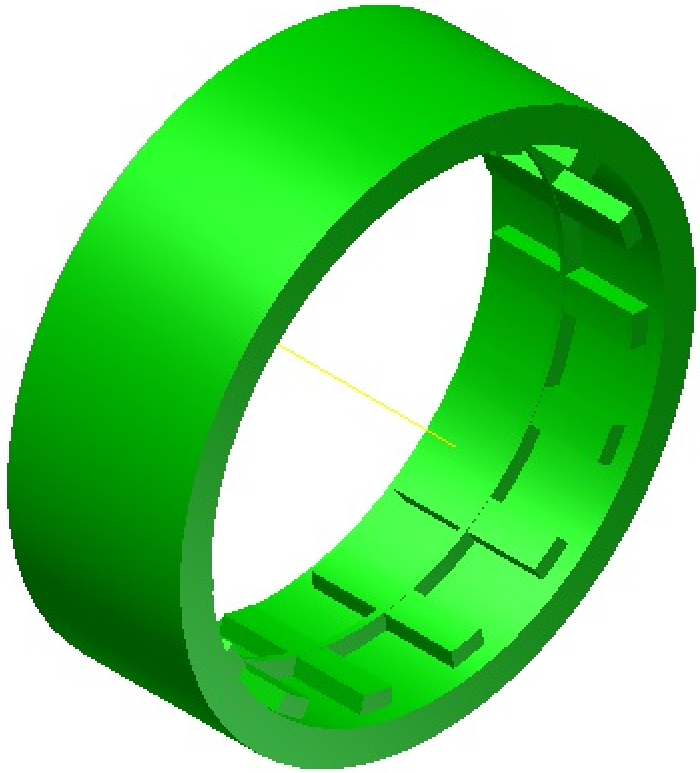
- Create a **Work Axis** using the Through Center of Circular or Elliptical Edge. You must select the appropriate axis tool and then select one of the circular edges on your model. This work axis will act as the center of the circular pattern.



- Use the circular pattern tool to create the remaining ribs.



- Use the Shared Sketch again to create the thin extrusion that runs around the inside center of the tire.



- Save the part to your Automoblox project folder as Tire*YourInitials*.ipt.

Rectangular Pattern

Sketch Tools – These are suggested tools for this activity:

- **Rectangle**
- **Circle**

Feature Tools – These are suggested tools for this activity:

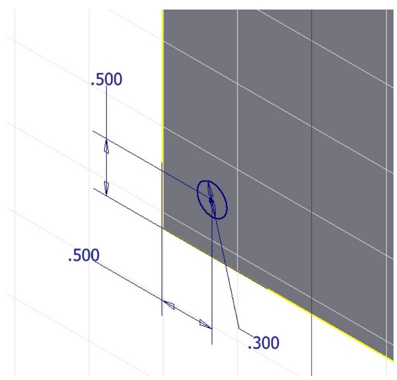
- **Extrude**
- **Rectangular Pattern**

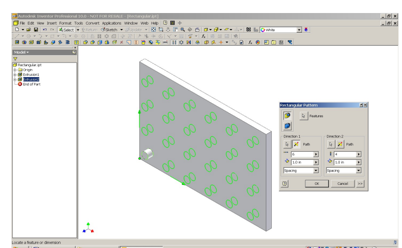
6. Create the rectangular plate with patterned pegs as shown in the images below. The **Rectangular Pattern** function allows the user to make copies of an existing feature in one direction or two directions simultaneously. Existing edges or the axes of the Cartesian coordinate grid must be selected to identify the desired direction(s).

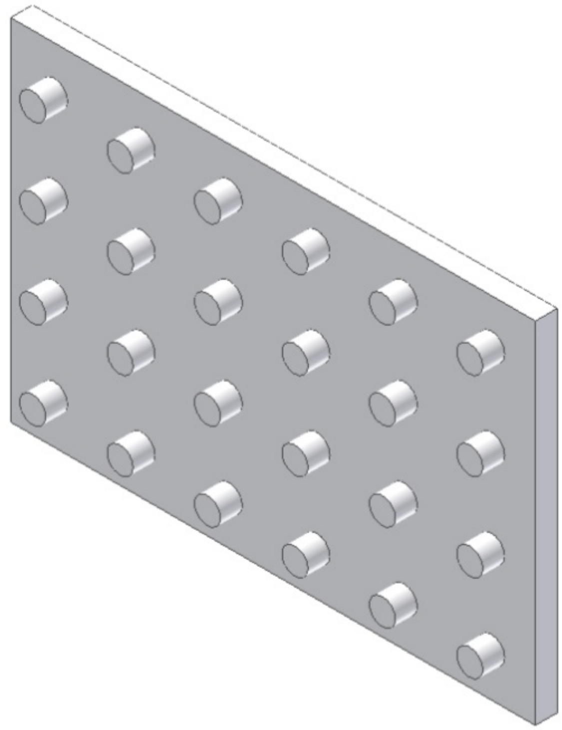
    -

        - Create a 6-in. wide x 4-in. high rectangle and extrude the rectangle to a depth of .5 in.

        - Use the following image of the sketch to draw the circle that will become the peg used in the pattern. Select the Rectangular Pattern tool from the Patterning section of the ribbon bar to replicate the existing cylindrical extrusion six times in the horizontal direction and four times in the vertical direction.

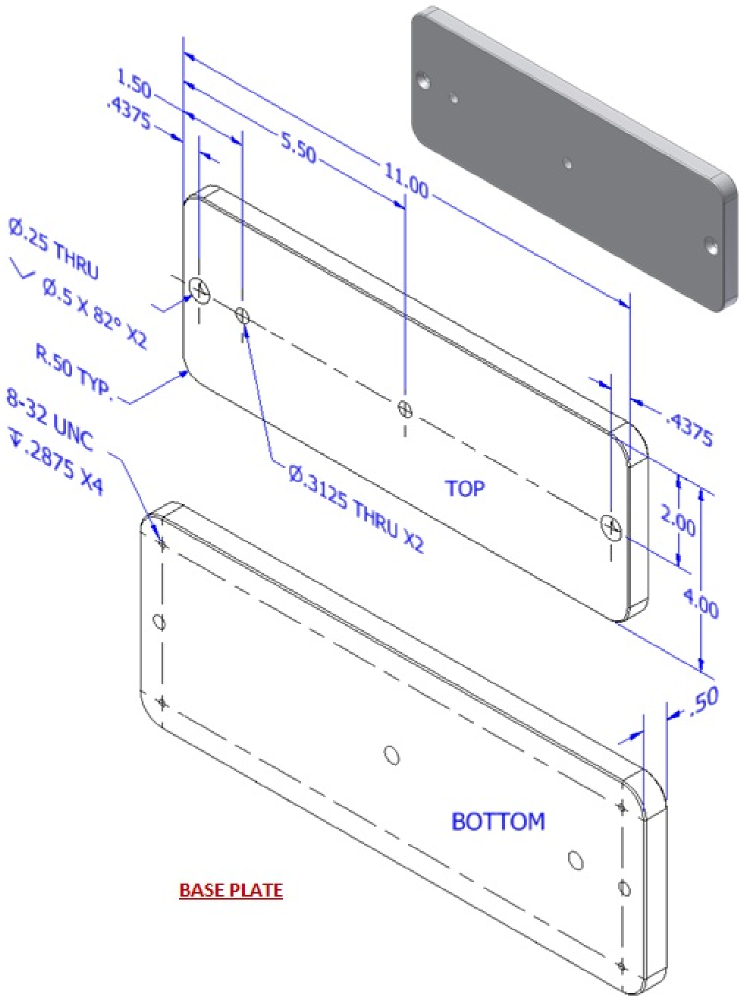






- Save the file in your Practice project folder as RectangularPattern.ipt.

7. Create the base plate solid model using the dimensioned pictorial. Create one of the holes in the bottom of the plate into which the rubber feet are screwed. Then use the **Rectangular Pattern** tool to pattern four holes on the bottom. Next create one of the through drilled (straight) holes and use another rectangular pattern to create the second drilled through hole. Then create the countersink holes. Use the **Chamfer** function to apply a 1/32” chamfer to all of the exterior edges of the Button Maker Base Plate. Save the file as BasePlate*YourInitials*.ipt to your Practice project folder.



BASE PLATE

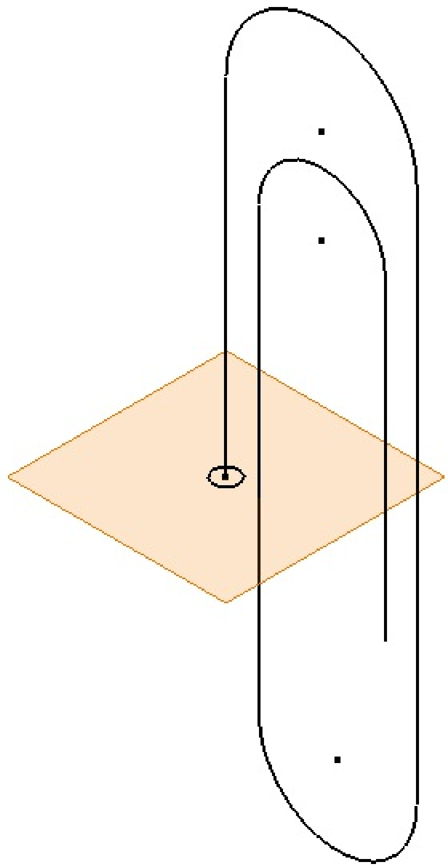
Sweep

Sketch Tools – These are suggested tools for this activity:

- **Line**
- **Circle**
- **Project Geometry**

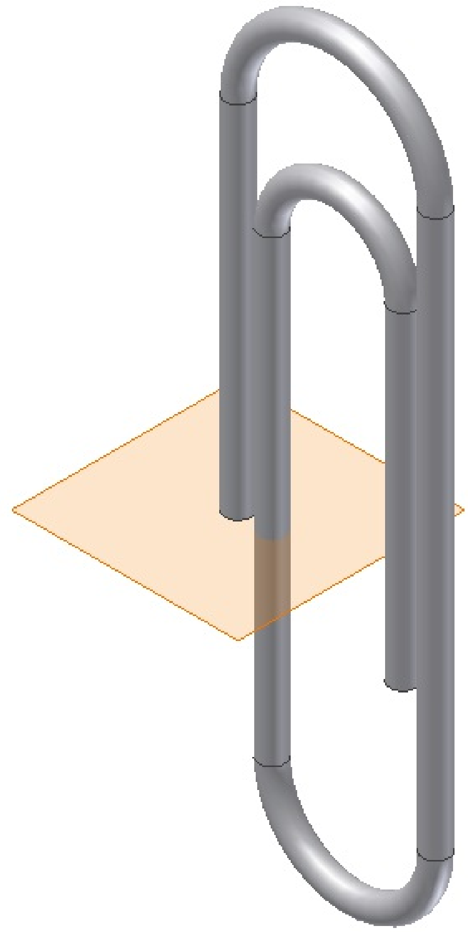
Feature Tools – These are suggested tools for this activity:

- **Workplane** on Point
- **Sweep**



8. Model a paper clip. The sweep function allows you to extrude a closed profile along a path. The path may be open or closed. The profile and the path must exist as two separate sketches.

   - Create a sketch to represent the path (the curving spiraling line along which the profile will be swept). The dimensions of the geometry are not important. Just try to approximate a real paperclip. Finish the sketch.
   - Select **Workplane** and pick the point that is at the end of the path. Click again to “set” the workplane.
   - Apply a sketch to the plane and then project the point at the end of the path to the sketch plane. Draw a circle centered on the projected point and finish the sketch.
   - Use the **Sweep** function to extrude the circle along the existing path to create the form of a paper clip. Note that two sketches are necessary to create a swept feature – a path and a profile.
   - Save the file to your Practice project folder as a *Paperclip.ipt*.



Conclusion

1. What 3D CAD functions could be used to create a wire coat hanger?

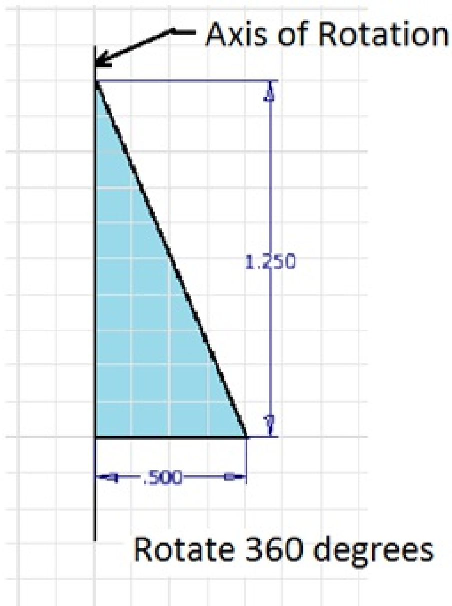
2. For each of the following, sketch a 2D shape and an axis of rotation that you could use to model each of the following solid forms using the Revolve function within 3D modeling software. Dimension each sketch and indicate the axis of rotation that you would use. You may use software to check your answers.

   - A solid **cylinder** with a **diameter** of 3.5 in. and a height of 7 in. Be sure to dimension the shape.

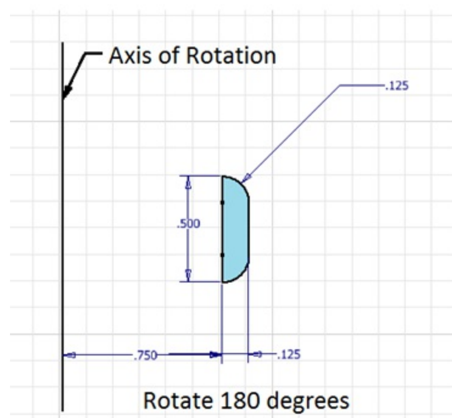
   - A solid sphere using the **Revolve** function. What rotation angle would you use?

3. For each of the following, describe the solid form that would result from rotating the given shape about the axis of rotation by the given rotation angle. Then sketch the resulting 3D shape and indicate important dimensions.

A


Axis of Rotation
1.250
.500
Rotate 360 degrees

B


Axis of Rotation
.125
.500
.750
.125
Rotate 180 degrees

Creating a Custom Drawing Sheet

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 5.5b

CAD Model Features Part 2

Introduction

Two dimensional sketches are nice, but parts have three-dimensional (3D) qualities that sketches can only imitate and communicate in an abstract manner. CAD 3D solid modeling programs can bridge the gap between 2D representations and 3D artifacts, by providing an electronic representation of an object that can be moved and rotated so that all aspects of the object can be viewed.

A sketch in a 3D Computer Aided Design (CAD) solid modeling program serves as the foundation for a three-dimensional feature. Some three-dimensional features require a sketch from which the 3D form is created. Other features do not require a sketch, but instead require a three-dimensional form.

In this activity you will learn about and use additional tools and features within a CAD program to enhance your knowledge of the capabilities of the program and improve your skill in producing 3D solid models.

Equipment

- Computer with 3D CAD modeling software

Procedure

To effectively use a CAD program as a design tool, a designer must know what model features are available and how they work. This activity will help you to understand and use the feature tools that are common to most CAD programs.

Mirror

Sketch Tools– These are suggested tools for this activity:

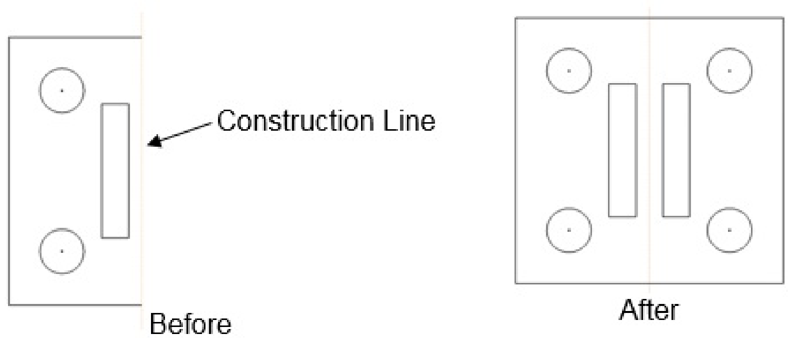
- **Line**
- **Rectangle**
- **Circle**
- Geometric Constraints

- Construction Line
- **Mirror**
- **Fillet**

Feature Tools– These are suggested tools for this activity:

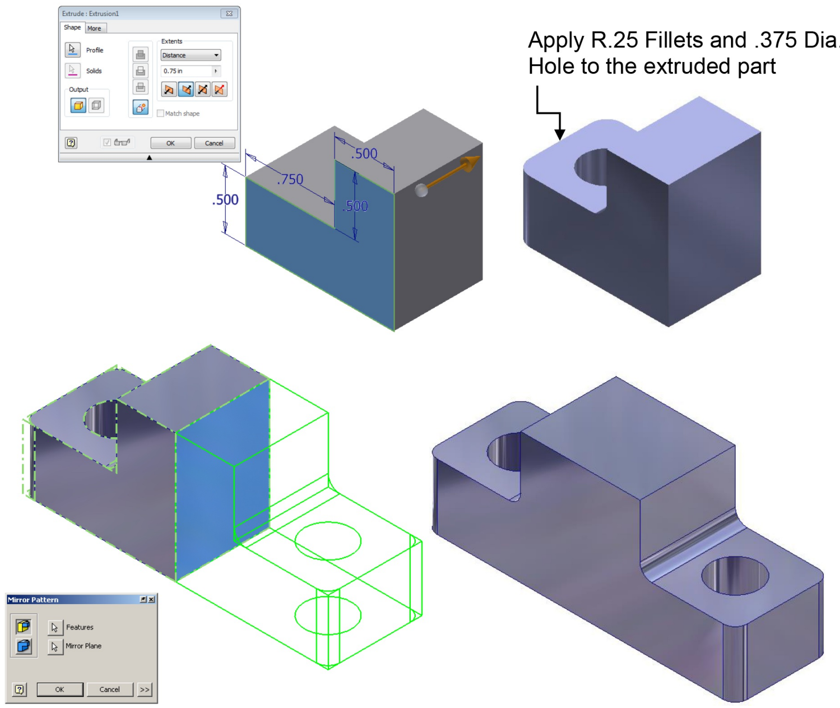
- **Extrude**
- **Rectangular Pattern**
- **Fillet**
- **Hole**
- **Mirror**

1. Create a sketch similar to that shown below. CAD programs allow the designer to mirror images across lines, which is a useful tool when designing parts that have high degrees of symmetry.



   - Create a new CAD file and use the line and circle sketch tools to create a figure similar to the one shown in the Before image. Exact dimensions are not important. A vertical construction line may be used as the mirror line. The top and bottom horizontal edges must terminate at the vertical mirror line.
   - Use the **Mirror** sketch tool to mirror the figure across the mirror line.
   - Save the file to your Practice project folder as Mirror*YourInitials*.ipt.

Mirror – Feature Application

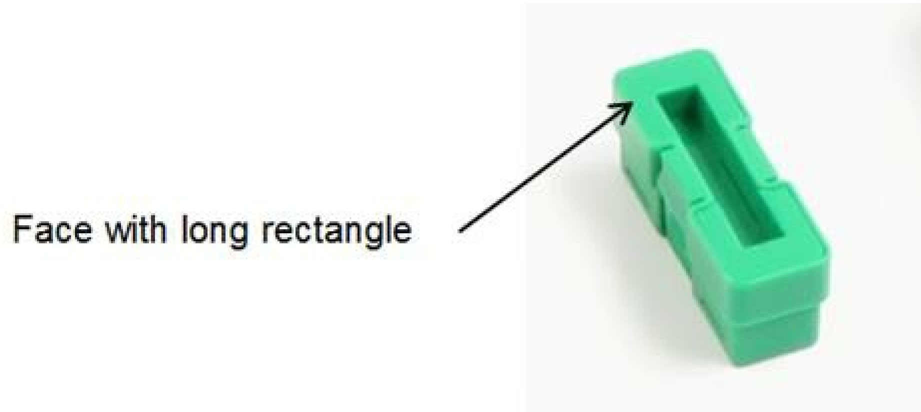


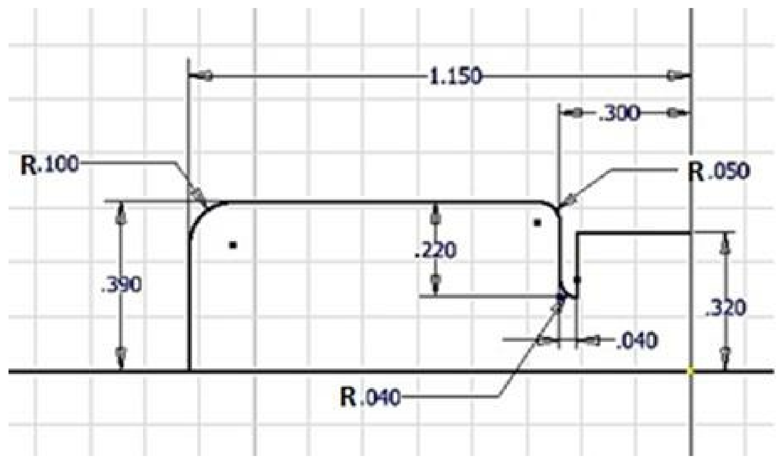
2. Create a part according to the above images. Mirror is a function that allows you to create a mirror image of existing geometry. This function requires an existing feature(s) and a surface or work plane to serve as the mid-plane of symmetry.

   - Create the part using the provided sketch and extrude to a depth of .75. Add the fillets and hole as shown in the figure above.
   - Use the mirror function to apply a mirror image of the existing geometry to the right face of the object as shown.
   - Save the file as *Mirror.ipt* to your Practice project folder.

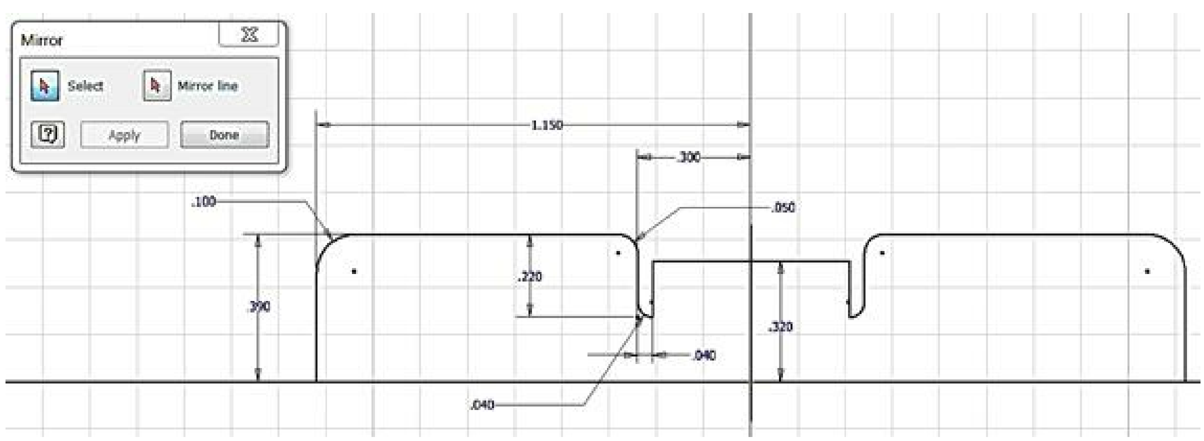
3. Create a solid model to represent the Automoblox connector piece. This part can be modified later to include more details and features.

   - Using your measurements (or the dimensions provided below), sketch the outline profile for one quarter of the face that includes the long rectangle as shown below. Sketch one quarter of the outline profile of the connector piece. **Do not sketch the rectangular hole.**

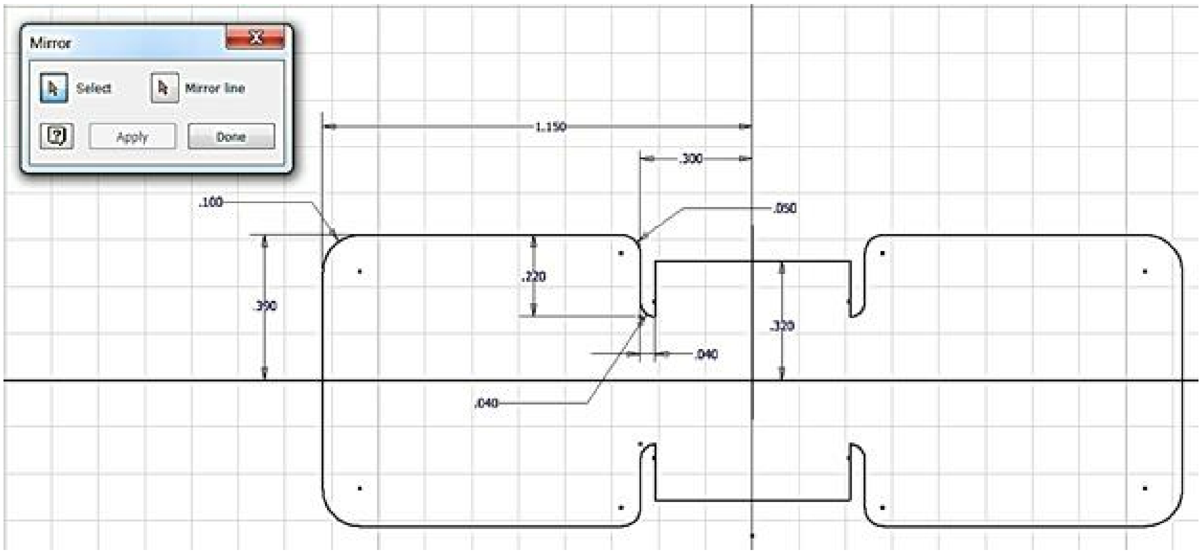




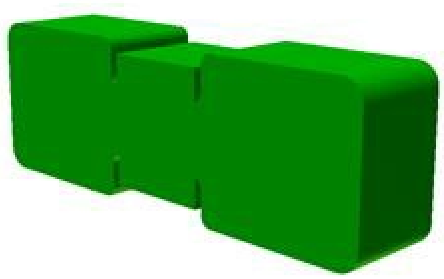
- Mirror the sketch to create half of the profile.



- Mirror the sketch a second time to complete the section.



- Extrude the sketch the appropriate depth according to your measurements. The connector will resemble the solid model below.



Note that if you have trouble extruding the sketch, you may need to use the Trim tool or Close Loop feature within the sketch to create coincident endpoints between adjacent lines and arcs. To close an open sketch loop, right-click on a line and choose Close Loop, then follow the instructions.

- Save the file as Connector*YourInitials*.ipt in your Automoblox project folder.

Loft

Sketch Tools – These are suggested tools for this activity:

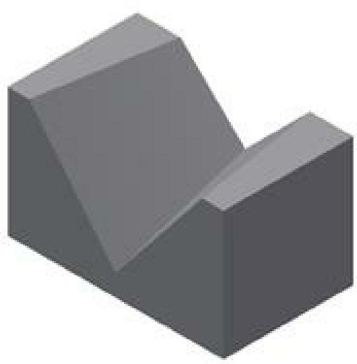
- **Rectangle**
- 2D Sketch on new surface
- Home View (View Cube)

- View Constraints (F8)
- **Polygon**
- **Offset Work plane** w/sketch
- **Projected Geometry**

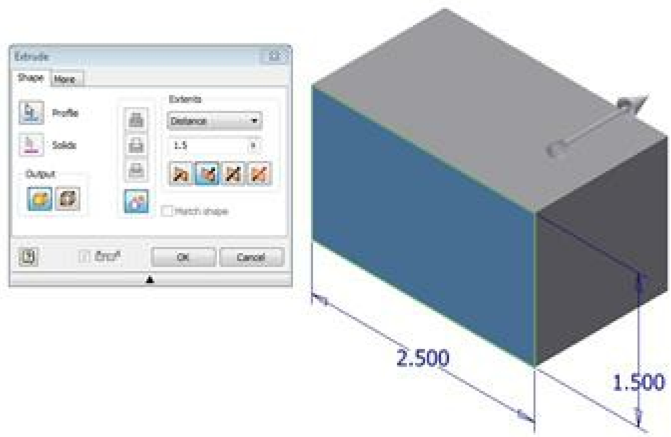
Feature Tools – These are suggested tools for this activity:

- **Extrude** (Add/Join)
- **Loft** (cut solution)
- **Revolve**
- **Work Axis**
- **Work Plane**

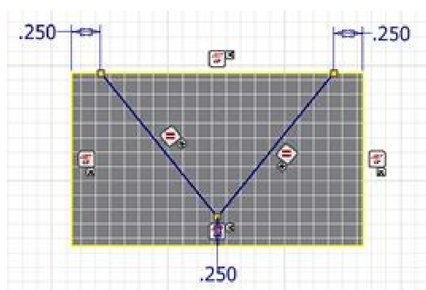
4. Model the part shown below. The loft function allows you to create a solid surface by blending two or more shapes that are located on different planes.



   - Create a rectangle and dimension it to the values shown in the image and then extrude it to a value of 1.5 deep.

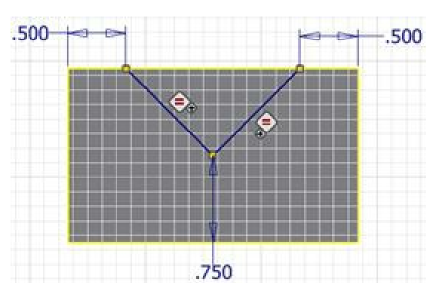


- Place a 2D Sketch on the front face of the block. Use the image below to draw and annotate the first of two sketches for the loft feature. Note that the sketch shows the equal constraints that need to be applied to the sketch. Finish the sketch.
- Apply a 2D sketch to the back face of the block and sketch the geometry shown in the right image below. Note that the sketches are placed on opposite faces of the rectangular solid. Finish the sketch.

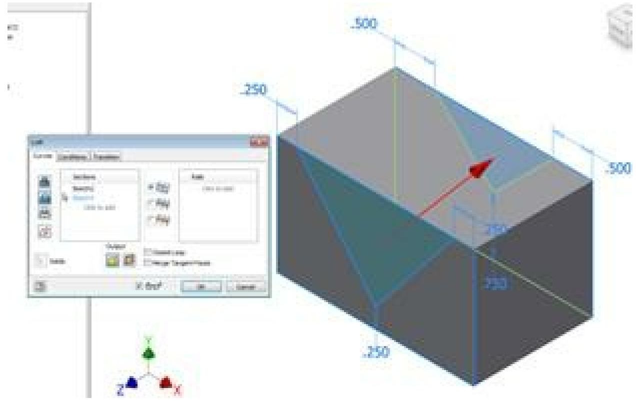


Front Face Sketch

- Select the **Loft** command from the 3D Modeling ribbon bar. Select the front sketch and then pick the deep “V” profile. This will highlight the shape that will start the loft. You must then select Click to add on the Loft palette, select the back sketch, and then pick the small “V” profile on that sketch. Choose the Cut option by selecting the Cut button. Then click OK.



Back Face Sketch



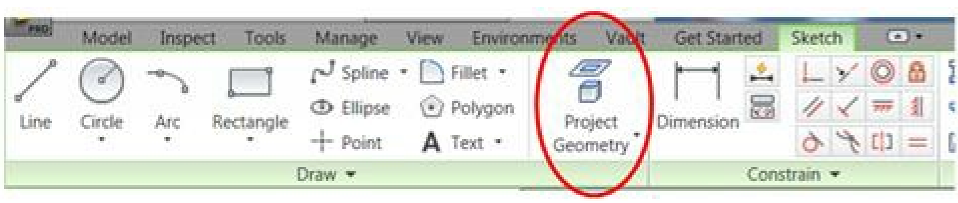
- Save the part as *LoftCut.ipt* in the Practice project folder.

Extrude

Sketch Tools – These are suggested tools for this activity:

- **Rectangle**
- Construction Line
- **Project Geometry**

  Helpful Hint: Project Geometry is a tool that will project the geometry of previously created features of a part onto the sketch plane, so that you may use the geometry in the construction of the sketch. The Project Geometry tool is accessible in the Sketch Ribbon in the Draw panel.



- **Offset**
- **Slice Graphics** (F7 and right mouse click functionality)

  Helpful Hint: Slice Graphics will cut the part at the current sketch plane and remove the solid material in the foreground (similar to a section view). This will allow you to see the geometry at the sketch plane and can provide better visibility of the sketch plane by removing obstructing material.

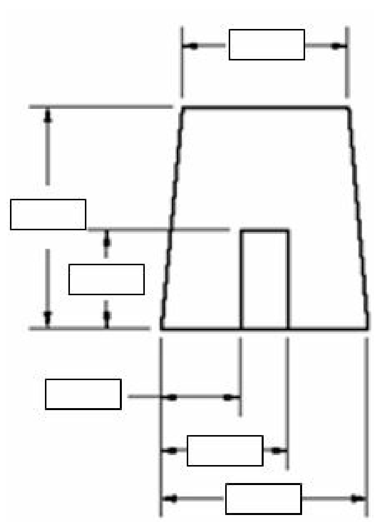
Feature Tools – These are suggested tools for this activity:

- **Extrude** (Add/Join)
- **Extrude** (Tapered / Intersection)
- **Work Axis**
- **Extrude** Intersection (Mid-plane or Symmetric)
- **Revolve**
- **Loft**

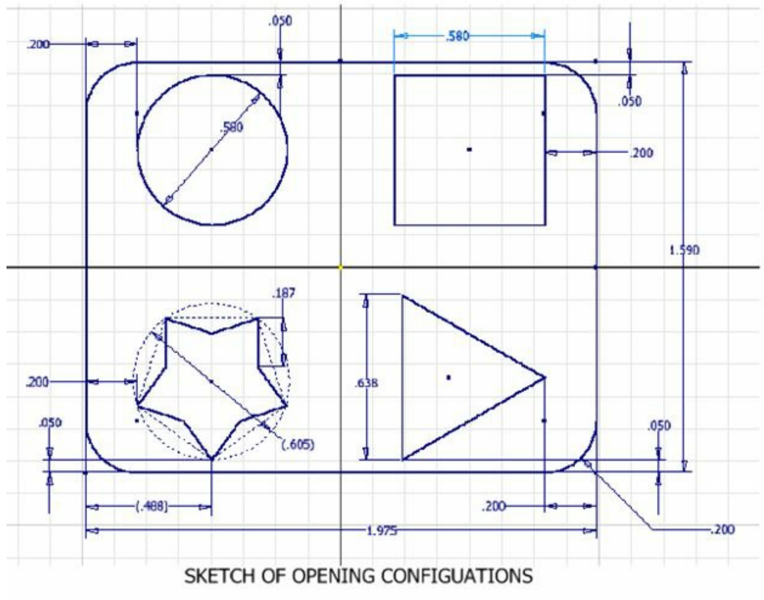
5. Create a new solid standing figure that will fit snugly into the passenger base. The figure should allow the windshield to be fully seated in the passenger section when the figure is installed.

    - Open a *standard.ipt* and create a sketch for the base of the figure. If you have not done so, measure the opening in the passenger base and record the dimensions on a sketch.

      For 2016 Automoblox vehicle models, or later, the base opening looks like this.



      For Pre-2016 Automoblox models, choose any one of the opening shapes in the passenger base (circle, **square**, **triangle** or star) to use as a base shape for your passenger model.



- Create your Automoblox figure using the **Extrude**, **Revolve**, and **Loft** features.
    - **Extrude** the base the appropriate distance.
    - Use additional features, including the **Loft** and **Revolve** features, to create the remainder of the body of the figure.
- Save the file to your Automoblox project folder as Automoblox Figure*YourInitials.ipt.*

Conclusion

1. What CAD feature would be used to most efficiently model a baseball bat (Extrude, Loft, Revolve, Sweep)? Explain your answer.
2. How does a 3D CAD solid model program display the progression of work involved in creating a model?
3. If a mistake is made, how does the user make a correction without using the undo function?

Activity 5.6

Physical Property Analysis

Introduction

What do you need to know about a product before it is built? Would you need to know its **volume**, **surface area**, or weight? Would the product weigh less if it were made of aluminum or mild steel? What about copper, brass, or cast iron? How could this information impact the product design?

How can you find the properties of a product before it is built? You can calculate them mathematically, providing you have the material specifications, but it will take time. In today's busy, fast-paced world, engineers use solid modeling software programs to speed up the calculating process. However, the user of the software must understand what the software is doing in order to estimate the answers and to be able to recognize a possible error.

Equipment

- Computer with 3D CAD solid modeling software
- Calculator

Resources

Physical Properties Analysis

Procedure

In this activity you will calculate the volume of a part and the surface area; you will look up the density of the material and then calculate the **mass**. Next, you will check your work using a 3D solid modeling software program. After you have learned how to calculate the physical properties of the example parts provided, you will then do an analysis on a puzzle cube piece and parts of your Automoblox vehicle or other consumer product.

Aluminum Object Example 1

The aluminum example is provided as an isometric drawing. The grid spacing for the object shown is 0.25 inch. Using the grid, determine the measurements for each facet of the part. Recreate the isometric sketch and record each facet's dimensions in your engineering notebook. Then calculate the volume and surface area of the object. Show your work in your engineering notebook. Next, create a model of the object with the required geometry using the 3D solid modeling software. You will assign aluminum as the object's material and perform a physical property analysis to determine the answers to the questions. Print a copy of the CAD Physical property values and insert into your engineering notebook. When you have completed the physical property analysis, answer the questions below.

You may need to review your notes and the Physical Properties presentation to recall how to generate the physical properties of a part.

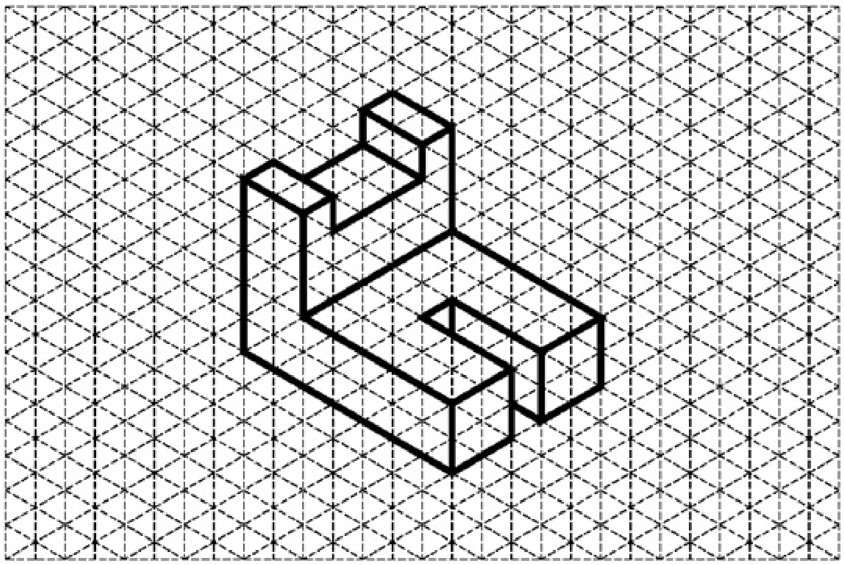


Figure 1: Isometric drawing of Aluminum Object One with 0.25" grid

Questions for Aluminum Object

Directions: Complete each calculation by hand. Show all work below and select the appropriate answer based on your calculations. Check your work using the 3D modeling software. If your answers differ, explain why you think they are different.

1. What is the volume of the part?

    - 1.875 in.³
    - 1.125 in.³
    - 1.375 in.³
    - 2.125 in.³

    SHOW WORK:

2. What is the density of aluminum in grams per cubic centimeter? (This may require research. Be sure to document your source.) Precision: X.XXX

3. What is the density of aluminum in pounds per cubic inch? Show your work including all conversion factors. Precision X.XXX

4. Find the mass of the object (in pounds-mass) if it is made of aluminum.

   - $0.125\ lb_m$
   - $0.135\ lb_m$
   - $0.257\ lb_m$
   - $0.312\ lb_m$

   SHOW WORK:

5. What is the surface area of the part?

   - $7.250\ in.^2$
   - $8.250\ in.^2$
   - $9.250\ in.^2$
   - $10.250\ in.^2$

   SHOW WORK:

6. What are the physical properties presented in the CAD software? Include units.

   - Density ________________
   - Mass ________________
   - Surface Area ________________
   - Volume ________________

   If physical properties are different from hand calculated values, explain why you think they differ.

7. If one quart of cleaning solution will clean $14400\ in.^2$, how many quarts will be required to clean 3000 parts? Use 3D software physical properties.

   - 2.000

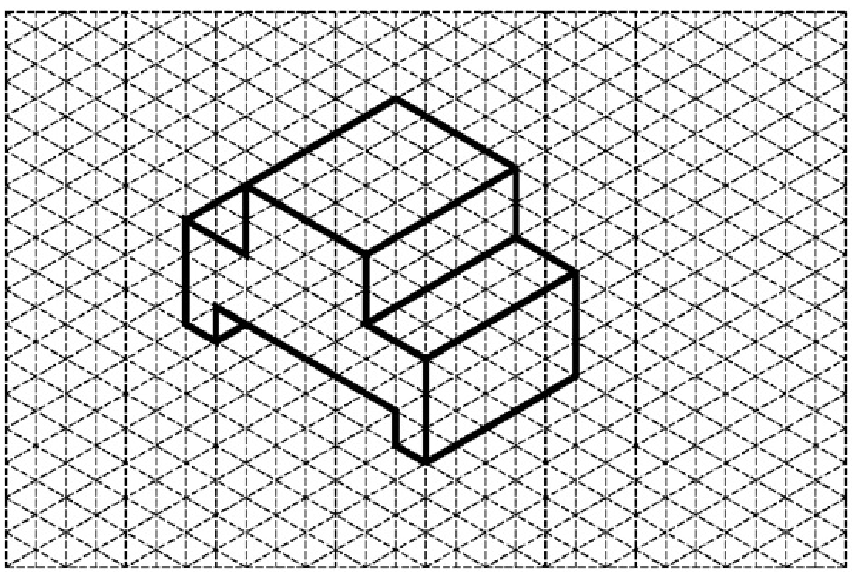
- 1.500
- 2.135
- 2.145

SHOW WORK:

Brass Object Example 2

An isometric drawing of a brass part is provided. The grid spacing for the object shown is 0.25 inch. Using the grid, determine the measurements for each facet of the part. Recreate the isometric sketch and record each facet's dimensions in your engineering notebook. Calculate the volume, mass, and surface area of the object and record below. Next, create a model of the object with the required geometry using the 3D solid modeling software. You will assign brass as the object's material and perform a physical property analysis to determine the answers to the questions. Print a copy of the CAD physical property values and insert into your engineering notebook. When you have completed the physical property analysis, answer the questions below.

Figure 2: Isometric drawing of Brass Object One with 0.25" grid



Questions for Brass Object

Directions: Complete the calculation by hand. Show all work below and select the appropriate answer based on your calculations. Check your work using the 3D modeling software. If your answers differ, explain why you think they are different where appropriate.

1. What is the volume of the part?

- $2.375 in.^3$
- $3.125 in.^3$
- $2.031 in.^3$
- $4.125 in.^3$

SHOW WORK:

2. What is the density of brass in grams per cubic inch? Precision: X.XXX
3. What is the density of brass in pounds per cubic inch? Show your work including all conversion factors. Precision: X.XXX
4. Find the mass of the object if it is made of brass.

   - $0.621 lb_m$
   - $0.547 lb_m$
   - $0.257 lb_m$
   - $0.312 lb_m$

   SHOW WORK:

5. What is the surface area of the part?

   - $6.000 in.^2$
   - $8.000 in.^2$
   - $0.250 in.^2$
   - $12.000 in.^2$

   SHOW WORK:

6. What are the physical properties presented in the CAD software? Include units.

   - Density ________________
   - Mass ____________________
   - Surface Area ____________________

- Volume ____________________

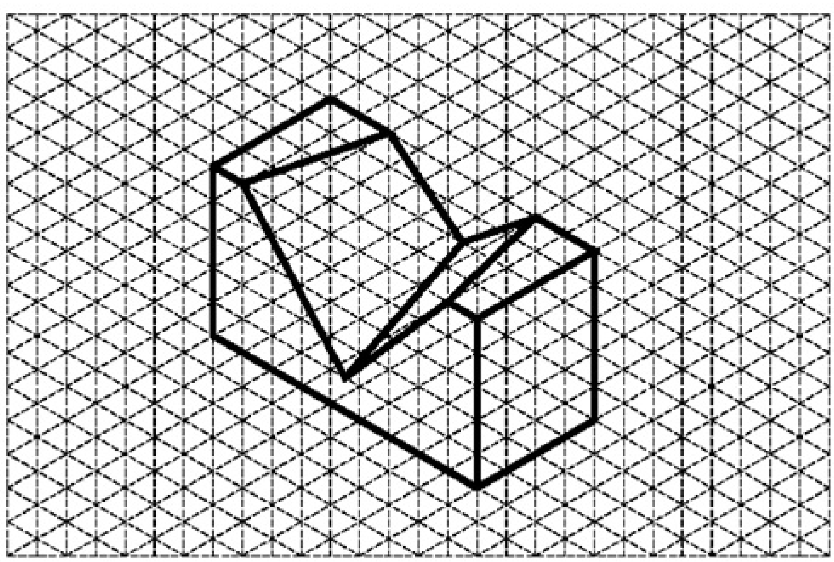
If physical properties are different from hand-calculated values, explain why you think they differ.

7. What will be the total cost to ship 100 brass parts if the shipping rate is $4.25 per pound? Use the physical properties from the CAD analysis. SHOW WORK.

High Density Polyethylene Example 3

You will begin by using Figure 2 isometric drawing to create a solid model. **The grid spacing for the object shown is 1 cm.** Note that this part has different dimensions (using metric units) than the similar part you created in Activity 5.5b CAD Modeling Skills Part 2. Recreate the isometric sketch and record each facet's dimensions in your engineering notebook. Next, create a model of the object with the required geometry using the 3D solid modeling software. (Hint: Use subtractive modeling by creating a rectangular solid, and then use the Loft tool to cut the V-notch.) Remember to use a metric part file template. Assign high density polyethylene as the object's material and perform a physical property analysis. Insert a copy of the CAD physical property values into your engineering notebook adjacent to the sketch. When you have completed the physical property analysis, answer the questions below.

Figure 3: Isometric drawing of High Density Polyethylene Object using a 1 cm grid



1. What are the physical properties presented in the CAD software? Include units.

- Density ____________________
- Mass ____________________

- Surface Area ___________________
- Volume ___________________

2. What is the surface area in square centimeters? SHOW WORK. Precision: X.XXX
3. What is the volume in cubic centimeters? SHOW WORK. Precision: X.XXX
4. What is the weight of the high density polyethylene part in pounds? Show your work and include all conversion factors. Precision: X.XXX
5. How many parts can be made from 152 pounds of high density polyethylene? SHOW WORK.

Physical Property Analysis of Your Manufactured Box

What if the material you plan to use is not listed in the software? There may be times that you will need to create a new material in the software and add the material specifications before you can perform the physical property analysis of a part. As in industry, there will be times that you need to "teach yourself" through use of the software tutorials and help menus.

Create a new material in the software called Box Material. To accomplish this task, you will independently research and discover how to customize a 3D modeling software application to add a new material and its properties. Use the density for the manufactured box you found in Activity 5.4 Calculating Properties of Solids. You may use the properties of birch for the other physical properties of the wood (therefore you may choose to create a copy of Birch and rename it).

You will conduct a physical property analysis on your manufactured box. Open the CAD part file, create a new material, and perform a physical property analysis using the new Box Material. Record the information below.

Print an isometric view of your manufactured box and a copy of the CAD physical property values. Insert both into your engineering notebook.

1. What are the physical properties presented in the CAD software? Include units.

   - Density (from Activity 5.4) ___________________
   - Mass ___________________
   - Surface Area ___________________
   - Volume ___________________

   If the physical properties are different from hand-calculated values in **Activity 5.4 Calculating Properties of Solids**, explain why you think they differ.

Physical Property Analysis of Automoblox Vehicle

Use the 3D CAD software to perform a physical property analysis of the connector piece of your Automoblox vehicle. Create a new material in the software called Automoblox Plastic. Use the density you found for a similar plastic in **Activity 5.3 Determining Density** and the other physical properties of ABS plastic.

Record the information below.

Print an isometric view of your connector piece and a copy of the CAD physical property values. Insert both into your engineering notebook.

1. What are the physical properties presented in the CAD software? Include units.

   - Density (from Activity 5.3) ____________________
   - Mass ____________________
   - Surface Area ____________________
   - Volume ____________________

2. If there is a 4% loss of material in the manufacturing process, how much material should be purchased to produce 10,000 connector pieces? SHOW WORK.

3. If the cost of the plastic to manufacture the connector parts is $0.015 per cubic inch of material, what is the cost to manufacture 10,000 connector pieces? SHOW WORK.

Conclusion

1. What do you need to know in order to perform a physical property analysis?

2. Why is it important to understand the mathematics used in physical property analysis?

3. Why is it important to perform a physical property analysis prior to producing a part?

4. The clear enclosure piece and the wheels of the Automoblox are manufactured from polycarbonate. Do you think that the connector pieces are also manufactured from polycarbonate? Justify your answer.

Physical Properties Analysis

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 5.7

Force and Stability

Introduction

Forces are everywhere. Gravity exerts a force on every **mass** on earth. Whenever two objects touch or collide, a force is applied to each. Wind, water, snow, ice, and soil can exert a force on an object they contact. Forces result when objects heat up and expand or cool down and shrink. Magnetic fields can exert force on metallic objects.

Engineers must take into account how forces will affect the design of nearly every physical object. Large objects, such as buildings, dams, bridges, and machines used for manufacturing, are obvious examples of engineered products that require careful consideration of forces. However, forces can affect the design of smaller objects, such as streetlights, highway signs, furniture, and toys. Engineers analyze forces, whether they are designing a building or a toy, to be sure that the design will work properly. Perhaps more importantly, engineers analyze forces to be sure every design is safe so that it will not harm people, property, or the environment.

In this activity, your team will investigate factors that affect the force required to tip an object over and will develop a mathematical model to represent the relationship among those factors.

Equipment

- 3D solid modeling application
- Spreadsheet program
- 8–10 different small cardboard boxes
- Materials of different densities that can be used to fill the boxes
- Scale
- Ruler

Procedure

Part 1 - Factors That Affect Tipping Force

Refer to your downloadable resources for this video.

1. As a team, brainstorm factors that might affect the magnitude of a **horizontal** force applied at the top of the box that is required to tip over an object.

2. Make a hypothesis about the relationship between each factor (that you identified in number 1 above) with respect to the magnitude of the (horizontal) force required to tip a box (rectangular prism).

   For example, if you think the height of the object being tipped is related to the tipping force, your hypothesis might be:

   - *As the height of the box increases, the magnitude of the horizontal tipping force decreases.*

3. With the help of your instructor, select one factor identified in number 1 above to investigate. Design an experiment to test your hypothesis. Perform the experiment and collect data. Record your data in a table similar to that shown. Note that you will vary ONLY the variable that you are investigating. The other variables under investigation should be the same for each trial.

Trial	**Mass of box, *m* (g)**	**Weight of box**, *W (N)*	**Base dimension (in direction of force),** ***b*** (*cm)*	**Height of force application,** ***h*** (*cm)*	**Magnitude of Tipping Force, *T*(**) (dependent variable)
1					
2					
3					
4					
5					
6					
7					

4. Create a scatterplot of your data. Graph the variable that you were investigating (independent variable) with the magnitude of the tipping force (dependent variable). The other variables should be constant in each of your trials.

5. Find a mathematical model to represent the data.

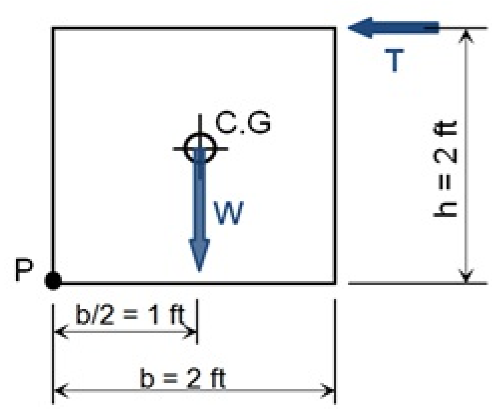
6. Present your findings to your classmates.

Part 2 – Engineering Design

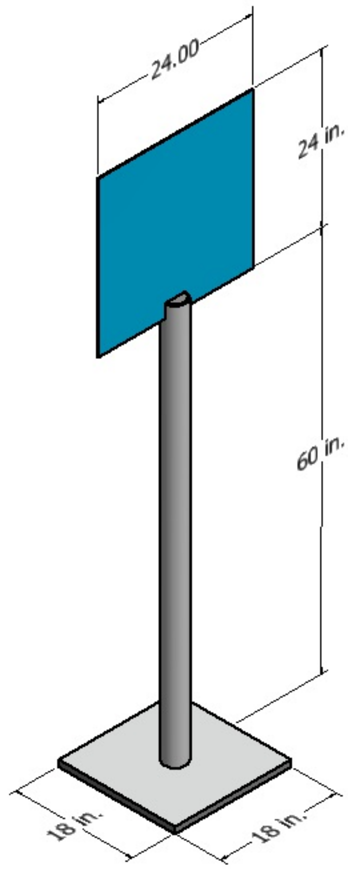
Refer to your downloadable resources for this video.

7. In your PLTW Engineering Notebook, write the mathematical model to represent the magnitude of the tipping force required to tip a box. Be sure to define all of the variables. Draw a free body diagram to illustrate the formula.
8. Review your experimental data. Does your data support this mathematical representation? Justify your answer. If not, explain why your data may not accurately reflect the true measurements?
9. For each of the following, draw a free body diagram to show the given information just before the object tips. Then, use the tipping formula to solve the problem.

   - A 2 ft x 2 ft x 2 ft box weighs 100 pounds, and the weight is evenly distributed. What is the magnitude of the minimum horizontal force, T, required at the top edge of the box to tip the box over? Assume that the box will not slide when the force is applied.



   - A sign (including the post and base) weighs 40 pounds and is supported by an 18 in. x 18 in. square base, as shown in the illustration.
     - If the wind applies a force of 13.2 lb to the sign at the geometric center of the sign surface, will the sign tip over?
     - If so, how much evenly distributed weight (sand bags) should be added to the base of the sign to keep it from tipping when the wind blows?

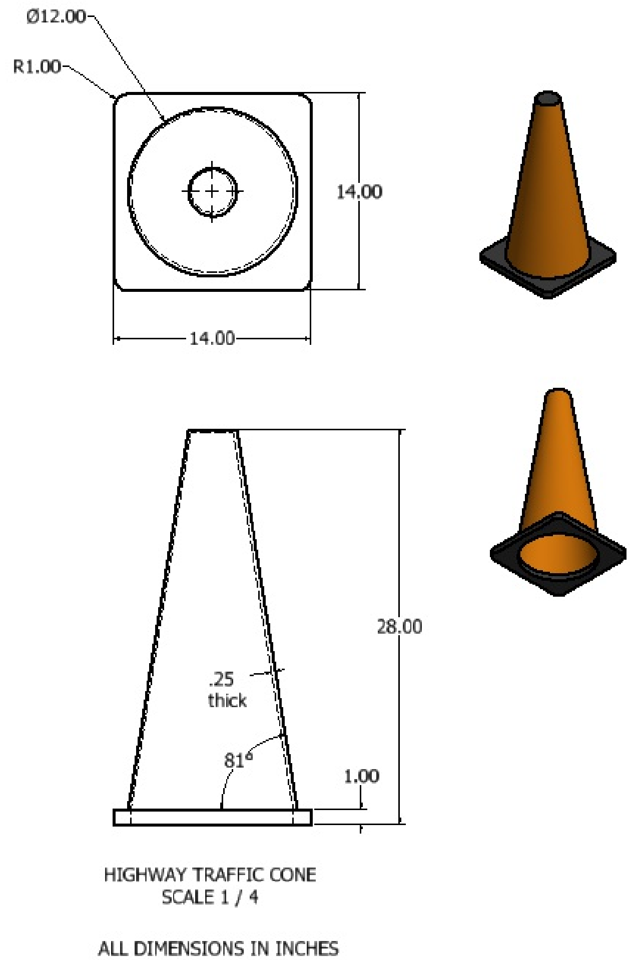


- A traffic cone is manufactured according to the technical drawing below. In order to meet state standards, the cone must resist a 3 pound horizontal force applied at the top edge of the cone (28 inches above the bottom of the cone). The force can be applied in any horizontal direction. Assume that the cone will not slide on the road surface when the design load is applied. Note that you may use 3D solid modeling software to estimate the **volume**, weight, and **center of gravity** of the traffic cone.

  Interpret the technical drawing

  Based on the part drawing of the traffic cone, does the 12 inch diameter dimension refer to the inside diameter or the outside diameter of the base of the cone?

  Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.



- What is the minimum cone weight that will resist an applied 3-pound horizontal force?
- What is the minimum **density** of material needed to achieve the minimum weight?
- What material would you use to manufacture the traffic cone? Why?

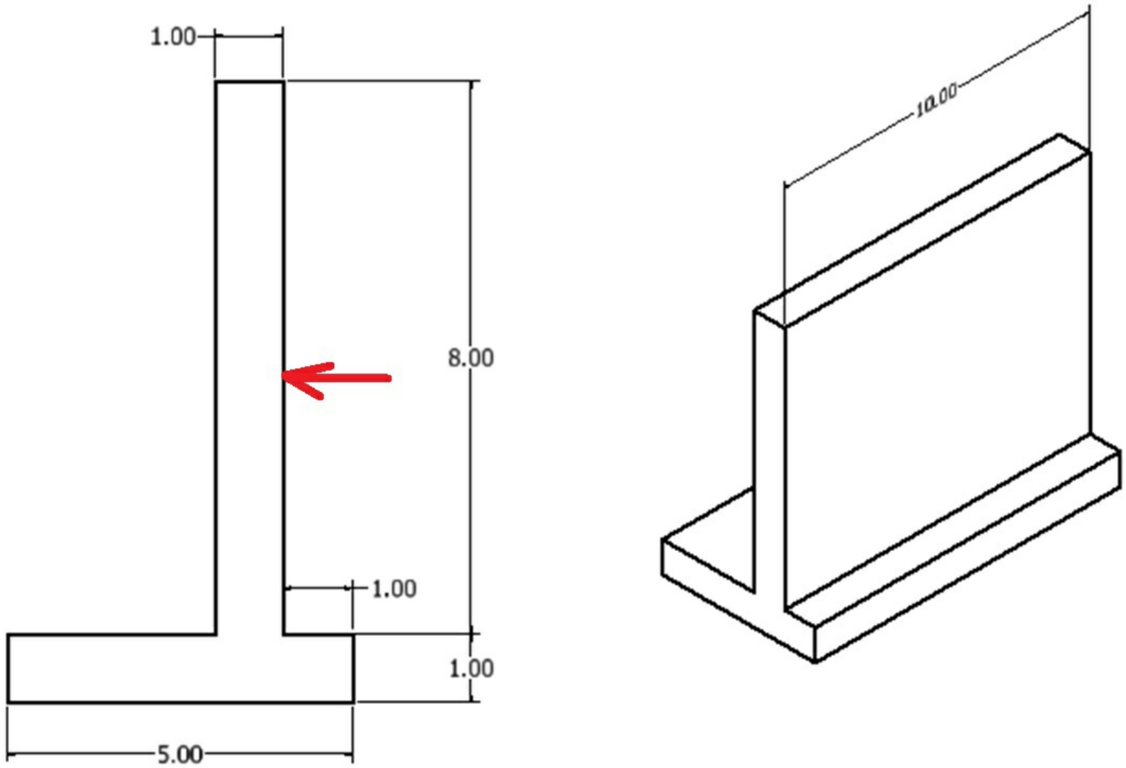
- A concrete retaining wall will retain (hold back) soil and water so that workers can repair an underground pipe. The soil and water applies a horizontal force of 15,000 pounds applied at a point 4.5 feet up from the base of the wall footing, as represented by the red vector in the drawing.

  Note that you may use 3D solid modeling software to estimate the volume, weight, and center of gravity of the retaining wall. Be sure to create your computer sketch of the retaining wall so that the origin is at the tipping point at the base of the wall. That way, you can take the center of gravity coordinates from that point.

  The following video tutorial demonstration how to move a sketch profile to the origin in Autodesk® Inventor®.

Video: Moving the Sketch Profile to Origin

Refer to your downloadable resources for this video.



RETAINING WALL
ALL DIMENSIONS IN FEET

- Will the retaining wall protect the workers from the force of the soil and water? Justify your answer.
- How would you revise the design of the retaining wall to improve a larger factor of safety?

Project 5.8

Reindeer Games Design Challenge

Introduction

A-1 Debris Removal hauls away tons of yard and construction debris each month. Currently wood debris is taken to the county landfill site where the debris is broken down into mulch. However, the owner of A-1 believes that some of the tree debris from tree removal and plywood scraps from construction sites can be reused in other ways. The owner would like to produce yard ornaments from logs, branches and large plywood scraps.

In this project, you will develop a conceptual design for a reindeer yard ornament that can be manufactured from tree debris or plywood scraps. You will present your proposed design to the leadership team of A-1 Debris Removal.

Equipment

- Computer with computer-aided design (CAD) software

Resources

Portfolio

Assembly Constraints (Optional)

Project 5.8 Reindeer Games Design Challenge Checklist and Rubric

CAD Tutorial Resources

Procedure

1. Design a reindeer yard ornament per the Reindeer Games Design Challenge Brief.

Reindeer Games Design Challenge Design Brief

Client Company	A-1 Tree Removal, Inc.

Target Consumer	General Public
Designer	____________________________________
Problem Statement	A local debris removal company disposes of a large amount of tree debris and plywood scraps. The owner of the company would like to investigate recycling some of the usable wood by building reindeer yard ornaments using the wood debris.
Design Statement	____________________________________
Constraints	1. The yard ornament must resemble and be proportional in size to a specific gender and subspecies of deer or elk (Key deer, white tailed deer, Rocky Mountain elk, etc.). Note that the yard ornament can be at a larger or smaller scale that the animal, but must be proportional. 2. The yard ornament must be constructed mostly of tree and plywood debris, but may include small ornamental parts to improve aesthetics, if deemed desirable. 3. Tree debris, if used, must reflect wood species typically found in the local area. 4. The yard ornament can weigh no more than 125 pounds. 5. The yard ornament must consist of separate pieces, as necessary, for easy assembly and disassembly. 6. The yard ornament must NOT tip over when a force of 50 pounds is applied at the top of the BODY of the animal (not including the neck or head).

2. Submit the following documentation:

   - PLTW Engineering Notebook with documentation of your design process. Include documentation, such as research, written work, sketches, CAD drawings, images, and calculations to support your design process and justify your design.
   - Peer reviews
   - Concept drawing that includes a multiview drawing of the fully assembled product. The purpose of the drawing is to present a *concept* of the final design to demonstrate compliance with design requirements, to gather client feedback, and to gain client approval before developing final drawings and a prototype.

- A self-assessment documented on the Project 5.8 Reindeer Games Design Challenge Rubric.

Conclusion

1. What advantages does 3D computer-aided design (CAD) provide over paper and pencil design? What advantages does paper and pencil design provide over CAD?
2. Which high school math topic/course, Algebra or Geometry, is more closely related to engineering? Justify your answer.

Portfolio

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Assembly Constraints (Optional)

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

CAD Tutorial Videos

Video: Work Plane at an Angle and Tangent to a Cylinder

Refer to your downloadable resources for this video.

Video: Work Plane Tangent to a Cylinder

Refer to your downloadable resources for this video.

Video: Moving Assembly to Origin

Refer to your downloadable resources for this video.

Project 5.8 Reindeer Games Design Challenge Checklists and Rubric

Resources

[Project 5.8 Reindeer Games Design Challenge Checklists and Rubric]

Interim Reviews and Assessment Checklists

Review Content	Needs Revision	Reviewer name, date	Reviewer Comments	Approved
CAD 3D solid model • All necessary dimensional and geometric constraints are properly applied to constrain sketch geometry. That is, CAD sketches cannot be altered by selecting and dragging elements. • Correct location of 3D solid model within CAD 3D plane to facilitate correct center of gravity coordinates. • Appropriate material assigned to 3D solid model. • The 3D solid model is sufficiently developed to provide acceptable estimates of physical properties. That is, the 3D model does not have to be a perfect representation of the final design, but an effective “model” of the design for the intended purpose.				
Engineering Calculations – Mathematical Modeling • Correct physical properties (as determined from 3D solid model) are used in calculations. • Appropriate mathematical model stating equations for static equilibrium is used to support final design solution. All variables defined.				

• Free-body diagram is correctly represented and provides values for all known forces and distances needed for static equilibrium calculations. Variables used to identify unknown quantities. • Calculations are documented step by step so that a person unfamiliar with the work can understand the solution process. • Calculations and results are mathematically correct. • Appropriate units and unit conversion factors (when necessary) are documented throughout the calculations and in results.				
CAD Drawing • All parts necessary to demonstrate design intent are included. • Front view was selected based on accepted practice. • An isometric view and an appropriate number of orthographic views are presented according to accepted practice. • Orthographic views are properly oriented. • A parts list specifies material and important physical properties including density, weight and center of gravity of components. • Enough dimensions are included to provide conceptual understanding of the design and show compliance with the specifications. • Dimensions are placed per dimensioning guidelines and accepted practice. • The drawing provides evidence that the design meets all design criteria.				

Peer Review Rubric – The following criteria will be assessed when you review your peer's work.

Criteria	Basic	Proficient	Advanced

Peer Review and Feedback LO: Analyze and evaluate the work of others to provide helpful and effective feedback.	Expends little effort to provide helpful feedback.	Carefully and thoughtfully assesses a peer's work.	Carefully and thoughtfully assesses peer's work and asks for clarification from the peer to fully understand thinking and process, when appropriate.
	Provides feedback that is often inaccurate or not specific, or is not actionable.	Provides effective and accurate feedback that is specific and actionable.	Provides effective feedback that is specific and actionable and refers to a learning objective or goal. Amount and detail of feedback is user friendly – not overwhelming and not too technical, but substantial enough to provide specific guidance for significant improvement.
	Sometimes shares feedback in a professional manner.	Usually provides feedback in a professional manner.	Always provides feedback in a professional manner.

Through Project Performance – The following criteria will be assessed at any time and/or at multiple stages of the design process.

Criteria	Basic	Proficient	Advanced
Engineering Mindset LO: Persevere to solve a problem or achieve a goal. LO: Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal. LO: Demonstrate flexibility and adaptability to change.	Frequently off task.	Often uses time wisely.	Plans and uses time efficiently.
	Frequently requires direct instructions before working on the project.	Often demonstrates self-direction with little direct oversight.	Always demonstrates independent thinking and self-direction in order to accomplish a goal.
	Inflexible and resists making changes.	Usually demonstrates flexibility and is adaptable to change.	Always demonstrates flexibility and adaptability to change. Can explain the benefits to changing direction in the design process.
	Gives up easily.	Usually perseveres to solve a problem, but sometimes requires intervention.	Perseveres to solve problems or achieve the goal until the problem is solved.
			Critically analyzes

	Does not consider or rejects effective feedback from peers or teacher without justification.	Often uses effective feedback from others to inform performance.	feedback and strategically implements feedback that will improve work. Provides appropriate justification when feedback is not implemented.
CAD modeling process LO: Create solid part model using 3D computer-aided design (CAD) to represent an object. An *inefficient* CAD model includes: • Unconsumed sketches • Unconstrained sketch geometry • Unused sketch components (stray lines, shapes, center points, etc.) that serve no purpose • Hidden or non-visible features • Unnecessary work features • Multiple sketches to create features that could be created from a single sketch. Example, three separate sketches used to model three separate holes on the same surface. • Using additive methods when subtractive methods would result in fewer features in the feature tree (as shown in part Browser) or vice versa.	Produces an *inefficient* 3D solid model to accurate size that resembles the design intent.	Produces a relatively efficient 3D solid model in enough detail to demonstrate design intent.	Produces a *highly efficient* 3D solid model. Purposely employs strategies to limit number of features in project browser.
	Produces a 3D solid model that is ***not*** accurate enough to estimate physical properties of an object to acceptable accuracy.	Produces a 3D solid model to successfully estimate physical properties of an object to acceptable accuracy.	Can describe how the location of the solid model within the grid system will affect the physical properties displayed in iProperties.
	Can ***not*** identify ways to improve an inefficient CAD model	Can identify inefficiencies in a CAD model.	Can identify specific ways to improve the efficiency of a CAD model.
	Can not distinguish between additive and subtractive methods in 3D solid modeling.	Can distinguish between additive and subtractive methods in a 3D model.	Can explain and justify the efficiency of a solid model with respect to the use of additive and subtractive methods.

Project Submittal – The following criteria assessed based on the project submittal(s).

Criteria	Basic	Proficient	Advanced
Design Process – Define the Problem LO: Synthesize an ill-formed problem into a meaningful, well-defined problem. LO: Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.	Presents minimal research that is directly related to the problem.	*Documented* research directly related to the problem is presented. (Key deer, African elephant, and human dimensions, as appropriate).	Comprehensive *documented* research that is directly related to the problem is presented. Uses research to inform problem statement.
	Does not include additional *measurable* requirements that will help define a successful solution, or the added criteria are vague and unmeasurable.	Identifies additional visual, functional, and structural design requirements with realistic criteria, by which solution alternatives can be compared.	Consideration is given to economic, environmental, social, political, ethical, health and safety, manufacturability, technical feasibility and sustainability considerations, as appropriate.
Design Process – Problem solving approach and documentation LO: Explain and justify an	Documentation reflects design work inaccurately or sporadically.	Documentation accurately reflects the design work (in PLTW **Engineering Notebook**).	Documentation is neat and clear and comprehensively reflects all design work (in **PLTW Engineering Notebook**).
	Documentation often does not follow best practice. Most steps of the design process are documented but may not be verified by appropriate outcomes.	Work is documented according to best practice. Each step of the design process is documented and verified by appropriate outcomes (i.e., a design brief, decision matrix, model, test report, and project recommendations (as appropriate).	Each step of the design process is fully documented in detail (in **PLTW Engineering Notebook**) and verified by appropriate outcomes. Where appropriate and indicated, *iteration* of steps of the design process are documented and justified by evidence.
	Documentation does not include	Documentation includes adequate	Documentation includes in depth explanations of, justifications of, or

engineering design process.	explanations of, justifications of, or reflections on design work.	explanations of, justifications of, or reflections on major design decisions.	reflections on major design decisions. Includes frequent notations of thoughts and reflections on work that inform the design process.
	The final design is not sufficiently validated.	The final design is compared to design criteria. Evidence is provided to show that the design either meets all criteria, or deficiencies in the design are identified. All deficiencies are addressed, and suggestions for improving the design are provided.	The final design is compared to the design criteria and fully validated using evidence. Additionally, the design is supported by consideration of economic, environmental, social, political, ethical, health and safety, manufacturability, technical feasibility and/or sustainability considerations, as appropriate.
Mathematical Modeling LO: Develop models to represent design alternatives and generate data to inform decision making, test alternatives, and demonstrate solutions. LO: Apply mathematical models and interpret the output of models to test ideas or make predictions.	Identifies the need for a mathematical model(s) to address a specific need in the design process, but selects an inappropriate mathematical model for the intended purpose.	Identifies an appropriate mathematical model to address a specific need in the design process. Correctly applies the mathematical model for the intended purpose.	*Develops* an effective mathematical model to represent and analyze data to define the problem, compare alternatives, and/or validate a design solution as is appropriate for the context of the problem.
	Calculations are sometimes poorly documented or do not meet all of the criteria listed in the **Engineering Calculations** checklist above. Difficult for a person unfamiliar with the work to understand how the model supports the design process.	Calculations are well-documented and meet all of the criteria listed in the **Calculations** checklist above.	Calculations are clear and easy to follow. Written explanations are provided, as appropriate, to help a person unfamiliar with the work understand how the calculations inform the design process, provide evidence used to identify deficiencies, or identify appropriate next steps in pursuit of a better solution.

LO: Make judgements and decisions based on evidence. LO: Apply physical properties in a design process.	Does not appropriately use the results obtained from applying the mathematical model.	Uses the results of mathematical model application to validate a final design solution.	Uses a mathematical model to inform the design process prior to validation of a final design. For example, a mathematical model is used to mathematically determine the critical weight of the design to avoid overturning; or to mathematically determine the orientation of the reindeer legs (given a height and weight of the reindeer) to provide the critical horizontal distance between the tipping point and weight vector. Or a mathematical model is used to find the optimal density of material to provide sufficient weight to resist overturning (given a specific geometry), to inform a material selection.
Technical Drawings LO: Create a set of working drawings using 3D computer-aided (CAD) software to represent an object. LO: Properly dimension technical drawings of simple objects or parts according to a set of dimensioning standards and accepted practices.	A concept drawing is presented but does ***not*** meet all criteria listed in the **CAD Drawing** checklist above.	A concept drawing is presented that meets all criteria listed in the **CAD Drawing** checklist above.	A concept drawing is presented that meets all criteria listed in the **CAD Drawing** checklist above and provides additional content such as an alternate view (detail view, section view), when appropriate, or an assembly view.

Instant Challenge: Popcorn Package (Optional)

Procedure

Divide into teams with direction from your teacher and create a solution to the following design challenge. Remember to record your design process.

- **Problem Statement**

  BEST Movie Theaters would like to increase child size popcorn sales during the summer months by making the popcorn container more desirable to both children and parents. The new popcorn container will be sold as a package deal with a child's movie ticket and juice box.

- **Design Statement**

  Design, build, test, document, and present an innovative container design that holds approximately 2 cups of popped popcorn. The container must be desirable to both children and their parents.

- **Design Criteria**

  - The container must be fabricated from no more than 1 sheet of 11"X17" paper.
  - The container must hold approximately 2 cups of popcorn.
  - The container must fold flat or stack to reduce space needed for storage and shipment.
  - The container must be easy for small children to grasp and eat out of.
  - Colors desirable to small children are encouraged.
  - If possible, a person should be able to open the container for filling with one hand.

Scoring

Your team may receive points for the following.

- Creativity: Up to 10 points for creativity in the design and use of materials.
- Teamwork: Up to 10 points for how well your team works together.
- Performance: Up to 30 points for how well the product meets the design criteria.

PLTW ENGINEERING

Unit 6

Reverse Engineering Overview

Preface

Through reverse engineering all aspects of a product can be analyzed. Reverse engineering can provide important information about products when documentation is not available. The information gathered can help designers improve the product or manufacturing process, provide interoperability between existing and new products or provide information on competitor products.

In this unit you will have an opportunity to reverse engineer a product by analyzing the product's function, structure, and visual elements.

Essential Questions

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

Activity 6.1 Visual Design Principles and Elements Identification

Activity 6.2 Visual Analysis Automoblox

Activity 6.3 Functional Analysis Automoblox

Activity 6.4 Structural Analysis Automoblox

Project 6.5 Product Reverse Engineering Presentation

PLTW ENGINEERING

Activity 6.1

Visual Design Principles and Elements Identification

Introduction

Following the steps in the design process and applying visual design principles and elements are key ingredients leading to the overall effectiveness and *tastefulness* of a design.

As you learned in previous lessons, the design process is a very important step-by-step framework that needs to be followed and revisited during a person's attempt at product design. Following this process by itself does not guarantee an awe-inspiring solution. Using the right blend of visual design principles and elements can greatly enhance your product's functionality, appearance, feel, and overall effectiveness. Selecting this proper combination is a difficult skill to develop, but can be achieved by immersing yourself in the design process throughout the year, tackling problem after problem, and letting your imagination run wild.

When you look at a product that you really like, what, besides its function, do you like? Is it the **color**? Is it the **form** or **shape** of the case? Maybe it's the **rhythm** in its appearance. Maybe it's the product's **proportion**. Then again, maybe it's the formal **balance** of its design that grabs your attention. With some insight into the visual design principles and elements, you will be able to create products that capture the attention and imagination of the viewer. Artists, graphic designers, architects, and industrial designers make up only a handful of the professionals that utilize the vocabulary of visual design principles and elements on a daily basis.

Equipment

- 3.5 index cards
- Digital camera
- (Optional) Activity 6.1a Visual Design Principles and Elements Matrix

Resources

Elements and Principles of Design

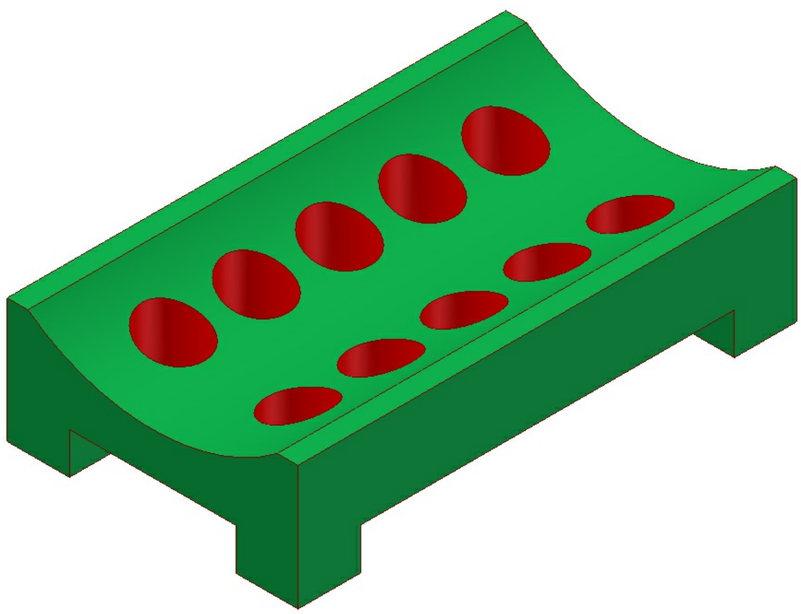
6.1a.A Visual Principles Elements Matrix Template.docx

Procedure

The purpose of this activity is to identify the visual design elements that appear in your environment and then identify the visual design principles by which they were arranged.

1. Locate five man-made items at home, school or elsewhere in your environment that are visually interesting. Take a photograph of each item. If it is not possible to take a photograph, sketch the item and shade it with colored pencils to closely represent the object.

2. Document your visual analysis on **Activity 6.1a Visual Design Principles and Elements Matrix** or on an index card. Attach your image to the matrix or card and include your name, the name of the product, and identify the visual design principles and elements that are evident in that product. [Also note and explain any obvious disregard for a principle of design. For example, if a design appears chaotic and lacks **unity**, note this and explain why.]



Example Index Card

Sue Smith

Soap Dish

Elements*: bright red and green colors, curved and straight lines, rectangular and circular shapes, geometric forms, smooth* **texture**

Principles:

Emphasis *- red color against green background.*

Contrast *− straight lines contrast curved edges, red and green colors contrast.*

Formal balance − created by **symmetry** *of shapes, forms and* **space***.*

Regular Rhythm − created by repeated use of circular holes.

Proportion − All elements seem proportional and of an appropriate size for function.

Unity − created by consistent use of geometric shapes, color, and smooth texture.

Economy − Simple lines and shapes. No extraneous elements.

Example Matrix

Activity 6.1a Visual Design Principles and Elements Matrix PLTW

Name: ______________________ Product: Soap Dish

Principles of Design	Elements of Design: Point	Line	Color	Value	Shape	Form	Space	Texture
Description of Use of Element of Design	n/a	Straight edges and curved top surface	Bright green and red	n/a	Geometric shapes - rectangular and circular	Solid forms created by rectangles and circles	Space around circular openings in top. Depth evident in holes.	Smooth
Balance					Formal Balance created by symmetry	Formal Balance created by symmetry	Formal Balance created by symmetry	
Emphasis			Red color emphasized against green background					
Contrast		Curved top edge contrasts with straight edges on sides	Red and green colors contrast					
Rhythm					Regular rhythm created by repeated use of circular holes			
Proportion					All shapes seem proportional and appropriate for function	All forms seem proportional and appropriate for function		
Unity					Consistent use of geometric shapes			Consistent smooth texture
Economy		Simple lines			Simple shapes – no extraneous elements			

3. **(Optional)** Create a 24” × 36” electronic poster to present your five objects. Include a photographic image and a text box containing your description of the visual elements and principles of design displayed for each object.

4. Be prepared to present each object and its visual design principles and elements.

Example Poster

Conclusion

1. How are visual design principles and elements utilized in a design?
2. Identify a product that you feel is aesthetically pleasing. What is it about the product that you find appealing?
3. Identify a product that you don't like the appearance of and identify the visual design principles and elements that lead to this feeling.
4. Identify the visual design principles and elements that were not used appropriately in some of the products shown.

Elements and Principles of Design

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 6.2

Visual Analysis Automoblox®

Introduction

What is it about an object that captures a person's attention? Is it the **color** of an object that **emphasizes** its presence? That might explain why a kindergarten classroom is full of reds, yellows, and blues. Is it the organic curves of an object's **form**, like the body of a sports car? Could it be a repeating series of **shapes**, such as a tile **pattern** in a bathroom? Is it the visual **rhythm** of the wood grain that makes a person purchase a fine piece of furniture? Perhaps it is a matter of **symmetry**, or a lack of it. Sometimes the sheer scale of an object or a **space** within it demands attention. Could that be another reason why people are attracted to cities?

In this activity, working in a team of two or three, you will act as an engineering team for a novelty toy company. Your company has noticed the skyrocketing sales of the Automoblox® vehicles and would like to design accessories or enhancements that can be purchased separately but will work with the existing toys. As a first step, your team has been assigned the task of **reverse engineering** one of the Automoblox® vehicles. This will begin with a visual analysis to identify the visual design principles and elements that give the vehicle its visual appeal, or lack thereof. You will use a digital camera to aid you in your visual analysis. And, finally, you will describe the Automoblox® vehicle using the language of visual design principles and elements.

Equipment

- Digital camera
- Automoblox® vehicle

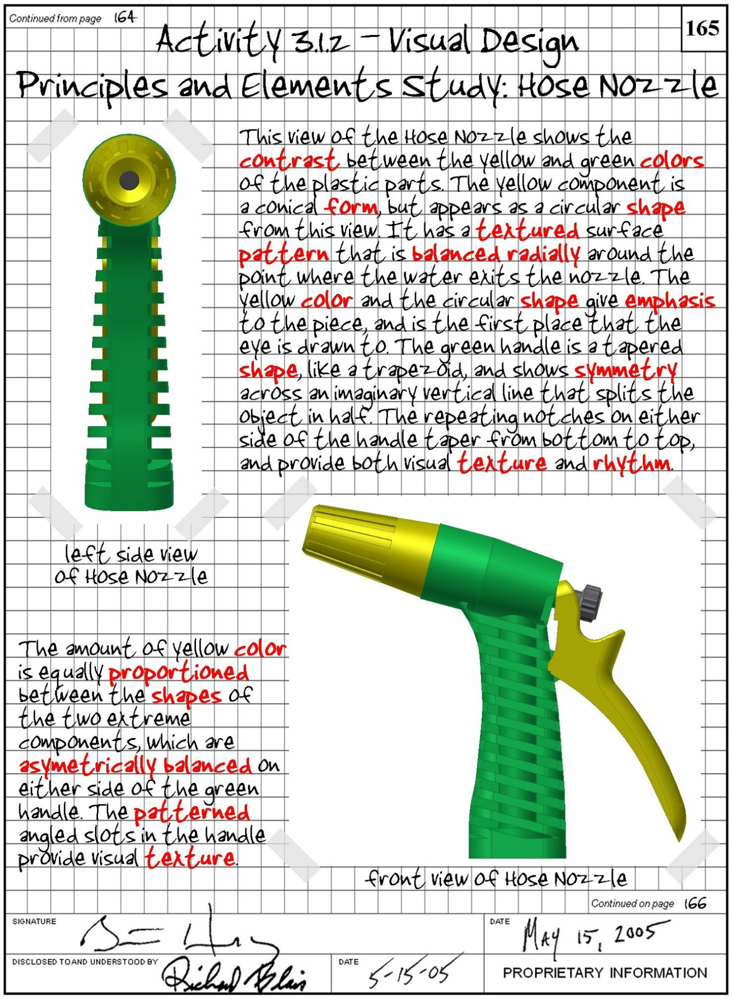
Procedure

Perform a visual analysis of the Automoblox® vehicle using the following procedure:

1. In your PLTW Engineering Notebook, identify the product and the manufacturer.
2. Using a digital camera, take at least three pictures of the product from different angles.
3. Print out the images on a color or laser printer, and neatly secure them in your engineering notebook.
4. Create a caption under each image that identifies the particular view – front view, right side view, isometric view, etc.
5. Next to each image, write a description of the visual design principles and elements that are

evident from that particular view.

Example Visual Analysis



6. Submit your engineering notebook to your instructor for evaluation.

Conclusion

1. How has this study affected your understanding of visual design principles and elements?
2. How will you look at products differently from now on, based on your understanding of visual design principles and elements?
3. How do visual design principles and elements relate to the natural world?
4. How do visual design principles and elements impact the commercial appeal of a product?

PLTW ENGINEERING

Activity 6.3

Functional Analysis Automoblox®

Introduction

You have performed a visual analysis of your Automoblox® vehicle to identify the visual design principles and elements that give the object its visual appeal, or lack thereof. The next step in the **reverse engineering** process involves the study of the object's function. This is done through careful observation of the object's sequential operation before it is disassembled. By first observing the product, you can hypothesize how a product operates and then compare your predictions to your actual findings after the part is dissected.

In this activity, you will perform a functional analysis of your Automoblox® vehicle

Equipment

- Example product observation
- Automoblox® vehicle

Resources

Reverse Engineering and Functional Analysis

Simple Machines

Product Observation Example

Procedure

Before measurement and dissection, theorize how the various sub-systems of the toy function through non-destructive observation. Study the toy and then document the following information in your PLTW Engineering Notebook.

Product Name:

Company Name:

1. What is the purpose or primary function of the object?

2. Sketch an isometric pictorial of the product in your engineering notebook and label the individual components. If you are not sure what a particular component is called, then make a logical guess.
3. Make an educated guess regarding each of the following.
    - Without removing any wheels from the vehicle, explain what design detail(s) allow the wheels to rotate freely while remaining attached to the axle pin?

      "The wheels of the Automoblox® vehicle rotate freely as a result of the following design details. ..."
    - Remove a wheel and examine the design of the wheel and axle pin. Was your hypothesis correct? If not, describe the operation of the wheel and axle that allows free rotation but secures the wheel to the axle pin.
    - Without disassembling the vehicle, hypothesize how the connector pieces (including all three separate pieces that make up the connector assembly) securely attach the body parts together while allowing easy disassembly by a child when an adequate force is applied.
    - Disassemble the vehicle and examine the connector pieces. Was your hypothesis on the operation of the connector pieces correct? If not, describe the operation of connector pieces such that connector assembly securely attaches the body parts together while allowing easy disassembly by a child.
    - What is the purpose of the raised ridge **pattern** on the top and bottom center clips of the connector piece?
    - What other elements of the product design appear to have a specific function or design intent? Consider the choice of materials, form/size of various pieces of the vehicle, durability, target market, and ease-of-use. Ask yourself, “Why did the designer make this choice?”
4. Identify the system inputs, intended product function, and outputs using a black box systems

model. You may document the information in your engineering notebook in a table similar to the table shown.

Inputs	Product Function	Output

Conclusion

1. Why do engineers perform reverse engineering on products?
2. What does a black box represent in the system input/output model?

Reverse Engineering and Functional Analysis

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Simple Machines

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 6.3 Product Observation Example

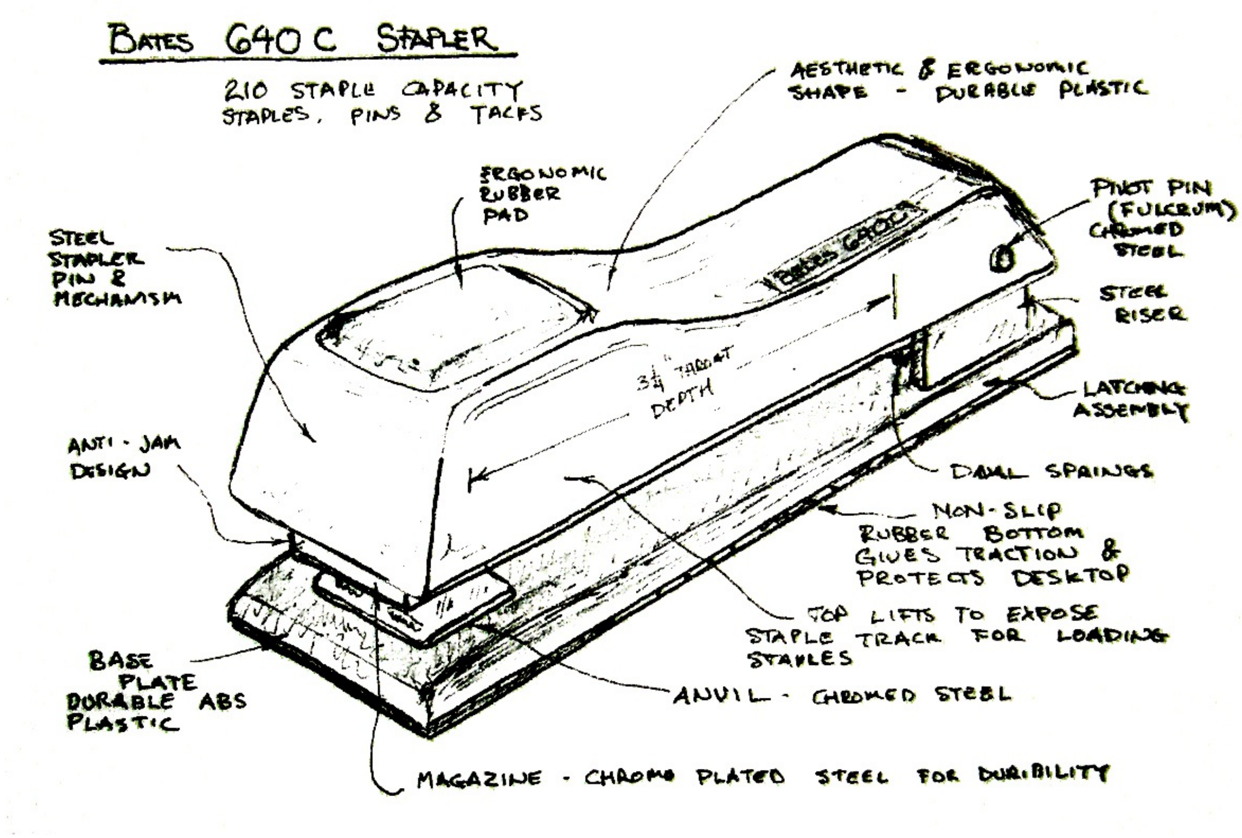
Product Name: Stapler

Company Name: Bates Model 640 Custom

1. What is the purpose or primary function of the object?

   This device is designed to perforate and mechanically bind sheets of paper together using metal wire.

2. Sketch an isometric pictorial of the product and label the individual components. If you are not sure what a particular component is called, then make a logical guess.



Sketch from engineering notebook

3. Make an educated guess as to how this product operates. Use simple machines' terminology to explain the operation.

   The top portion of the stapler serves as a lever arm and rotates about a pivot pin. The pivot pin functions as a fulcrum. An effort force is applied downward on the end of the lever arm, which moves the top assembly down toward a small metal plate, called the anvil. The top assembly consists of the top portion of the stapler and the magazine.

The magazine, which is located on the underside of the lever arm assembly, is compressed against the corner of a stack of papers that rests on top of the anvil. The top portion of the stapler continues to move downward, which causes a single piece of metal wire, bent in an upside down U-shape, to be ejected from the magazine. The ends of the wire are small enough in diameter to puncture several sheets of stacked paper. The wire is pushed through the paper until it contacts the anvil.

The anvil has two indentations that function as inclined planes. These inclined planes cause the wire ends to deform and hook inward toward each other as the wires continue to make their way through the paper sheets. The hooked ends form a mechanical connection that binds the papers together. When the U-shaped wire bottoms out on the top sheet of paper, the stapling action is complete.

Force is removed from the top portion of the stapler and the lever returns to its original position, as if it were pushed by some internal force. This action seems to automatically reset the magazine to eject another metal wire staple when the process is repeated.

4. Identify the system inputs, intended product function, and outputs in the table below.

Input	Function	Output
Staples		Noise
Loose Paper	Fasten Paper	Heat
Applied Force		Bent Staple

5. What mechanical components are visible?

   Base plate, riser, pivot pin, magazine, anvil, upper stapler lever arm

6. What is it about this device's function that you cannot identify because the mechanical components are hidden from plain view?

   It is not obvious what is causing the magazine to advance another staple after each cycle.

   It is also not obvious what is causing the lever arm assembly to return to its original position.

Activity 6.4

Structural Analysis Automoblox®

Introduction

You have already performed a Visual Analysis and a Functional Analysis of your Automoblox® vehicle. During this activity you will investigate vital product characteristics with regard to the structure of the product. You will research and document your findings using careful measurements, sketches, and notes which will complete the **reverse engineering** of your product. You will use the information you have gathered during the process in the next unit when you design an enhancement or accessory for the Automoblox® vehicle.

Equipment

- Automoblox® vehicle

Resources

Product Disassembly

Product Disassembly Material Usage Chart

Product Disassembly Chart

Procedure

Identify each part of the Automoblox® vehicle by name, quantity, size, function, material, finish, interaction of parts, and general notes using the **Product Disassembly Chart** to record your work.

1. Create annotated pictorial sketches, as necessary, to communicate the internal operation of the product. Identify each component of the product on the sketches.
2. If you have not already done so, carefully measure each part using appropriate measuring devices.
3. If you have not already done so, create annotated sketches of each part including an isometric pictorial (at least) and orthographic projections (as necessary) to detail the part with dimensions, material, and other characteristics. You may simply need to add annotations to sketches that you have previously created.
4. Consider the choice of materials for the toy. For each part listed below, research the material

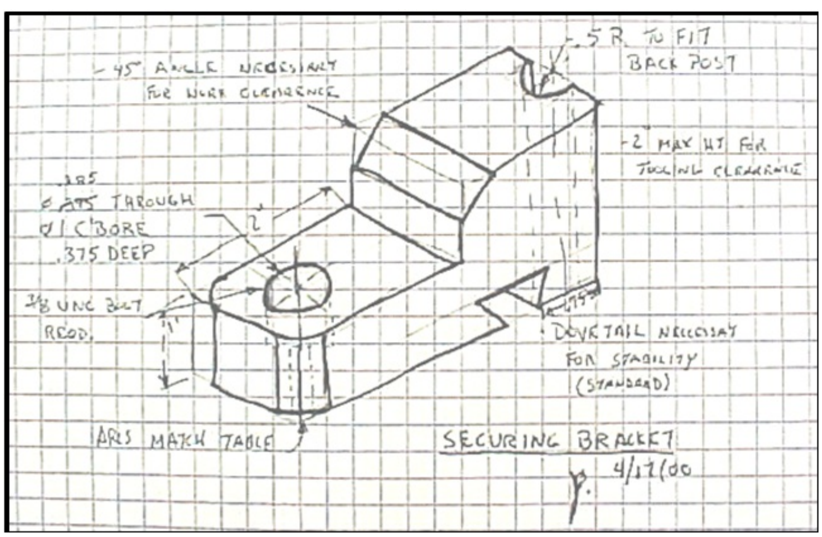
used. Then either justify the choice of material or present an alternate material that you believe would be more appropriate for the part. Include mass, workability (in manufacturing), durability, strength, transparency, frictional properties, flexibility, and resistance to fatigue (failure due to repetitive use) in entries.

Part	Material	Justification or Alternate
Windshield	Polycarbonate	
Tire	Rubber	
Body	Hardwood	
Connector	ABS	
Axle	Proprietary polycarbonate blend (which includes a lubricant)	

5. Complete the **Product Disassembly Chart** to detail important aspects of each part.

Sample Annotated Sketch of Part Documentation

The following is an example of a part documentation using an isometric sketch with annotated notes of fillet, hole location, materials, finish part location, and interactive parts.



Conclusion

1. Describe the process of Reverse Engineering.

2. Part of the mission of Automoblox® is to “offer a high quality building system that will delight and inspire children while fostering the development of important skills and learning foundations.” If given the opportunity, how would you improve the Automoblox® design (visually, functionally, or structurally) while furthering the mission of the company at minimal cost?

Product Disassembly

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 6.4 Product Disassembly Material Usage Chart

Ferrous Metals

Cast Iron	Heavy equipment, machine frames.
Carbon Steel 1000,4000,5000 series	Fasteners like rivets, nails, wire, chains and machine parts. Medium carbon steel is used for gears, shafts, tool shanks. High carbon steel is used for screwdrivers, cutting tools, blades, drills, springs, bearings and knives.
Stainless Steel	Sinks, cutlery, kitchen utensils, surgical tools.

Nonferrous Metals

Aluminum	Used in chemical and food processing, fasteners, structural members, aircraft structural components, hardware, car and truck wheels, decorative trim, awnings, siding, storage tanks, boats, missiles, truck and trailer assemblies.
Copper	Water pipes, electrical circuit boards, electrical wire, roofing.
Brass	Jewelry, water valves, boats, fittings, hardware, electrical sockets, bullet casings, ornaments.
Bronze	Pipe fitting, statues, coins, and bearings.
Tin Plate	Tin cans.

Ceramics

Abrasives	Belts, paper, grinding wheels, sand blasting.
Clay	Tiles, pottery, stoneware.
Glass	Windows, bottles, jars, cookware.
Porcelain	Bathroom fixtures, insulators for spark plugs, and other electrical applications.

Plastics

Acrylonitrile-Butadiene-Styrene (ABS)	Kitchenware, food processors, mixers, camera cases, appliances and tool housings, instrument panels, luggage, sporting goods, safety helmets, telephones, battery cases.
Cellulose Acetate (CA)	Photo films, magnetic recording films, handles and knobs, sheet packaging for products, brushes, combs, textiles.
Polyamide (PA) and Nylon	Bearings, gears, casings for power tools, packaging for foods such as bacon and cheese. Textiles, fishing lines, carpet, rollers and bearings.
Polycarbonate	Electrical components (due to heat resistance and insulation properties) glazing, eyewear lenses, CDs, bullet-proof glass, theft-proof packaging.
Polyethylene (PE)	Food and liquid containers, squeeze-type bottles, toys, garbage cans, milk crates, buckets, bowls.
Polypropylene	Medical equipment, syringes, containers with hinges, automobile ducts and trim, outdoor carpet, string, rope, nets, crates, and kitchenware.
Polymethyl Methacrylate Acrylic	Models, automobile taillights, aircraft canopies, windows, furniture, illuminated signs.
Polystyrene (PS)	Model kits, blister packaging, lenses, disposable plates, cups, utensils, sound and heat insulation, marine applications.
Polyvinyl Chloride (PVC)	Film for meat packaging, pipes, gutters, bottles, soles of shoes.
Styrene-Butadiene - Rubber	Sealants, adhesives, vibration mounting materials, footwear, tires, hoses, and latex paint.
Epoxy Resin	Adhesives, surface coatings, castings, electronic components.
Melamine-Formaldehyde	Coatings (Formica counter tops), electrical insulation.
Polyester Resins	Gears, pump impellers, lawn sprinklers, boat and car bumpers, shell chairs, and containers.
Silicones	Molds, finishes for glass and fabrics, adhesives, sealants and gaskets, Silly Putty, electrical insulation on wire and components.

Urea-Formaldehyde	Appliance parts such as pot handles and knobs.

Composites

Fiber Glass	Automobiles, trucks, aerospace industry, sporting goods such as archery bows, golf clubs, skis, bicycles, tennis rackets, circuit boards.
Plywood	Construction sheathing and furniture.
Sandwich Boards	Hollow-core doors, room dividers, display models, and furniture.

Hardwoods

Ash	Tool handles, ladders, laminating, and sports equipment.
Balsa	Commercial model making especially aero modeling industry, sandwich construction in aircraft and boats.
Beech	Chairs, toys, tool handles, turnings, steam bending
Elm	General furniture construction, garden furniture, and turned items.
Oak	General furniture construction and veneer plywood. Boat building, garden furniture, and posts.
Poplar	General furniture construction and model construction.
Walnut	Veneer and solid wood for furniture, handles such as gun stocks.
Cherry	Solid wood for furniture.
Maple	Solid wood for furniture.
Mahogany	Solid wood for furniture.
Basswood	Commercial model making, carving and pattern making.

Softwoods

Cedar	Outdoor furniture and siding, posts.
Fir/Hemlock	Residential construction.
Pine	Finish construction work, trim, furniture.

Material uses charts can be found in Chapter Eleven of the text listed below.
Hutchinson, J. & Karsnitz, J.R. (1997). *Design and problem solving in technology*. Glencoe McGraw-Hill.

Project 6.5

Product Reverse Engineering Presentation

Introduction

Displaying your work is an important aspect in many fields of engineering. How you arrive at your ideas, solutions, and conclusions must be communicated. Presenting your work is often part of a review process used by engineering firms to assess the design work of the team.

In this project you will complete several pre-activities that will enable you to collect the information needed to make a visual display of your work. It is imperative that you keep good notes and confer with other team members to make sure everyone has the same information. Team whose members are consistent in their understanding and who communicate with each other are more successful.

Your team will make a poster presentation of your findings. You will create either a physical tri-fold poster or an electronic poster to display your product and the information that you have gathered.

Equipment

- Product Disassembly Chart
- Product part sketches
- Product part 3D models
- Mass property analysis results
- Paper
- Computer with 3D CAD modeling software
- Disassembled consumer product
- (Optional) Tri-fold foam board

Resources

Project 6.5 Product Reverse Engineering Presentation Rubric

ADDITIONAL OPTIONAL Resources

Metal Fasteners, Joining, and Adhesives

[Plastic Fasteners, Welding, and Bonding]

[Wood Fasteners, Joinery, and Adhesives]

Procedure

In Activity 6.4 Structural Analysis Automoblox (or Activity 6.4b Product Disassembly), you and team mate(s) examined the structural characteristics of your consumer product. You created a chart that identified the parts and measurements, and you created and gathered other important information, such as isometric sketches for each part and mass property analysis results. You will document and present the findings that resulted from your **reverse engineering** process.

1. **If you have not already done so,** create an isometric sketch and quick orthographic projections of each part of your product. Note that these sketches are intended to provide a means to record dimensions and notes – they should be neat but not necessarily to scale. Measure each part then label and dimension the sketches. Be sure to annotate the sketches with all dimensions necessary to accurately model each part.
2. Create a 3D solid model of each part of your consumer product. Discuss with your team mate(s) who will model each part. Also, determine to what degree of accuracy you will dimension the parts in the CAD software, what file name you will use to save each part model, where the files will be saved, and what part modeling procedures you will use. Communicate with your partner throughout this assignment so that both of you abide by the standards identified.
3. Have your teacher check your progress and the modeling of your parts as you work.
4. Perform a mass property analysis of each part using the 3D modeling software.
5. Create a multi-view drawing for each part to include necessary orthographic projections and an isometric projection. You need only provide overall dimensions on the orthographic projections. You will create fully dimensioned part drawings in the **next** unit.
6. According to the instructions of your teacher, create a physical poster, an electronic poster, or a slide show presentation that includes the following:

    - Rendered isometric drawing with a title bar and notes showing the following information for each part of the product:

        - Name of Part
        - Overall Dimensions of Part
        - Material of Part
        - Density of Material
        - Volume

        - Surface Area
        - Mass

    - A photographic image of each part with a part label that corresponds to the drawing of each part
    - A photographic image of the complete consumer product.
    - A brief description of your findings during each phase of the reverse engineering process to include:
        - Visual Analysis. Include photographic images of various views and a description of the visual elements and principals of design.
        - Functional Analysis. Include an explanation of the operation of the product using photographic images or views of the part solid models where appropriate.
        - Structural Analysis. Include the Disassembly Chart.

7. **(Optional) Prepare a three-minute presentation that answers the following questions**:
    - What is your product?
    - What is your product's function?
    - What did you learn about the product's mass property analysis?

Conclusion

1. Is there another reason for product disassembly besides the modeling and electronic documentation of parts?
2. Explain the process used to complete a mass property analysis, and explain why this process is commonly used in industry.
3. Describe how important it is to have good interpersonal communication skills in a technically related field, such as engineering and design.

Project 6.5 Product Reverse Engineering Presentation Rubric

Resources

[Project 6.5 Produce Reverse Engineering Presentation Rubric]

Elements	5 Points	4 Points	3 Points	2 Points	1-0 Points
Content	The information included is accurate and completely addresses each component of the assigned topic or research question.	The information included adequately addresses each component of the assigned topic or research question.	The information included inadequately addresses the assigned topic or research question. The information included is sometimes inaccurate.	The information included does not address the assigned topic or research.	There is no evidence of accurate content information.
Delivery (Optional)	The presenter effectively and creatively delivers the information while staying on topic. The presenter appears relaxed and self-confident. Body language, voice modulation, and eye contact are effectively used.	The presenter adequately delivers the information while staying on topic. The presenter appears relaxed and self-confident. Body language, voice modulation, and eye contact are mostly appropriate.	The presenter delivers the information but does not stay on topic. The presenter appears tense or nervous. Body language, voice modulation, and eye contact are inappropriate or lacking.	The presenter omits important information and does not stay on topic. The presenter appears tense or nervous. Body language, voice modulation, and eye contact are inappropriate or lacking.	The presenter does not effectively deliver the necessary information.
Organization	The presentation content has been organized using a	The presentation content has been mostly organized using a logical	The presentation content has been organized using a somewhat	The presentation content is disorganized, unclear, or confusing.	The presentation does not include

	logical sequence. The presentation is engaging and effective.	sequence, but some flaws exist. The presentation is adequate.	logical sequence. The presentation is sometimes confusing.	The presentation is not adequate.	evidence of organization.
Preparation	Presentation indicates detailed preparation.	Presentation indicates adequate preparation.	Presentation indicates minimal preparation.	Presentation indicates a lack of preparation.	Presentation shows no evidence of preparation.
Visual Aids	Visual aids are of excellent quality, easy to read, and relevant to the presentation. Visuals of all required elements are present.	Visual aids are adequate, easy to read, and relevant to the presentation. Visuals of all required elements are present.	Visual aids are somewhat effective but may include vocabulary or spelling errors. Visuals of all required elements are present.	Visual aids lack effectiveness. Aids may lack appropriate content. Aids include multiple vocabulary or spelling errors. Visuals of all required elements are not present.	The presentation shows no evidence of visual aids.

Metal Fasteners, Joining, and Adhesives

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Plastic Fasteners, Welding, and Bonding

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Wood Fasteners, Joinery, and Adhesives

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Unit 7

Documentation Overview

Preface

Effective communication of ideas and information has been a goal of humans since the beginning of time. Technical communication became especially important during the Industrial Revolution as manufacturing changed from one-off fabrication of a product by an individual to large-scale mass production of parts and assemblies. To effectively communication technical information standards were developed to guide the technical documentation of parts. The drafting, dimensioning, and tolerancing standards are a design language that allow designers to clearly and accurately communicate their ideas about form and function to people all over the world, regardless of what language they speak.

Essential Questions

1. What quality makes a set of drawings sufficient to adequately represent the design intent?
2. Is it always necessary to indicate a tolerance for every dimension on a technical drawing? Justify your answer.
3. Stephen Covey includes Begin with the End in Mind as one of the seven habits listed in his book The 7 Habits of Highly Effective People. How can this habit make an engineer more effective?

Activity 7.1: More Dimensioning

Activity 7.2: Sectional Views

Activity 7.3 Tolerances

Activity 7.4: Assembly Models

Project 7.5 Engineering Documentation Automoblox

Activity 7.6: Design Brief Apollo 13

Problem 7.7: Automoblox Product Enhancement

PLTW ENGINEERING

Activity 7.1

More Dimensioning

Introduction

The basic standard dimensioning method established by the **American National Standards Institute** and the **American Society of Mechanical Engineers** (ANSI or ASME) is used to apply measurement to parts to enable clear communication. In order to communicate effectively, a person needs to understand the rules of the language and to follow the standards set down so that anyone who reads a dimensioned drawing will understand the intent and then be able to manufacture the part correctly.

In Unit 3 you were introduced to dimensioning and practiced applying dimensions to technical drawings. In this activity you will continue your practice by applying the appropriate dimensions and develop an understanding of the thought process that is used to create a clear and concise message regarding the size, form and featurs of an object or a product.

Equipment

- Computer with 3-D CAD solid modeling program
- **Dimensioning guidelines**

Resources

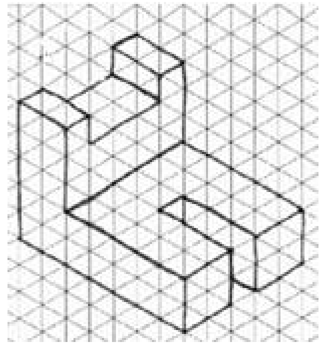
Dimensioning Standards

Activity 7.1.a More Dimensioning Part Pictorials

Procedure

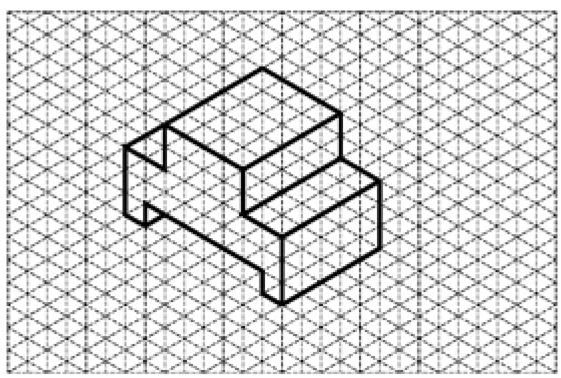
In this activity you will create **part drawings** of various parts that you have previously created. Your drawings should clearly document the parts such that a manufacturer can accurately create the parts. You may download and print 7.1.a.A More Dimensioning Part Pictorial.docx, if desired, to help you create your computer models.

1. Create a multi-view CAD part drawing of the following part that you modeled during Activity 5.6 Mass Property Analysis. The grid spacing is 0.25 inch. Use **datum dimensioning** and **aligned dimensioning**. Save the file and document its name and location (in the text box or another location per your teacher's instructions).

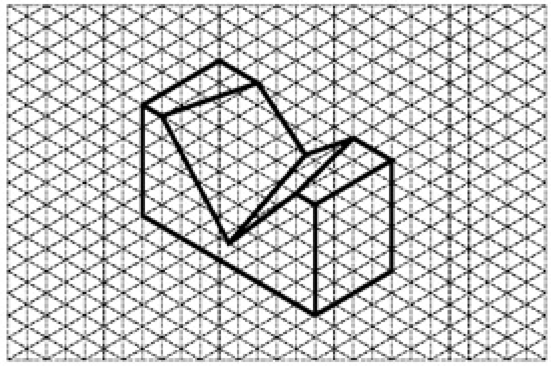


Note: To change the dimensioning style of a particular dimension, right click on the dimension, choose New Dimension Style, and then select the Text tab. In the Orientation area under Linear, select the Inline-Aligned choice in the angled and vertical dimension drop-down menus. Then depress the OK button. This will create a new dimensioning style (Default (ANSI)-01) and change the selected dimension style. To change the style for the other vertical dimensions, you must change the format for each dimension. To change the style for a dimension once you have created a new style, select the dimension to change. Open the Annotate tab in the ribbon. In the Format panel, change the Dimension style from the default to your new style. Note that if you create a new dimension style for every vertical dimension, you will add multiple styles to the styles library.

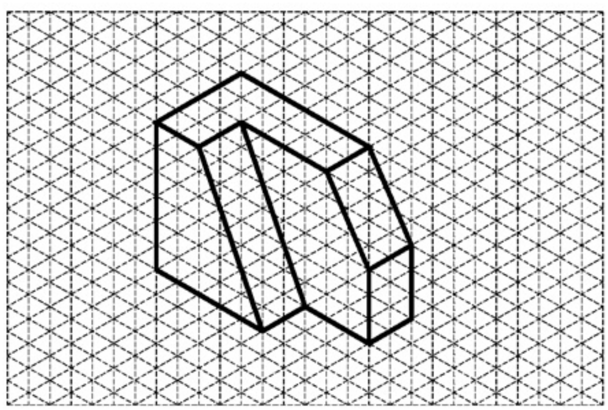
2. Create a multi-view CAD part drawing of the following part that you modeled as part of Activity 5.6 Mass Property Analysis. The grid spacing is 0.25 inch. Use **chain dimensioning** and **unidirectional dimensioning**. Save the file and document its name and location.



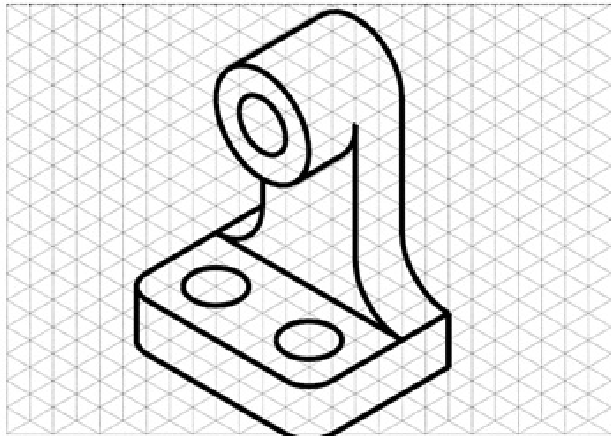
3. Create a multi-view CAD part drawing of the following part that you modeled as part of Activity 5.6 Mass Property Analysis. The grid spacing is 1 centimeter. Dimension the part drawing using the **coordinate method** for dimensioning angles and **datum dimensioning**. Save the drawing file and document its name and location.



4. Create a computer model of the part shown below using 3D solid modeling software. The grid spacing for the part is 0.25 inches. Then create a fully dimensioned part drawing to represent the part using the **angular method** to dimension the angles. Use the least number of views necessary to adequately detail the part for manufacturing. Save the part and the drawing files and document the file names and locations.



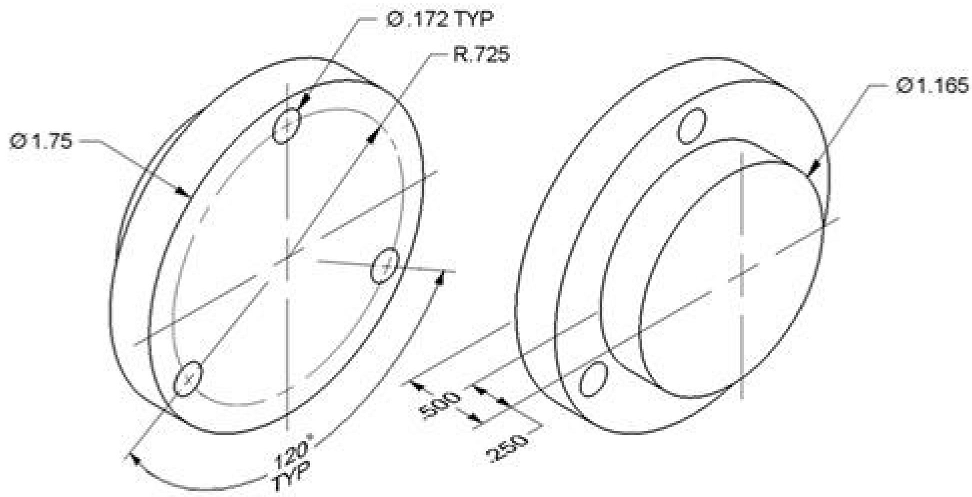
5. Create a computer model of the part shown below using 3D solid modeling software. The grid spacing for the part is 0.25 inches. Then create a fully dimensioned part drawing to represent the part using the appropriate dimensioning techniques for circles and arcs. Use **reference dimensions** (to indicate multiple occurrences) when circles or arcs are repeated. Assume that all holes cut completely through the part. Indicate this by adding the word “Thru” after the hole diameter in the dimension note. Save the part and the drawing file and document the file names and locations.



6. Print the part drawing created for the part in number 5 above. Exchange your drawing with another student. Using the **Dimensioning Guidelines** as a guide, make corrections to your partner's drawing using a red pen or pencil. Be sure to document which guideline is violated for each correction. Return the mark-up to your partner.

7. Based on the marked up drawing, make appropriate corrections to your part drawing created for the part in number 5 above. Save your files. Print your revised drawing. Next to each dimension, indicate whether the dimension is a **size dimension** (by writing the letter "S) or a **location dimension** (by writing the letter "L").

8. Create a computer model of the part shown below using 3D solid modeling software. Then create a fully dimensioned part drawing to represent the part using the appropriate dimensioning techniques. Dimension the cylindrical features on a view in which they **do not** appear as a circle (presented in the Dimensioning Standards.ppt). Note that TYP means "typical" and indicates that the dimension is typical for all similar features. However, in this case use a reference dimension that indicates the exact number of occurrences (using the "X" symbol) for each repeated feature. Assume that all holes cut completely through the part. Indicate this by adding the word "Thru" after the hole diameter in the dimension note. Save the part and the drawing files and document the file names and locations.



Conclusion

1. Why is it important to have your drawing dimensioned completely?
2. What is the difference between size dimensions and location dimensions?
3. What is the difference between chain dimensioning and datum dimensioning? Which method generally results in smaller dimensional deviation in manufactured parts?
4. What are the similarities and differences between communicating about an object or product part through a dimensioned drawing and through a written description?

Dimensioning Standards

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 7.2

Sectional Views

Introduction

Have you ever noticed that some objects have more going on inside than outside? Take an apple, for instance. How would you communicate the intricate details hidden inside an apple's core? You would have to cut the apple in half in order to show someone that there are spaces inside that house seeds. If you were to make a sketch of the apple, you could show the spaces and the seeds as hidden lines, but too many hidden lines can serve to confuse the issue. Sectional views are another alternative.

The main purpose of a sectional view is to effectively communicate internal details to enhance the viewer's understanding of the part. There are several different types of section views that engineers use to communicate internal geometry.

In this activity you will visualize and create section views, both by hand sketching and CAD of parts that have interior features not easily documented with orthogonal projections.

Your teacher should provide you with a printed version of this activity.

Equipment

- Computer with 3D CAD solid modeling software

Resources

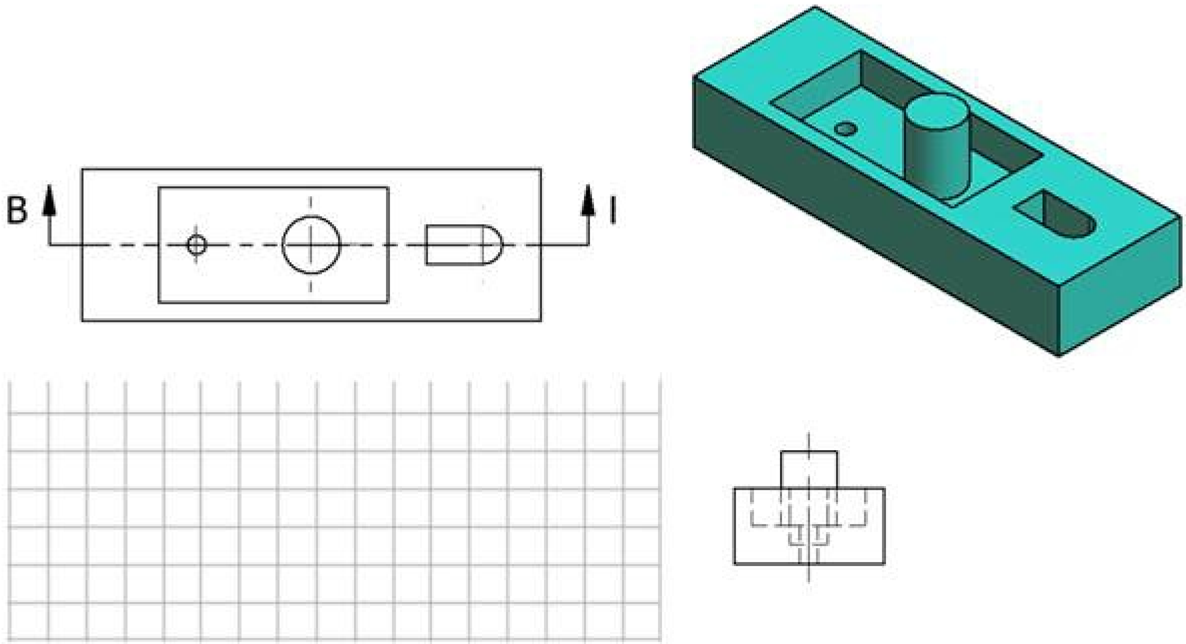
Alternate Views

Holes and Hole Notes

Procedure

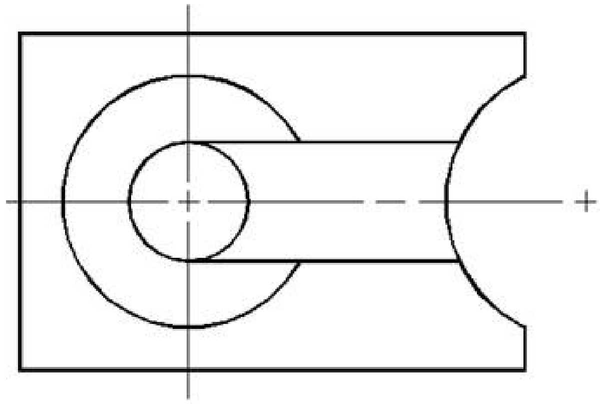
Your teacher should provide you with a printed version of this activity.

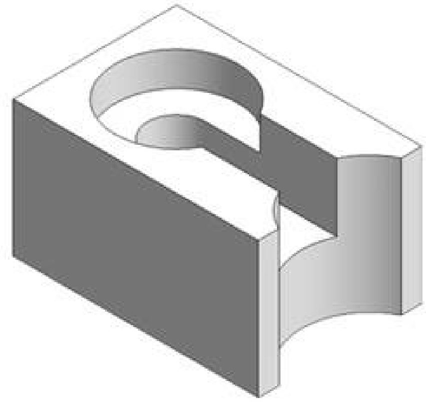
1. Study the figure below. Use points and construction lines to lay out a **section view** on the grid provided. The **cutting plane line** will tell you where the **full section** is cut. Delineate the visible edges of the sketch with object lines. Use **section lines** to indicate which surfaces were cut by the cutting plane. DO NOT ERASE YOUR POINTS AND CONSTRUCTION LINES.



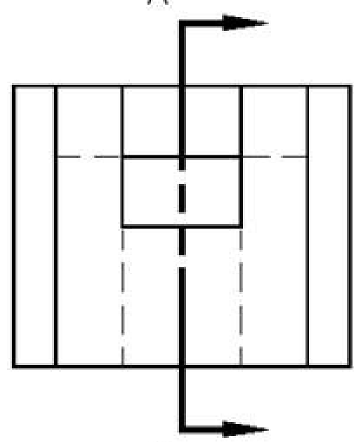
SECTION B-B

2. Study the figure below. Use points and construction lines to lay out a section view on the grid provided. The cutting plane line will tell you where the full section is cut. Delineate the visible edges of the sketch with object lines. Use section lines to indicate which surfaces were cut by the cutting plane. DO NOT ERASE YOUR POINTS AND CONSTRUCTION LINES.

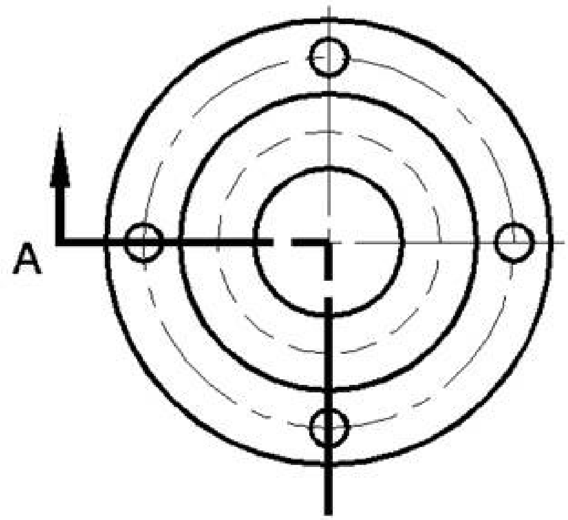


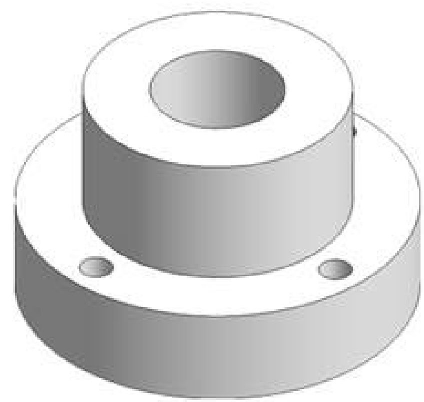


Section A-A

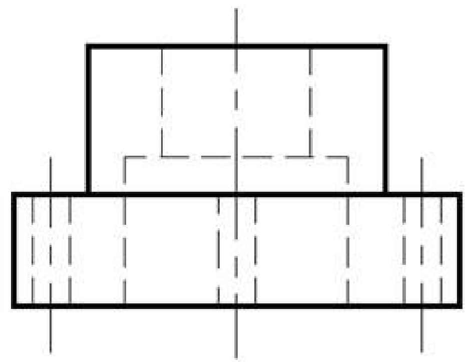


3. Study the figures below. Use points and construction lines to lay out a **half section** view of the object. The cutting plane line will tell you where the section occurs. Delineate the visible edges of the sketch with object lines. Use section lines to indicate which surfaces were cut by the cutting plane. DO NOT ERASE YOUR POINTS AND CONSTRUCTION LINES.

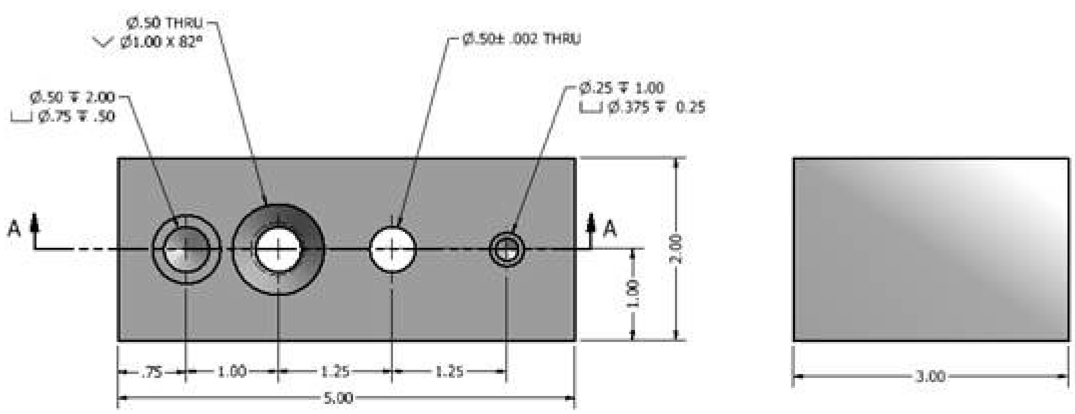




Section A-A



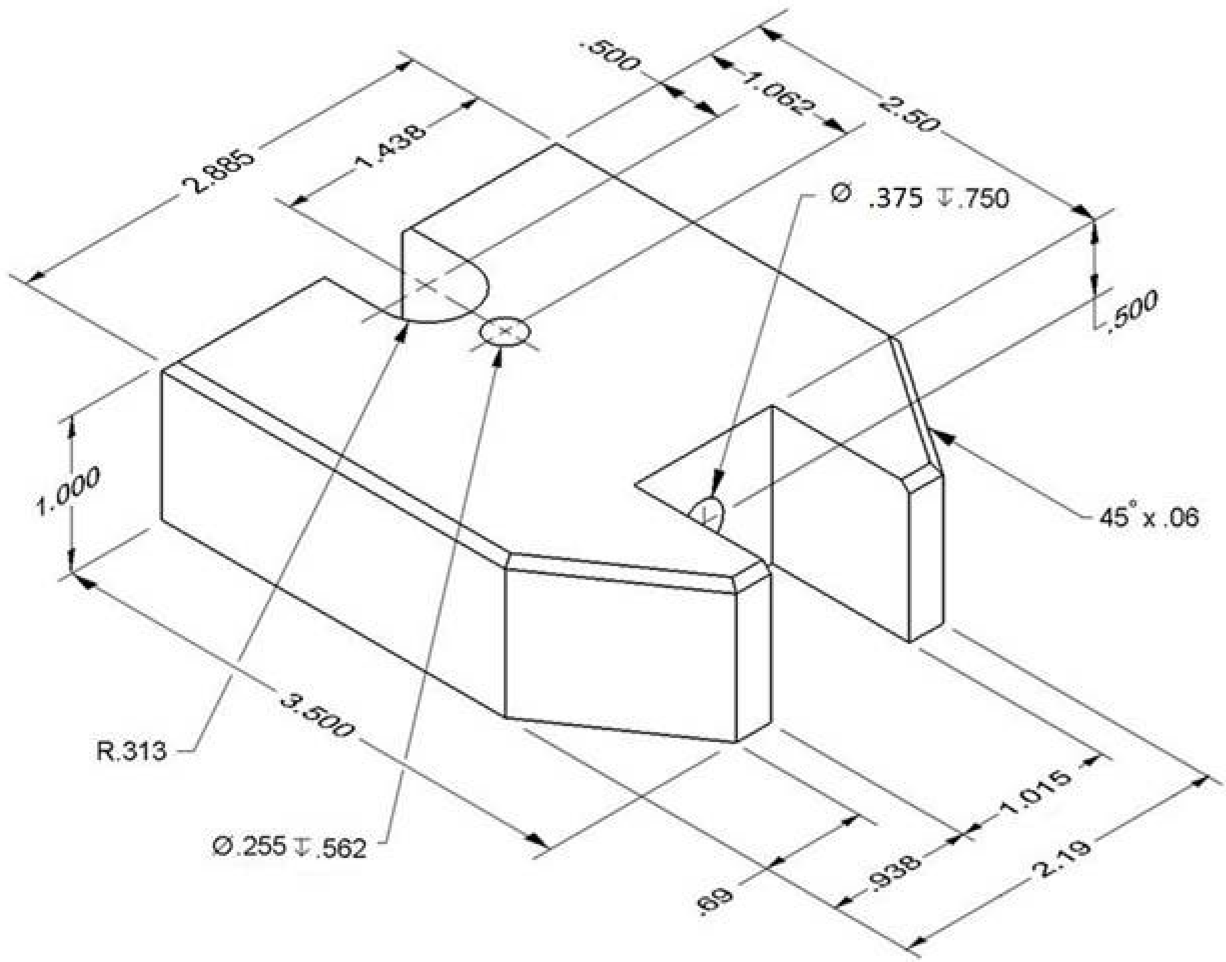
4. Cut and paste the front and right side views of the drill block below into your engineering notebook. Sketch an isometric view of the object in your notebook. Then create a **full scale** section view as indicated by the cutting plane line, but do not dimension the section view. Use appropriate object and section lines. Note that the section view will appear larger than the views below (which are not shown to scale).



5. Create a solid model of drill block in number 4 above. Then create a computer-generated fully dimensioned multi-view **part drawing** showing the front view and full section view (as indicated by the cutting plane line A-A). Save the files and document the file name and

location.

6. Make a three-view multi-view sketch of the part (arbor press base) illustrated below in your engineering notebook. You must decide which three views are most appropriate to show. One of these views must be a full section, showing the depth of the two holes. Include a cutting plane line to indicate the location of your section. Use section lines to indicate which surfaces were cut by the cutting plane. Leave space between all of the views for dimensions, but DO NOT DIMENSION THE SKETCH.

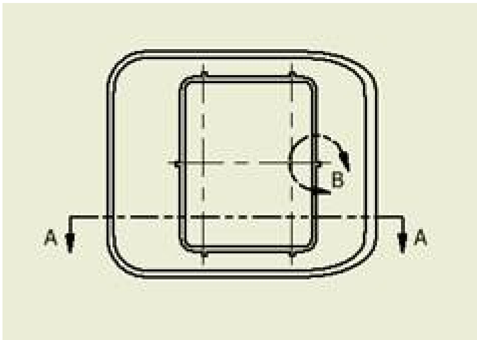


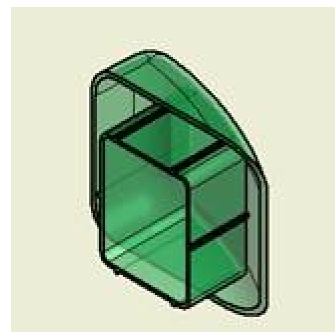
7. Create the object shown (arbor press base) in the drawing in number 6 above as a solid CAD model. Then create a fully dimensioned multi-view drawing to document the part, save the CAD files, and document the file names and locations .

Extend Your Learning

8. Open the part file Windshield*YourInitials*.ipt that you created in Activity 5.5 CAD Model Features. Use 3D modeling software to create a multi-view part drawing of the part such that the orthogonal projection shown below is the front view. Include a full section view as indicated by the cutting plane line with coordinate dimensions to specify the curvature of the top surface of the par according to the method presented in Dimensioning Standards.ppt. Also include a detail view as indicated by the detail mark to detail the ribs in the interior shell.

Note that you can dimension the curve on the drawing (**within the drawing file**) by placing a sketch on the section view, projecting the geometry of the curve, and placing points along the curve. It is best to space the points at a constant interval (say 0.5 in. horizontally).





Conclusion

1. What do the arrows on a cutting plane line indicate?
2. What is the difference between a half and a full section?
3. Are hidden lines shown in a section view?
4. What conventions are associated with section lines?

Alternate Views

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Holes and Hole Notes

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 7.3

Tolerances

Introduction

The term *variation* describes the degree to which an object or idea differs from others of the same type or from a standard. Examples of variation are everywhere you look. When you see yourself in the mirror, you notice the left side of your face is not exactly the same as the right side. There is a variation. Or, if you see identical twins, they are not exactly the same. Likewise, no two manufactured objects are the same. A degree of variation will exist.

The use of tolerance in engineering design provides a means by which variance can be controlled within acceptable limits so that parts of a product fit together in a way that allows the product to function properly. In the field of mathematics and science, **tolerances** are used regularly. You will see reference to an **allowance** or tolerance given in many settings. After completing this activity, take note when you see tolerances given in the media or on product labels.

In this activity you will analyze engineering drawings, identify tolerances, explain the meaning and purpose of those tolerances, and calculate allowances between mating parts of a product. You will also assess the need for tolerances in the manufacture of a consumer product and create **part drawings** to specify your recommended tolerances.

Equipment

- Highlighter

Resources

Tolerances

Activity 7.3 Tolerances Student Handout

Procedure

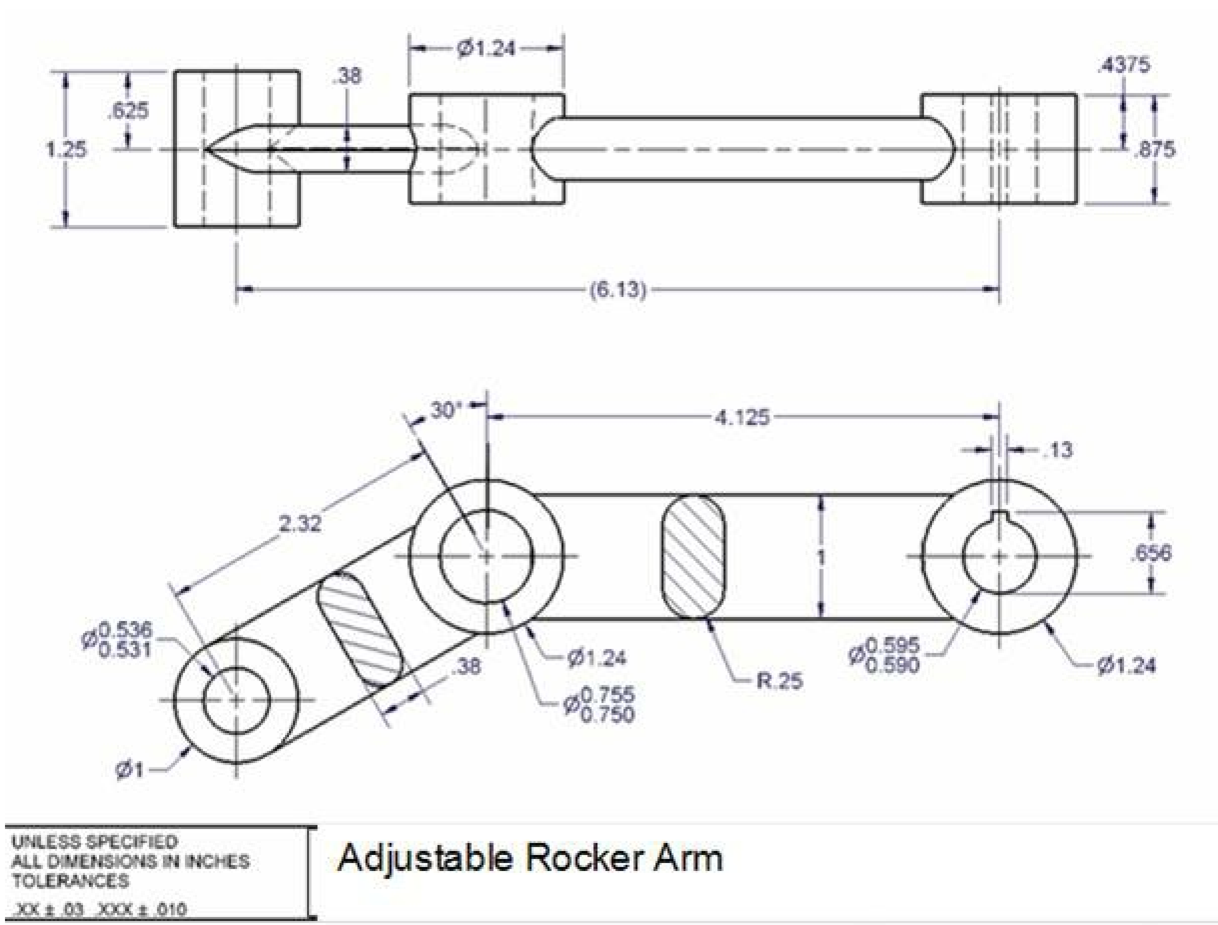
Download and print **7.3.A Tolerances Student Handout** to respond to the items below, as indicated.

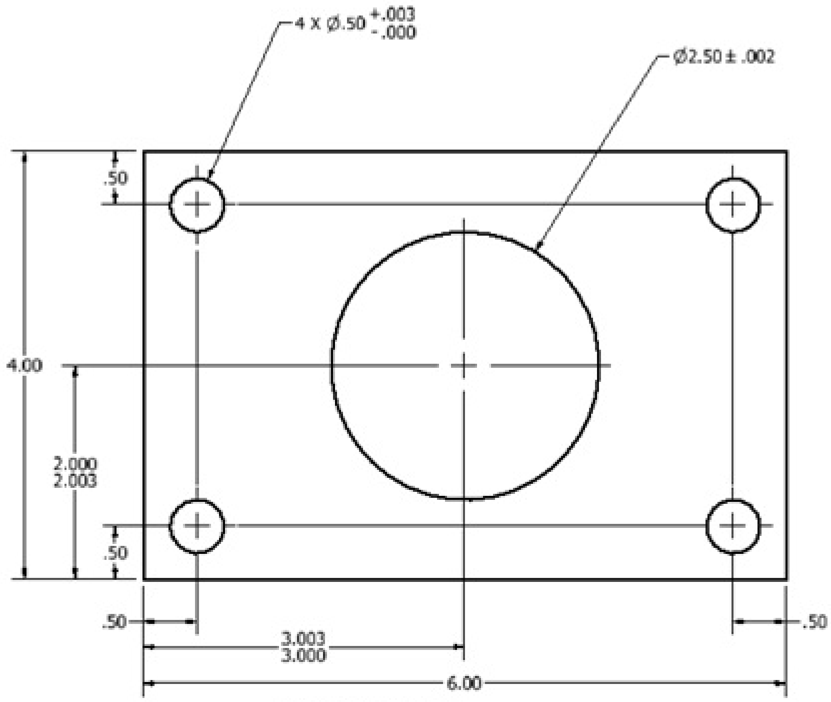
1. Study the drawings below to identify specified tolerances.
    - Highlight each dimension that has a tolerance associated with it using something like a

highlight marker. Note that duplicate drawings are provided in the Activity 7.3 Student Handout which may be cut out and inserted into your PLTW Engineering Notebook.

- Identify the type of tolerance in each highlighted example by labeling each tolerance dimension with one of the following: **limit dimensions**, unilateral tolerance, or **bilateral tolerance**.
- Label each identified tolerance with a separate letter, A through Z.
- Beginning on a new page in your engineering notebook for each part, record the letter of each tolerance identified on that part drawing, the type of tolerance, a short written phase that describes the dimensional variation allowed for that dimension, the *tolerance* (a number representing the total allowed dimensional variation), and an explanation as to why that particular dimension requires a tolerance. You may wish to duplicate the following table in your notebook to organize your notes.

Letter	Tolerance Type	Written Explanation	Tolerance	Why?



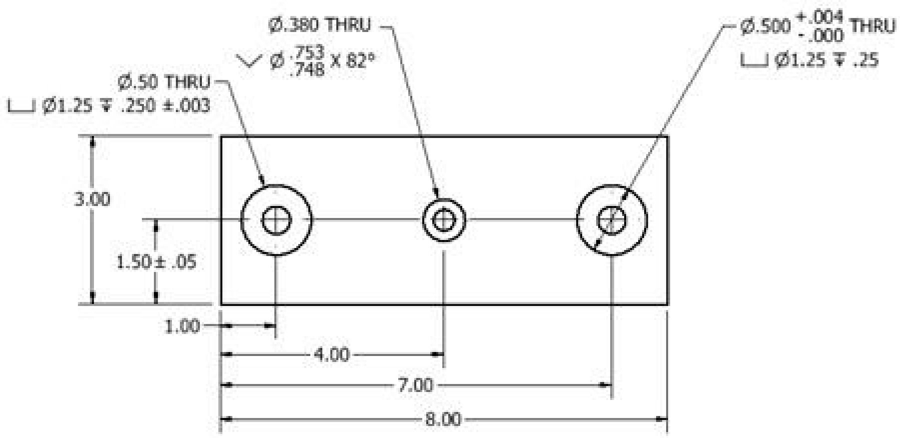


BASE PLATE

PLATE THICKNESS: 0.25

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES

DECIMALS:		ANGLES:
X.X	± 0.020	± 0.5°
X.XX	± 0.010	
X.XXX	± 0.005	



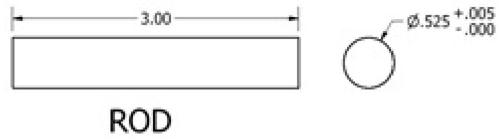
DRILL BLOCK

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES

DECIMALS:		ANGLES:
X.X	± 0.020	± 0.5°
X.XX	± 0.010	
X.XXX	± 0.005	

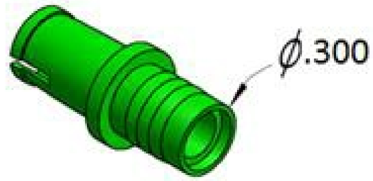
2. Consider the adjustable rocker arm represented in the drawing above. An axle is to pass through the smallest hole. The manufacturer is considering buying bar stock for the axle that is

manufactured according to the following drawing using the same general tolerances as those specified on the Rocker Arm Drawing. Answer the following questions and SHOW YOUR WORK.

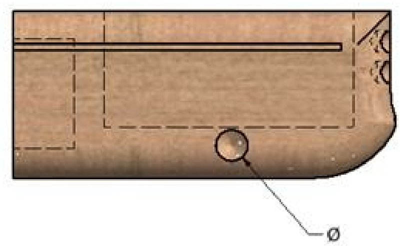


- What is the tolerance (the acceptable amount of dimensional variation) for the diameter of the rod?
- What is the tolerance for the rod length?
- Is the fit between the rod and the hole a **clearance fit**, **interference fit**, or **transition fit**? Explain your answer.
- What is the allowance between the rod and the smallest hole?
- If the design of the assembled machine requires that the rod is sized such that the actual clearance between the rod and the hole is never greater than 0.005 inches, will the current rod design meet the requirement? Explain.
- The machine specification requires that the rod is no longer than 3.025 inches and no shorter than 2.955 in.
    - Let L represent the actual length of the rod. Write the length constraint as a compound inequality.
    - Will the stock rods always meet the length constraint? Explain.
- If the stock rods do not always meet the machine specifications for rod length, how can the manufacturer alter the rod part drawing such that the rod length will always conform to the specifications?

3. Design a rod that will have an interference fit so that the allowance (the maximum **interference**) is 0.010 with the center hole in the Rocker Arm and the tolerance on the rod diameter is .002. Sketch a **section view** of your rod design below. Be sure to specify the tolerance in the diameter dimension of your design.
4. Consider the axle pin and the body of the Automoblox® vehicle (shown below). The axle is designed to remain inserted into the body of the vehicle so that it cannot be removed by a child.



- What type of fit would you recommend for the axle and body? Why?



- Assume an interference fit is used and that the ideal interference between the axle and the hole in the body of the vehicle is 0.005 inches. However, the interference can increase to as much as .010 without damage to the parts. With the addition of glue to help adhere the two pieces, an interference of .002 can be used successfully. Assume that the specified diameter of the axle is 0.300 inches as shown on the pictorial above. On the images above indicate your recommendation for:

    - the specific tolerance to the axle diameter dimension

    - the diameter and associated tolerance for the hole in the bed

- Calculate the following for the exterior axle pin diameter using your suggested dimension tolerances. SHOW YOUR WORK.

  Specified dimension: 0.300 inches

  Upper Limit: ________________

  Lower Limit: _______________

Tolerance: ________________

- Calculate the following for the diameter of the hole in the body using your dimensioned part drawing. SHOW YOUR WORK.

  Specified Dimension: _______________ (if applicable)

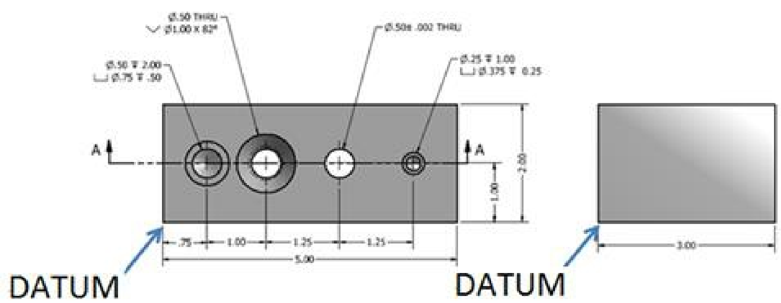
  Upper Limit: _______________

  Lower Limit: ______________

  Tolerance: ________________

- Calculate the allowance between the hole and the axle pin diameter based on your recommended dimensions and tolerances. SHOW YOUR WORK.

5. Open the drill block drawing file that you created in Activity 7.2 Sectional Views. The drill block drawing is shown below.



Edit the dimensions to show specific tolerances to the following dimensions. Note that instructions for including tolerance specifications on an Inventor drawing are given below.

- A bilateral (symmetric) tolerance of 0.10 inches for the overall length, width, and depth.
- Stack limit dimensions to locate the holes along the depth dimension (2 in.) such that the dimension can vary between the dimension given above and 0.03 inches larger.
- To better control the hole locations, use **datum dimensioning** for the dimensions along the long dimension (5 in.). Note that the **datum** location is shown on the drawing above.
- A unilateral (deviation) tolerance of +.003 inches for the **counterbore** diameter on the 0.25 inch diameter hole. Change the precision of the counterbore diameter to show three

digits to the right of the decimal place.

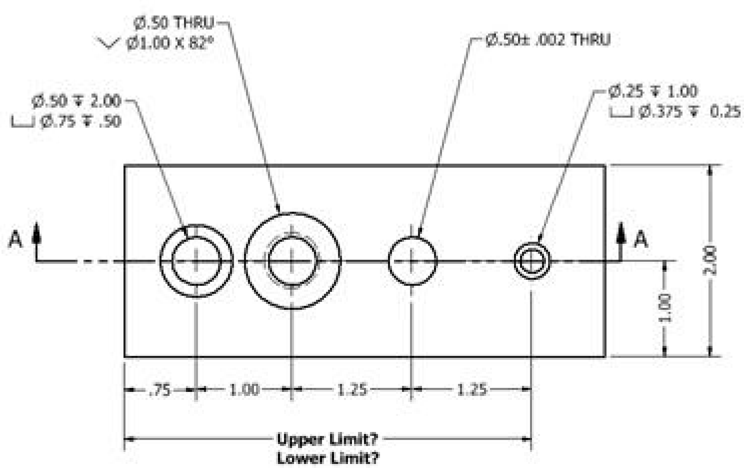
- A bilateral (symmetric) tolerance of 0.002 on the 0.50 inch diameter counter sunk hole.

Add the following General Tolerances notes to the drawing.

Linear Dimensions **X.X = ± .020** **X.XX = ± .010** **X.XXX = ± .005**	**Angles = ± .5°**

6. Consider the drill block from the question above.

   - If the **detail drawing** used **chain dimensioning** to locate the holes along the 5 in. dimension as shown in the image below (and therefore the tolerances are additive), what would be the upper and lower limit of the dimension from the left edge to the center of the 0.25 inch diameter hole on the right (see below) assuming general tolerances apply?



   - What is the upper and lower limit of the dimension from the left edge to the center of the 0.25 inch diameter hole in the drawing you created (using datum dimensioning) assuming general tolerances apply?

Showing Tolerances in Inventor

You can edit dimensions and include tolerances in both a part file and a drawing file. For now, we will simply add tolerances to the drawing (not the part). One option is to simply change the dimension text to include the tolerance. However, it is not possible to add stacked text. A better way to include a tolerance in a dimension or hole is to change the precision and tolerance of the dimension itself.

To include a tolerance in a dimension on a drawing in Inventor.

1. Select the dimension.
2. Right click and choose Edit.
3. Check the Override Displayed Value box.
4. Select the Tolerance Method.
5. Select the precision (number of decimal places).
6. Input the required upper/lower values.
7. Depress the OK button.

To include a tolerance in a hole note on a drawing in Inventor.

1. Select the hole note.
2. Right click and choose Edit Hole Note.
3. Depress the Precision and Tolerance button.
4. Uncheck the Use Global Precision box.
5. Depress the additional options arrow button (bottom right).
6. Select the precision (number of decimal places) for each dimension value using the drop-down menus.
7. Use the check boxes to choose the dimension to which you will add a tolerance. Choose the tolerance method and precision of the tolerance value(s).
8. Depress the OK button.

Conclusion

1. Why do engineers place tolerances on dimensions?
2. What are the three types of tolerances that appear on dimensioned drawings?
3. What is the difference between a general and a specific tolerance, and how can you tell the difference on a drawing?

Tolerances

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 7.4

Assembly Models

Introduction

Have you ever pieced together a jigsaw puzzle? The individual puzzle pieces have to be rotated and sometimes flipped around. A piece that makes up an outside edge of the puzzle must have its flat edge flush with other pieces of that side. Pieces that have exterior protrusions must be mated to their counterpart interior recesses. The process of putting a jigsaw puzzle together is very similar to building an assembly of components in a CAD program.

In this activity you will develop your knowledge of CAD assembly modeling by first practicing on a relatively simple mechanical device called a **Jack Lift**. This will include performing an interference analysis to determine if any unnecessary overlaps occur between the various components. Next, you will apply your skills to assemble an Automoblox® toy vehicle.

Resources

Documentation

Assembly Constraints

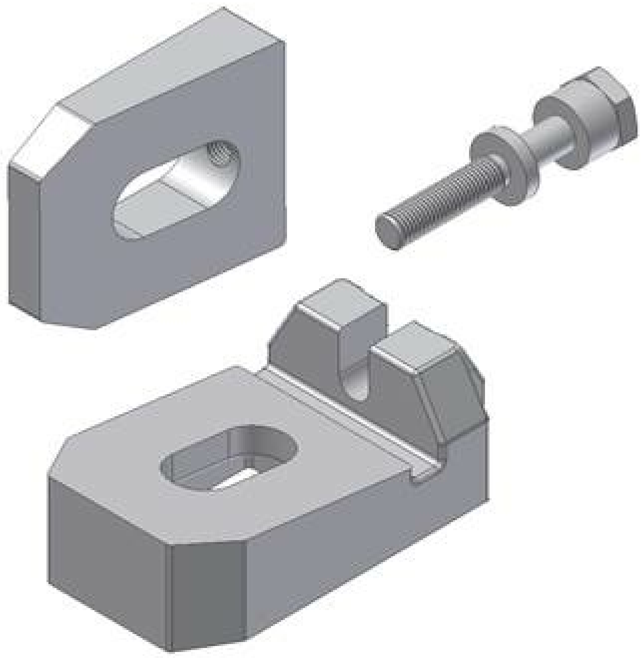
Jack LIft Inventor Files (.zip)

Procedure

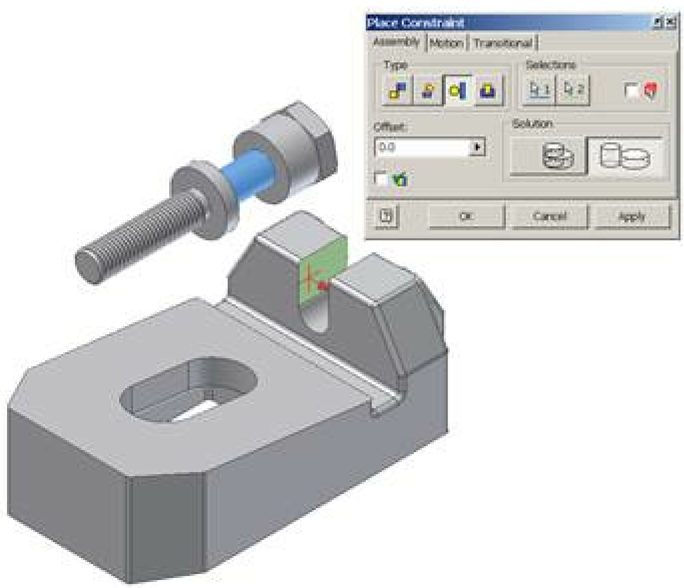
Part I.

Use Autodesk® Inventor modeling software to create an assembly of the Jack Lift. You will need access to the five parts of the machine: Base, Wedge, and Wedge Screw.

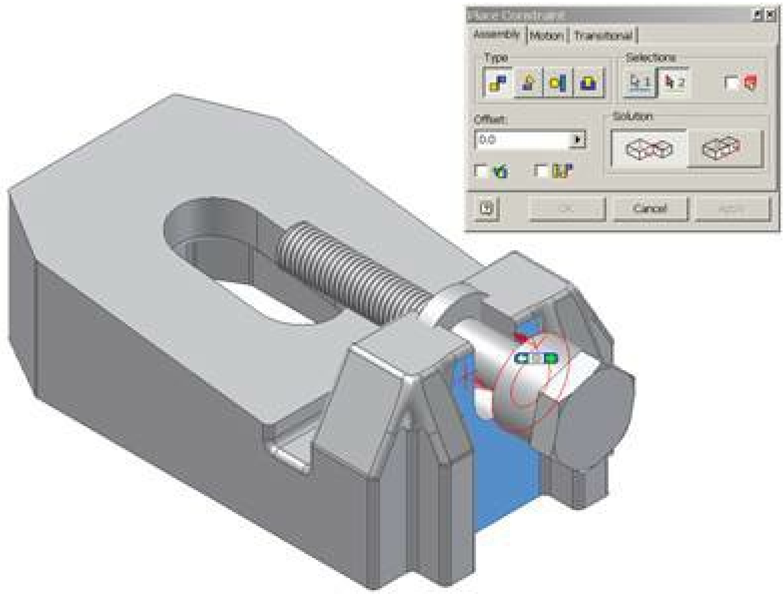
1. Create a new assembly file titled *Jack Lift* and save it to your student folder.
2. Place the Base component into the assembly. This component will be *grounded* and, therefore, locked in space. Next, place the Wedge and Wedge Screw components into the assembly.



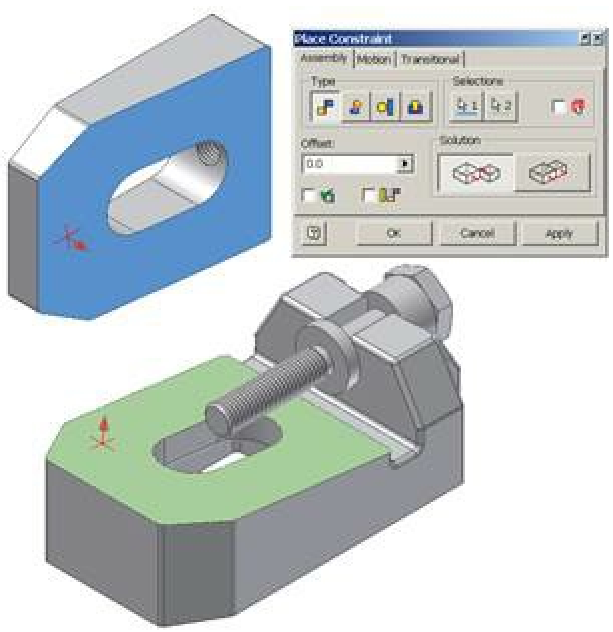
3. Apply a tangent constraint to the neck of the Wedge Screw component (selection shown in blue) and one of the vertical walls of the open slot on the Base component (selection shown in green).



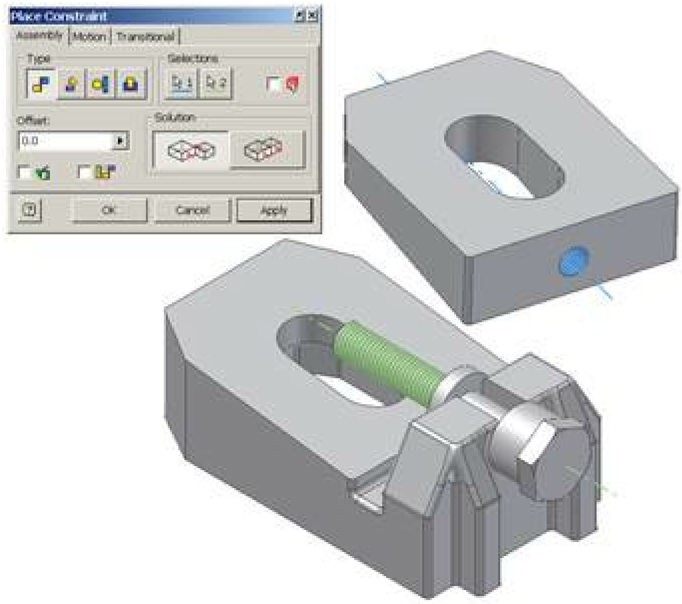
4. Apply a mate constraint to the back face of the Base component (shown in blue) and the circular face on the underside of the Wedge Screw's head.



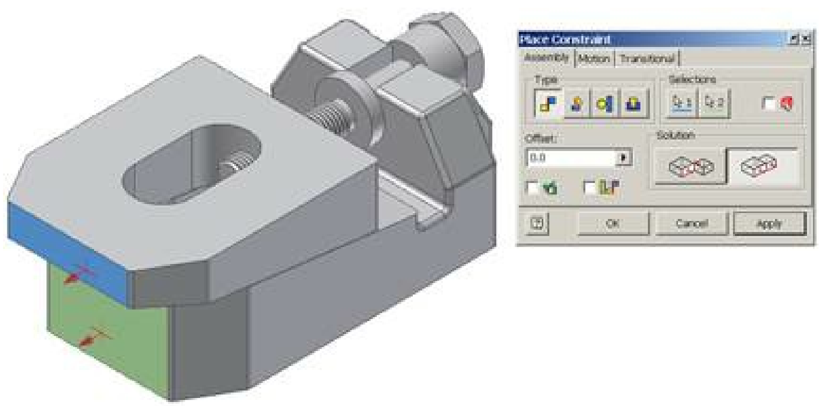
5. Apply a mate constraint to the bottom face of the Wedge component (shown in blue) and the top angled face on the Base component (shown in green).



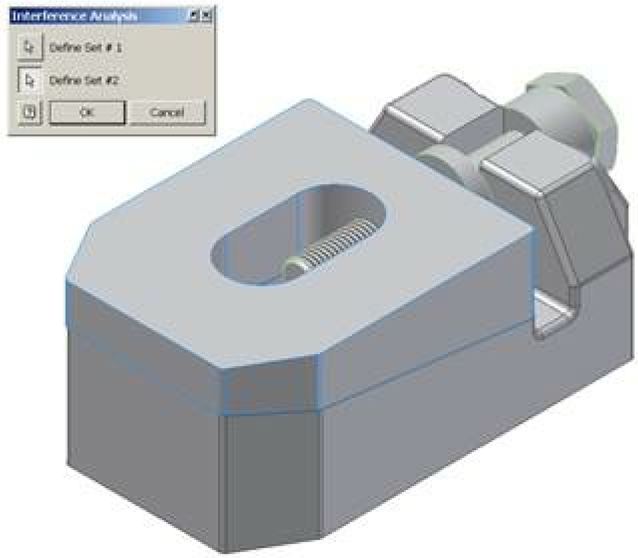
6. Apply a mate constraint between the center axis of the threaded hole in the Wedge component (shown in blue) and the center axis of the Wedge Screw component (shown in green).



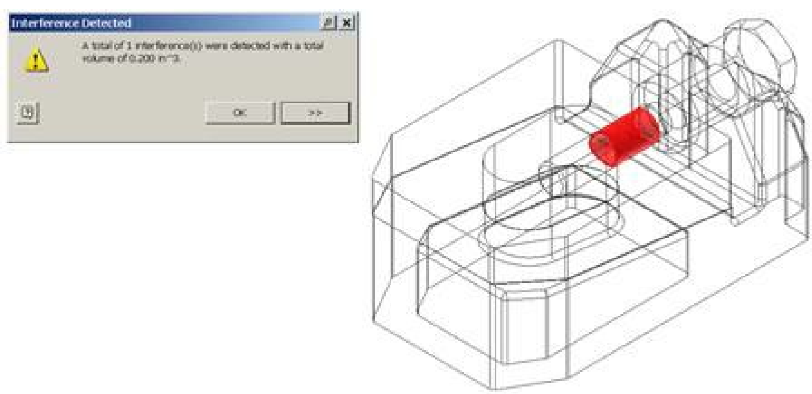
7. Apply a flush constraint to the front faces of the Wedge component (shown in blue) and the front face of the Base component (shown in green).



8. Perform an interference analysis between the Wedge and Wedge Screw components.



9. Revert to wireframe screen mode and take a screen capture of the image. Print the image and affix it to a page in your engineering notebook. Make an entry in your notebook that speculates as to why **interference** exists between these two components.



10. Save the Jack Lift assembly file.

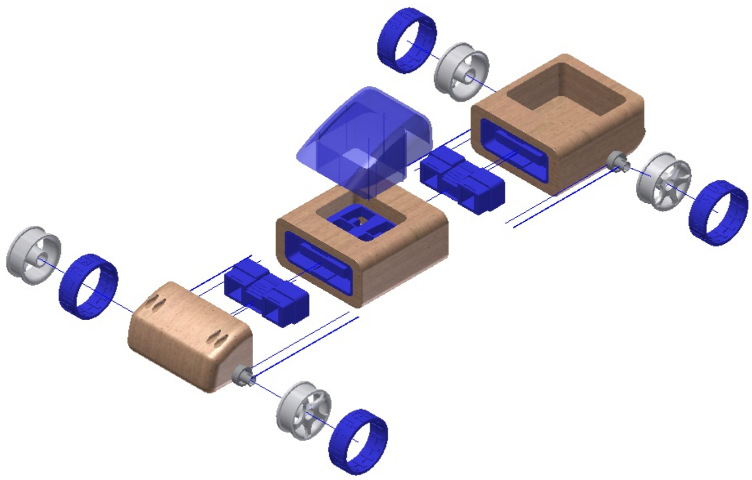
Part II.

Use the CAD modeling software to create an assembly of the Automoblox® T9 vehicle (or another Automoblox® model). Use subassemblies as detailed below for parts that are to be permanently connected.

The following should be assembled separately and used as subassemblies in the final assembly drawing.

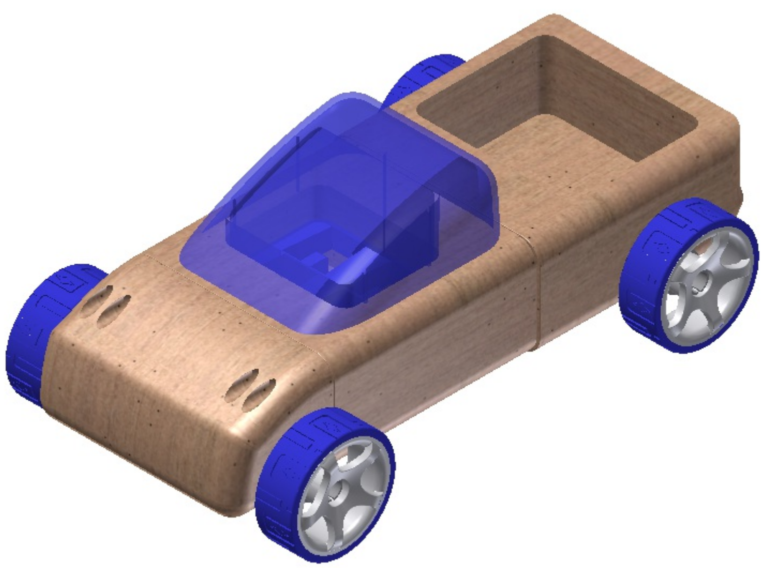
- Subassembly 1: T9 Bed, (2) T9 Axles, and T9 One Block Socket

- Subassembly 2: T9 Front, (2) T9 Axles, and T9 Two Block Socket
- Subassembly 3: T9 Passenger Section, T9 Two Block Socket, T9 One Block Socket, and T9 Passenger Base



Sub Assembly of T9 Automoblox

Use the image of the assembled vehicle below to help you assemble the vehicle correctly. Save your assembly files (for the complete vehicle and for the subassemblies).



Assembly of T9 Automoblox®

Take a screen capture of each assembled subassembly and the complete assembly. Print each image and affix it to a page in your engineering notebook. Label each subassembly and the assembly.

Conclusion

1. What is an offset and how is it used?
2. What is the difference between a mate and flush constraint?
3. What constraint would you use to place a pin inside a hole? Which degrees of freedom does this constraint remove? Use a sketch to define the degrees of freedom.
4. Describe a situation in which you would use a tangent constraint. Which degrees of freedom does a tangent constraint remove? Use a sketch to define the degrees of freedom.
5. What is a subassembly? How is it useful in the assembly of a complex product that involves multiple parts?

Documentation

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Assembly Constraints

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Engineering Documentation Automoblox®

Introduction

The reverse engineering process involves the study of an object's visual, functional, and structural qualities. Though it does not imply redesign, reverse engineering is often a tool that is used to aid in the redesign of an object so that its performance may be improved. Other reasons for performing reverse engineering include reducing an object's negative environmental impacts, maximizing manufacturing techniques through the substitution of more appropriate materials, discovering how a competitor's product works, and increasing a company's profit margin.

In this project you and your team will continue your effort as engineers from a novelty toy company working to design accessories or enhancements to the existing Automoblox® vehicles. Remember, the design intent is that the accessories or enhancements can be purchased separately but will work with the existing toys. Your team has already completed the task of reverse engineering one of the Automoblox® vehicles and reporting your findings (in Activity 6.5). In this project you will detail the Automoblox® vehicle with technical drawings in order to provide detailed information necessary to design accessories and enhancements that will properly connect with the toy. In addition, you will begin the process of assembling a portfolio to present your reverse-engineering efforts and technical documentation of the product. You will add to this portfolio later to document your design of accessories and enhancements to the product. Until then, the Portfolio will provide the product information on which you will base your later product design.

Equipment

- Product Disassembly Chart
- Automoblox® vehicle

Procedure

Create technical drawings to document the Automoblox® vehicle. Then assemble a Portfolio detailing the results of your work. At this time the Portfolio should include the following:

1. Title Page
2. Purpose of the Reverse-Engineering Project (reread the Introduction of this activity)
3. Technical documentation (a set of **working drawings**) of the product to detail the parts and assembly of your Automoblox® vehicle. This should include:

- A dimensioned **part drawing** for each part of the Automoblox® vehicle.
- A **ballooned** isometric view of each subassembly and other orthographic and/or **section view(s)** of the subassemblies as needed to fully describe the sub-assemblies.
- A ballooned isometric view of the complete assembly (with all parts assembled together) and orthographic and/or section view(s) of the assembly as needed to fully describe the assembly.
- A **parts list** giving part names, material, density, volume, surface area, and mass.
- **General notes**, including general tolerances.

4. Documentation detailing the reverse engineering process and findings as presented in Project 6.5 Product Reverse Engineering Presentation.

    - Visual Analysis
    - Functional Analysis
    - Structural Analysis

5. Conclusions and Recommendations. Offer suggestions as to how the design of the existing toy vehicle could be improved or the cost of manufacture reduced. Note that this pertains only to improving the existing design and not to the design of accessories or enhancements. The design of accessories and enhancements will be completed in a later activity.

Conclusion

1. Why is detailed documentation important in the design of a product?
2. What is the purpose of engineering documentation in reverse engineering?
3. Do you agree with the Automoblox® claim that their vehicles provide opportunities for children to practice creative problems solving, gross and fine motor skills, and visuospatial processing? Justify your answer with specific examples on how each is accomplished, or not.

PLTW ENGINEERING

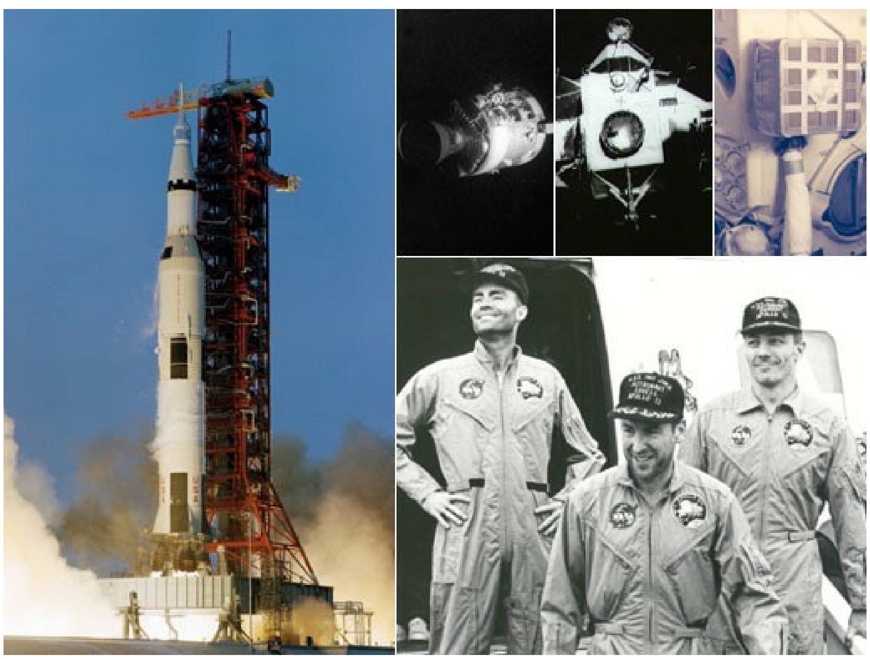
Activity 7.6

Design Brief (Apollo 13)

Introduction

“Houston, we’ve had a problem” was the first indication that the Apollo 13 mission was in danger. This was said after an explosion destroyed crucial components aboard the spacecraft. On Saturday, April 11th, 1970, NASA engineers and astronauts faced one of their most difficult challenges: safely bring home three astronauts onboard a critically damaged space craft. NASA engineers and technologists faced a difficult design challenge based on limited resources onboard a crippled spacecraft.

In this activity you will create a design brief based on the events that day as dramatized in the video Apollo 13.



Equipment

- Apollo 13 DVD or Blu-ray

Resources

Design Brief Example

[Design Criteria and Constraints]

[Writing a Problem Statement]

Procedure

1. Watch the following segments of the Apollo 13 video.
    - Chapter 6 (Houston, We Have a Problem) from 0:49:39 to 0:54:46.
    - Chapter 12 (The CO_2 Problem) from 1:15:08 to 1:16:25.
2. Write a design brief using the format shown.
3. As a follow-up to the solution, your teacher may present Chapter 12 (The CO Problem) from 1:28:08 to 1:33:00.

Design Brief

Client:	______________________
Designer:	______________________
Problem Statement:	______________________ ______________________ ______________________ ______________________
Design Statement:	______________________ ______________________ ______________________ ______________________
Design Criteria:	1. ______________________ 2. ______________________ 3. ______________________ 4. ______________________ 5. ______________________ 6. ______________________

Design Constraints:	1. ______________________ 2. ______________________ 3. ______________________ 4. ______________________ 5. ______________________

Conclusion

1. How does the short deadline to solve the problem affect the design solution?
2. Explain the importance of a design brief for this problem.

Activity 7.6a Design Brief Example

Client:	Playskool™
Target Consumer:	Parents (purchasers) and Infants or Toddlers (end users)
Problem Statement:	Most parents expect their children to be able to walk, talk, sing, count, and recite their ABCs before they enter elementary school. A growing demand is being placed on infants and toddlers to develop their cognitive abilities and fine motor skills during the first three years of life.
Design Statement:	Design, market, test, and mass-produce a multi-use educational toy that serves as an infant activity center and a toddler's walking aid.
Design Criteria:	• Safe for child under three years of age • Easy to assemble • Visually stimulating to a child • Contains multiple shapes, numbers, and letters • Plays music • Meets all health and safety codes • Easy to clean • Easy to transform between infant and toddler mode • Weighs less than 4 lbs • Retail cost under $20
Design Constraints:	• Design completed in one week • Parts made primarily from injection molding

Design Criteria and Constraints

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Writing a Problem Statement

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Problem 7.7

Product Enhancement

Introduction

Reverse engineering is performed for many different reasons – to document a product design, to understand important aspects of a product for academic reasons or to design for interoperability, to investigate the reasons for the success or failure of a device or system, or to improve or redesign the product.

In this activity your team will design an enhancement or accessory to an Automoblox® toy vehicle that can be sold separately or that can be marketed to Automoblox® as an additional line of products. The accessory or enhancement must somehow attach to the vehicle and can include anything that would appeal to the target market.

Equipment

- Digital camera
- Graph paper
- All related CAD models from your reverse-engineered product
- CAD solid modeling software
- Internet access
- Library access
- Printer

Resources

Decision Matrix

Technical Writing Elements and Standards

Problem 7.7 Automoblox Product Enhancement Checklists and Rubric

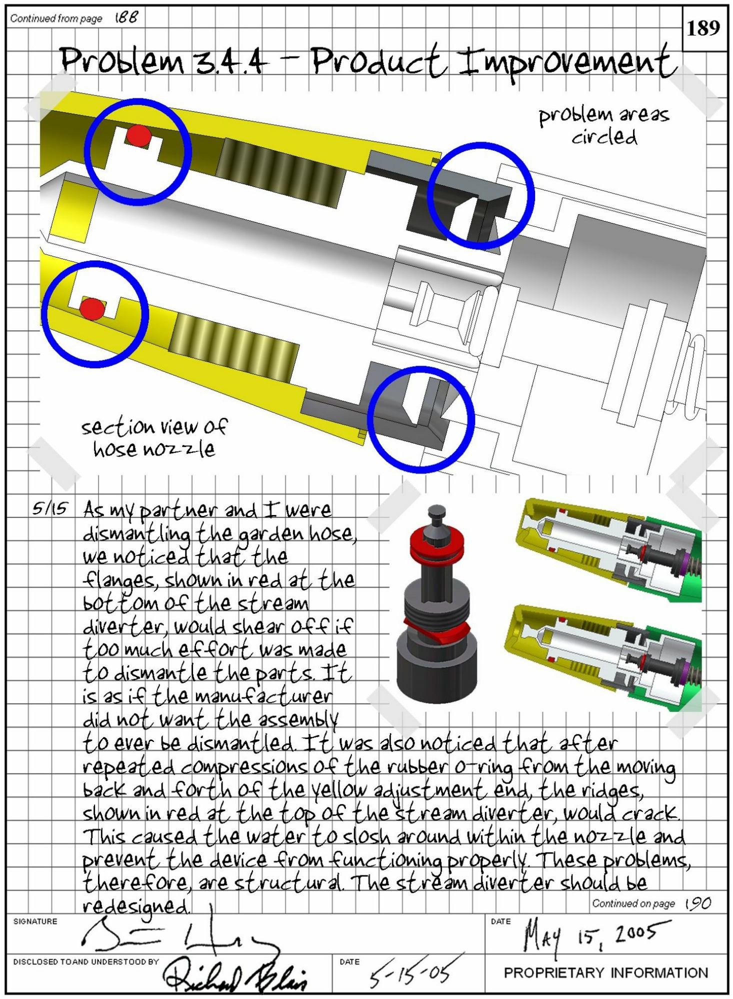
7.7.B.SR Decision Matrix Template Word.docx

7.7.B.SR Design Brief Template.docx

7.7.P.SR Decision Matrix Template Excel.xlsx

Procedure

1. As a team, identify an enhancement to the Automoblox vehicle that you have reverse-engineered. Begin the process by recording any visual, structural, or functional design issues in your engineering notebook.



2. As a team write a design brief that explains the problem, identifies the solution expectations and the degree to which that solution will be realized, and lists any appropriate project constraints.

3. Generate enhancement ideas through brainstorming. Be sure to document every idea. Then conduct whatever research may be necessary and expand on the ideas. Narrow down the number of plausible ideas to a few of the most promising ideas.

4. As a team, develop and use a **decision matrix** to help select a solution path to pursue.

5. Once an idea has been selected, develop it into a solution using a 3D CAD solid modeling program. Your team will produce technical drawings to document your design.

6. (Optional) If possible, create a prototype of your design solution as directed by your instructor.

7. Add documentation of your design process and final solution to your project portfolio (begun in Activity 7.5). Be sure to review the design process flow chart. Include a discussion and documentation of **each** step of your design process. Note when you revisited a step or iterated on your design.

Conclusion

1. What factors must be considered when changing or enhancing a design?
2. Why it is important to document the brainstorming process?
3. What is the purpose of sketching your ideas?

Decision Matrix

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Technical Writing Elements and Standards

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Problem 7.7 Automoblox Product Enhancement Checklists and Rubric

Resources

[Problem 7.7 Automoblox Product Enhancement Checklists and Rubric]

Interim Reviews and Assessment Checklists

Review Content	Needs Revision	Reviewer name, date	Reviewer Comments	Approved
CAD 3D solid model • All necessary dimensional and geometric constraints are properly applied to constrain sketch geometry. That is, CAD sketches cannot be altered by selecting and dragging elements. • Appropriate material assigned to 3D solid model. • The 3D solid model is sufficiently developed to provide acceptable estimates of physical properties. That is, the 3D model does not have to be a perfect representation of the final design, but an effective “model” of the design for the intended purpose.				
Engineering Calculations – Mathematical Modeling • Correct physical properties (as determined from 3D solid model) are used in calculations. • Mathematical model(s) developed to define tolerances to support final design solution. All variables defined.. • Calculations are documented step by step so that a person unfamiliar with the work can understand the solution process.				

• Calculations and results are mathematically correct. • Appropriate units and unit conversion factors (when necessary) are documented throughout the calculations and in results.				
Technical Drawing(s) • All parts necessary to demonstrate design intent are included. • Front view was selected based on accepted practice. • An isometric view and an appropriate number of orthographic views are presented according to accepted practice. • Orthographic views are properly oriented. • A parts list specifies material and important physical properties including density, weight and center of gravity of components. • Material(s) and important physical properties including density, weight and center of gravity of components are specified. • Dimensions are included to fully define the solution, including appropriate tolerances. • Dimensions are placed per dimensioning guidelines and accepted practice. • The drawing provides evidence that the design meets all design criteria.				

Peer Review Rubric – The following criteria will be assessed when you review your peer's work.

Criteria	**Basic**	**Proficient**	**Advanced**
	Expends little effort to provide helpful	Carefully and thoughtfully assesses a	Carefully and thoughtfully assesses peer's work and asks for clarification from the peer to fully understand thinking and process, when

Peer Review and Feedback LO: Analyze and evaluate the work of others to provide helpful and effective feedback.	feedback.	peer's work.	appropriate.
	Provides feedback that is often inaccurate or not specific, or is not actionable.	Provides effective and accurate feedback that is specific and actionable.	Provides effective feedback that is specific and actionable and refers to a learning objective or goal. Amount and detail of feedback is user friendly – not overwhelming and not too technical, but substantial enough to provide specific guidance for significant improvement.
	Sometimes shares feedback in a professional manner.	Usually provides feedback in a professional manner.	Always provides feedback in a professional manner.

Through Project Performance – The following criteria will be assessed at any time and/or at multiple stages of the design process.

Criteria	Basic	Proficient	Advanced
Engineering Mindset LO: Persevere to solve a problem or achieve a goal. LO: Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal. LO: Demonstrate flexibility and adaptability to change.	Frequently off task.	Often uses time wisely.	Plans and uses time efficiently.
	Frequently requires direct instructions before working on the project.	Often demonstrates self-direction with little direct oversight.	Always demonstrates independent thinking and self-direction in order to accomplish a goal.
	Inflexible and resists making changes.	Usually demonstrates flexibility and is adaptable to change.	Always demonstrates flexibility and adaptability to change. Can explain the benefits to changing direction in the design process.
	Gives up easily.	Usually perseveres to solve a problem, but sometimes requires intervention.	Perseveres to solve problems or achieve the goal until the problem is solved.
	Does not consider or rejects effective feedback from peers or teacher without	Often uses effective feedback from others to inform performance.	Critically analyzes feedback and strategically implements feedback that will improve work. Provides appropriate justification

	justification.		when feedback is not implemented.
CAD modeling process LO: Create solid part model using 3D computer-aided design (CAD) to represent an object. An *inefficient* CAD model includes: • Unconsumed sketches • Unconstrained sketch geometry • Unused sketch components (stray lines, shapes, center points, etc.) that serve no purpose • Hidden or non-visible features • Unnecessary work features • Multiple sketches to create features that could be created from a single sketch. Example, three separate sketches used to model three separate holes on the same surface. • Using additive methods when subtractive methods would result in fewer features in the feature tree (as shown in part Browser) or vice versa.	Produces an *inefficient* 3D solid model to accurate size that resembles the design intent.	Produces a relatively efficient 3D solid model in enough detail to demonstrate design intent.	Produces a *highly efficient* 3D solid model. Purposely employs strategies to limit number of features in project browser.
	Produces a 3D solid model that is ***not*** accurate enough to estimate physical properties of an object to acceptable accuracy.	Produces a 3D solid model to successfully estimate physical properties of an object to acceptable accuracy.	
	Can ***not*** identify ways to improve an inefficient CAD model	Can identify inefficiencies in a CAD model.	Can identify specific ways to improve the efficiency of a CAD model.
	Can not distinguish between additive and subtractive methods in 3D solid modeling.	Can distinguish between additive and subtractive methods in a 3D model.	Can explain and justify the efficiency of a solid model with respect to the use of additive and subtractive methods.

Project Submittal – The following criteria assessed based on the project submittal(s).

Criteria	**Basic**	**Proficient**	**Advanced**

Design Process – Define the Problem LO: Synthesize an ill-formed problem into a meaningful, well-defined problem. LO: Collect, analyze, and interpret information relevant to the problem or opportunity at hand to support engineering decisions.	Presents minimal research that is directly related to the problem.	*Documented* research directly related to the problem is presented. (Key deer, African elephant, and human dimensions, as appropriate).	Comprehensive *documented* research that is directly related to the problem is presented. Uses research to inform problem statement.
	Missing one or more elements of the design brief (problem statement, design statement, design criteria, design constraints). Information provided is insufficient to define a successful solution. Design criteria/constraints are vague and unmeasurable.	All elements of the design brief are clearly presented. Information is sufficient to define a successful solution. Includes visual, functional, and structural design requirements with realistic criteria, by which solution alternatives can be compared.	Consideration is given to economic, environmental, social, political, ethical, health and safety, manufacturability, technical feasibility and sustainability considerations, as appropriate.
Design Process – Problem solving	Documentation reflects design work inaccurately or sporadically.	Documentation accurately reflects the design work (in PLTW **Engineering Notebook**).	Documentation is neat and clear and comprehensively reflects all design work (in **PLTW Engineering Notebook**).
	Documentation often does not follow best practice. Most steps of the design process are documented but may not be verified by appropriate outcomes.	Work is documented according to best practice. Each step of the design process is documented and verified by appropriate outcomes (i.e., a design brief, decision matrix, model, test report, and project recommendations (as appropriate).	Each step of the design process is fully documented in detail (in **PLTW Engineering Notebook**) and verified by appropriate outcomes. Where appropriate and indicated, *iteration* of steps of the design process are documented and justified by evidence.

approach and documentation LO: Explain and justify an engineering design process.	Documentation does not include explanations of, justifications of, or reflections on design work.	Documentation includes adequate explanations of, justifications of, or reflections on major design decisions.	Documentation includes in depth explanations of, justifications of, or reflections on major design decisions. Includes frequent notations of thoughts and reflections on work that inform the design process.
	The final design is not sufficiently validated.	The final design is compared to design criteria. Evidence is provided to show that the design either meets all criteria, or deficiencies in the design are identified. All deficiencies are addressed, and suggestions for improving the design are provided.	The final design is compared to the design criteria and fully validated using evidence. Additionally, the design is supported by consideration of economic, environmental, social, political, ethical, health and safety, manufacturability, technical feasibility and/or sustainability considerations, as appropriate.
	Identifies the need for a mathematical model(s) (dimensional tolerances of mating parts) to address a specific need in the design process, but selects an inappropriate mathematical model for the intended purpose. Example: In order for the design to operate as intended, a certain type of fit (interference/clearance/transition) will likely be necessary between your design and the original Automoblox components. Therefore, you need to consider the allowance (maximum interference or minimum clearance) in the connection and the dimensional tolerance of each connecting component. Tolerances are a form of mathematical models expressed	Identifies an appropriate mathematical model (dimensional tolerances of mating parts) to address a specific need in the design process. Correctly applies the mathematical model for the intended purpose.	*Develops* an effective mathematical model (dimensional tolerances of mating parts) to represent and analyze data to define the problem, compare alternatives, and/or validate a design solution as is appropriate for the context of the problem.

	as compound inequalities. [lower limit ≤ specified dimension ≤ upper limit]		
Mathematical Modeling (Tolerance) LO: Develop models to represent design alternatives and generate data to inform decision making, test alternatives, and demonstrate solutions. LO: Apply mathematical models and interpret the output of models to test ideas or make predictions. LO: Make judgements and decisions based on evidence. LO: Apply physical properties in a design process.	Calculations are sometimes poorly documented or do not meet all of the criteria listed in the **Engineering Calculations** checklist above. Difficult for a person unfamiliar with the work to understand how the model supports the design process.	Calculations are well-documented and meet all of the criteria listed in the **Calculations** checklist above.	Calculations are clear and easy to follow. Written explanations are provided, as appropriate, to help a person unfamiliar with the work understand how the calculations inform the design process, provide evidence used to identify deficiencies, or identify appropriate next steps in pursuit of a better solution.
	Does not appropriately use the results obtained from applying the mathematical model (dimensional tolerances of mating parts).	Uses the results of mathematical model (dimensional tolerance of mating parts) application to validate a final design solution.	Uses a mathematical model (dimensional tolerance of mating parts) to inform the design process prior to validation of a final design. For example, a mathematical model is used to mathematically determine the critical weight of the design to avoid overturning; or to mathematically determine the orientation of the reindeer legs (given a height and weight of the reindeer) to provide the critical horizontal distance between the tipping point and weight vector. Or a mathematical model is used to find the optimal density of

			material to provide sufficient weight to resist overturning (given a specific geometry), to inform a material selection.
Technical Drawings LO: Create a set of working drawings using 3D computer-aided (CAD) software to represent an object. LO: Properly dimension technical drawings of simple objects or parts according to a set of dimensioning standards and accepted practices.	Provides a part drawing for each important component of the design; however, the technical drawings do ***not*** meet all criteria listed in the **Technical Drawings, Part Drawings** checklist above.	Provides technical drawings that include a part drawing for all important components and an assembly drawing of the design and meet all criteria listed in the **Technical Drawings** checklist above.	Provides technical drawings that include all criteria listed in **Technical Drawings** checklist above as well as additional content such as an alternate view (detail view, section view), when appropriate, or exploded assembly view.

PLTW ENGINEERING

Unit 8

Advanced Computer Modeling Overview

Preface

This unit presents many of the 3D functions used to develop individual and assembly CAD solid models. You will build your modeling skill and use these modeling functions to develop design solutions to various projects and problems throughout the rest of the course.

Essential Questions

1. Are working drawings always necessary in order to communicate the design of a consumer product? Justify your answer.
2. Beyond creating working drawings to document a design, how can 3D computer modeling be used in the design process? Beyond the design process? How can it be used beyond the design process?

Activity 8.1: Parametric Constraints

Problem 8.2: Automata Design Challenge

Optional Activity 8.3: Instant Challenge: Air Vehicle

PLTW ENGINEERING

Activity 8.1

Parametric Constraints

Introduction

You likely have received email spam that includes your personal information. A custom spam inserts your personal information from a database into an advertisement at key places. It may seem like a lot of work for an organization to customize the spam. This does take a lot of preplanning, but the effort is rewarded by increasing the number of people who respond. A similar kind of information substitution can be done in a 3D CAD solid modeling software. **Numeric constraints** called parametric dimensions may not always have a fixed number value and instead can be customized automatically.

If you were to visit an elementary school classroom, you might think that someone scaled down normal-sized furniture to meet the needs of children. That might have been done using a 3D CAD solid modeling program. The furniture that you use as an adult can be scaled down by changing one or more dimensions. Organizations build this type of design flexibility into online ordering systems. If a customer enters specific dimensional values, colors, and materials into an order, then this information updates the sizes and features of the associated parts to be used for manufacturing. There are many other examples of the power of parametric modeling.

In this activity you will learn how to take advantage of parametric dimensions by using algebraic **formulas** to replace numeric values in a 3D CAD solid model.

Equipment

- Computer with 3D CAD solid modeling software

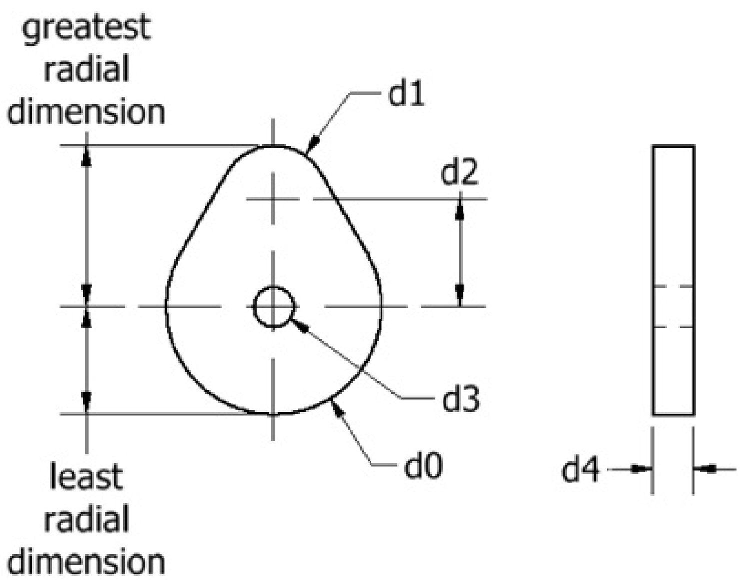
Resources

Parametric Modeling

Activity 8.1.a Parametric Constraints Practice

Procedure

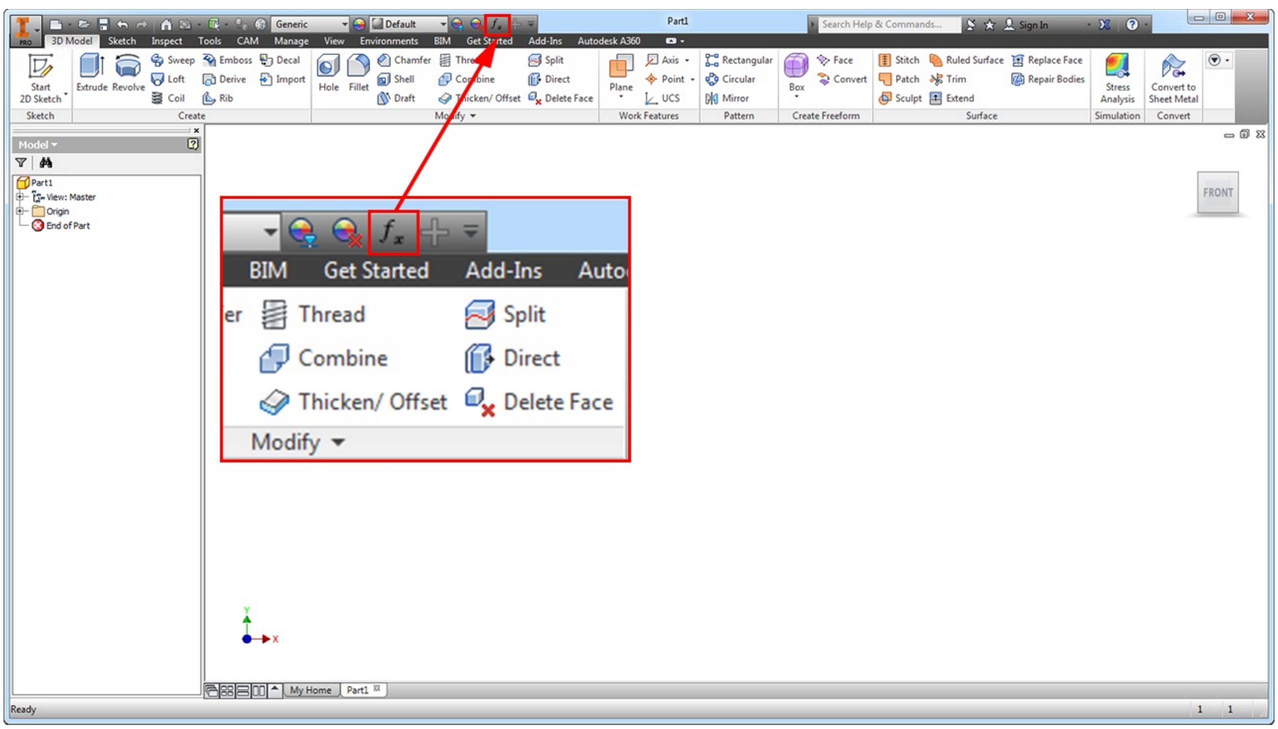
1. Study the image of the pear cam and table. You will use the parameters presented as you complete the tasks that follow.



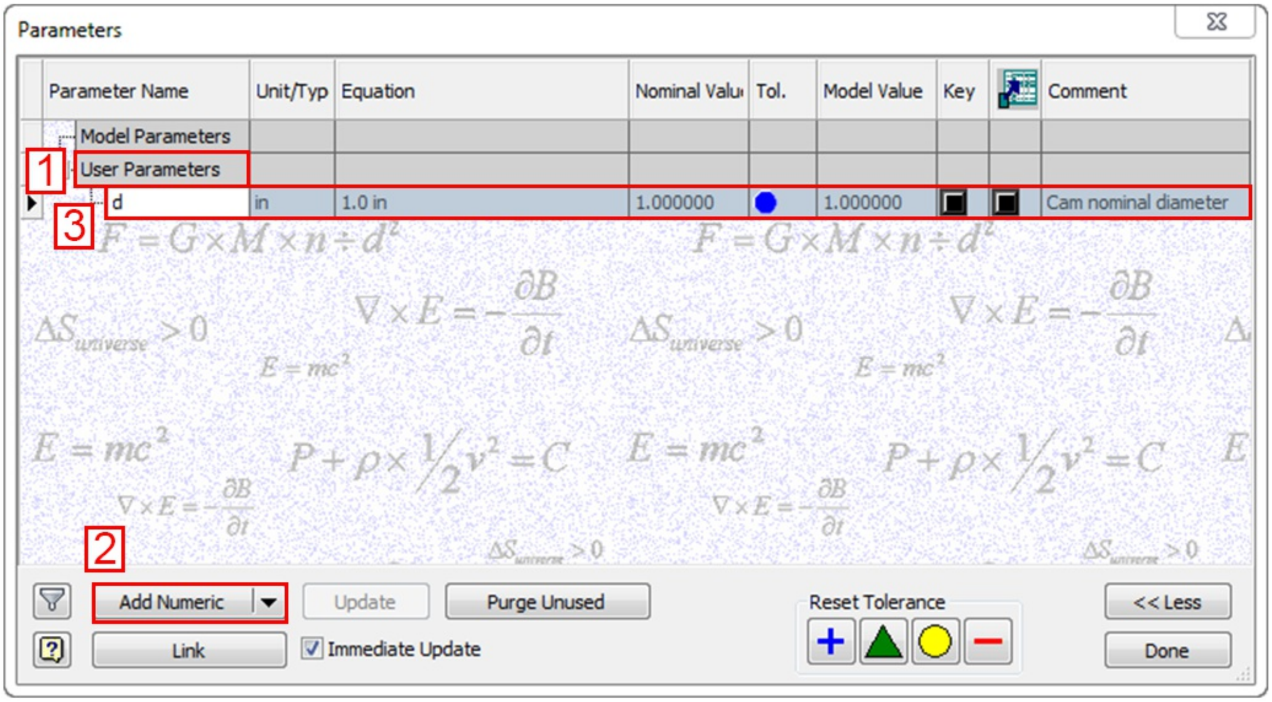
Parameters

Dimension	Description
d	Nominal Diameter
d0	Radius of Maximum
d1	Radius of Minimum
d2	Offset of Minimum
d3	Hole Diameter
d4	Thickness of Cam
d5	Extrusion Taper Angle

2. In a new part file, select the **Parameters** icon to display the parametric modeling window.



3. Select **User Parameters** (1) and then **Add Numeric** (2). Enter a variable named **d** (3) to represent the cam nominal diameter and then select the cells to the right and enter the remaining data as shown.



- Without using the 3D CAD tool, fill in the missing parametric formula and missing numeric values for each based on the parameter description in number 1.

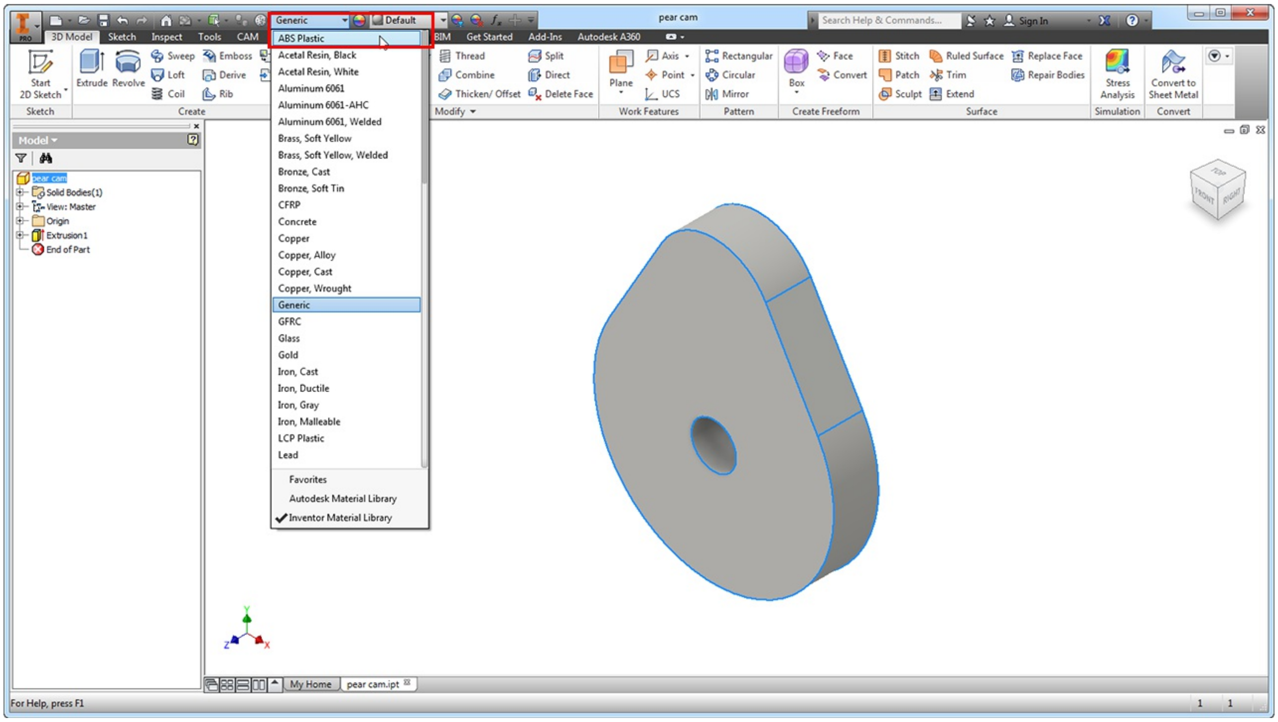
Dimension	Description	Geometric Relationship	Parametric Equation	Value
d	Nominal Diameter	n/a	n/a	1 in.
d0	Radius	One half of the nominal diameter	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.	
			Refer to your downloadable resources for this material.	

d1	Minimum Radius	One quarter of the nominal diameter	Interactive content may not be available in the PDF edition of this course.	
d2	Offset of Minimum	One half of the nominal diameter	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.	
d3	Hole Diameter	Fixed to be 3/16 in.	n/a	
d4	Thickness of Cam	Fixed to be 3/16 in.	n/a	
d5	Extrusion Taper Angle	Fixed to be 0 deg	n/a	Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

4. Use your parametric formulas to create the object in a 3D CAD solid modeling program. Be sure to use the same parameter names for each dimension as identified in the table in step 1. Add the description of the parameter in the Comment column of the parameter table. The only numeric values that you should enter directly are “3/16 inch” for dimension d3 and “3/16 inch” for dimension d4. Use a formula to define all other parameters. When finished, save the file

and identify its name and location in your assigned student folder.

5. Set the material to be ABS Plastic as shown below. This should have a default density of 1.060 g/cm^3.



6. What are the volume and weight of the part as shown in the iProperties dialog? If the the volume or weight shown for your cam do not agree with the values indicated, review your computer model and parameters to identify and correct errors.

☐ Volume

-
-

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

- ☐ Weight
-

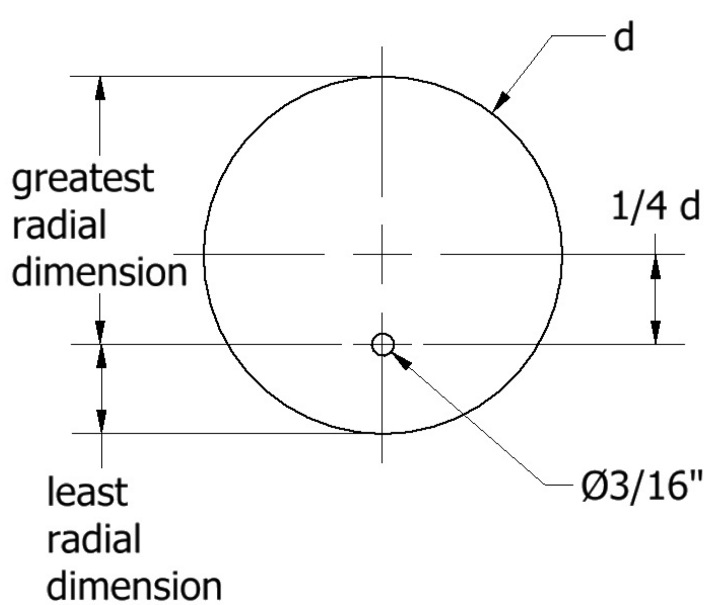
Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

7. The parametric model can be updated easily by adjusting a dimension or variable if other dimensions are dependent on it. Create a table similar to table shown in your PLTW Engineering Notebook. Adjust the cam nominal diameter and document the new part volume and weight for each of the values shown.

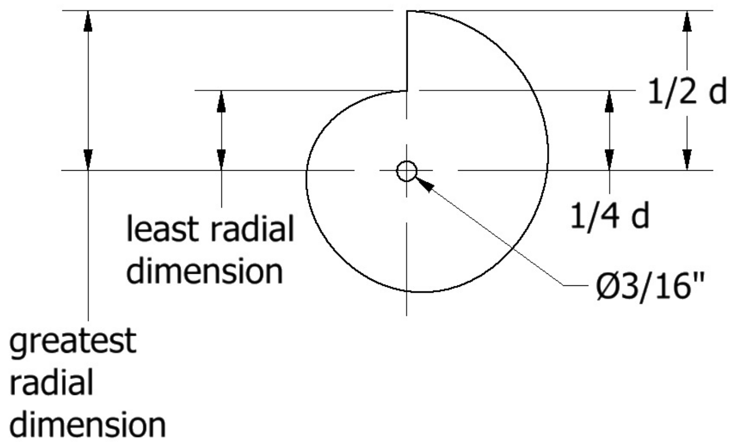
Nominal Diameter (**in**.)	**Volume** (**in^3**)	**Weight** (**lb$_{mass}$**)
1.5		
2.0		
2.5		
3.0		

8. Create a parametric 3D model of each of the cams represented below. When finished, save each file and identify its name and location in your student folder. Use a cam nominal diameter d = 2 in. and a thickness (depth) of 3/16 in.

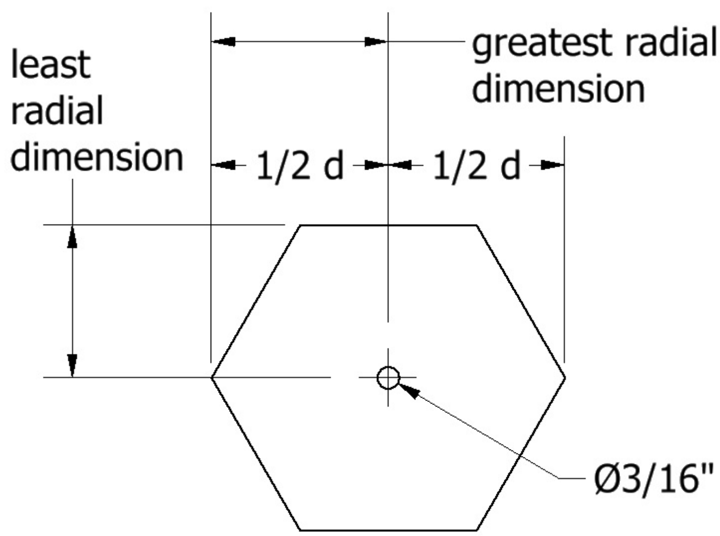
    - Eccentric cam



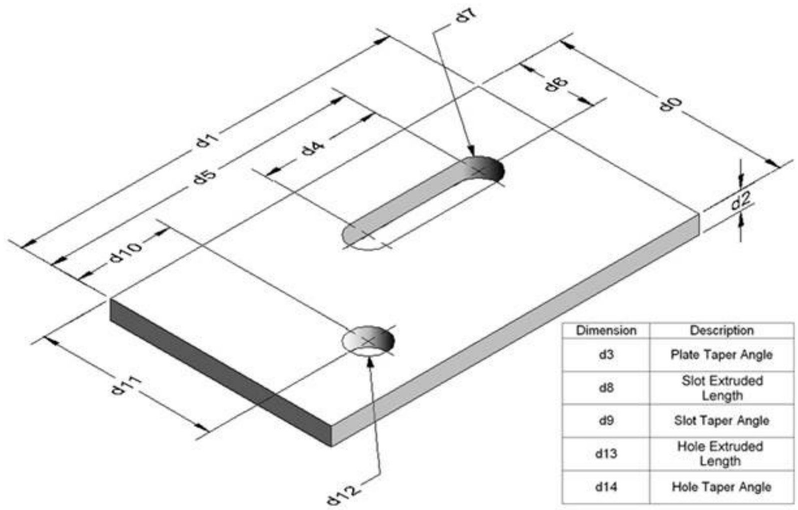
- Snail cam



- Regular Hexagonal cam



9. Use the image below to complete the table.



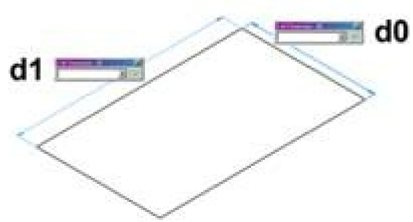
Dimension	**Description**	**Geometric Relationship**	**Parametric Equation**	**Value**
d0	Overall Plate Depth	--	--	3 in.
d1	Overall Plate Width	5:3 ratio; overall plate width to overall plate depth	d0*(5/3)	
d2	Plate Thickness	20 times smaller than the overall width	d1/20	
d3	Plate Taper Angle	perpendicular to the top and bottom plate surfaces	--	0°
d4	Slot Width	1/2 the overall plate depth	d0/2	
d5	Slot Width Location	4/5 of the overall plate width		
d6	Slot Depth Location	1/3 of the overall plate depth		
d7	Slot Diameter	same as the plate thickness	d2	
d8	Slot Extruded Length	same as the plate thickness		
d9	Slot Taper Angle	same as the plate taper angle	d3	

d10	Hole Width Location	1/4 of the overall plate width		
d11	Hole Depth Location	2/3 of the overall plate depth		
d12	Hole Diameter	twice the slot radius	2*d7	
d13	Hole Extruded Length	same as the slot height		
d14	Small Hole Taper Angle	same as the slot taper angle	d9	

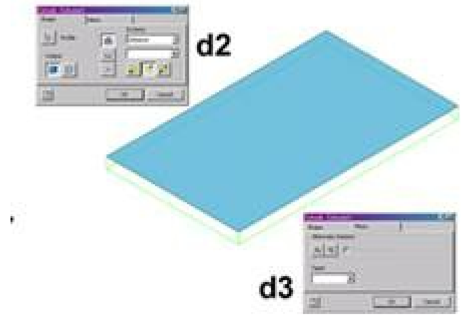
- Use your parametric equations to create the object in a 3D CAD solid modeling program. Be sure to use the same parameter names for each dimension as identified in step 1 of the table. The only numeric values that you should enter are “3 inches” for dimension d0, and “0°” for dimension d3. Use a formula to define all other parameters. When finished, save the file and identify its name and location in your student folder.

  Note: The hole (diameter d12) was created using the CIRCLE, tool.

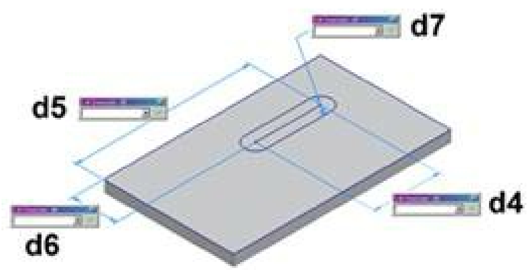
  - Sketch a rectangle. Dimension the depth first (d0) and then the width (d1).



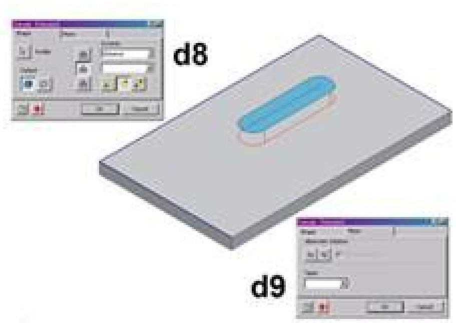
  - Use a formula to extrude the rectangle the appropriate distance (d2). Note that a parameter will automatically be assigned for the taper angle (d3) of the extrusion. The default taper angle is zero degrees.



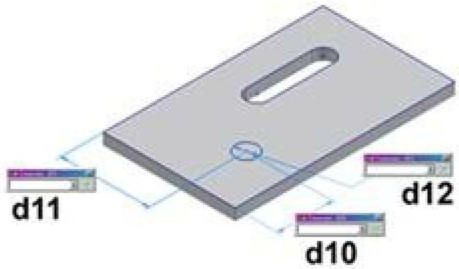
- Sketch and dimension the slot on the top surface of the plate using the parameter names shown and the appropriate formulas. Make sure that the semicircular ends of the slot are tangent to the straight edges of the slot.



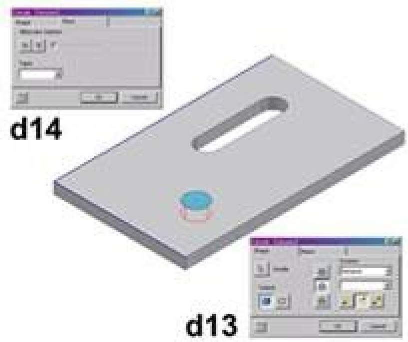
- Extrude Cut the slot the appropriate distance (d8). Again, a parameter will automatically be assigned for the taper angle of the extrusion (d9).



- Sketch and dimension a circle on the top surface of the plate to represent the hole using the parameter names shown and appropriate formulas.



- Extrude Cut the hole the appropriate distance (d14). A parameter will automatically be assigned for the taper angle (d13).



- Record the physical properties of the part.
  Volume: _____________ Surface Area: _____________
- Change the overall plate depth to 1.5 inches, that is d0 = 1.5 in. Be prepared to demonstrate the change to your teacher.
  - Describe what happens to the plate and the features when you revised the dimension.
  - Record the physical properties of the part after it is resized. Volume: _________
    Surface Area: _________

Conclusion

1. What is the difference between a numeric and a geometric constraint?
2. What advantages are there to using parametric formulas instead of numeric values
3. What disadvantages are there to using parametric formulas for numeric values?

4. Describe a situation in which using parametric formulas to dimension an object would be helpful.

Parametric Modeling

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Problem 8.2

Automata Design Challenge

Introduction

Automata (aw-'tom-uh-tuh) is derived from a Greek word that means self-acting. With an automata, an input such as a falling mass, a motor, or your hand movement is used to move parts that ultimately result in the motion of a figure. In this problem, you will design, build and test a mechanical system to automate the motion of objects. The automata will be designed as a toy for a child between the ages of 9 and 12 years old.

Equipment

- Box constructed in Project 3.9 Manufacturing a Box
- Computer with the following software:
    - Spreadsheet application
    - 3D CAD solid modeling program
- Tools
    - Dial caliper
    - Protractor
    - Carpenter's square
    - Ruler
    - Utility Knife
    - Clamps
    - Saw
    - Miter box
    - Push/pull spring scale (one per class)
    - 3D Printer (optional)

- Laser Cutter (optional)

- Isometric paper
- Polar grid paper
- Assorted material for construction, such as the following examples:
    - Adhesive such as Quick-dry Tacky Glue
    - 1/4” square dowel
    - 1/8” round dowel
    - Sand paper (180 grit)
    - Fishing line
    - Wire
    - Corrugated plastic or foam board
    - Fasteners such as screws, bolts, and nuts
    - Drinking straws
    - Cardboard
    - Washers
    - Thumbtacks
    - Paper
    - Index cards or cardstock

Resources

Problem 8.2 Automata Design Challenge Checklists and Rubric

Procedure

1. Locate your box created in Project 3.9 Manufacturing a Box.
2. Read the Automata Design Brief and Problem 8.2 Automata Design Challenge Checklists and

Rubric.

3. Under the direction of your teacher, add product safety requirements.
4. Use the design process to generate solutions to the problem and document the process in your PLTW Engineering Notebook.
5. Use the Problem 8.2 Automata Design Challenge Checklists and Rubric to self-assess your solution process and result. Improve your documentation, as needed. Submit your scored checklists and rubric with notes to indicate the revisions you made as a result of the self-assessment.
6. Submit a project portfolio to include the following:
    - Title page
    - Design Brief
    - Image of the final working prototype
    - Design process documentation to include a summary of your work during each step of the design process.
    - Working drawings that include:
        - A fully dimensioned part drawing for each individual part to include appropriate tolerances.
        - An assembly drawing of the automata toy to guide the construction. Update the drawing to represent the final product.
7. Present your automata.

Automata Design Brief

Client Company	Automata Toys
Target Consumer	Child between the ages of 5 and 12 years old.
Designer	___________________________________

Problem Statement	A manufacturer opened a competition to design and build an original hand-operated toy for its U.S.-based market for girls and boys age 5 to 12 years.
Design Statement	Design a toy that includes a mechanical system that will produce realistic motion of a figure(s) or object(s) resulting from the rotation of an axle. The motion results in the interaction or coordinated movement of at least two separate displayed objects.
Constraints	1. The design of the system must include a wood box manufactured in Project 3.9 Manufacturing a Box. 2. The mechanical system must be human powered. 3. The cost of the system must not exceed $15.00, excluding the cost of the box manufactured in Project 3.9 Manufacturing a Box. 4. The system must produce repetitive motion of figures or objects related to a theme agreed upon with the teacher. Write your theme on the rubric checklist and obtain teacher permission to continue. 5. The assembled hand-operated toy must fit completely within a rectangular prism that measures 6 in. x 8 in. x 12 in. when in a static state. 6. The axle must pass through the wood box. Turning the axle must convert the rotational motion of the axle to linear motion of objects outside of the wood box. 7. In addition to an axle, the mechanical system must include at least two cams. You may include additional components, such as gears, levers and cranks, may be included to create a more realistic motion, if desired. 8. The system must include components manufactured from at least four different materials, including the wood used to construct the box. Connectors or adhesives are not considered to be materials. 9. The automata objects should display realistic motion of the real objects they represent. Before manufacturing the mechanical components, students must create a motion graph to represent the desired motion(s) of the displayed object(s). The motion of the displayed objects should accurately reflect the vertical motion represented by the motion graph within 1/8 in. 10. A 3D solid model of the system must provide the ability to alter the nominal diameter of each cam causing an automatic change

in the scale of the cam. This requires that each cam incorporate **parameter** variable.

11. The toy must meet quality and reliability specifications:

    - When a force of 4.8 Newtons is exerted horizontally on any component and in any direction at a height of 5 cm above the surface, the system must remain solidly founded (no part of the design lifts off of the surface).
    - The system must operate as designed for at least one minute at a sustained speed of one revolution per second without noticeable damage to any component of the design.
    - There must be no visible “slip” or “disconnect” between components in all cycles.

12. The design must allow for the reduction of friction during operation:

    - Between the fingers and the handle
    - Between the axle and its support
    - Between the follower rod and the components that guide the rod

13. The product is safe within the criteria established by the teacher.
14. Additional criteria as determined by the class.

Problem 8.2 Automata Design Challenge Checklists and Rubric

Resources

Problem 8.2 Automata Design Challenge Checklists and Rubric

Interim Reviews and Assessment Checklists

Review Content	Needs Revision	Reviewer Name, date	Reviewer Comments	Approved
Theme • Theme must include how design will produce repetitive motion of figure(s) or object(s). • [Replace with theme to be approved by teacher]				
Minimum Constraints • The design of the system includes a wood box manufactured by the class in Project 3.9 Manufacturing a Box. • The mechanical system is human powered. • The mechanical system produces repetitive motion of figures or objects. • The cost of materials is less than $15, excluding the cost of the box manufactured in Project 3.9 Manufacturing a Box.				
Quality and Reliability Specifications • Engineering calculations are provided and fully documented. Calculations are documented step-by-step so that a person unfamiliar with the work can understand the solution process.				

• There is no visible “slip,” “disconnect,” or binding between components in all cycles. • The system operates as designed for at least one minute at a sustained speed without noticeable damage to any component of the design. • Physical testing to verify the motion of the figures is documented. • Physical stability testing using a push/pull scale is documented.				
Friction Reduction • The design allows for the reduction of friction during operation between the fingers and the handle. • The design allows for the reduction of friction during operation between the axle and its support. • The design allows for the reduction of friction during operation between the follower rod and the components that guide the rod.				
CAD 3D solid model • All necessary dimensional and geometric constraints are properly applied to constrain sketch geometry. That is, CAD sketches cannot be altered by selecting and dragging elements. • The 3D solid model is correctly located within CAD 3D plane to facilitate the correct center of gravity coordinates. • Appropriate material is assigned to the 3D solid model. • The 3D solid model is sufficiently developed to provide acceptable estimates of physical properties. That is, the 3D model does not have to be a perfect representation of the final design, but an effective “model” of the design for the intended purpose. • Each cam is properly resized (to scale) when the nominal diameter is revised.				

- Assembly constraints are properly applied in the 3D computer assembled model to produce realistic degrees of freedom. - Motion constraints are properly applied in the 3D computer assembled model so that rotational motion is converted to linear motion in a realistic way. - All cams rotate with the axle when the axle is rotated with a crank. - The followers remain in contact with the edge of the cams as the cams rotate to simulate real motion. - The themed figures move vertically up and down simultaneously with the followers. - All components are designed to be stationary.				
Product Safety Requirements (add criteria established by the teacher or class)				
Technical Drawings **Part Drawings** - All parts necessary to demonstrate the design intent are specified. - For each part, an isometric view and an appropriate number of orthographic views are presented according to accepted practice. - For each part, the front view is selected based on accepted practice. - For each part, orthographic views are properly oriented.				

- Each part drawing has necessary size and location dimensions present and properly located. - Each part drawing provides dimensions according to dimensioning guidelines. - Tolerance dimensions provide an effective interference fit between the axle and cams. - Tolerance dimensions provide effective clearance fit between the follower rod and the opening that it passes through.				
Assembly Drawing - All parts necessary to demonstrate the design intent are included in the assembly. - Front view was selected based on accepted practice. - An isometric view and an appropriate number of orthographic views are presented to illustrate how components fit together and interact. - Parts of the assembly are identified using identification numbers. - A parts list specifies material and important physical properties including cost, density, weight, and center of gravity of components. - Enough dimensions are included to provide conceptual understanding of the design and show compliance with the size specifications. - Dimensions are placed properly according to dimensioning guidelines and accepted practice. - The motion graph for each figure is displayed with appropriate axes labels and units. - The drawing provides evidence that the design meets appropriate design criteria.				
Portfolio				

• Title page includes appropriate information.
• Design Brief (includes added criteria, if any)
• Image (or video) of the solution prototype
• Design process documentation includes a summary of your work during each step of the design process.
• Summary is well written and easy to understand.
• Working drawings
  ◦ Part drawings
  ◦ Assembly drawing				

Peer Review Rubric – The following criteria will be assessed when you review your peer’s work.

Criteria	Basic	Proficient	Advanced
Peer Review and Feedback LO: Analyze and evaluate the work of others to provide helpful and effective feedback.	Expends little effort to provide helpful feedback. Provides feedback that is often inaccurate or not specific, or is not actionable. Sometimes shares feedback in a professional manner.	Carefully and thoughtfully assesses a peer’s work. Provides effective and accurate feedback that is specific and actionable. Usually provides feedback in a professional manner.	Carefully and thoughtfully assesses peer’s work and asks for clarification from the peer to fully understand thinking and process, when appropriate. Provides effective feedback that is specific and actionable and refers to a learning objective or goal. Amount of detail of feedback is user friendly – not overwhelming and not too technical, but substantial enough to provide specific guidance for significant improvement. Always provides feedback in a professional manner.

Through Project Performance – The following criteria will be assessed at any time and/or at multiple stages of the design process.

Criteria	Basic	Proficient	Advanced

Engineering Mindset LO: Persevere to solve a problem or achieve a goal. LO: Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal. LO: Demonstrate flexibility and adaptability to change.	Frequently off task. Requires direct instructions before working on the project. Inflexible and resists making changes. Gives up easily. Does not consider or rejects effective feedback from peers or teacher without justification.	Often uses time wisely. Often demonstrates self-direction with little direct oversight. Usually demonstrates flexibility and is adaptable to change. Usually perseveres to solve a problem, but sometimes requires intervention. Often uses effective feedback from others to inform performance.	Plans and uses time to best advantage. Always demonstrates independent thinking and self-direction in order to accomplish a goal. Always demonstrates flexibility and adaptability to change. Can explain the benefits to changing direction in the design process. Perseveres to solve problems or achieve the goal until the problem is solved. Critically analyzes feedback and strategically implements feedback that will improve work. Provides appropriate justification when feedback is not implemented.
CAD modeling process LO: Create solid part model using 3D computer-aided design (CAD) to represent an object. LO: Create an assembly model using 3D computer-aided design (CAD) software to represent an assembly of parts. An *inefficient* CAD model includes: • Unconsumed sketches • Unconstrained sketch geometry • Unused sketch components (stray lines, shapes, center points, etc.) that serve no purpose	Produces an *inefficient* 3D solid model to accurate size that resembles the design intent. Produces a 3D solid model that is ***not*** accurate enough to estimate physical properties of an object to acceptable accuracy. Can ***not*** distinguish	Produces a relatively efficient 3D solid model in enough detail to demonstrate design intent. Produces a 3D solid model to successfully estimate physical properties of an object to acceptable accuracy. Can distinguish between additive and subtractive methods in a 3D model.	Produces a *highly efficient* 3D solid model. Purposely employs strategies to limit number of features in project browser. Can describe how the location of the solid model within the grid system will affect the physical properties displayed in iProperties. Can explain and justify the efficiency of a solid model with respect to the use of additive and/or subtractive methods. Correctly applies

- Hidden or non-visible features - Unnecessary work features - Multiple sketches to create features that could be created from a single sketch. Example: three separate sketches used to model three separate holes on the same surface. - Using additive methods when subtractive methods would result in fewer features in the feature tree (as shown in part Browser) or vice versa.	between additive and subtractive methods in 3D solid modeling. Can identify appropriate assembly constraints and correct degrees of freedom for each component. Can ***not*** identify ways to improve an inefficient CAD model.	Correctly applies appropriate assembly and motion constraints to 3D assembly model resulting in *mostly* realistic motion. Minor motion deviations may occur. Can identify inefficiencies in a CAD model.	appropriate assembly and motion constraints to 3D assembly model resulting in *fully* realistic motion. Can identify specific ways to improve the efficiency of a CAD model. Produces an animated assembly demonstrating realistic motion of the mechanical system. Produces an animated exploded view of an assembly.

Project Submittal – The following criteria will be assessed through the project submittals.

Criteria	Basic	Proficient	Advanced
Design Process – Problem-solving approach and documentation LO: Explain and justify an engineering design process.	Documentation reflects design work inaccurately or sporadically. Documentation often does not follow best practice. Most steps of the design process are documented but may not be verified by appropriate outcomes. Documentation does not include explanations of,	Documentation accurately reflects the design work (in PLTW **Engineering Notebook**). Work is documented according to best practice. Each step of the design process is documented and verified by appropriate outcomes (i.e., a design brief, decision matrix, model, test report, and project recommendations (as appropriate).	Documentation is neat and clear and comprehensively reflects all design work (in PLTW Engineering Notebook). Each step of the design process is followed and documented in detail (in PLTW **Engineering Notebook**). Where appropriate and indicated, ***iteration*** of steps of the design process are documented and justified. Documentation includes in-depth explanations of, justifications of, or reflections on major design decisions. Includes frequent notations of thoughts and reflections on work that inform the design process.

	justifications of, or reflections on design work.	Documentation includes adequate explanations of, justifications of, or reflections on major design decisions.	
Technical Drawings LO: Create a set of working drawings using 3D computer-aided design (CAD) software to represent an object. LO: Properly dimension technical drawings of simple objects or parts according to a set of dimensioning standards and accepted practices.	Provides a part drawing for each important component of the design; however, the technical drawings do ***not*** meet all criteria listed in the **Technical Drawings, Part Drawings** checklist above.	Provides technical drawings that include a part drawing for all important components and an assembly drawing of the design and meet all criteria listed in the **Technical Drawings** checklist above.	Provides technical drawings that include all criteria listed in **Technical Drawings** checklist above as well as additional content such as an alternate view (detail view, section view), when appropriate, or exploded assembly view.
Tool/Machine Use LO: Construct physical objects using hand tools and shop tools.	Team members require some prompting to use tools and machines safely and as instructed.	Team members use tools and machines safely and as instructed most of the time.	Team members always use tools and machines safely and as instructed.
Tolerance LO: Apply appropriate engineering tolerances to specify the allowable variation, size of individual features, and orientation and location between features of an object.	Incorrect tolerances to ensure proper fit of mating parts in CAD assembly have been determined and documented.	Most tolerances to ensure proper fit of mating parts in CAD assembly have been determined and documented.	All tolerances to ensure proper fit of mating parts in CAD assembly have been determined and documented.

Mathematical Modeling (Stability and Parametric Formula) LO: Develop models to represent design alternatives and generate data to inform decision making, test alternatives, and demonstrate solutions. LO: Apply mathematical models and interpret the output of models to test ideas or make predictions. LO: Make judgements and decisions based on evidence. LO: Apply physical properties in a design process.	Identifies the need for a mathematical model to address a specific need in the design process but selects an inappropriate mathematical model for the intended purpose. Calculations are sometimes poorly documented or do not meet all of the criteria listed in the **Quality and Reliability Specifications** checklist above. Difficult for a person unfamiliar with the work to understand how the model supports the design process. Does not appropriately use the results obtained from applying the mathematical model.	Identifies an appropriate mathematical model to address a specific need in the design process. Correctly applies the mathematical model for the intended purpose. Calculations are well-documented and meet all of the criteria listed in the **Quality and Reliability Specifications** checklist above. Uses the results of mathematical model application to validate a final design solution.	*Develops* an effective mathematical model to represent and analyze data to define the problem, compare alternatives, and/or validate a design solution as is appropriate for the context of the problem. Calculations are clear and easy to follow. Written explanations are provided, as appropriate, to help a person unfamiliar with the work understand how the calculations inform the design process, provide evidence used to identify deficiencies, or identify appropriate next steps in pursuit of a better solution. Uses a mathematical model to inform the design process before validation of a final design. For example, a mathematical model is used to mathematically determine the critical weight of the design to avoid overturning; or to mathematically determine the orientation of the reindeer legs (given a height and weight of the reindeer) to provide the critical horizontal distance between the tipping point and weight vector. Or a mathematical model is used to find the optimal density of material to provide sufficient weight to resist overturning (given a specific geometry), to inform a material selection.
Presentation LO: Communicate effectively with an audience based on audience characteristics.	Does not appropriately use established conventions of written, oral, and electronic communications (grammar, spelling, usage, and mechanics). Formats of technical writing and professional presentation are incomplete.	Identifies the need for established conventions of written, oral, and electronic communications (grammar, spelling, usage, and mechanics) but not always applied. Follows acceptable formats for technical writing and professional presentation.	Adheres to established conventions of written, oral, and electronic communications (grammar, spelling, usage, and mechanics). Follows acceptable formats for technical writing and professional presentation.

Comments:

Activity 8.3

Instant Challenge: Air Vehicle (Optional)

Introduction

There are many ways to solve a problem. Sometimes it is as simple as applying a piece of duct tape. Other times it takes months or years for a product to progress from an idea into full-scale production.

In this activity your team will design and build a device that will transport items without letting them touch the ground.

Equipment (may vary)

- Paper (used to design the device, but cannot be used in final product)
- Pencil (used to design the device, but cannot be used in final product)
- Scissors (used to design the device, but cannot be used in final product)
- Timer (used to measure the results, but cannot be used in final product)
- 18 inches of string
- 10 straws
- 4 mailing labels
- 4 paper clips
- 5 rubber bands
- 2 marbles
- 1 pencil

Procedure

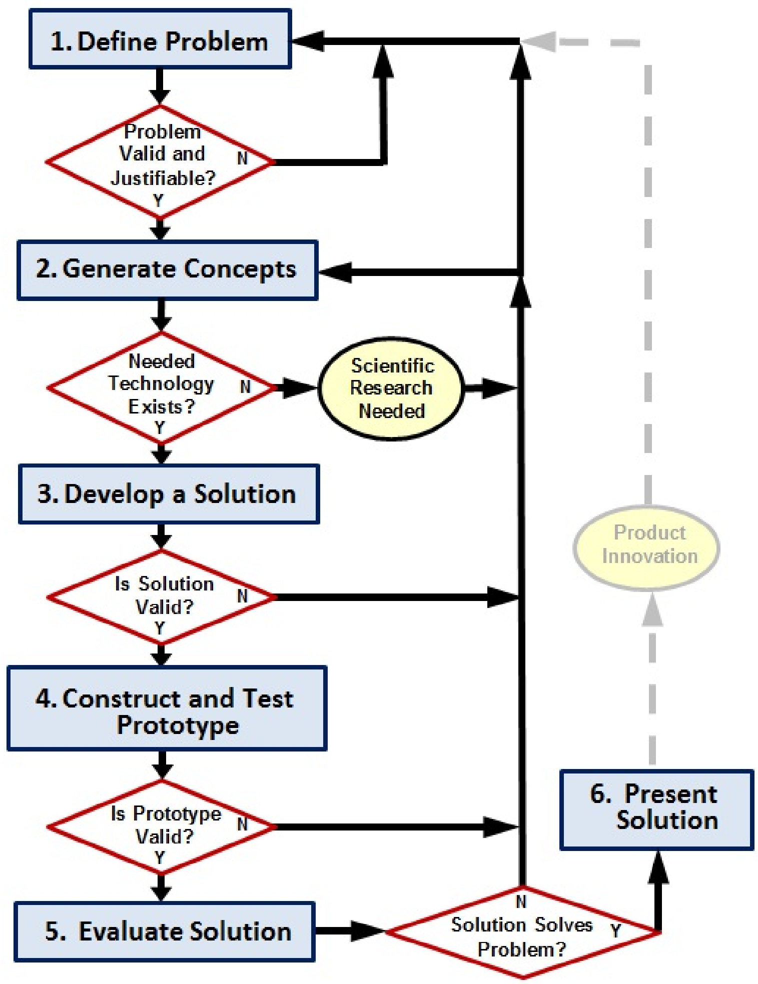
Using only the materials provided, design and build a system that will carry items at least 6 inches in distance. During the 6 in. flight neither your items nor your carrier can touch the ground. Each item transported may only be scored once. The items may travel in only one direction to score. The movement of the carrier may be initiated by a team member, but a team member may not be the carrier.

1. Your team will have 15 minutes to devise a solution and document the solution both in writing and in graphical form with a drawing.

2. Your team will have 5 minutes to build your solution.

3. Finally, your team will have 2 minutes to demonstrate your solution.

4. Use the design process learned in Unit 1. Document each step in your engineering notebook as you complete this design challenge.



Scoring

Your team may receive points for the following.

- Creativity: Up to 20 points for creativity in the design and use of materials.
- Teamwork: Up to 20 points for how well your team works together.

- Performance: 5 points each for items transported together and 10 points each for items transported individually.

Conclusion

1. If you had the opportunity to optimize your design, how would reduce the amount of materials used?
2. If you had the opportunity to optimize your design, how would you increase the distance that the cotton ball moves?
3. How could you improve the effectiveness of your team?

PLTW ENGINEERING

Unit 9

Design Team Overview

Preface

More and more often design team members are separated by distance. This separation requires a different approach than a design team who can meet face to face. In this unit you will learn and practice processes to solve a design problem with a geographically separate team. You will also experience shared decision-making as your team investigates different materials, manufacturing processes, and the impacts that engineering decisions may have on society or potentially on the world.

Essential Questions

1. Is it ever advantageous to create a design or solve a problem individually as opposed to using a team approach? Explain.
2. What strategy would you use to form a design team in order to obtain the best solution possible?
3. What does it mean to be “ethical” in your work? Do engineers need to be taught to be “ethical”?
4. It has been said that, “Having a vision without action is a daydream; Taking action without a vision is a nightmare!” How does this apply to engineering design?

Activity 9.1: Product Lifecycle

Problem 9.2: Engineering Design Ethics Design Brief

Project 9.3: Virtual Design Challenge

Activity 9.4: Team Norms

Activity 9.5: Product Research

Activity 9.1

Product Lifecycle

Introduction

Have you ever wondered how the components in your computer, television, or any other product that you may use on a daily basis actually become finished products? For example, the plastic case that surrounds your computer or television is not mined from the earth; it begins as crude oil. How does a viscous, gooey substance such as oil become a plastic shell for consumer electronics? What happens to that plastic case once it has fulfilled its usefulness?

All things have a beginning and an end. With respect to consumer products, engineers refer to this as a **product lifecycle**. **Raw materials** are extracted from the earth, processed into a more useable form, manufactured into a consumer product that serves a specific purpose, sold, used for a certain amount of time, and either thrown away or **recycled**.

In this activity you will select a consumer product and research its lifecycle from the beginning to end. In groups of two, pick a consumer product that is used every day. The product must be instructor-approved.

Equipment

- Internet access
- Library resources
- Presentation software

Resources

Global, Human, and Ethical Impacts

Activity 9.1 Rubric

Procedure

1. Investigate the lifecycle of this product as discussed in the **Global and Human Impacts** PowerPoint® presentation.
2. Create a timeline of your product using PowerPoint® or other presentation software.

- The timeline should discuss the five steps of the product lifecycle.
- Investigate how this material can be recycled and reused after it has outlived its usefulness.
- Include at least three different cited sources using APA style on the final slide in the presentation.

3. Present your research results to the class.

Conclusion

1. What is meant by *product lifecycle*?
2. Why is it important for companies who make products to research and determine a product's potential lifecycle?
3. What would you change about your product? Why?
4. Do you think your product will evolve or become obsolete over time? Why?
5. What is a trade-off?
6. Do you think that trade-offs were made during the design phase of your product?
7. Why is it important to recycle?
8. How do product designers play a role in recycling?
9. What role does society play in the recycling effort?
10. What can you do to help?

Global, Human, and Ethical Impacts

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Activity 9.1 Product Lifecycle Rubric

Resources

[Activity 9.1 Product Lifectyle Rubric]

Topics	4 points	3 points	2 points	1 point
Content	Thoroughly and clearly states the five steps of the product's lifecycle in precise detail and sequentially explains the steps involved in the recycling of the given material. Gives precise and accurate details on the recycling process.	Adequately states four of the five steps in the product's lifecycle in precise detail. Adequately explains the steps involved in the recycling of the given material. Gives details on the recycling process.	States three of the five steps in the product's lifecycle in precise detail and most of the steps involved in the recycling of the given material. Contains some unnecessary information.	States fewer than half of the five steps in the product's lifecycle in precise detail. Gives a minimal description of the recycling process of the given material. Most of the information is confusing or unrelated to the recycling process.
Organization	Clearly organized into a logical sequence. Excellent use of an outline. Excellent flow throughout the presentation.	Adequate evidence of a logical sequence of information. Good use of an outline. Satisfactory flow throughout the presentation.	Fair evidence of a logical sequence of information. Some use of an outline. Weak flow throughout the presentation.	Minimal or no outline followed. No logical organization; some deviations from the subject. Unclear, confusing. No flow throughout the presentation.
Collaboration	Team cooperation was a shared responsibility, and each member worked toward clear communications, shared decision making, and resolution of conflicts.	In general, team cooperation was a shared responsibility; however, one member did not take full responsibility for his/her work or help to resolve conflicts.	Responsibility for work to be completed was led by one member. There were many conflicts.	There was no team cooperation. No one took responsibility for the work to be completed.
		The presentation is well-prepared	The	

Quality	The presentation is well- prepared with proper grammar and correct spelling. It is easy to read and understand.	with proper grammar and correct spelling. Some information is illogically placed, making the document a little difficult to understand.	presentation is written with one or two grammatical mistakes or spelling errors. It is somewhat difficult to understand.	The presentation has many spelling and grammatical errors. It is very hard to read and understand.
Bibliography	Three or more sources have been cited using APA style and all data has been verified for accuracy.	Resources are from two sources; data has been verified for accuracy.	It was evident that resources were from only one source.	There is no indication of resources used or how information was gathered.

PLTW ENGINEERING

Problem 9.2

Engineering Design Ethics Design Brief

Introduction

Ethics is a complex word. When you hear it used, sometimes you are not really sure what it means. The word is often used in several different ways. Ethics is generally defined as the study of morals, which is the study of what is right and wrong or beneficial or harmful to others. In the field of engineering and science, it is a very important concept that is considered in the daily workings of engineers and scientists.

The codes of professional engineers and scientists vary widely within different professional societies. Many professional societies maintain a set of codes, such as the American Institute of Chemists, the American Mathematical Society, the Association of Computer Machinery, and the American Council of Engineering Companies.

These codes of conduct or **ethical** guidelines are used to govern the practices of the engineers, engineering technicians, scientists, and mathematicians. Sometimes the codes are extensive and may even result in persons losing their advanced degree if they are found to plagiarize work. You may be surprised to learn that there is also a set of codes for student organizations that includes a Hippocratic oath for scientists, engineers, and executives.

This problem is designed to enable you to learn more about engineering design **ethics** and how ethics should play a role in the work of engineers and scientists.

Equipment

- Computer with Internet access
- Access to library

Resources

Ethics Design Brief Sample

Problem 9.2 Design Ethics Design Brief Template

Procedure

1. With a partner select a category of potential ethical issues.

2. Within that category research a particular case and study the ethical issues encountered. The research does not have to focus on a particular situation, such as stem cell research, but may research the ethics surrounding such an issue.
3. After completing the research create a design brief that will enable another student to research your chosen case study and develop a report of relevant findings. Additionally choose one of the following deliverables to depict your findings:
    - Design a DVD cover depicting the key findings of the case study.
    - Design a book cover depicting the key findings of the case study.
    - Design a poster depicting the key findings of the case study.

Notes

To save time, the deliverables have been designated on the design brief for you. An example of a completed design brief is also provided to guide you. The example case study may not be used by a team.

The following Internet sites may prove helpful to you in your research:

Online Ethics Center for Engineering and Science | National Academy of Engineering

Markkula Center for Applied Ethics | Santa Clara University

Civil Engineering Ethics Site | Texan A & M University

It is critical that you and your partner keep detailed records of your research so that you are able to include the information in the design brief. The research information is critical in that it must be used by the team in order to successfully complete the design brief.

Multiple teams may research the same category; however only one team may research a single topic.

Note: You and your partner are not permitted to use the sample ethical design brief provided.

The following are the categories within which you and your partner may find an ethical case study to research and then to prepare your design brief.

Category	Sample Ethical Topics
Agricultural and Food Biotech	Trench failure
Business Ethics	Anhydrous ammonia hose failure
Campaign Ethics	Conflict of interest

Character Education	Whistle blowing
Cloning and Stem Cell Research	Cloning or stem cell research
End-of-Life	Rights of choice
Environmental Ethics	Good engineer vs. protecting the environment. Three Mile Island nuclear disaster
Ethical Theory	Gift giving or receiving
Ethics Centers and Institutes	General research regarding different groups and opinions
Foundations	Hyatt Regency walkway collapse
Global Leadership and Ethics	Encryption and national security
Government Ethics	The Aberdeen Three and chemical weapons
Health Care Ethics	Designer medicines
Legal Ethics	What is plagiarism? What is cheating? Equal justice under the law.
Media Ethics	TV antenna collapse
Non-profits	Research ethical issues with groups, such as Greenpeace and CARE
Public Policy	Ultra-lightweight vehicles
Religious Perspectives on Ethics	General research regarding different points of view
Science and Research Ethics	Challenger disaster
Supranational Organizations	The World Bank or The World Health Organization
Technology and Biotechnology	Biopharma issues

United Nations Organizations	Research on third-world peasant farmers in cultivating their small plots of land
University-Affiliated Groups	General research regarding different points of view, such as conflict of interest

Conclusion

1. What is ethics?
2. What actions are considered cheating?
3. What are your rights and responsibilities as a potential engineer?

Problem 9.2a Sample Engineering Ethics Design Brief Sample

Client:	Johnson-Susan Company
Designer:	Joyce Q. Public
Problem Statement:	It has come to the attention of the owners of Johnson-Susan Company, a pharmaceutical company, that they need to educate their employees regarding the proper use of ethics and the code of conduct.
Design Statement:	Research the aspects of a case study within the ethical category of Technology and Biotechnology. In particular, review a case study regarding stem cell research and the related ethical issues and codes of conduct. Document all research using proper APA Style citations. Record the ethics or codes that were misused and the results of the case. Design and create either a CD cover, book cover, or poster that depicts the findings of the research.
Constraints:	1. Use reputable research sources, in particular those on the Internet ending with either .gov, .edu, or .org. 2. Create a Design Brief: three-day research, design, and creation time limit. 3. Use ethical practices in the creation of your model. 4. Complete the Design Brief: three-day research, design, and create time limit.
Deliverables:	1. Initial research citations 2. Documentation 3. Engineering notebook 4. Choose one: ◦ CD cover depicting the key findings of the case study ◦ Book cover depicting the key findings of the case study ◦ Poster depicting the key findings of the case study

Project 9.3

Virtual Design Challenge

Introduction

Where did the food come from that made up your breakfast this morning? Was it grown, picked, processed, packaged, and sold to you by the same person? Was the vehicle that brought you to school today designed and manufactured by a team of people that went to work in the same building, took their lunch breaks together, and communicated with each other using the same language?

Being able to see and talk with your teammates is an ideal situation, but technological systems typically rely on the expertise of individuals that are scattered across the world. For years, engineers have worked in **virtual teams** to develop solutions to problems. As communication tools such as email become integrated into cultural practices, so too does the practice of working in virtual teams.

A virtual team is made up of people that rely primarily or exclusively on electronic forms of communication to work together to accomplish a goal. Up until this point, you have worked in teams that use face-to-face contact as the primary means of communication. There are inherent benefits to this. Teams that exist under one roof have the ability to converse spontaneously when generating ideas and often read each other’s body language to identify and thwart conflicts before they occur. Teams that rely on face-to-face contact often socialize with each other and build personal bonds of friendship that result in a level of trust that is critical to tackling responsibilities that are beyond the capability of one individual. In order to develop a greater understanding of what it is like to function as an engineer in the 21st century, engineering students must be willing to step outside of their comfort zone to experience teamwork through a virtual environment.

Equipment

- Solid CAD modeling program
- Presentation software
- Printer
- Scanner
- Digital camera
- Internet access
- Email access
- Tools for established communication method

Resources

[Design Brief Options]

[Gantt Chart]

[Teamwork]

[Project 9.3 Rubrics and Resources (.zip)]

Procedure

In this project you will be teamed up with another student who is not in your class. You will use your knowledge of design process, engineering tools, the Internet, and methods other than direct face-to-face contact to communicate and work with your partner to solve a given problem.

1. Once your teacher has paired you up with a virtual teammate and informed you of your design challenge, work with your partner to establish team norms and a project timeline through Activity 9.4 Team Norms.
2. Make at least one entry in your engineering notebook for every class period. Identify all of your research sources and sketch all of your ideas in your engineering notebook. Use the Project 9.3f Engineering Notebook Evaluation Rubric as a guide.
3. Use teacher preference as your primary means of communication. If you expect your teammate to respond to you, indicate this in your message. Do not assume that your partner has received your message.
4. Take pictures of your sketches and send them to your partner based on teacher preference.
5. Create a file folder structure within your student folder that follows the team **norms** that you and your partner have established. As you receive files from your teammate, save the file to your network folder according to the file revision **protocols**. This will be especially important with CAD and PowerPoint® files.
6. Every five class days, fill out and submit a Project 9.3d Periodic Teammate Ten Point Evaluation and a Project 9.3e Periodic Self-Evaluation form. This is a requirement. These documents will be kept confidential and will be stored by your instructor until the end of the project.
7. For this project create a set of working drawings that will completely communicate the necessary information for someone to fabricate your design solution. This set of drawings will comply with the appropriate ANSI / ASME drawing standards.
    - All non-standard parts must be represented by dimensioned technical drawings, complete with notations and title blocks.
    - A multi-view assembly drawing assembly with balloons and parts list.

- (Optional) An exploded isometric assembly view.
- Balloons (attached to the assembly view or optional exploded assembly view) and a parts list.
- Completed title block.

8. At the conclusion of this project, you and your partner will create a summary presentation using software such as PowerPoint® or Prezi that you will deliver individually to your classmates. This presentation is to last no more than five minutes. Use the Project 9.3i Summary Presentation Evaluation as a guide in the development of this presentation. Use this evaluation to gauge the quality of each team's delivery of their presentation
9. When the presentation is finished and the final class evaluation of the visual, structural, and functional qualities of each team's design has been conducted, fill out the Project 9.3j Teammate Performance Summary.

The Design Briefs are as follows:

- Modular Coffee Shop Table Design Brief
- Speaker Support System Design Brief
- Antique Goblet Display Case Design Brief
- Happy Meal Toy Design Brief
- Wooden Mechanical Toy Design Brief
- Locker Organizer Design Brief

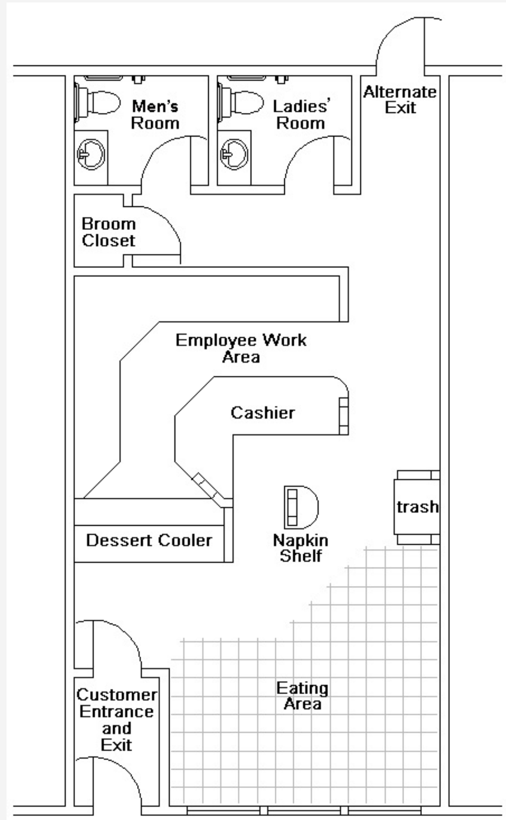
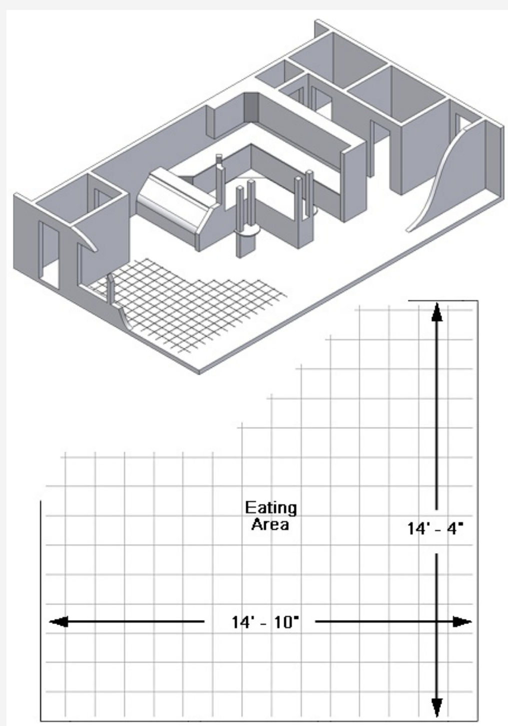
Conclusion

1. What forms of communication did you utilize while working with your virtual teammate?
2. Did you experience any conflicts with your partner, and if so, how did you resolve them?
3. What was the most challenging part of this design experience?
4. How was the design process utilized through this design challenge?
5. What are the advantages of working in a virtual team over working in a team that relies solely on face-to-face contact?
6. Did you add any other constraints to your design challenge? If so, why?

Project 9.3a Virtual Design Briefs

Project 9.3a(i) Modular Coffee Shop Table Virtual Design Brief

Client:	Mr. Smith’s Coffee Shop
Target Consumer:	University students 17-30 years old
Designer:	___________________________
Problem Statement:	The current lounge chair and living room-style seating areas in Mr. Smith’s Coffee Shop are too large and cannot accommodate the growing number of patrons.
Design Statement:	Design and model a modular table that will allow a greater number of patrons to be serviced at Mr. Smith’s Coffee Shop.
	1. Minimum of two (2) adults seating per table. 2. Modular table design must interlock for stability. 3. Maximum material costs are $200 per table. 4. Maximum weight limit of 50 lb per table. 5. Initial design concept is due in 1 week.

Constraints:	 

Project 9.3a(ii) Speaker Support System Virtual Design Brief

Client:	Worldwide Stereo
Designer:	____
Problem Statement:	The teacher does not have sufficient space in the classroom to utilize a set of quality speakers. One speaker sits on the floor and one sits on top of a bookshelf, thus occupying space that is needed for classroom activities and storage. Also, the sound quality is poor due to the current arrangement.
Design Statement:	Design a speaker support system that will allow the two speakers to be securely mounted to the classroom's concrete block wall(s).
Constraints:	1. The design must be ready for manufacturing in 4 weeks. 2. Each speaker is 12"H x 9"W x 9"D. 3. Each speaker weighs 10 lbs. 4. The system must be able to fit in an 11"x 8.5"x 5.5" USPS Priority Mail Flat Rate Box for shipping purposes (not including the speakers). 5. The system must weigh less than 20 lbs (not including the weight of the speakers). 6. The support system must be mechanically fastened to a concrete block wall (mechanical fasteners provided by the clients). 7. The system must allow speakers to be adjusted by tilting forward/backward and panning left/right.

Project 9.3a(iii) Antique Goblet Display Case Virtual Design Brief

Client:	Sweeney & Meltzer Antiques LLC
Designer:	________________________
Problem Statement:	Existing shipping containers for antique goblets provide protection while in transit but do not allow for easy viewing of the goblet. Existing display cases offer great visibility but do not protect goblets during shipping. The owner of an antique priceless goblet has agreed to allow the artifact to travel among museums only if the item will be protected and if people will be able to clearly see it.
	Design a shipping container for an antique goblet that will protect the goblet

Design Statement:	during shipping but can also be used to give an unobstructed view of the goblet when it is on display. The case should be able to be modified on the inside to accommodate other goblets that vary slightly in size. Also the case should be designed to fit into a larger flight case that holds four (4) of the display cases.
Constraints:	1. The container must accommodate the goblet provided by the client. The file has been provided for your use in the design (grail.ipt). 2. The case must be made of 8 parts minimum, with each team member creating 4 parts minimum. 3. The case must be assembled with simple joinery (no butt joints). Constraints do not count as joinery. 4. The case should be designed to fit four (4) cases into the flight case provided by the museum. See photo at end of document. 5. The case must have a device that holds the goblet secure when the case is open and does not obstruct the viewing of the goblet. 6. The case must have a latch or locking mechanism to provide a secure closure while in transport.

Image of the Goblet (grail.ipt)

Goblet Specifications:
Overall Height = 7.59 inches
Base Diameter = 3.96 inches
Mouth Diameter = 4.97 inches

Image of Flight Case

Flight Case Specifications

```
Exterior Dimensions    Interior Dimensions **
  Height = 22.5 inches   Height = 21 inches
 Width = 26.75 inches   Width = 25.25 inches
  Depth = 13.5 inches    Depth = 12 inches
```

** These values do not include any interior case padding.

Project 9.3a(iv) Happy Meal Toy Virtual Design Brief

Client:	McDonald's Restaurant Chain
Target Consumer:	Children 3-7 years old
Designer:	______________________________
Problem Statement:	McDonald's has recently acquired the film rights to all Disney Entertain films. The first film project that they are going to use in the Happy Meal is based on the film "Rolie Polie Olie – The Great Defender of Fun."
Design Statement:	Design a Happy Meal Product Line based on the Disney Film "Rolie Polie Olie – The Great Defender of Fun". The toy should reflect the theme of the film.
	1. The toy must reflect the theme of the film.

Constraints:	2. The toy must be made up of at least 5 parts. 3. The toy must be able to do something related to the film (i.e., ride, fly, etc.). 4. The toy must have an additional feature that functions as an accessory. 5. The toy may not exceed 3” x 3” x 5”. 6. The toy must comply with U.S. Consumer Safety Commissions child safety regulations.

Project 9.3a(v) Wooden Mechanical Toy Virtual Design Brief

Client:	Craft supply and toy sellers
Target Consumer:	People who like to construct home craft projects
Designer:	___________________________
Problem Statement:	Do-it-yourself home projects are becoming increasingly popular. People are often looking for beginner to intermediate home craft projects.
Design Statement:	Design and model a mechanical toy that can be assembled with small rubber bands and/or glue.
Constraints:	1. Must be a free standing toy. 2. May not have a footprint that exceeds 6” depth x 12” width x 10” height. 3. Must be manually operated. 4. Must have a minimum of three separate motions or moving actions once assembled. 5. Must be made of wood or plastic. 6. Motions should be cause/effect.

Project 9.3a(vi) Locker Organizer Virtual Design Brief

Client:	School Superintendent
Target Consumer:	High school students
Designer:	___________________________
Problem Statement:	School lockers are a mess. Students can never find a pen, pencil, or calculator, and their homework is always getting lost. Those who bring their lunch to school often find their food crushed under a sea of books and binders. Because of the clutter, it is often difficult for students to close their locker doors completely.
Design Statement:	Design a high school locker organization system that will neatly contain items commonly used and kept at school.
Constraints:	1. Design must fit within your school locker. 2. Design must be easy to install. 3. Must hold/organize a minimum of 5 typical locker items other than books. 4. All items must be modeled and inserted in the final assembly. 5. No flammable materials may be used in the design.

Gantt Chart

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

Teamwork

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

PLTW ENGINEERING

Activity 9.4

Team Norms

Introduction

When you walk into a library, how are you supposed to behave? What do you say when you answer a telephone or end a phone call? If you want to ask the teacher a question in the middle of a lecture, what do you do? All of these scenarios should bring about similar, if not identical, responses from everyone in the class. Each of these scenarios would result in a behavioral response that follows guidelines, **protocols**, or rules of acceptable behavior, also known as **norms**. Norms regulate proper and acceptable behavior by and among individuals.

Teams develop and agree upon norms through **consensus** to ensure efficiency and to avoid potential conflicts. Acceptable and preferred communication protocols, decision-making rules, and methods of conflict resolution are only a few examples of team norms.

Equipment

- Access to a fax machine, or scanner and email or a method for electronic signature of documents

Procedure

In this activity you and your teammate will formulate team norms that will serve to guide your actions throughout your design challenge.

Using email, instant message, web cam, telephone, or some other means of appropriate communication, you and your **virtual teammate** will brainstorm ideas for team norms that address the following topics one at a time. Use your engineering notebook as a repository for your ideas.

- Code of conduct
- Standard communication method(s)
- Frequency of communication
- File management structure
- File revision management
- Process for making design decisions
- Process for dealing with differences of opinion and conflict

Analyze the ideas for each topic and discuss their **impact** on the team and the overall goal.

Identify key norms that you and your teammate can come to consensus on and finalize them as formal statements in your engineering notebook.

Establish consequences for each norm should they be broken by either teammate. Write these consequences after each norm in your engineering notebook.

In your engineering notebook, create a project timeline in the form of a **Gantt chart**. The Gantt chart will reflect all of the phases of the design process that you are using to guide your efforts in the design challenge.

Using Microsoft® Word, recreate the design brief for your design challenge. Construct the Gantt chart using the draw tools. On the second page, list the team norms and violation consequences that you and your teammate have agreed to. At the bottom of the second page, you will include three sentences for teammate and teacher signatures. The first two sentences are to be signed by the teammates. The last sentence is to be signed by both students' teachers after they have reviewed your document.

- Read, understood, and agreed to by ________________ on ___________.
- Read, understood, and agreed to by ________________ on ___________.
- Accepted by _________________ and __________________.

Have one teammate print out the document, sign it in the appropriate spot, and pass the document off to his/her teacher for a signature. The document will then be sent to the other school to be signed and dated by the other teammate and teacher. Finally, the document will be delivered back to its origin point. Both you and your partner will keep one signed copy that you will affix within your engineering notebook. Each teacher will receive a copy for his or her records.

Conclusion

1. What are team norms?
2. Why do teams establish norms?
3. What is consensus?
4. Why is consensus important in the development of team norms?
5. What is the purpose of a Gantt chart?

PLTW ENGINEERING

Activity 9.5

Product Research Documentation

Introduction

Before a product can be designed, it must be researched to ensure that it has not been previously produced. Many of the consumer products designed today are innovations or improvements to a design that are already on the market place.

Equipment

- Computer with Internet access

Resources

Citations in APA Style

Product Research Sample

Procedure

In this activity you and your teammate(s) will research via the Internet existing products that align with the design brief for the project. Each of you will be responsible for locating three (3) existing products that will be used to inspire your design. These examples will include elements that you find to be desirable and may be included in your product design. You are not conducting a search for objects to replicate as part of your design, as that would violate copyright and patent laws. You will compile the following information about the products you find online and develop a sheet that will be shared with your partner(s). Each member of the design team is responsible for completing an individual product research document.

You must use the Internet to research the following product information:

- Name of the product (company, distributor, etc.)
- URL link to the web page
- A brief statement about the elements that you find interesting
- Picture of the product

You will then create an information sheet for each of the three (3) objects in the format that is shown on the Sample Product Research Document.

******Each partner is responsible for locating three (3) products to exchange with all team members.******

Citations in APA Style

Introduction

The following style of citation is based on the sixth edition of *Publication Manual of the American Psychological Association* (APA). It is recommended that this document be purchased and used as a reference in the classroom or laboratory.

Additional online resources include the following:

- Purdue University Online Writing Lab (OWL)
  American Psychological Association (APA) Basics of APA Style® Tutorial
  American Psychological Association (APA) APA Style Blog
  Cornell University Library Citation Management

Journal article, one author, doi available

Format

- Author, A. A. (year). Title of article. *Title of Periodical*, xx, pp-pp. doi:xx.xxxxxxxxxx

Example

- Shyndale, G.W. (2010). Virtual truss design. *Journal of Software Engineering*, 14, 84-87. doi: 14.3291/0632-7640.42.4.756

Note: The digital object identifier (doi) is a document identification number that can be found on most (but not all) digital journal articles. If the doi is listed with the reference information, include it in your citation as indicated below.

Journal article, one author, doi not available

Format

- Author, A. A. (year). Title of article. *Title of Periodical*, xx, pp-pp. Retrieved from http://www.xxxxxxxxxx

Example

- Shyndale, G.W. (2010). Virtual truss design. *Journal of Software Engineering*, 14, 84-87. Retrieved from http://www.jrnsoftwareeng/trussdesign

Note: If the doi is not listed with the reference information, indicate the URL of the home page from which you retrieved the journal article.

Magazine article

Format

- Author, A. A. (year, month). Title of article. *Title of Magazine*, xx(x), pp-pp. Retrieved from http://www.xxxxxxxxxx

Example

- Williamson, H. K. (2011, January). Discrete transistor circuit design. *Tomorrow's Electronics*, 24(1), 15-22. Retrieved from www.tomorrowselectronics.com/discretetransistor

Note: Provide the date shown on the publication. Provide the month for monthlies or month and day for weeklies.

The xx(x) in the format sample below represents volume and issue number. Please provide volume and issue number in your reference.

If the magazine article is retrieved from a hard copy magazine, no URL is necessary. If the magazine article is retrieved online, please include the appropriate URL.

Daily newspaper article, no author

Format

- Title of article. (year, month day). *Title of Newspaper*, pp.
- **OR**
- Title of article. (year, month day). *Title of Newspaper*. Retrieved from http://www.xxxxxxxxxx

Example

- Stem cell differentiation. (2012, March 14). *The Gazette*, C8.
- **OR**

- Stem cell differentiation. (2012, March 14). *The Gazette*. Retrieved from http://www.gazettedaily.com

Note: If the newspaper article is retrieved from a hard copy newspaper, include the page number. If the newspaper article is retrieved online, please include the newspaper's homepage URL.

Daily newspaper article with author

Format

- Author, A. A. (year, month day). Title of article. *Title of Newspaper*, pp.
- **OR**
- Author, A. A. (year, month day). Title of article. *Title of Newspaper*. Retrieved from http://www.xxxxxxxxxx

Example

- Burkowski, D. O. (2009, January 14). Environmental impact of bioethanol. *Savannah Times*, A14.
- **OR**
- Burkowski, D. O. (2009, January 14). Environmental impact of bioethanol. *Savannah Times*. Retrieved from http://www.SavannahTimes.org

Book with author or editor

Format

- Author, A. A. (date). *Title of book*. doi:xx.xxxxxxxxxx
- **OR**
- Author, A. A. (date). *Title of book*. Retrieved from http://www.xxxxxxxxxx
- **OR**
- Author, A. A. (date). *Title of book*. Publication location: Publisher.
- **OR**
- Editor, A. A., Editor, B. B., & Editor, C. C. (date). *Title of book.* Publication location: Publisher.

Example

- Grantham, T. G. (2006). *Fluid mechanics*. doi:10.6024/8473629821.001.0001
- **OR**
- Grantham, T. G. (2006). *Fluid mechanics*. Retrieved from http://www.intechopen.com/books/FluidMechanics
- **OR**
- Grantham, T. G. (2006). *Fluid mechanics*. Pittsburgh, PA: Mechanical Advantage, Inc.
- **OR**
- Smith, A. K., Trudeau, C. D., & Filan, J. T. (2008). *In pursuit of cures.* Hartford, CT: Biolabs, Inc.

Note: If the book is retrieved online and provides a doi, include the doi in the reference.

If the book is retrieved online but does not provide a doi, include the URL of the retrieval site.

If the book is retrieved as a hard copy, include the publication information.

If the book is edited rather than authored, please reference all authors.

Documentaries or motion pictures

Format

- Producer, A. A. (Producer), & Director, B. B. (Director). (Year). *Title of recording*. [Documentary]. Country of Origin: Studio.

Example

- Jarrett, G. A. (Producer), & Schultz, B. Q. (Director). (2012). *What makes us move? Innovation in biomechanics*. [Documentary]. Canada: Educast, Inc.

Note: Identify the nature of the recording in brackets after the title.

Software

Format

- Title of Software. (Version number) [Computer software]. Publication location: Publisher.

Example

- CircuitDesign. (4.0) [Computer software]. Seattle, WA: Oakdeck, Inc.

Activity 9.5a Product Research Documentation Sample

Design Team Name: Weston Shirk Associates

Product to be researched: Speaker Mounting Systems

Product #1 - Atlantic Mounting Kits

URL: http://www.google.com/products/catalog?hl=en&rls=com.microsoft:*:IE-SearchBox&rlz=1I7SKPB_en&resnum=0&q=Speaker+mounting+brackets&um=1&ie=UTF-8&cid=14726119412955341039&ei=q_G9S7XYF4Kdlgf35bneBg&sa=X&oi=product_catalog_res

Comments: I like the small base size and the threaded locking nut that holds the speaker in position.

Product #2 – Bose UB-20 Wall/Ceiling Speaker Mount

URL: http://www.abt.com/product/14320/Bose-33550.html?source=alsoviewed

Comments: I like the sleek lines in this design. The absence of visible adjustment hardware is also very appealing.

Product #3 – Bose UB-31 Wall/Ceiling Speaker Mount

URL: http://www.abt.com/product/14320/Bose-33550.html?source=alsoviewed

Comments: I like base that covers the mounting hardware and lack of overall bulk in the design.

Unit 10

OPTIONAL
Design Challenges Overview

Preface

As time and technology have advanced, the process of designing products has become quicker, more precise, and more efficient, which enables changes to be made when needed. The process for getting a concept to a marketable solution is also being completed with higher quality and in far less time.

In this unit you will work in a team of two to solve a problem. Your team will then make plans to market your solution.

Essential Questions

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

Optional Project 10.1: Design Challenge

Project 10.1

Design Challenge (Optional)

Introduction

Design challenges provide opportunities to apply skills and knowledge in unique and creative ways. Designers are often asked to come up with solutions to problems that exist. Their supervisor or board of directors may give them a few constraints to adhere to and then ask the designers to solve the problem.

Designers are sometimes put together to form a team and asked to collaborate to create the solution. When you are a one-person design team, the task of effective communication is rather simple. However, what happens when you must communicate your ideas to others, or when the responsibility of a team's solution falls on the shoulders of the entire team? This increases the level of responsibility significantly and requires the development of effective team working skills.

This project will provide you with the opportunity to work together in teams of two. The team will need to come up with a solution to a stated problem. The design process introduced and used in Unit 1 will be applied to this project.

Equipment

- Computer with 3D CAD solid modeling software

Resources

Project 10.1 Rubric

Decision Matrix Template Excel spreadsheet

Decision Matrix Template Word document

Isometric Graph Paper

Procedure

1. Divide into teams under the direction of your teacher.
2. Read the five design briefs below.
3. Decide within the team on a design brief that you will address.

4. Use the design process to generate solutions to the problem.
5. Use isometric graph paper to sketch ideas and at least three possible solutions.
6. Create three possible solutions. Determine the final solution using a decision matrix.
7. Create a CAD model and complete set of working drawings using specifications given by your teacher.
8. As a team create a three-fold brochure marketing the solution to the design problem.

Train Car Design Brief

Client Company:	A Miniature Train Manufacturer
Target Consumer:	All Ages
Designer:	______________________________
Problem Statement:	A miniature train manufacturer has asked your design team to create a train car that can be hooked be the same relative scale as the engine car.
Design Statement:	Design and model a train car that can hook on the engine car created in Project 8.1c Model Miniatur
Constraints:	1. Must have a minimum of seven different parts once assembled. 2. Must be the same relative scale as the engine car. 3. Must be able to attach to the engine car.

Desk Organizer Design Brief

Client Company:	Office Supply Chain
Target Consumer:	Teachers, Corporate Executives, and home office workers
Designer:	______________________________
Problem Statement:	Keeping an office desk from becoming cluttered with papers, devices such as pens, pencils, staplers pads is a never-ending task. This hinders work space and organization.
Design Statement:	Design and model a product that will reduce the clutter that accumulates on office desks and free up

Constraints:	1. Must not attach to the desk. 2. Must fit into a box with interior dimensions of 6 in. depth x 12 in. width x 10 in. height. 3. Must include a recessed area, a bent plastic part, and must have a base ¾ in. thick. 4. Must have a minimum of five different parts once assembled. 5. Must hold a minimum of six items.

Emergency Supply Organizer Design Brief

Client Company:	Auto Parts Stores
Target Consumer:	Owners of automobiles with trunks
Designer:	______________________________
Problem Statement:	Even when placed carefully in the trunk of a car, emergency supplies and other items slide around a products are damaged or fall into the crevices of the spare tire compartment.
Design Statement:	Design a low cost organization system that will neatly contain emergency supplies that are commonl
Constraints:	1. Must not attach to any part of the car. 2. Must fit within a box with interior dimensions of 14 in. wide x 12 in. deep x 10 in. high. 3. Must be an assembly of a minimum of six different parts. 4. Must hold a minimum of seven items. 5. Must be made of a durable material.

Candy Dispenser Design Brief

Client Company:	A Leading Candy Company
Target Consumer:	Children ages 5 to 12
Designer:	______________________________
Problem Statement:	The Candy Company is celebrating its 50th year anniversary and would like to provide consumers w four existing bite-size candies that they currently produce. They also want new shapes created for ea

Design Statement:	Design and model a new hand-held dispensing system.
Constraints:	1. Must be durable. 2. Must fit into a box with interior dimensions of 8 in. wide x 4 in. deep x 4 in. high. 3. Must be an assembly of a minimum of four different parts. 4. Must hold the four new candy shapes. 5. The new candy shapes cannot exceed ½ in. width, depth, height, or diameter.

Conclusion

1. Why is it important to model an idea before making a final prototype?
2. Based on your experiences during the completion of the Design Challenges, what was the hardest thing about working as a team?
3. What is a design brief?
4. Besides a three-fold brochure, how else can you market your design?

Project 10.1 Design Challenge Rubric (Optional)

Resources

[Project 10.1 Design Challenge Rubric (Optional)]

Design

Elements	5 Points	4 Points	3 Points	2 Points	1-0 Points
Freehand Sketching	Produces accurate pictorial and sketches of the required design concepts. Is properly detailed for effective communication.	Produces marginally sufficient freehand sketches of required design concepts. Is partially detailed for effective communication	Produces marginally sufficient freehand sketches of required design concepts. Is marginally detailed for effective communication	Produces freehand sketches that are difficult to visualize. Lacks details in sketches.	Produces incomplete sketches. Does not present concept.
Consideration of Alternatives	Generates at least three viable concepts. Selects most appropriate concept and clearly justifies the choice using the appropriate criteria.	Generates three concepts. Selects an appropriate concept and is somewhat able to justify the choice using marginally acceptable criteria.	Generates three concepts. Selects an appropriate concept, but cannot justify the choice.	Generates three concepts. Selects one using inadequate criteria.	Generates one concept.
Design Requirements	Fully meets design requirements.	Meets most design requirements and supports the design function.	Meets most design requirements, but not enough to support the design function.	Meets some requirements, but not enough to support the design function.	Does not meet any requirements.
Teamwork	Both team members worked well together and settled differences the correct way.	Showed good team working skills the majority of the time.	Showed good team working skills the some of the time.	Showed that understands team working skills, but does not apply well.	Did not present any team working skills.
Three-fold	The team created an exciting	The team created a	The team created a brochure that	The team had the start of a brochure, but	Did not present the

Brochure	brochure that marketed its solution completely.	brochure that marketed its solution.	attempted to market a solution.	failed to market the solution effectively.	teacher with a brochure.

Drawings and Assembly

Elements	**5 Points**	**4 Points**	**3 Points**	**2 Points**	**1-0 Points**
Model Generation	Presents, locates, and sizes all model features properly. Model is completely and efficiently constrained.	Presents, locates, and sizes most model features properly. Model is inefficiently constrained or is missing a few constraints.	Presents, locates, and sizes most model features properly. Model is inefficiently constrained or is missing many constraints.	Some model features are missing or improper. Model is missing several constraints.	Model is missing most features or constraints.
Assembly	Verifies the assembly thoroughly and clearly documents and presents it. Interprets verification results.	Completes required verification as specified by the instructor. Presents clearly, but results are not interpreted well.	Completes required verification as specified by the instructor. Presents fairly well, but results are not interpreted well.	Presents incomplete and/or poor verification.	Submits no verification of assembly.
Part	Verifies the part thoroughly; clearly documents and presents it. Interprets verification results.	Completes required verification as specified by the instructor. Presents clearly, but results are not interpreted well.	Completes required verification as specified by the instructor. Presents fairly well, but results are not interpreted well.	Presents incomplete and/or poor verification.	Submits no verification of part.
Dimensions and Annotation	Dimensions and annotates properly and clearly.	Supplies most dimensions and annotations. Locates most dimensions and annotations them properly.	Supplies most dimensions and annotations. Locates most dimensions, but does not annotate them properly.	Omits many dimensions or annotations. Some mislabeling exists.	Dimensions or annotations have not been added, leaving only software-determined defaults.
Views	Locates all appropriate views properly and clearly.	Locate most views clearly or properly.	Does not locate all appropriate views clearly or properly.	Omits views needed for clarity. Includes inappropriate views.	Incomplete drawing submitted.

Remarks

Remark Title

Text of remark.

Glossary

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.

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.

Multiview 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 multiview drawing.

Width

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

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.

Assembly Line

A line of workers (or robots) and machines in a production setting. Each worker has a task. The process moves from worker to worker until the product is complete.

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.

Effective

Adequate to accomplish a purpose; producing the intended or expected result.

Efficient

Performing a function in a way that results in the least waste of time, energy or materials.

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.

Mass Production

The method of producing a large volume of product for a lower cost.

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.

Quality Control

A system used to verify the quality of a product.

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.

annotate

To add explanatory notes to a drawing.

automata (automaton)

A moving mechanical device that performs a repetitive function.

average speed

The rate with respect to time at which an object travels over distance. Speed is a scalar quantity.

cam

A rotating or sliding part in a mechanism used especially to transform rotational motion to linear motion or vice versa.

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.

concept modeling

Listing or mapping the concepts involved in a design or process under investigation.

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

The 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.

distance

A measure of how far an object has traveled from its starting point regardless of its staring or ending position. Distance is a scalar quantity.

displacement

The change in position of an object from its starting position to its final position. Displacement is described by a magnitude and direction. Displacement is a vector quantity.

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.

follower

A machine part that receives motion from another part.

function

1. A relationship of 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 relationship between the parts of a geometric figure. Examples include parallelism, perpendicularity, and concentricity.

graphical modeling

Representing information in the form of charts, graphs, maps, or geometric figures.

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.

Polar Coordinate System

A two-dimensional coordinate system in which each point on a plane is determined by a distance from a reference point and an angle from a reference direction.

portfolio

A collection of documents selected for a particular purpose that may include 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.

squareness

The lack of deviation from a right angle.

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.

trueness

The lack of deviation from straightness or flatness.

velocity

The rate with respect to time that an object changes position (regardless of the path taken). Velocity is described by a magnitude and a direction. Velocity is a vector quantity.

working drawings

Drawings that convey all of the information needed to manufacture and assemble a design.

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.

Static Equilibrium

The state of a body when the forces acting on the body are balanced and the body is at rest.

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.

Aesthetic

1. Concerned with beauty or the appreciation of beauty. 2. Of pleasing appearance.

Asymmetry

Symmetry in which both halves of a composition are not identical. Also referred to as informal balance.

Balance

A condition in which different elements are equal or in the correct proportions. There are three types of visual balance: symmetry, asymmetry, and radial.

Color

The property possessed by an object of producing different sensations on the eye as a result of the way it reflects or emits light.

Contrast

The state of being noticeably different from something else when put or considered together.

Element

A basic constituent part.

Emphasis

Special importance, value, or prominence given to something.

Form

1. Having the three dimensions of length, width, and depth. Also referred to as a solid. 2. The organization, placement, or relationship of basic elements, as volumes or voids in a sculpture, so as to produce a coherent image.

Gestalt

The principle that maintains that the human eye sees objects in their entirety before perceiving their individual parts.

Graphic Design

The art of combining text and pictures in advertisements, magazines, books, etc.

Harmony

1. The quality of forming a pleasing and consistent whole. 2. Agreement or concord.

Message Analysis

The process of deciding what information needs to go into the graphic design, as well as how to effectively use the design elements and principles to present the information. This analysis is based on a thorough analysis of the audience.

Pattern

A repeated decorative design.

Pictograph

A pictorial symbol for a word or phrase.

Principle

The method of formation, operation, or procedure exhibited in a given instance.

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.

Radial Symmetry

Symmetry about a central axis.

Reverse Engineering

The process of taking something apart and analyzing its workings in detail.

Rhythm

A regularly recurring sequence of events or actions.

Shape

The two-dimensional contour that characterizes an object or area, in contrast to three-dimensional form.

Space

1. The dimensions of height, depth, and width within which all things exist and move. 2. A free or unoccupied area or expanse.

Symbol

A thing that represents or stands for something else, especially a material object representing something abstract.

Symbolism

1. The use of symbols to represent ideas or qualities. 2. The symbolic meaning attached to material objects.

Symmetry

The correspondence in size, shape, and relative position of parts on opposite sides of a median line or about a central axis. Also referred to as formal balance.

Texture

The feel, appearance, or consistency of a surface, substance, or fabric.

Typography

The style and appearance of printed matter.

Unity

The state of being united or forming a whole.

Value

The lightness or darkness of a color in relation to a scale ranging from white to black.

Variety

A thing which differs in some way from others of the same general class.

Aligned Dimension

A system of dimensioning which requires all numerals, figures, and notes to be aligned with the dimension lines so that they may be read from the bottom (for horizontal dimensions) and from the right side (for vertical dimensions).

Allowance

The tightest possible fit between two mating parts.

American National Standards Institute (ANSI)

A private, non-profit organization that coordinates the development and use of a voluntary consensus standards in the United States.

American Society of Mechanical Engineers (ASME)

A professional engineering organization that is known for setting codes and standards for mechanical devices in the United States.

Audience Analysis

The understanding of the consumer group for which the design is targeted. This would include the audiences, demographics, physical location, amount of time available to view the design, and interest in the subject matter.

Auxiliary View

A view that is used to show features that are located on an inclined surface in true size and shape.

Baseline Dimensioning

System of dimensioning in which all dimensions are placed from a datum and not from feature to feature. Also referred to as Datum Dimensioning.

Balloon

A circle with a single number connected to an assembly component with a leader line to refer to parts.

Bilateral Tolerance

A tolerance in which variation is permitted in both directions from the specified dimension.

Blind Hole

A hole that does not go completely through the work piece.

Broken-Out Section

A section of an object broken away to reveal an interior feature for a sectional drawing.

Chain Dimensioning

Also known as point-to-point dimensioning where dimensions are established from one point to the next.

Clearance Fit

Limits the size of mating parts so that a clearance always results when mating parts are assembled.

Counterbore

A cylindrical recess around a hole, usually to receive a bolt head or nut.

Countersink

A conical-shaped recess around a hole, often used to receive a tapered screw.

Cutting Plane Line

A line drawn on a view where a cut was made in order to define the location of the imaginary section plane.

Datum

A theoretically exact point, axis, or plane derived from the true geometric counterpart of a specific datum feature. The origin from which the location, or geometric characteristic of a part feature, is established.

Datum Dimensioning

A dimensioning system where each dimension originates from a common surface, plane, or axis. Also known as baseline dimensioning.

Decision Matrix

A tool used to compare design solutions against one another, using specific criteria.

Detail Drawing

A dimensioned, working drawing of a single part. Also referred to as part drawing.

Detail View

A view that is used to show a magnified view of features that are too small to adequately specify in another view.

Dual Dimensions

Where alternate units are displayed within the same dimension.

Fillet

An inside radius between two intersecting planes.

Foreshorten

To show lines or objects shorter than their true size. Foreshortened lines are not perpendicular to the line of sight.

Full Section

A sectional drawing based on a cutting plane line that extends completely through an object.

Half Section

A sectional drawing based on a cutting plane line that cuts through one-quarter of an object. A half section reveals half of the interior and half of the exterior.

General Notes

Notes placed separate from the views; relate to the entire drawing.

Interference

The amount of overlap that one part has with another when assembled.

Interference Fit

Limits the size of mating parts so that an interference always results when mating parts are assembled.

International Organization for Standardization (IOS)

This is a worldwide organization that creates engineering standards.

Least Material Condition (LMC)

The smallest size limit of an external feature and the largest size limit of an internal feature.

Limit Dimensions

The largest and smallest possible boundaries to which a feature may be made as related to the tolerance of the dimension.

Local Notes

Connected to specific features on the views of the drawing. Also known as annotations.

Location Dimension

A location dimension that defines the relationship of features of an object.

Market Research

The activity of gathering information about consumers' needs and preferences.

Nominal Size

The designation of the size established for a commercial product.

Part Drawing

A drawing that contains all the information for making one part of the design.

Parts List

A list of materials or parts specified for a project. Also referred to as a bill of materials or BOM.

Pitch

A distance of uniform measure determined at a point on one unit to the same corresponding point on the next unit; used in threads, springs, and other machine parts.

Reference Dimension

A dimension, usually without a tolerance, used for information purposes only. A reference is a repeat of a given dimension or established from other values shown on a drawing. Reference dimensions are enclosed in ( ) on the drawing.

Round

An outside radius applied to corners.

Section Lines

Thin lines used in a section view to indicate where the cutting plane line has cut through material.

Section View

A view that is used to show details not apparent on the exterior of the part.

Size Dimension

Placed directly on a feature to identify a specific size or may be connected to a feature in the form of a note.

Specified Dimension

The dimension noted or, in the case of a tolerance, the part of the dimension from which the limits are calculated.

Spotface

A shallow recess like a counterbore, used to provide a good bearing surface for a fastener.

Survey

An investigation of the opinions or experience of a group of people, based on a series of questions.

Taper

Gradual diminution of width or thickness in an elongated object.

Technical Writing

A type of expository writing that is used to convey information for technical or business purposes.

Tolerance

The acceptable amount of dimensional variation that will still allow an object to function correctly..

Transition fit

Occurs when two mating parts can sometimes have a clearance fit and sometimes have an interference fit.

Unidirectional Dimension

A dimensioning system which requires all numerals, figures, and notes to be lettered horizontally and to be read from the bottom of the drawing sheet.

Unilateral Tolerance

A tolerance in which variation is permitted in only one direction from the specified dimension.

Working Drawings

Drawings that convey all of the information needed to manufacture and assemble a design.

Exploded Assembly

An assembly drawing in which parts are moved out of position along an axis so that each individual part is visible.

Formula

A mathematical relationship or rule expressed in symbols.

Numeric Constraint

A number value or algebraic equation that is used to control the size or location of a geometric figure.

Parameter

A property of a system whose value determines how the system will behave.

Parametric Dimension

A type of constraint within the sketch environment to control the size and position of geometry.

Parametric Modeling

A CAD modeling method that uses parameters to define the size and geometry of features and to create relationships between features. Changing a parameter value updates all related features of the model at once.

Phantom Line

A line used to show the alternate positions of an object or matching part without interfering with the main drawing.

Ratio

The quantitative relation between two amounts showing the number of times one value contains or is contained within the other.

Rib

A relatively thin flat member acting as a brace support. Also called a web.

Arbitration

The hearing and determination of a dispute or the settling of differences between parties by a person or persons chosen or agreed to by them.

Attorney General

The principal legal officer of the Crown or a state.

By-product

Something produced in the making of something else; a secondary result; a side effect.

Carcinogen

A substance capable of causing cancer.

Consensus

General agreement.

Critique

A detailed analysis and assessment.

Ecosystem

A biological community of interacting organisms and their physical environment.

Environmental Protection Agency (EPA)

The US federal agency with a mission to protect human health and the environment.

Ergonomics

The study of workplace equipment design or how to arrange and design devices, machines, or workspace so that people and things interact safely and most efficiently.

Ethical

Conforming to an established set of principles or accepted professional standards of contact.

Ethics

The moral principles governing or influencing conduct.

Evaluate

To form an idea of the amount or value of; assess.

Gantt Chart

A time and activity bar chart that is used for planning, managing, and controlling major programs that have a distinct beginning and end.

Hazard

A danger or risk.

Impact

The effect or influence of one thing on another. Some impacts are anticipated, and others are unanticipated.

Landfill

A low area of land that is built up from deposits of solid refuse in layers covered by soil.

Mediation

The act or process of using an intermediary to effect an agreement or reconciliation.

Negotiation

Mutual discussion and arrangement of the terms of a transaction or agreement.

Norms

Principles of right action, binding upon the members of a group and serving to guide, control, or regulate proper and acceptable behavior.

Occupation Safety and Health Administration (OSHA)

A government organization whose mission is to assure the safety and health of America's workers by setting and enforcing standards; providing training, outreach, and education; establishing partnerships; and encouraging continual improvement in workplace safety and health.

Product Lifecycle

Stages a product goes through from concept and use to eventual withdrawal from the market place.

Protocol

The accepted code of behavior in a particular situation.

Raw Material

Any natural resource that is used to make finished products.

Recycle

To reclaim or reuse old materials in order to make new products.

Refurbish

To renovate or redecorate.

Refuse

Matter thrown away as worthless.

Residue

A small amount of something that remains after the main part has gone or been taken or used.

Synergy

When the unit or team becomes stronger than the sum of the individual members.

Trade-off

An exchange of one thing in return for another: especially relinquishment of one benefit or advantage for another regarded as more desirable.

Virtual Team

A group of people that rely primarily or exclusively on electronic forms of communication to work together in accomplishing goals.

Waste

Material which is eliminated or discarded as no longer useful or required.