Engineering the Future
Science, Technology, and the Design Process

Engineer's Notebook: Project 1.0

Design the Best Organizer in the World

National Center for
Technological Literacy®
Museum of Science, Boston

Key Curriculum Press
Emeryville, CA

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Publisher: Steven Rasmussen

Published by Key Curriculum Press.

Cover Photo Credit: PhotoDisc "Popular Objects" by Ryan McVay, PhotoDisc "Portfolio," PhotoDisc Volume 95 "Youth Culture," PhotoDisc Volume 4 "Science, Technology and Medicine" Version 2

Key Curriculum Press
1150 65th Street
Emeryville, CA 94608
510-595-7000
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Printed in the United States of America

10 9 8 7 6 5 4 3 2 1   10 09 08 07

ISBN: 978-1-55953-965-4

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This program was made possible through grants from the U.S. Small Business Administration, Massachusetts Technology Collaborative Renewable Energy Trust, Lockheed Martin, Cisco Systems, Inc., National Institute of Standards and Technology, and the Highland Street Foundation.

National Center for Technological Literacy (NCTL)
Engineering Education for All

The goal of the NCTL is to foster appreciation and understanding of the human-made world by infusing technology and engineering into K–12 schools and museums nationwide. By applying science and mathematics as well as engineering processes, children and adults will solve real-world problems and learn about the creation and implications of technologies.

For more information, visit www.nctl.org.

Project 1.0

Design the Best Organizer in the World

This course consists of four major projects that will help you gain the skills and knowledge to understand what engineers do. Each project is divided up into individual tasks and this *Engineer's Notebook* will guide you through the tasks and projects. Write your name at the top of each page, and initial and date the bottom of the page when you have completed it.

The purpose of the first project is for you to learn how new technologies are developed and manufactured and how they affect your way of life. You will complete a few introductory tasks about developing new products, the engineering design process, and how to make engineering drawings. You will also design your own new products, first as an individual, then as a member of a design team.

Name ______________________________

Project 1 Gantt Chart

A Gantt chart is a project-planning tool that shows when tasks should be completed in order to finish a project on time. This is an example of how Project 1 might be planned if you have 45-minute class periods. Use a separate page to create a new one if your scheduling is different. You can insert the page at this point in your *Engineer's Notebook.*

Task	Class Periods								Text Chap.	Check for Completion
	5	10	15	20	25	30	35	40		
1.1 What Is Engineering?									1	
1.2 Design a Cell Phone Holder									2, 3	
1.3 Engineering Drawing									4	
1.4 Define the Problem									5	
1.5 Research the Problem									6	
1.6 Develop Possible Solutions										
1.7 Choose the Best Solution									7	
1.8 Create a Prototype										
1.9 Test and Evaluate									8	
1.10 Communicate the Solution									9	
1.11 Redesign										

Initial ______________ Date __________

TASK 1.1 What Is Engineering?

- Express your own ideas about engineering, technology, and design.

What do you think about engineering, technology, and design? Answer the following questions and think about how new products are created. If you don't know an answer, make the best guess that you can.

Getting Started

1) Select a technology or product of your choice and briefly describe what steps you would take to improve it.

What Do You Think?

1) Which of the following are examples of technology? (Circle letters of all that apply.)

A. Cell phone	E. Computer	I. Water	M. Car
B. Pencil	F. Paper	J. Chair	N. Book
C. House	G. Language	K. Hot dog	O. Drain pipe
D. Tree	H. Rock	L. Television	P. Sand

2) A mock-up is a... (Circle the letter of the best answer.)

A. Fake B. Scale model C. Rough 3-D model D. Prototype E. Drawing

3) What advantages do teams have for solving problems? (Circle letters of all that apply.)

A. With more people, the work goes faster.
B. People bring different points of view to the task.
C. It's easy for people to agree if they are all working on the same task.
D. Different people have different skills.
E. The product is usually better than if only one person did the work.

4) Draw a line connecting the word on the left with its definition on the right.

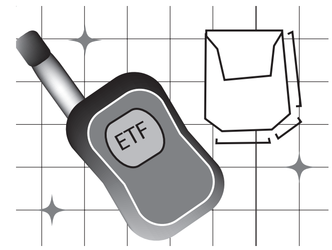
Scientist	A person who develops creative new solutions or products
Designer	A person who designs or improves devices to solve problems, meet people's needs, and are attractive to look at.
Engineer	A person who actively investigates the natural world.
Inventor	A person who applies science and mathematics to improve or design technologies to solve problems and meet people's needs.

Read Chapter 1, "Welcome to the Designed World," in the textbook *Engineering the Future* to find out what engineering is all about. Use notebook paper to answer the questions at the end of the chapter. Sign, date, and number each page. Insert the pages at this point in your *Engineer's Notebook.*

TASK 1.2 Design a Cell Phone Holder

- Examine a need and design a solution.
- Summarize the engineering design process.
- Describe the work of industrial designers, engineers, and scientists.

Ideas for new products often come from things that already exist. In this task, you will consider how a cell phone holder could be improved.



What will your cell phone holder look like?

DESIGN CHALLENGE

Design a Cell Phone Holder

Using a manila folder and tape, build a mock-up (model) of a new kind of cell phone holder. Think about new features or improve some old ones.

Your challenge is to design a cell phone holder and calculate how much you can sell it for based on the cost of manufacturing and distributing the new product.

Follow the steps on the next few pages and be ready to share your ideas and mock-up with the class.

If only he had a cell phone holder!

Name ______________________________

The Engineering Design Process

Before you get started, use the engineering design process to think about what you're going to do. Then discuss it with your classmates and make some notes on these two pages before building a mock-up. Feel free to use separate pieces of paper as necessary.

Define the Problem

Design a new cell phone holder!

Research the Problem

If you have your own cell phone holder, consider the following, or discuss with someone who has one.

- Why do you use a cell phone holder?
- If you don't, why not?
- What do you like about your favorite cell phone holder?
- What could be improved?

Develop Possible Solutions

Sketch at least two different ideas for a cell phone holder. Which components are the most important to you?

Initial ____________ Date __________

Choose the Best Solution

- Which solution will you make a mock-up of with manila folders?
- How will you cut the material and construct the design?

Create a Prototype

- Build a mock-up with the available materials.

Test and Evaluate

Try putting a cell phone in your holder.

- Does it fit? Did you measure and assemble it correctly?
- What works well? What needs to be improved?
- How much do you think you could sell a final version for?

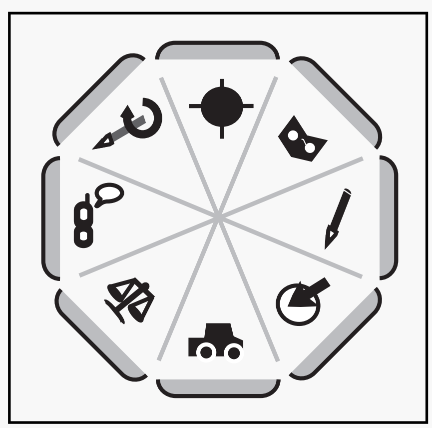
Communicate

- Why should someone buy your cell phone holder?
- What makes it worth it?
- If you had enough time and materials, what would you do differently?

Redesign

Now that you've thought more about designing your own cell phone holder, go back to the first step and add some ideas about the problem you are trying to solve.

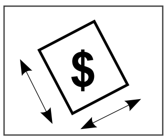
Because the **engineering design process** nearly always ends with a better understanding of the problem, or a new problem to solve, it's best to think of it as a wheel rather than a series of steps. It's a constant cycle.



The Cost of Manufacturing

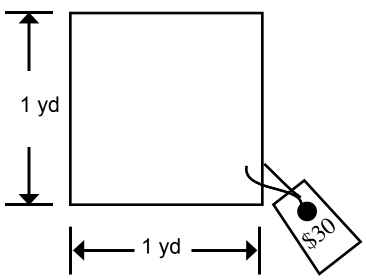
Whatever the purpose may be, any product that an engineer designs has to be affordable or no one will buy it. Use this outline to determine how much your cell phone holder would sell for in a store.

1. Cost of Materials



For your cell phone holder, a materials engineers explored a wide variety of materials and decided that you should use a material that costs $30.00 for each square yard (yd^2) of it:

$$\frac{\$30}{1\ yd^2\ \text{material}}$$



Notice how "$30.00 for each square yard" became a mathematical relationship. You might read this relationship as "$30.00 per square yard," but the word *per* is really just another way of saying "for each."

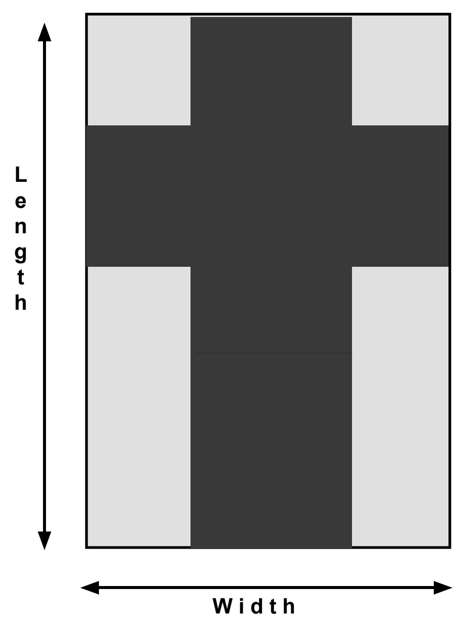
As a manufacturing engineer, you won't want to waste materials because that will increase the cost of the product. So you will try to create as many cell phone holders as possible out of the $30 sheet. It's like trying to figure out how many cookies you can cut from a tray of rolled-out cookie dough.

Start by figuring out how much material you will need to make one cell phone holder. If you can, unfold your mock-up so that it creates a pattern (also called a ***template***). Lay it down on a piece of paper and draw a rectangle around the outside to show how much material you will need to make another cell phone holder. You will probably have some waste.

1) Measure the length and width of the rectangle, then calculate the area:

Area = length × width = ______ inches × ______ inches

= ______ $inches^2$



 Initial ____________ Date __________

In order to determine how many patterns you can fit onto a square yard of fabric, you will need to convert the area from square yards (yd^2) to square inches (in^2).

You know from a yard stick that there are 36 inches in a yard. You need to find out how many square inches there are in a square yard.

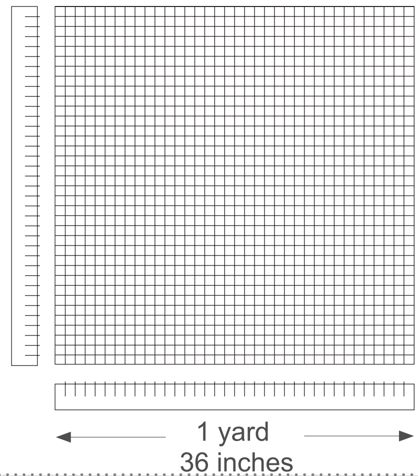
2) Calculate the number of square inches in a square yard. Remember:

Area *(A)* is length *(l)* multiplied by width *(w)*.

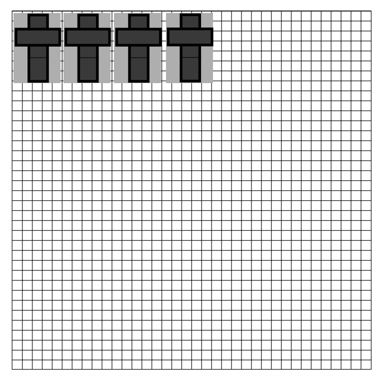
$$A = l \times w$$

$1\ yd^2 =$ _______ in^2

This square represents a square yard. Each tiny square represents a square inch. How many square inches does the square yard contain?

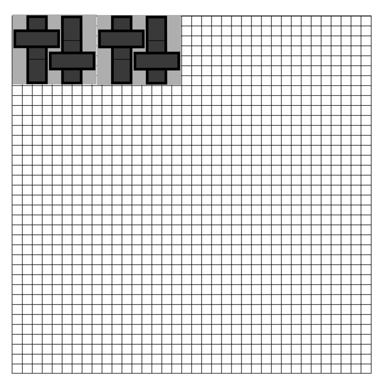


3) If you were to lay out your cell phone holder template onto a square yard and trace it so the patterns are easy to cut out, how many could you fit on one square yard?



4) What would the material cost be for one cell phone holder? (Remember, one yard of material costs $30.)

5) Can you reduce the cost of the cell phone holder further by reducing waste? Try making two or three templates and fitting them together in different ways to minimize waste. Sketch a pattern that results in minimum waste.



6) How many templates can fit on one square yard? Calculate the lowest material cost for one cell phone holder. Use this information and the fact that 1 yard of material is $30.

$$\text{material cost} = \frac{\text{cost for } 1\ yd^2}{\#\text{ of holders on } 1\ yd^2} = \underline{\hspace{3cm}} =$$

2. Cost of Labor

In addition to buying materials, the manufacturer needs to pay the employees who produce the cell phone holders.

1) If a factory worker is paid $15 per hour, how much will the worker earn in an 8-hour day?

2) How much will the worker earn in a 5-day work week?

3) How much will the worker earn in a 52-week year?

4) If a worker can make 1 cell phone holder every 10 minutes, how many cell phone holders can he or she make in an 8-hour work day?

5) Using the daily pay rate you calculated above, what would the labor cost be to make each cell phone holder?

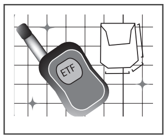
3. Overhead Cost

Overhead: The cost to rent the factory, pay the utility bills, and other business maintenance costs are grouped together as the cost of overhead.

A simple way to estimate manufacturing overhead on a single product is to determine a plant's overhead during a year and divide by the total number of products produced in that time.

1) Assume that your factory can produce 100,000 cell phone holders per year, and the overhead costs are $200,000. What is the overhead cost per cell phone holder?

4. Total Production Cost



Calculate the total cost to produce one cell phone holder.

Material Cost + Labor Cost + Overhead = Total Production Cost

____________ + ____________ + ____________ = ____________

5. Manufacturer's Markup

$

If you sell the product for the same amount it costs you to produce it, you won't make a profit. If you mark up the price too much, the customer might look elsewhere.

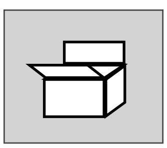
The manufacturer's markup is a percentage added to the cost of production. For example, to make a 10% profit, the manufacturer would add 10% of the total production cost to the total cost of production. To find 10% of the production cost, multiply the cost by 0.10. To make a 25% profit, the manufacturer multiplies the production cost by 0.25 and adds that value to the cost of production. The final sum is the wholesale cost.

Decide how much markup you think is appropriate and calculate the wholesale cost as follows:

Production Cost + (Manufacturer's Markup × Production Cost) = Wholesale Cost

______________ + (______________ × ______________) = Wholesale Cost

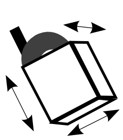
6. Packing for Shipment



Factories do not sell their products one at a time. Instead, they sell full shipping boxes, called ***cases,*** to stores that will sell the products to individual customers. Assume the holders will be tightly packed in the shipping box with cardboard packaging to protect them.

1) To find the volume of one cell phone holder in cubic inches, measure the overall volume of the assembled mock-up, adding about 1/4 inch on all sides to allow for the cardboard packaging.

	Length (in.)	Width (in.)	Height (in.)
Holder Measure			
Packaging Measure = holder measure + 0.25 in.			



Volume *(V)* is length *(l)* multiplied by width *(w)* multiplied by height *(h)*. What is the volume of the packaging?

Volume = $l \times w \times h$

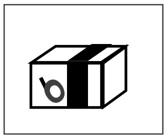
$V_{packaging}$ = _______ in. × _______ in. × _______ in.

= _______ $in.^3$

2) The company has a big supply of shipping boxes, or cases, that are 18 in. long, 12 in. wide, and 10 in. high. What is the volume of one shipping box?

3) How many cell phone holders could you fit inside one case? Show how you calculated your answer.

7. Retail Pricing



When a store buys cell phone holders, it pays a "wholesale price." Then the store sells the items at a higher "retail price" that is usually twice the wholesale price. When setting your wholesale price per unit, you must consider all of the costs it takes to produce one unit, the amount of money you want to make beyond your costs (your "profit"), and whether people will buy your product at the final "retail price."

1) What is the wholesale price that your manufacturing plant will charge for one cell phone holder?

Material Cost __________

Labor Cost __________

Overhead __________

Total Production Cost __________

Manufacturer's Markup __________

Wholesale Cost per Item __________

> Material Cost + Labor Cost + Overhead
> = Total Production Cost
>
> Total Production Cost +
> (Manufacturer's Markup × Total Production Cost)
> = Wholesale Cost per Item

2) Calculate the price your manufacturing plant will need to charge for a case of cell phone holders.

Items per Box __________

Wholesale Cost per Box __________

Shipping & Handling ($25/box) __________

Total Store Cost __________

> Wholesale Cost per Item × Items per Box
> = Wholesale Cost per Box
>
> Wholesale Cost per Box + Shipping & Handling
> = Total Store Cost

3) Calculate the retail price. Assume a store owner would need to charge a markup of 50% to cover salaries, rent, overhead, and profit.

Store Cost of Each Item __________

Store's Cost Markup __________

Retail Price Tag __________

> Total Store Cost / Items per Box
> = Store Cost of Each Item
>
> Store Cost of Each Item +
> (Store's Cost Markup × Store Cost of Each Item)
> = Retail Price

4) Do you think people will pay the retail price for your cell phone holder? Why or why not?

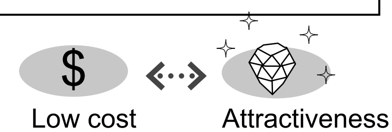
8. What Are the Trade-Offs?

Competition often means that the manufacturer has to find a way to reduce the cost of the product or go out of business. The last step is to think about how you might reduce costs.

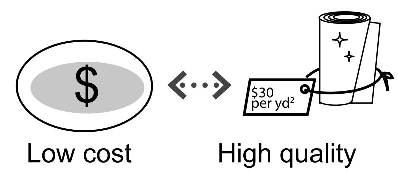
- Reducing the cost of an item almost always involves trade-offs.

> A **trade-off** is a design choice in which one benefit is chosen at the expense of another.

- For example, attaching gemstones to the cell phone would make it very attractive to many people; it would also require more materials and more labor, so it would be more expensive.



- Making the cell phone holder out of a **cheaper material** will make it **less expensive,** but it may wear out sooner, so people are less likely to buy it.



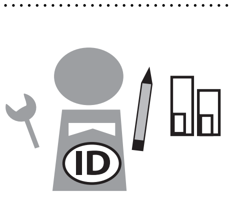
1) Write about one trade-off that would make the product less expensive. Do you think this is a good trade-off?

2) Write about one trade-off you think would help sell more products.

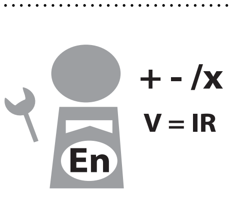
Read Chapter 2 and 3, "Birth of a New Technology" and "Designs That Take Flight," in the textbook *Engineering the Future.* Think about the kinds of work done by Amy Smith, Shawn Frayne, and Jamy Drouillard, and compare it with the work you did in designing a cell phone holder. Use notebook paper to answer the questions at the end of the chapter. Sign, date, and number each page.

Benchmark

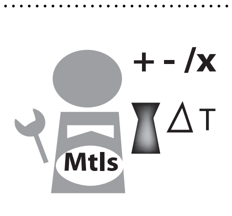
The Work of Engineers



The work of industrial designers and engineers is similar in many ways. People in both professions improve technologies and invent new devices to solve problems that meet human needs and desires. What defines **engineering** is the application of mathematics and science to the industrial design process.



Engineers and scientists do similar kinds of things such as conduct experiments and build models, but their goals are different. Scientists' goals are to learn about the natural world, while engineers' goals are to solve problems to meet human needs and desires.



There are many different kinds of engineers. For example, materials engineers apply chemistry and methods of testing materials to determine which are the best for different uses. Structural engineers carry out calculations and conduct tests to be sure that buildings and bridges are strong, safe, and economical.

1) How was the work that you did to develop a cell phone holder *similar* to the work of the engineers in the first three chapters of the textbook?

2) How was the work that you did *different* from the work of the engineers in the first three chapters?

3) If you were to undertake a design task again, what would you do differently?

Congratulations! You have just engineered your first product!

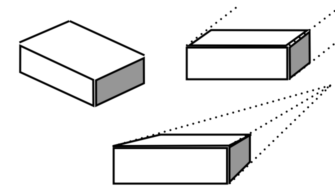
 Initial ______________ Date ___________

TASK 1.3 Engineering Drawing

- Explain why engineers use practical drawing methods.
- Recognize and be able to use different technical drawing methods.

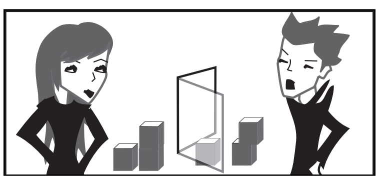
Engineers need to communicate their ideas about designs to the people who will build them. There are several different types of drawings that are useful in different situations. In this task you will learn about **orthographic, oblique, isometric,** and **perspective drawings.**

The following game will demonstrate why good drawings are needed to communicate ideas when manufacturing something an engineer designed.

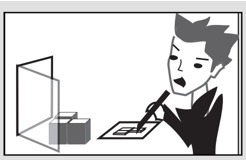


Can you tell what methods were used to make these drawings?

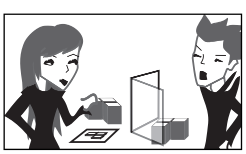
Drawing Exercise



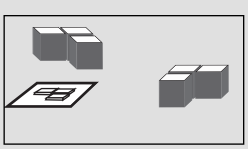
You and a partner will sit facing each other at a table or desk. In front of you are some blocks, a sheet of paper, and a manila folder. Your partner also has some blocks just like yours, and a sheet of paper. Position the manila folder so that you cannot see your partner's blocks and he or she cannot see yours.



Now arrange your blocks in any way you'd like, and make a drawing to show how they are positioned. You will have just two minutes to make your drawing.



Give your drawing to your partner, who will try to arrange his or her blocks just as you have drawn them without asking questions or looking at your blocks. Your partner will have just two minutes. Watch the process, but don't offer any hints!



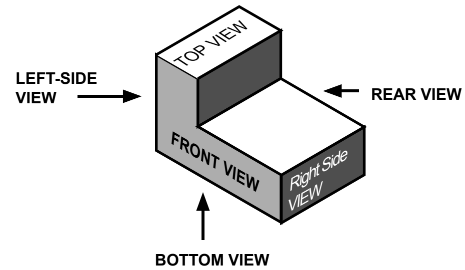
Then remove the folder so your partner can compare his or her blocks with yours. Are they positioned the same way?

Now switch. Have your partner arrange the blocks and create a drawing for you to follow. Again, talk about the experience.

What did you learn from this experience?

Viewing an Object

On the right is a drawing of an L-shaped box. There are six sides to the box, and you could choose to call any one of them the "front view." We decided to label the light gray side the "front view." The top view is white, and the right-side view is dark gray. The other three sides (the rear, bottom, and left side) can't be seen in this drawing.

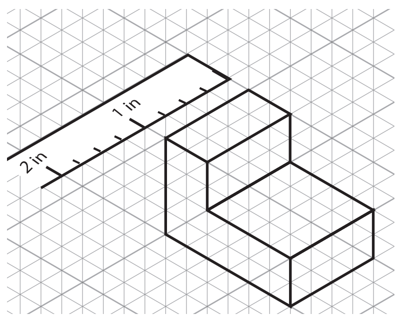


Understanding Scale

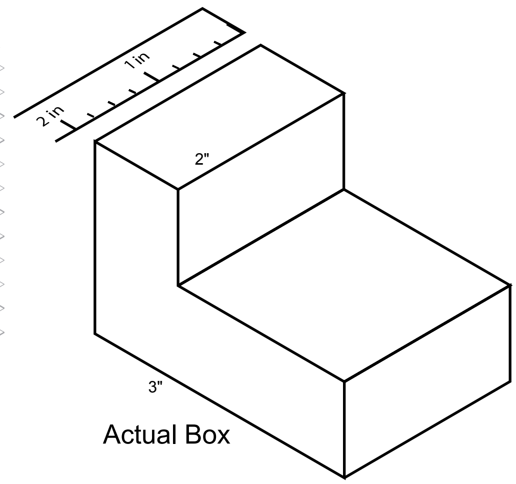
What Is Scale?

If an object is too large to draw a full-size picture of it on a piece of paper, a drawing can be scaled down. Scale is a ratio of a length used in a drawing to the actual length of the object.

1 inch may also be written as 1"
1 foot may also be written as 1'
Ex. 12 inches = 12" = 1 ft = 1'



Drawing Scale 1:2



Actual Box

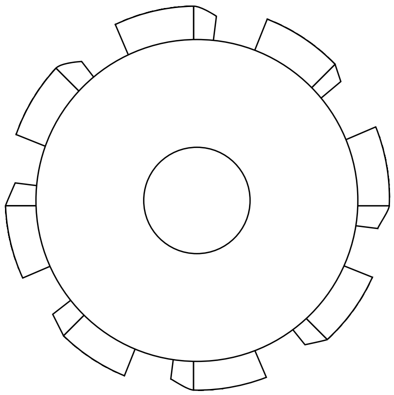
For the L-shaped box, 1 inch on the drawing represents 2 inches on the actual box. The scale is 1/2, or 1:2.

1) How long should a 3" side of the object be in this drawing?

2) What would the scale on the drawing be if you wanted to make it three times bigger than the actual object?

Practice with Scale

1) The actual gear represented in the drawing below has an outside diameter (including gear teeth) of 16 inches. Measure the drawing and write the correct scale.



scale: ______:_______
model actual

HINT: When writing the scale as a ratio, use the same units on both sides of the colon.
For example:

1:4 means 1 inch: 4 inches, or 1 foot: 4 feet.

2) What is the scale if a 4-inch length on the drawing corresponds to a 4-foot length on the actual object?

scale: ______in. :_______in.

3) A building has a wall of windows that is 12 feet across. If a scale of 1:24 is used, how wide is the wall of windows on the drawing, in inches?

4) Car designers build models of new designs because, unlike a drawing, a model can be seen from all sides. If you built a 1:10 scale model of a car that is 15 feet long, how long would the model be? Give your answer in inches.

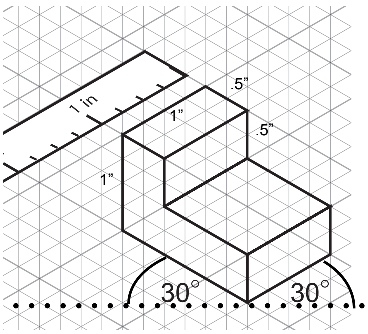
5) If you are a carpenter following a 1:20 blueprint for a house and you measure one wall on the blueprint to be 8 inches long, how long should you build the wall for the house? Give your answer in inches.

6) If you discovered that the architect who made the blueprint made a mistake, and the scale should really have been 1:25, how would you need to change the length of the wall of the house?

Types of Drawing

There are many different ways to draw an object. Each type of drawing can communicate an idea in a different way. Because they serve different purposes, it's good to know multiple ways of drawing. The two most useful kinds of drawings for engineers are isometric and orthographic drawings.

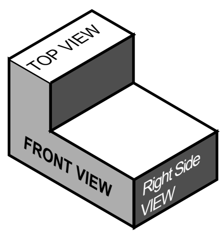
Isometric Drawing

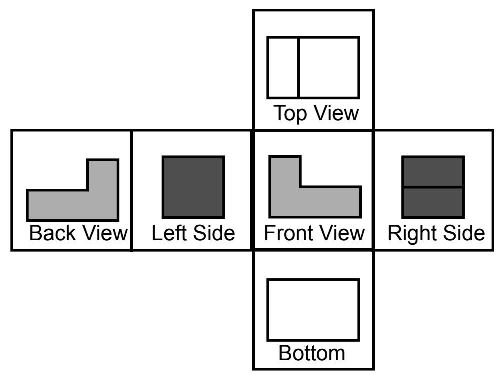


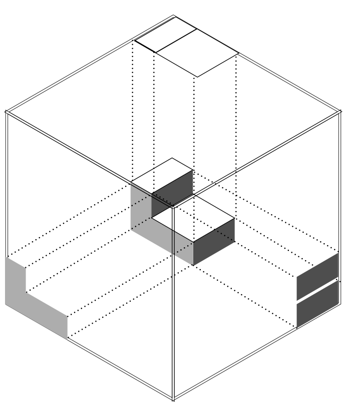
The L-shaped box drawing you've seen is an isometric drawing. **Isometric** drawings show the front, top, and right-side views, and all lines are drawn to scale. The word "isometric" is from the Greek, meaning "equal measure." Depth is shown by slanting the edges up at a 30° angle from the horizontal. This type of drawing is especially useful to engineers because it shows depth, and each line is drawn to scale.

Orthographic Drawing

Orthographic drawings show the top, sides, and bottom of an object, which is why they are also called "multi-view" drawings.



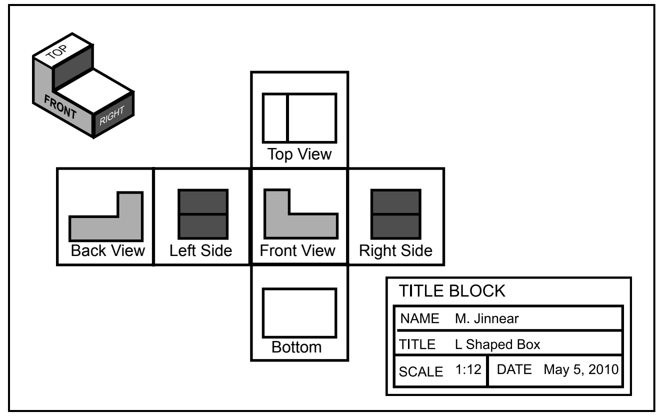




One way to think about how orthographic drawings are made is to imagine the object you are trying to draw in a transparent plastic box. You could look at the box from the front side and trace the shape of the object on the box. You could then go around to all the other sides and trace what you see from that point of view.

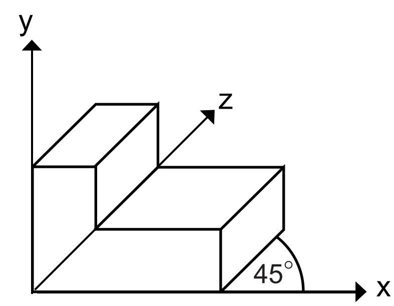
As you can see, there are six different drawings in all. If the box is then opened up and laid flat, you would see the six drawings shown here. However, people usually just draw the front, top, and right-side views, because the back, bottom, and left-side views are almost the same. The drawings are drawn to scale.

1) Both isometric and orthographic drawings are used for manufacturing drawings. Why do you think that is?



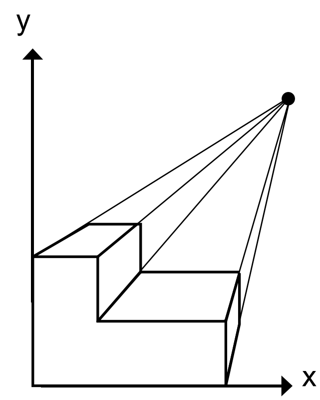
Oblique Drawing

Oblique drawings show the front, top, and one side of an object. The front face of the object is drawn as though you are looking at it from the front. Horizontal edges are then drawn back from the front at a 45° angle to give the impression of depth, but these lines are not drawn to scale. Because oblique drawings are not drawn to scale, they are not as useful to engineers as isometric or orthographic drawings.



Perspective Drawing

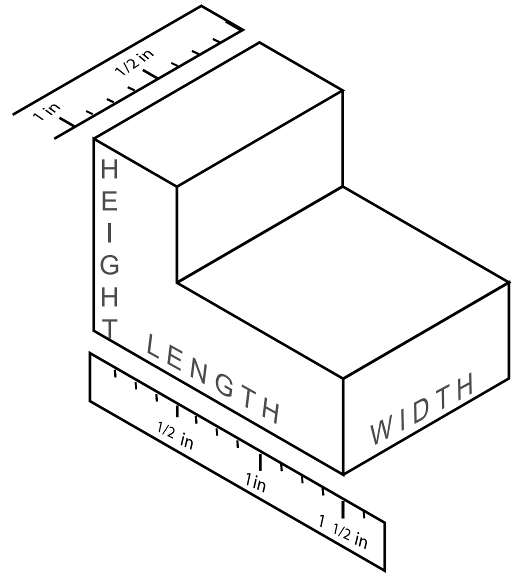
Perspective drawings show objects as they would appear to the naked eye, or as they would appear in a photograph. Lines showing depth converge toward an imaginary "vanishing point." This creates the appearance of distance.



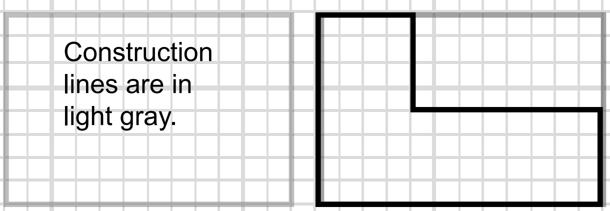
1) Artists and architects like oblique and perspective drawings because they make it easy to picture what buildings and other three-dimensional objects look like in the real world. Do you think engineers would find perspective drawings useful? Explain your answer.

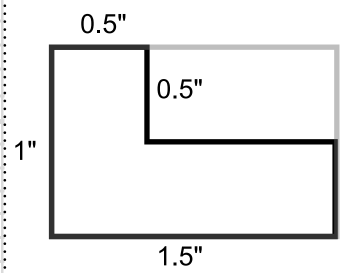
Make an Orthographic Drawing

When you make an orthographic drawing use a pencil for your drawings and draw lightly to start. That way you can draw guidelines (called "construction lines") that you can later erase. The following are the steps to make an orthographic drawing of the L-shaped object on this page.



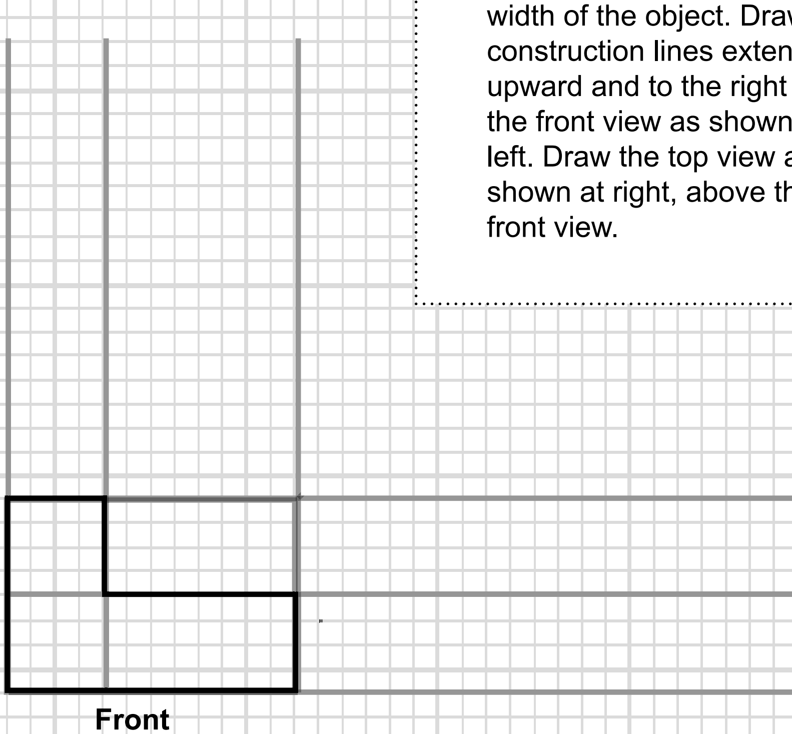
1) Front view. Measure the length and height of the object, and decide on the scale for the drawing. Draw light construction lines to frame the front view. Then make any other relevant measurements and draw the front view in the lower-left side of the paper within the construction lines, as shown below.

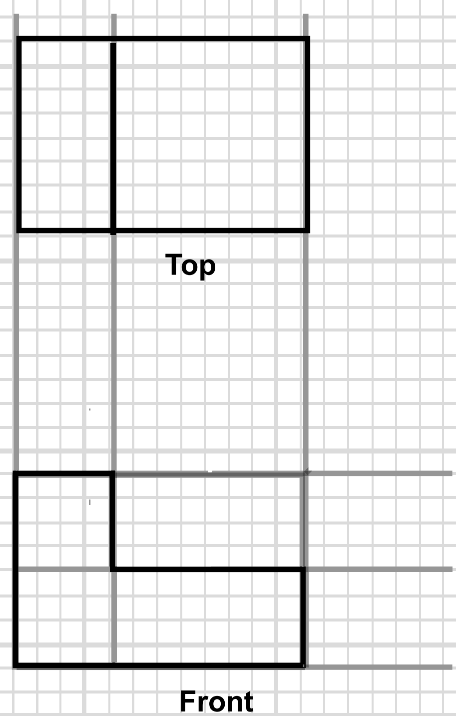




Note: Make a sketch of the object and write down the measurements so you don't forget them.

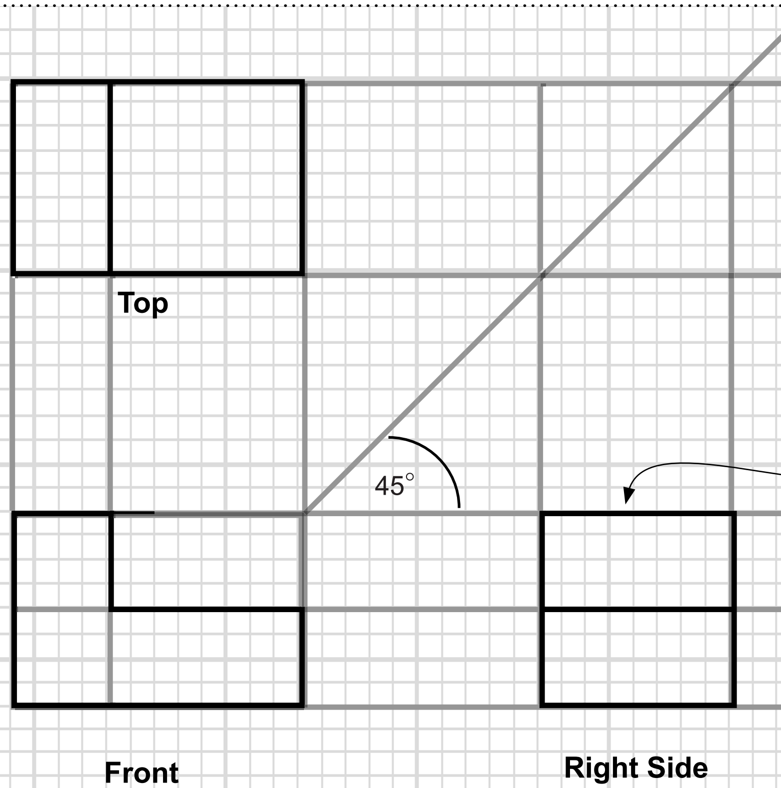
2) Top view. Measure the width of the object. Draw construction lines extending upward and to the right from the front view as shown at left. Draw the top view as shown at right, above the front view.





3) Right-side view. Draw construction lines from the top view to the right. Draw a line from the corner of the front view block at a 45° angle so it crosses the construction lines. Drop construction lines downward from where the lines cross to frame the right-side view.

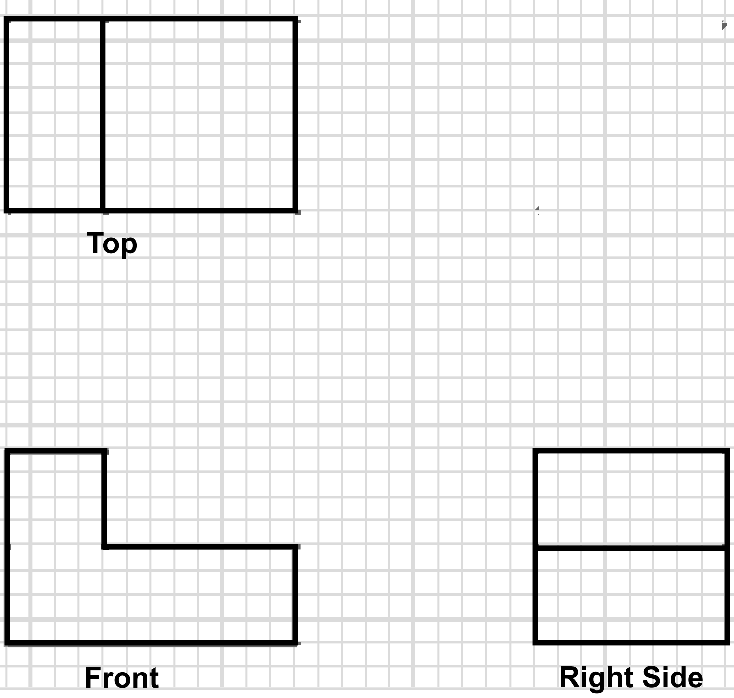
4) Confirm measurements. Look at the three views, recalling which should represent the length, width, and height of the object. Use a ruler to confirm that each of the three views is drawn accurately. If corrections are needed, erase and redraw.



Note: The top edge of the right view is the same as the right edge of the top view.

5) Erase the construction lines to make a nice, clean drawing.

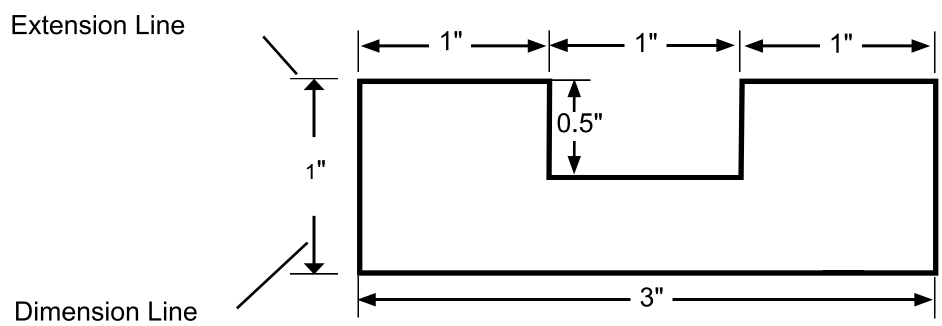
6) Add dimensions and labels. Read the next page about how to add dimensions to engineering drawings. Then write in all of the dimensions on all three views.



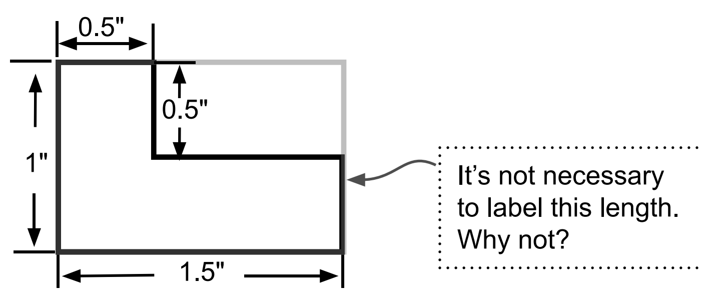
Labels and Dimensions

All engineering drawings should indicate **dimensions**—the distances and locations on the actual object.

- Each dimension often consists of a **dimension line,** capped by two arrowheads and broken in the middle for the measured distance on the real object.
- Two **extension lines** may extend from the edges of the object to show clearly where the dimension line begins and ends.
- There should be enough dimensions to fully show the details of the object. Both dimension and extension lines should be lighter than object lines.



1) The front view of the drawings shown on the previous page should be labeled as shown at right. Return to the previous page and label all of the dimensions on the three views.



Title blocks are used to give essential information on technical drawings. They typically include the name of the drafter, the title of the drawing, scale, and date, and are located on the lower-right side of the engineering drawing.

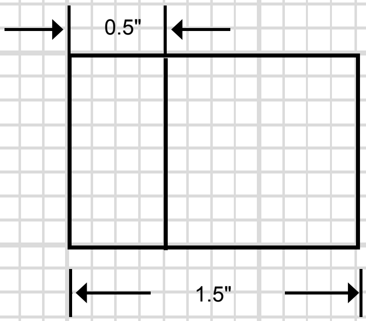
2) Make a title block for the drawing on the previous page. Use your name, a title for the drawing that describes the shape, the actual scale of the drawing, and today's date.

TITLE BLOCK

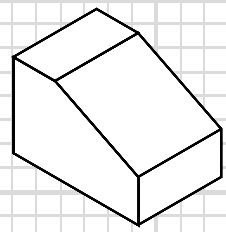
NAME Justin Tyme	
TITLE Town Hall	
SCALE 1:24	DATE July 4, 1776

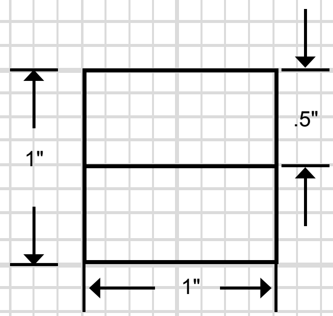
Practice Drawing I

1) The orthographic drawing below shows the top and right-side views. Draw the front view.



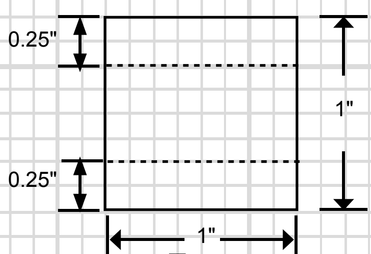
Top



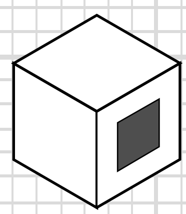


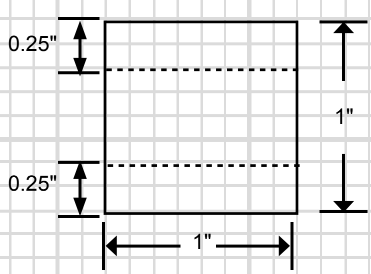
Front **Right Side**

2) The orthographic drawing below shows the top and front views. Notice that the dotted lines show the position of the hole in the block, even though they are not visible on the top and front view. Draw the right-side view.



Top



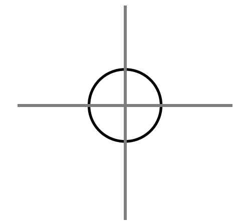


Front **Right Side**

Name ______________________________

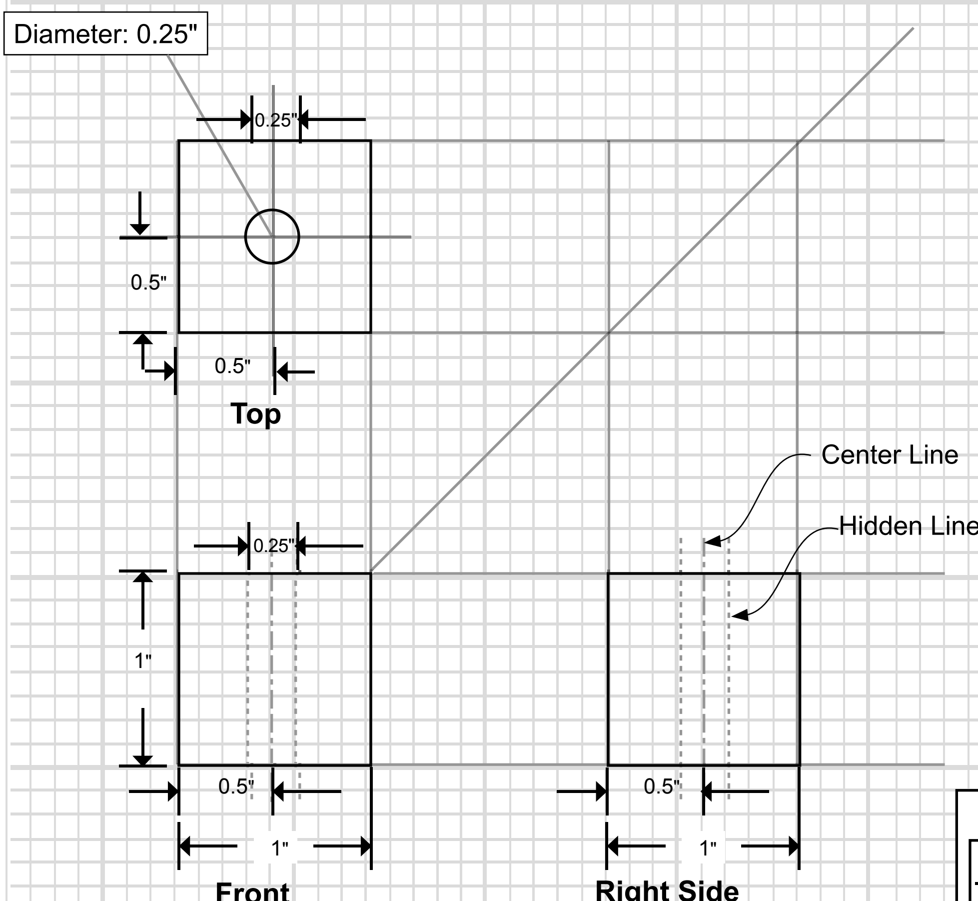
Holes and Circles

Circles: Top View. To draw a circle, start with a center point. Draw horizontal and vertical construction lines. If the circle is small, you can draw it with a plastic or metal template. For medium to large circles, to make them you will need a compass. As illustrated in the "Top" view below, you should indicate both the center of the circle and the diameter of the circle.



Circles: Front and Side Views. Because you cannot see the hole from the side, its location in the object is shown by hidden lines, drawn as short dashes. A **centerline,** drawn through the middle of the hole is indicated by alternating long and short dashes. Both hidden lines and centerlines are lighter than object lines.

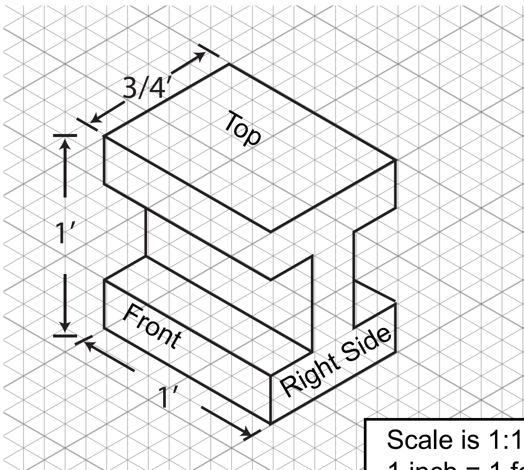
Using the orthographic drawing below, sketch what you think the original object looks like.



TITLE BLOCK	
NAME Dinna Time	
TITLE Block with Hole	
SCALE 1:1	DATE May 1, 2010

Initial ______________ Date ___________

Practice Drawing II



Scale is 1:12
1 inch = 1 foot

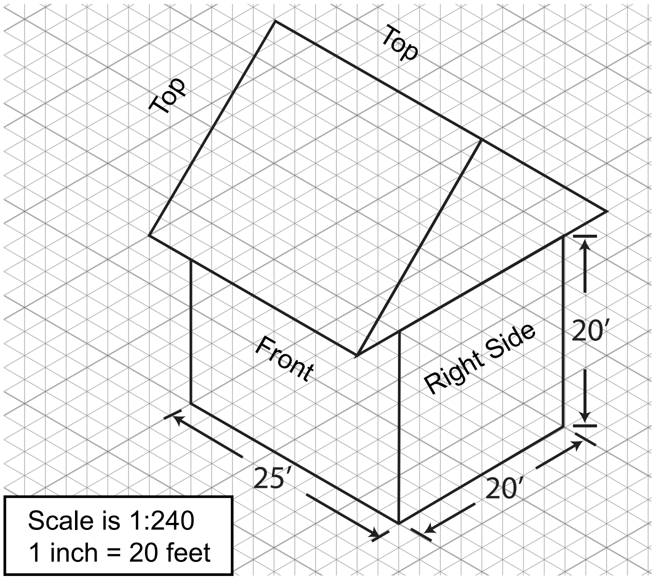
Convert this isometric drawing to an orthographic drawing.

- Remember that in isometric drawings you can take accurate measurements of all edges directly from the drawing.
- Use solid lines to show edges that are visible to the viewer. Use dotted lines to show hidden edges that are not visible from that view. (Hint: the top view should show two hidden edges.)
- The graph paper has eight lines per inch.

Draw the orthographic version below showing the front, top, and right side. Label your drawing with dimension lines and extension lines, and complete the title block at the bottom of the page.

TITLE BLOCK	
NAME	
TITLE	
SCALE	DATE

Name ___



Convert this isometric drawing to an orthographic drawing.

- The greatest challenge in this task is to measure and draw the roof.
- Be sure to show both sides of the roof in the top view. Use dotted lines to show the hidden walls of the house covered by the overhang.
- Be sure to include the roof in the front and right-side views.
- Remember that in isometric drawings you can take accurate measurements of all edges directly from the drawing.

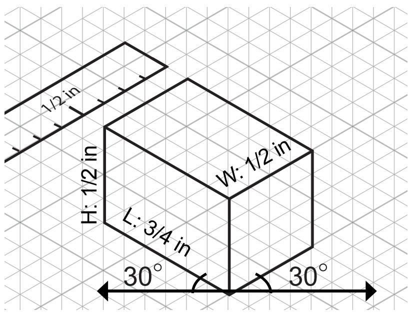
Draw the orthographic version below showing the front, top, and right side. Label your drawing with dimension lines and extension lines, and complete the title block at the bottom of the page.

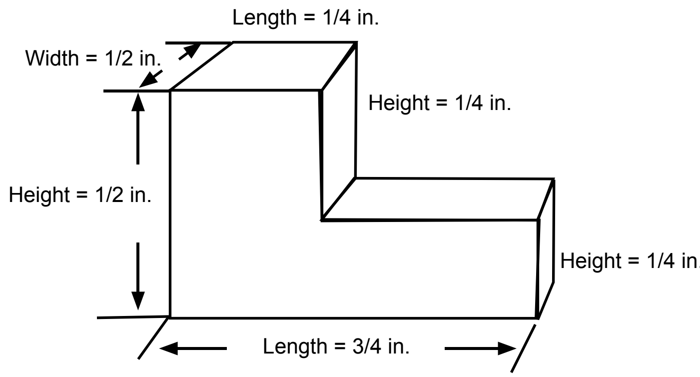
Initial ___ Date ___

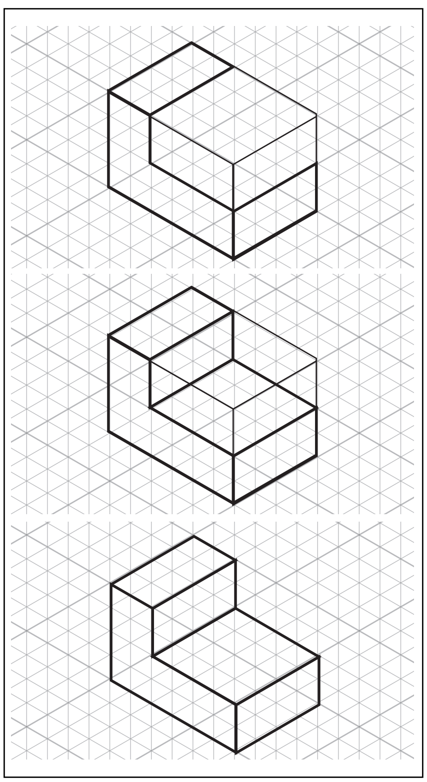
Make an Isometric Drawing

To make an isometric drawing, start with an orthographic drawing or with the object itself.
In this case, the measurements are from a perspective drawing of an L-shaped block.

1) Measure the overall length, width, and height, and use isometric graph paper to draw a scaled 3-D box that will fit the object.



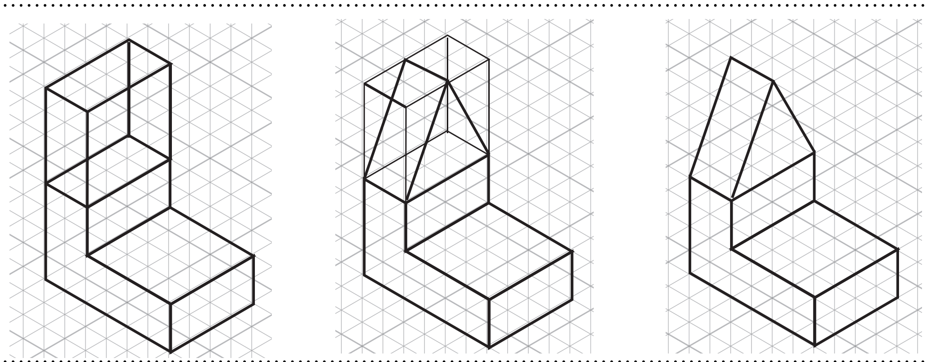




2) Using light pencil lines, draw the front, top, and right-side views on this scaled box with construction lines.

3) Add additional lines for further details of the object. As you add these lines, the process might feel a little like sculpting away the material you want removed.

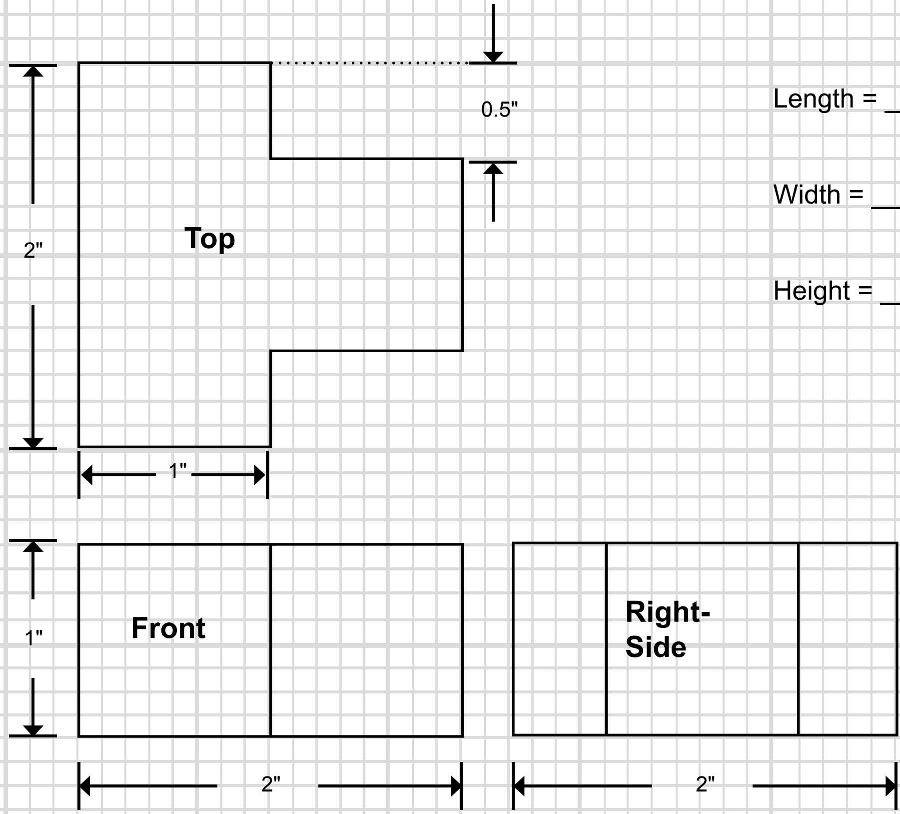
4) Darken the object lines and erase the construction lines to finish your isometric drawing.



5) This technique can be used to add material onto an isometric drawing, making it a very useful way to sketch out ideas quickly!

Practice Isometric Drawing

Convert the orthographic drawing to an isometric drawing. First, try to picture the object in your mind. Then follow the steps on the previous page.



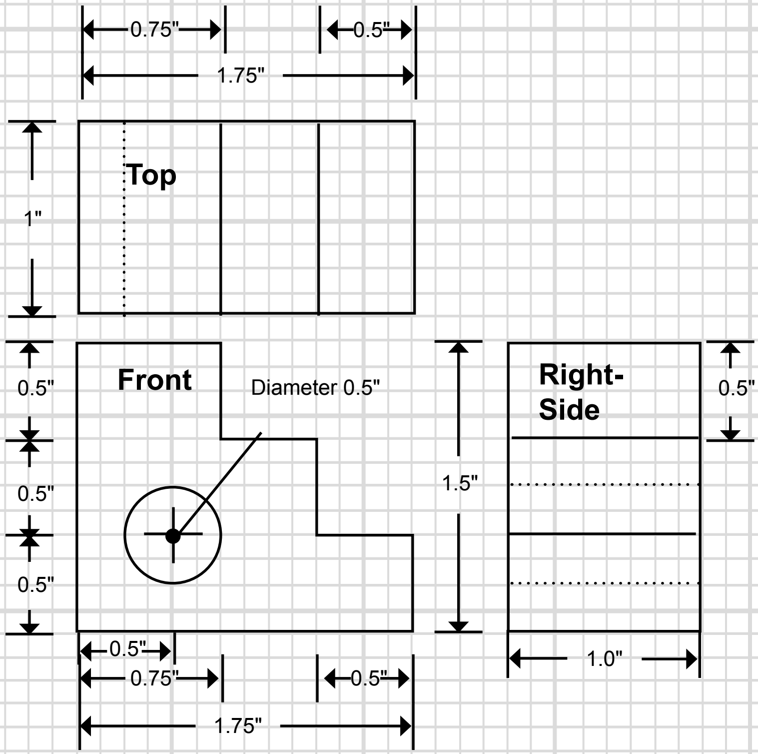
Length = __________ in.

Width = __________ in.

Height = __________ in.

Initial ______________ Date __________

Convert the orthographic drawing to an isometric drawing. Notice that hidden shapes are shown with dashed lines. Again, try to picture the object before drawing it.



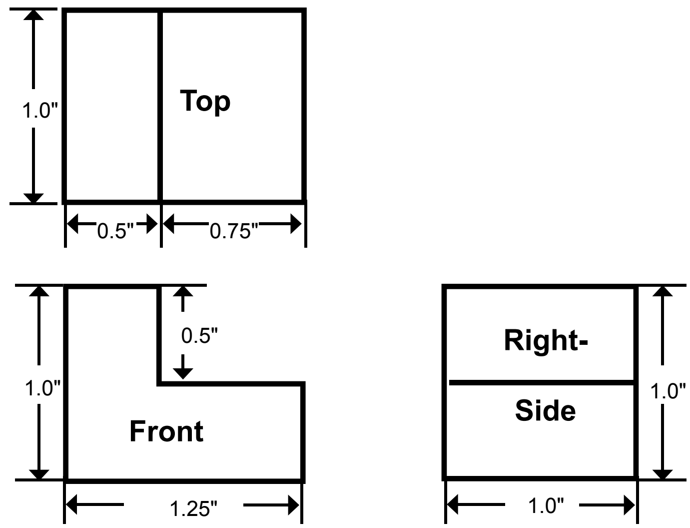
Name ______________________________

Find your own objects and practice isometric drawing.

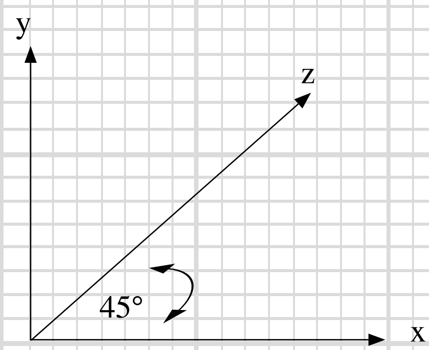
Initial ______________ Date __________

Make an Oblique Drawing

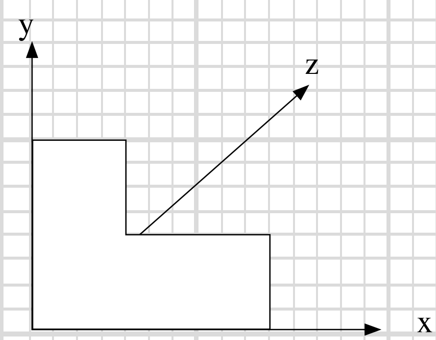
An oblique drawing of an object can be made from its orthographic drawing. Here is the orthographic drawing of an object that was used in previous examples. To convert an orthographic drawing to an oblique drawing, follow these steps:



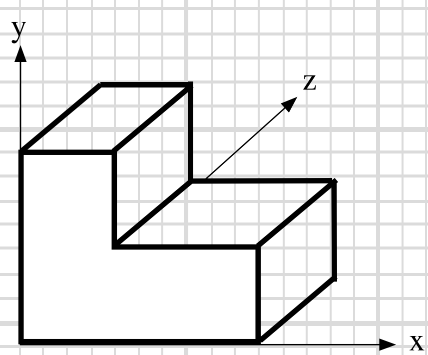
1) Use light pencil lines to draw three axes. Imagine x- and z-axis to be flat on the ground, while the y-axis points straight up. Draw the z-axis 45° from the x-axis.



2) Use a ruler to measure the front side in the orthographic drawing. With light pencil lines, draw this shape using the x- and y-axis. Erase the part of the z-axis behind the figure.



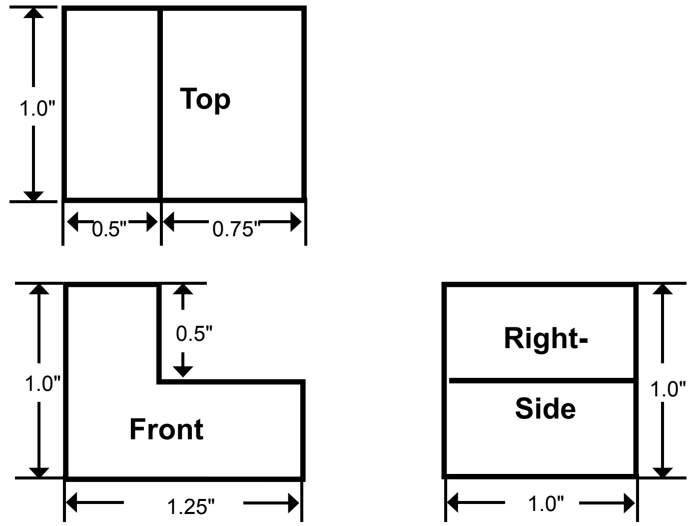
3) Lightly draw lines parallel to the z-axis from each corner of the front that will be visible. These lines should be one half the actual length. Connect the ends of the lines with short lines parallel to the x- and y-axis. Now darken the final lines of the oblique figure.



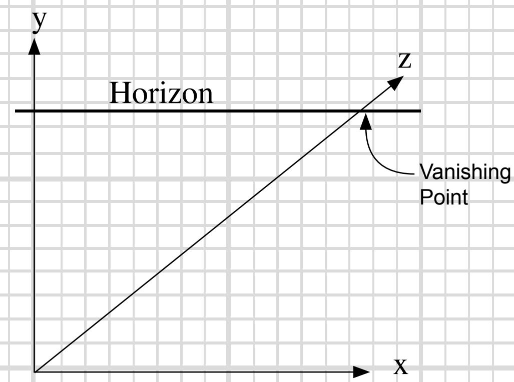
Name ______________________

Make a Perspective Drawing

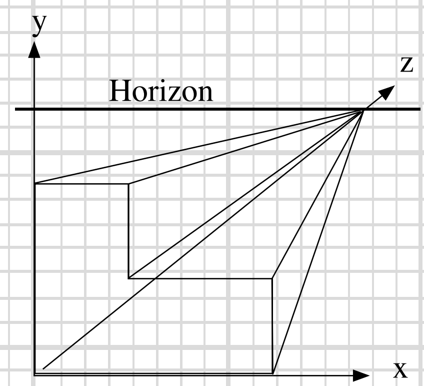
A perspective drawing of an object can be made from its orthographic drawing. Here is the orthographic drawing used in previous examples. To convert an orthographic drawing to a perspective drawing, follow these steps:



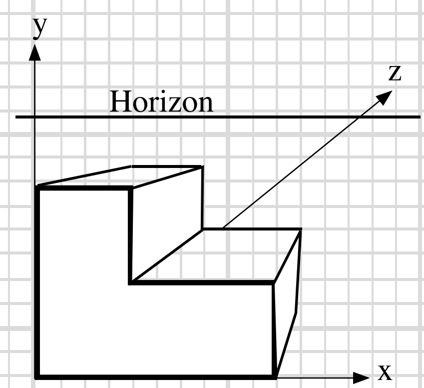
1) Use light pencil lines to draw x-, y-, and z-axes. The z-axis can be at any angle. Draw a horizontal line that will be the "horizon" (where the sky appears to meet the land). The spot where the horizon meets the z-axis is called the "vanishing point."



2) As you did in making an oblique drawing, use a ruler to measure the front side in the orthographic drawing, and draw this shape using the x- and y-axis. Use a ruler to draw straight, light pencil lines from each corner of the front that will be visible to the vanishing point.



3) Lightly draw horizontal and vertical lines parallel to the x- and y-axis to show the approximate depth of the figure. Now erase the lines behind the figure, and darken the final lines of the perspective drawing.



Initial ____________ Date __________

Practice Oblique and Perspective Drawing

Select an object of your choice and make an oblique and a perspective drawing of it on this page.

Initial ______________ Date __________

Name ______________________________

Compare Drawing Methods

Engineers are expected to communicate ideas about their designs accurately and clearly so that items they design can be built. Please consider the pros and cons of each of these drawing methods.

Pros of Orthographic Drawing

Cons of Orthographic Drawing

Pros of Oblique Drawing

Cons of Oblique Drawing

Pros of Perspective Drawing

Cons of Perspective Drawing

Pros of Isometric Drawing

Cons of Isometric Drawing

No single drawing method is perfect, so most engineers use at least two kinds of drawings to communicate their ideas. Most engineers choose orthographic and isometric drawings. Why do you think they chose those two kinds of drawings?

Read Chapter 4, "Beyond Words," in the textbook *Engineering the Future* to find out about the importance of good engineering drawing. Use notebook paper to answer the questions at the end of the chapter. Sign, date, and number each page. Insert the pages at this point in your *Engineer's Notebook*.

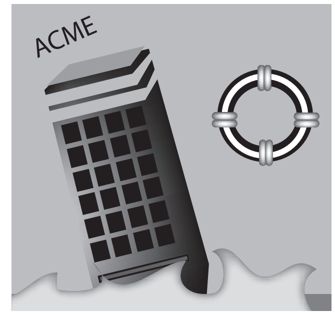
Initial ______________ Date ___________

TASK 1.4 Define the Problem

- Identify criteria and constraints.
- Plan ahead to finish the project.
- Define the problem to be solved.

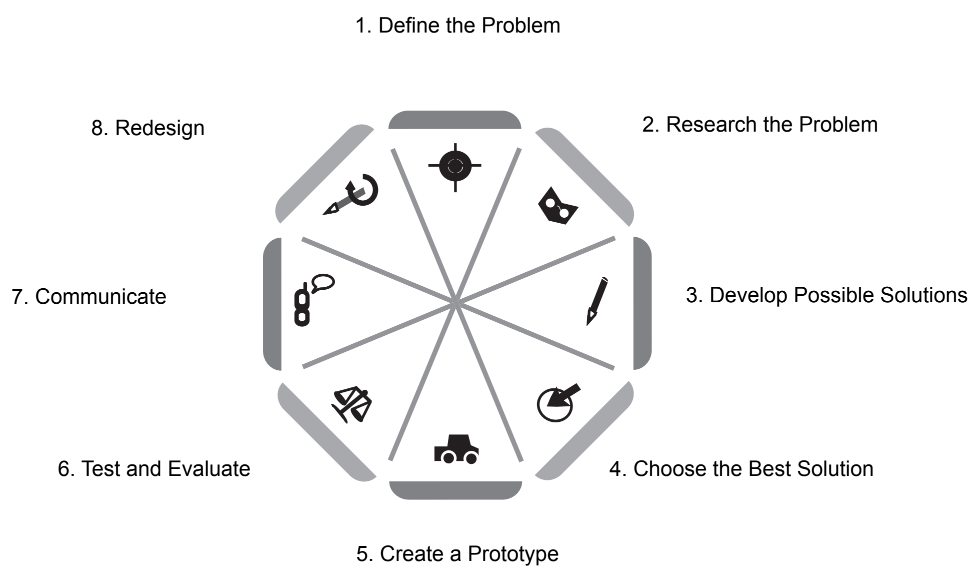
In designing a cell phone holder, which steps in the engineering design process did you use?

This task requires you to define a new problem. If you complete each of the subsequent steps, you will end up with an excellent solution to the problem as well as a good understanding of the entire engineering design process.



How will you use the engineering design process to rescue Acme?

Engineering Design Process



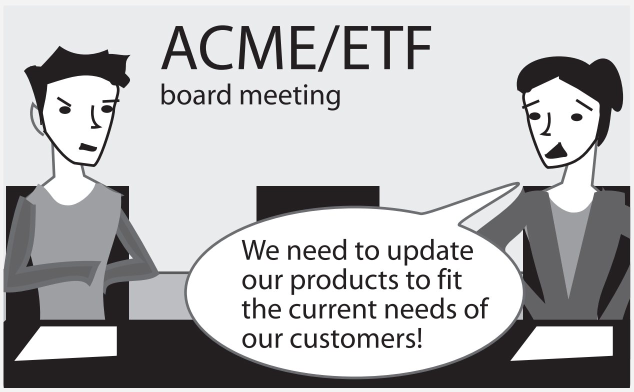
In future tasks, you'll see an icon like this in the task heading to remind you which step of the process you are working on. The picture indicates the step, and the shaded section indicates the place in the sequence.

Carefully read the following scenario, then define the problem.

DESIGN CHALLENGE

Save Acme Organizer Company

The Acme Organizer Company, the largest business in a small town, needs your help!



For the past 40 years, Acme has produced and sold organizers all over the country. While they have produced many products over the years, about ten years ago they discontinued most of their products and focused on making cabinets for storing videotapes. The organizers were sturdy and attractive and sold very well. When DVDs came into general use, the company added a new product line to include cabinets for storing DVDs. They gradually sold fewer cabinets for storing videotapes and more cabinets for storing DVDs.

In recent months, business has begun to fall off. Acme's Marketing Group found that digital cable services were becoming more popular, and people have begun to get movies directly through satellite or cable services, so fewer people need to purchase DVDs. Although Acme has not had to lay off any of their employees yet, it is clear that if business continues to decline they will have to do so, and they may eventually go out of business. That would be a catastrophe for the small town where the company is located, and hundreds of people will be out of work. With no regular income, they will not be able to purchase food, clothing, or other items from local stores, so more businesses will be forced to close; and with no businesses to pay taxes, the town will not be able to pay for police, fire protection, or schools.

Your job is to work as a team of engineers to design a new product for the Acme Organizer Company. Your product will be an organizer that will save the company and prevent the hardship that would occur if the company goes out of business.

 Initial ____ Date ____

What Is an Organizer?

Before joining a team, it's a good idea to think about the problem on your own.

Begin by expanding your understanding of what an organizer is. Here's one definition:

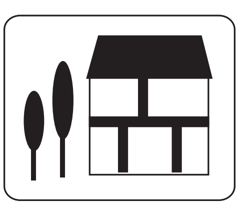
> **or·gan·iz·er (noun):** anything designed to keep smaller things so they stay together and are easy to find and retrieve when needed.

Look around you and identify all of the organizers you can see. List at least five of them below.

Type of Organizer	Types of Things It Organizes
1)	
2)	
3)	
4)	
5)	

Now imagine that all of these organizers disappeared!

In the space below, describe what this room would look like if the organizers disappeared but the things in them remained.



How is a house like an organizer? Write your answer here.

Name ___

Criteria and Constraints

Defining the problem means describing the requirements for the new product that you are developing. Requirements include **criteria,** or the desired elements of the final product, and **constraints,** limitations to the design or the design process. Criteria such as attractive design and multiple storage compartments help you choose the best solution to the problem. Constraints such as size, time, and cost for construction help you eliminate attractive but impractical solutions.

In Your Own Words

What is the company's problem, and what have you been asked to do?

Finding Criteria

What are the criteria by which you will determine whether or not you have been successful? List at least three criteria.

1)

2)

3)

Finding Constraints

What are the constraints of this problem? These might have to do with the materials you have available or the time allowed for the project. List at least three.

1)

2)

3)

Initial ___ Date ___

Form a Team

A diverse team of people with a wide variety of backgrounds and skills is very helpful in creating excellent products that will meet people's needs. In the space below, list the strengths that you bring to the team, as well as your teammates' strengths. All of you will need to work together to design a successful product for the Acme Organizer Company.

My Strengths

My Teammates' Strengths

Meet your teammates! In the spaces below, write their names and their strengths:

Name Strengths

Name Strengths

Name Strengths

Name Strengths

Meet in Teams

1) Organize your team by designating co-leaders and specialists for critical objectives.

2) Review the Teamwork Guidelines and amend them as agreed.

3) Jointly agree upon your mission, objectives, and commitment to accomplish the challenge.

4) Schedule your team effort by setting a timeline of tasks and delegated responsibilities.

5) Carry out your plan on schedule, documenting procedures and results as you go.

6) Prepare a presentation of your team's conclusions and results.

Teamwork Guidelines

A team shares resources, information, and talent to develop the best solutions to problems. Here are some descriptions of a good team member collected from working engineers:

A good team member...

- Works well within and outside of the group.
- Encourages and values differences in people and perspectives.
- Treats others with fairness and respect.
- Shares time, materials, ideas, and information openly.
- Maintains focus on common goals.
- Gives credit to others when credit is due.
- Does his or her share of the work.
- Remembers that everyone succeeds if the team succeeds.

Be a Good Team Member

There are seven behaviors that should be displayed by members of a team. They are the following:

Helping,
offering assistance to others.

Listening,
working from each others' ideas.

Participating,
contributing to the project.

Persuading,
exchanging, defending, and rethinking ideas.

Questioning,
interacting, discussing, and posing questions to all members of the team.

Respecting,
encouraging and supporting the ideas and efforts of others.

Sharing,
offering ideas, and reporting findings to each other.

Read Chapter 5, "The Art of Engineering," in the textbook *Engineering the Future.* Robert Hartmann works for IDEO. Pay attention to what he says about working on a team. Use notebook paper to answer the questions at the end of the chapter. Sign, date, and number each page. Insert the pages at this point in your *Engineer's Notebook.*

Looking Ahead

After you design your project, you will have an opportunity to build a scale model. Depending on time and materials available, you may also have a chance to construct a prototype. One of the most important constraints in any design project is the materials that will be available. If you know what materials you can use, list them on this page. If not, you can come back to this page later.

Materials for Scale Model

A **scale model** is a three-dimensional model of the design that is constructed with a scale factor. Scale models are made out of materials that are easy to cut, tape, or glue together, so you can change it easily. It is likely to be smaller than the final product, but the proportions should be correct. List materials that will be available for your scale model here:

Materials for Prototype

A **prototype** is usually a full-size model of the product constructed from the same material that will be used for manufacturing. For this project your prototype material may not be the same as what you propose for manufacturing. List materials that might be available for your prototype here:

Important—Keep Good Records!

At the conclusion of this project, you will be evaluated on how well you've done. Save all models and prototypes. Place sketches and notes into your notebook in the appropriate places. Your work on all Tasks from 1-4 to 1-11 will be included in this evaluation. Read the Project 1 Evaluation Rubric to see the evaluation criteria.

Initial ____________ Date ____________

Benchmarks

1) In what ways is a city an organizer?

2) Organizers are commonly made for each of the following technologies. What do you call these organizers? (If there is more than one, then name both.)

Technology	Name of Organizer
Books	
Socks	
Shirts and pants	
Money	
Dishes	
Papers	
Electronic information	
Cars	

3) Name three reasons why teams usually create better solutions than individuals.

TASK 1.5 Research the Problem

- Research competition.
- Plan and conduct market research.
- Compare "mass markets" vs. "niche markets."

Like all companies, the Acme Organizer Company has competition. Each member of your team will visit stores as well as browse catalogues, magazines, and the web to determine what organizers are being sold, who buys them, and what they cost. Then your team will share information and develop initial ideas about what kinds of organizers are still needed and who might buy them. Finally, you will decide on a market and audience. Your team should conduct research "in the field" to better define the problem and identify criteria for a successful solution.

Research the Competition

Gather information on organizers that are currently being sold. List the information you collect below.

Type of Organizer	Customer Group	Cost

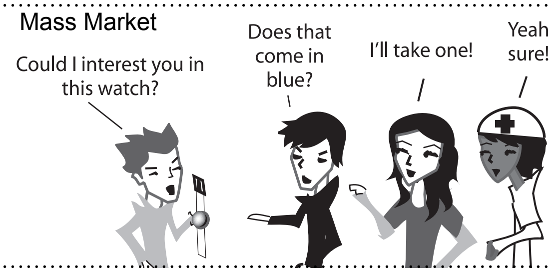
Mass Markets vs. Niche Markets

Have each person on your team share what he or she learned about the competition. Then discuss the pros and cons of a mass market versus a niche market for the organizer you will design. Finally, list several possible audiences for your new organizer.

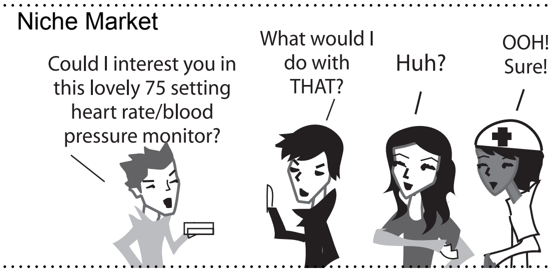
Definitions

The **market** for a given product refers to a group of customers who might be interested in purchasing these products.

Mass market means the product would be of interest to very large groups of people, such as all adults or all children between the ages of eight and eleven.



Niche market means that a relatively small group of people who have certain occupations or interests might purchase the product.



Choosing Your Market

1) What are the advantages of a mass market?

2) What are the advantages of a niche market?

List several groups of people who may be interested in purchasing new or improved organizers. Make a separate list of niche markets and mass markets.	Mass Markets	Niche Markets

Initial ____________ Date ____________

Plan a Marketing Study

1) Each person on your team should choose a possible group from the previous list. Two people may choose the same group, but overall your team should consider at least two or three different possible groups to research. Which will you research?

Name of Group:_______________________ Is this a mass market?___ Niche market?___

2) At the bottom of the page, list a series of questions to ask people in that group such as what organizers they use, what they like and dislike about their organizers, and what other things they might like to have organizers for. While coming up with questions, keep in mind the possibility of making improvements in current products, as well as the possibility of inventing an entirely new kind of organizer.

3) So that your team will end up with a wide variety of questions, do NOT share these ideas with your team members until after each of you has made a list of possible questions.

Possible Questions

Conduct Marketing Study and Summarize Results

Compare Notes

1) Compare questions with other members of your team. It is okay if two members have chosen the same market to research, as long as different team members interview different individuals.

2) Remember, you are trying to come up with the best set of interview questions, so feel free to borrow ideas from each other to determine the best set of questions you could ask in your interviews.

Final List of Questions

1) Your final list should be about six to ten questions. A shorter list is not likely to produce enough information to determine people's needs, and a longer list might discourage them from participating in your interview.

2) Make your final list of questions on a separate sheet of paper. The paper should have your name, the date, and a list of numbered questions. Each time you interview someone in the target group, record his or her answers on a sheet of paper with the corresponding question number. Be sure to write clearly enough so you can read your own writing later!

Conduct Interviews

1) Interview 8–9 people in your target group.

2) When you have finished your interviews, use a blank sheet to summarize the results. Insert the summary sheet into your notebook at this point.

Research Summary

Summarize the results of your research below.

1) What does this group need or want? State what might make a good design project.

2) What specific requests from possible customers seem practical and worth designing?

Redefine the Problem

Share the results of your research with your teammates. Decide together what market has the greatest potential for a new or improved organizer. Go back one step in the engineering design process and write a more precise definition of the problem that is based on the results of research conducted by the team.

1) The problem we are trying to solve is:

2) Our criteria for success are as follows:

3) Our constraints are as follows:

Read Chapter 6, "Bringing Designed Ideas to the Market," in the textbook *Engineering the Future.* Notice what Araceli Ortiz says about what can happen if a company fails to do adequate market research. Use notebook paper to answer the questions at the end of the chapter. Sign, date, and number each page. Insert the pages at this point in your *Engineer's Notebook.*

Initial ______________ Date ___________

Benchmark

1) Which of the following products are designed for niche markets, and which for mass markets? In each case, explain your reasoning.

Products	Niche or Mass Market?	Explain
Eyeglasses		
Pots and pans		
Violins		
Ties and belts		
Surgical instruments		
Drafting tools		
Hammer		
Books		

2) Some companies prefer to focus on niche markets, even though there are not as many potential customers in a niche market. Name two reasons you think a company might choose its specific market.

3) An engineer whose primary goal is to promote health conducts a market survey for every new produce she develops. List three questions she probably asks in her market surveys:

A.

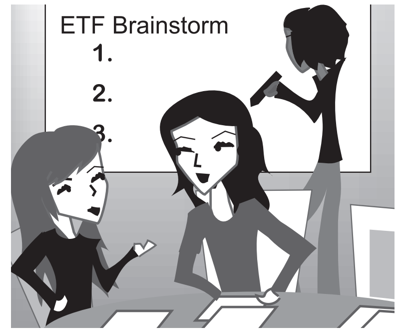
B.

C.

TASK 1.6 Develop Possible Solutions

- Brainstorm and sketch possible solutions to the problem.
- Share ideas with other members of your team.

One of the most enjoyable parts of the engineering design process is coming up with creative ideas. But as you learned from Jamy Drouillard in the textbook, brainstorming is also very challenging. One way to generate different ideas is for each member of the team to work on his or her own to think up various ways to solve the problem, then share those ideas and generate new ones as a group. Keep the potential customers' needs in mind, but be creative!



What solutions will your team come up with?

Individual Brainstorming

Following are some suggestions to help you develop some new ideas. Sketch at least three different ideas on your own before sharing them with your teammates. Use additional sheets of notebook paper or graph paper to sketch your ideas, and insert them into the notebook after this page. Be sure to write your name and date on each page.

1) Audience Interests

What are the special interests of the people in your target audience? What do they care most about? Convenience? Cost? Attractiveness?

2) Things to Organize

What are the qualities of the things that must be stored? What is their size and shape? What is the best quantity? How can you make it easy to retrieve an object? Are there additional items that could be stored as well to make the organizer more valuable or unique?

3) Qualities of the Organizers

Think about unique qualities that would encourage a customer to purchase your product instead of a competitor's product. How might it take up less space, or be lighter, or more colorful, or less expensive? How could you advertise your product so it would stand out?

Name ________________________________

Brainstorm as a Team

After you have sketched at least three different ideas, and your teammates have had a chance to do the same, sit around a table and take turns sharing your favorite ideas.

Lay out your sketches on the table or tape them to the wall. Make sure everyone has a chance to share his or her ideas, but take time for questions and allow for new ideas to pop up during the discussion. Some of the best ideas come in response to someone else's initial brainstorm.

Combining Ideas

Look for opportunities to combine two or three different good ideas. The person who came up with the Swiss Army Knife™ combined a dozen good ideas, and the invention has more than paid off. Combining two or three good ideas may result in a fabulous invention!

Be Sure That Everyone Has a Voice

It's easy to get carried away and forget that the quieter people in the group may have the best ideas. Be sure that everyone in your group has a chance to share his or her initial ideas before decisions are made. Remember that diversity is one of any group's greatest strengths.

Focus

At some point the ideas will flow a little slower, and it will be time to focus in on the best ideas. It's very important at this stage not to think about whose idea is whose. **All of the ideas now belong to the team.** Make a clear decision to change the purpose of your discussion from coming up with new ideas to talking about which are best. Give each person a chance to say which ideas he or she likes best and why.

Vote

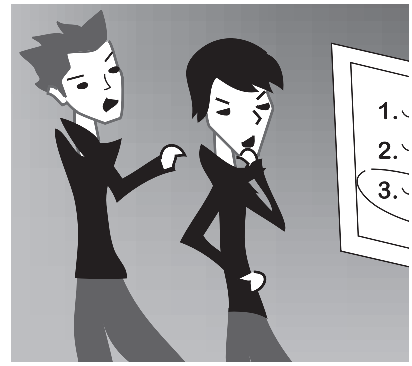
Before ending the discussion, vote on the top three or four ideas. A good way to do this is to give everyone three sticky dots, or Post-it® notes. Team members can vote by placing a dot or note on what they consider to be the three best designs. The three or four ideas that most people choose will be the starting point of Task 1-7. Write and sketch these ideas on a separate page and insert them at this point in your *Engineer's Notebook.*

Initial ______________ Date ___________

TASK 1.7 Choose the Best Solution

- Analyze solutions with respect to criteria and constraints in an organized manner.
- Use a Pugh chart to select the best solution and develop it further.

You are now halfway through the engineering design process. Your team has defined the problem and come up with several types of organizers that would be good solutions. How are you going to choose the best solution to develop further? Engineers commonly use a method called a Pugh chart to systematically rate different solutions. A Pugh chart shows how the different designs compare on each of the criteria and constraints, so as to make it easier to judge which solution is best.



Example of a Pugh Chart

Look at the following Pugh chart that was made to compare two different MP3 players.
Which device is easiest to use?_______ Which device will work with a Mac or PC? ______
Which scored highest overall? ________

List criteria and constraints of the problem on the left side of the chart. Label the criteria to be as descriptive as possible.

Determine Value. If there is a criterion you value more than the others, give it additional points. For example, the chart at right allows up to five points for storage amount but only up to three points for appearance.

List the Solutions you want to compare along the top.

Rate the Solutions. If the design meets the requirement perfectly, it gets the maximum number of points; if it only partially meets the criterion, it gets only some of the points.

Add up the total points for each option.

The Pugh chart helps you compare different solutions, but it does not make the decision for you. You may decide that one solution with fewer points is actually the best choice in the end.

CRITERIA	VALUE	Giga play	Micro music
Storage amount	0–5	5	4
Ease of use	0–4	5	4
Durability	0–4	5	2
Appearance	0–3	5	3
CONSTRAINTS			
Mac/PC compatible	0–5	0	5
Affordable $	0–5	3	1
TOTAL			

Which MP3 player would you choose and why?

Work with Teammates

Work with your teammates to create a Pugh chart to choose the best design. You will first need to list the criteria and constraints of the problem from Task 1.5 in the left-hand column. For each criterion and constraint, list a range of points to indicate its value. Then list the major choices across the top. The choices may be in the form of words or a sketch. Each team member should have the same Pugh chart in front of him or her.

Work Alone

Working alone, each team member should rate each design against each criterion and constraint. Decide how many points to award in each cell of the chart, then add up the points.

Compare Results with Team

Compare your results as a team. Did you all agree? If you disagreed, find out why. Why did one person rate a design highly on a certain criterion and another team member rate it lower? Discuss each item to see if you can all come to consensus—that is, everybody agrees—on the best solution. You might want to combine your ideas into a new and better solution. If consensus is not possible, take a vote.

Criteria/Constraints	Value	Solution 1	Solution 2	Solution 3	Solution 4
TOTAL					

Read Chapter 7, "A Universe of Systems," in the textbook *Engineering the Future.* In the next few tasks, you will be developing a manufacturing system for your organizer. In this chapter, you'll find out how Dudley Green uses the idea of a system to continuously improve the performance at his company. Use notebook paper to answer the questions at the end of the chapter. Sign, date, and number each page. Insert the pages at this point in your *Engineer's Notebook.*

Initial ______________ Date ____________

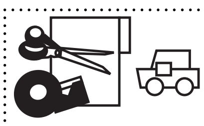
TASK 1.8 Create a Prototype

- Identify tools and safety rules for building prototypes.
- Construct a scale model and/or prototype for the organizer.

Depending on the time and resources available, you may have an opportunity to build a mock-up, scale model or prototype of the organizer your team selected.

Plan the Work

Mock-Up

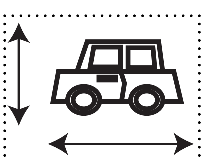


A mock-up is a very simple model used to try out ideas. As you learned when making a mock-up of your cell phone holder design, a mock-up can help you visualize the final product and determine whether there are ways you want to improve it without investing a lot of time or using up expensive materials. If you have time, make a mock-up of your organizer design with a manila folder, tape, and scissors.

Scale Model

A scale model is a three-dimensional model of the design that is constructed with a set scale factor. For example, if the scale factor is 1:4 ("one to four"), then all measurements on the model are one-fourth the length they will be in the final design. Scale models are usually made out of material that is easy to cut and glue together. Because scale models have the same relative dimensions of the final product, they are very valuable in seeing where mistakes can be avoided and improvements may be made. Cardboard or foamcore and glue or pins are often used for constructing scale models.

Prototype



A prototype is the first full-scale three-dimensional model of a design that is usually built of the same materials that will be used to manufacture the product. The experience of constructing a prototype can be especially helpful in testing initial expectations about the look and feel of the final product, how strong or heavy it will be, and what the order of manufacturing processes should be. After the prototype is built and tested, it is not too late to make improvements in the design.

Your instructor will tell you which of these models can be built, what materials are available for you to use, and how much time you will have. Before you make your model, make orthographic drawings of the design, which is the first step in constructing any model.

Document Your Team's Model Building Process

Insert several pages into this *Engineer's Notebook* to document your team's model building process. You may want to use three-hole-punched graph paper or notebook paper. Number the pages so they become part of this notebook. Sign and date each page. The pages should include engineering drawings, parts list, and a summary.

Safety Rules

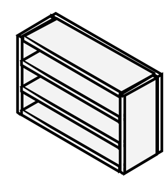
Every set of materials has a corresponding set of safety rules. Whether you will be working with cardboard and glue or power tools, you will need to know what these safety rules are. Ask your job site leader (teacher) for the safety rules so they can be included in your *Engineer's Notebook.* And, of course, be sure to follow the rules.

Engineering Drawing

Create an orthographic drawing showing the three views of your selected design. You may need a fourth or fifth view if the design is more complicated. All drawings must include a scale and dimension lines to clarify the size and shape of the actual product.

Parts List

Make a separate set of drawings and a list of all the parts your team will need in order to make the scale model and/or the prototype. Each team member should make his or her own drawings and parts list. Compare your drawings and lists to see if they are all the same. If not, what are the differences? Are they due to mistakes or ideas for improvement? Following is a sample of what this may look like:



Parts List

Part	Material	Dimensions	Sketch
1 Left side	Pine board	3/4" × 6" × 12"	
1 Right side	Pine board	3/4" × 6" × 12"	
1 Top	Pine board	3/4" × 6" × 18"	
1 Bottom	Pine board	3/4" × 6" × 18"	
2 Dividers	Pine board	3/4" × 6" × 18"	
1 Back	Plywood	1/4" × 13-1/2" × 18"	
16 Screws	Steel	1/8" × 1.5" long	

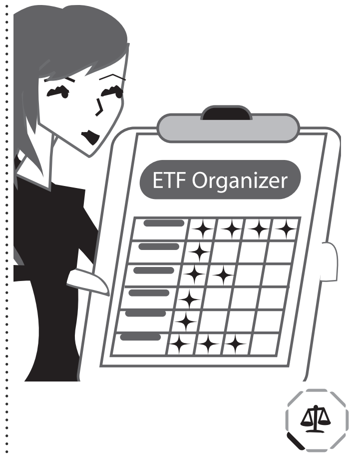
Summary of What You Learned

On a separate page, keep a log describing what you learned about your design, including the improvements and ideas that occurred to you or to other people on your team. Give credit to others for their ideas. Describe any problems your team had in creating the models, and what you learned from those problems.

TASK 1.9 Test and Evaluate

- Evaluate the prototype against criteria and constraints.
- Determine an appropriate material for the final product.

An important step in the engineering design process is to evaluate the prototype. Will it function properly? Is it safe? Does it meet the criteria and constraints? Will it sell? Now is the time to experiment with the prototype to see how effectively it serves the customers' needs. Make minor improvements, and keep a list of changes that you would like to see in a redesign. In this task you will also consider how alternate materials might affect weight, manufacturability, and customer appeal.

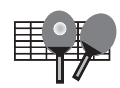


Test the Prototype

1st Test — Will it do what it was intended to do?

Suppose your team designed an organizer to store ping-pong equipment. The first test of your prototype would be to bring in ping-pong equipment and try it out. So, the first test of your team's prototype will be to bring in whatever your organizer is intended to hold and see if it stores everything conveniently.

2nd Test — How well does it fit the criteria and constraints?



Copy the criteria and constraints from your original Pugh Chart in Task 1.7 here. Each person on the team should rate how well it meets the criteria and constraints and make comments in the chart. Discuss how to improve the product before it goes into production.

Criteria	Value	Value and Notes
Constraints		
TOTAL		

3rd Test

Show your organizer to your classmates to get their feedback on how it might be improved.

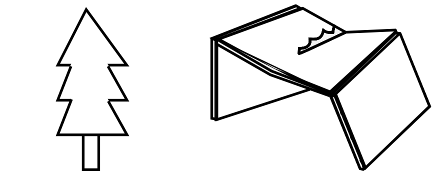
Summarize

On a separate sheet of paper, summarize what you learned from these tests. Insert it at this point in your *Engineer's Notebook.*

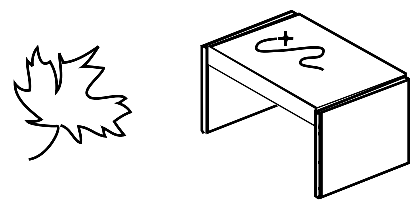
Choose a Material

Selecting the right material for a product is very important. In fact, you won't be able to develop a plan for manufacturing until you know what materials will be used. When choosing a material, keep in mind that the decision always involves trade-offs. For example:

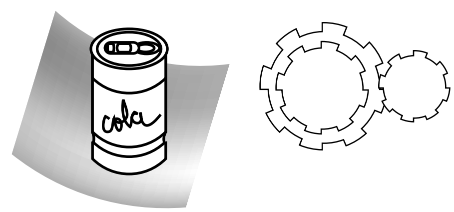
Pine is one of the "soft woods." It is easy to cut, fasten, and finish by sanding and staining or painting. However, soft woods are easily damaged and can warp.



Maple is one of the "hard woods." It is harder to work with than pine, but it is also more durable. It has a beautiful wood grain and it looks terrific with a clear finish.



Aluminum is a light, strong metal. It does not rust, and it's much more durable than wood. However, aluminum requires more machinery to cut, shape, and fasten together.



Plastic. If the goal is to reduce cost, plastic is a good choice. It comes in many different textures and colors, but most people do not find it as attractive as wood or metal.

1) Which of these materials do you think people would prefer for your organizer, and why?

2) Before making a decision, you will need to consider weight. Even if the dimensions of the product are exactly the same, if you choose one material, it may weigh a lot more than if you choose a different material. What do you think the disadvantages would be of a product that is too heavy?

Understanding Density

In order to calculate exactly how much your organizer would weigh if made from different materials, you will need to know the density of each material. Density is abbreviated by the greek letter ρ (pronounced "row").

Density (ρ) is the amount of mass (***m***) of a material in a given volume (***v***). $\rho = \frac{m}{v}$

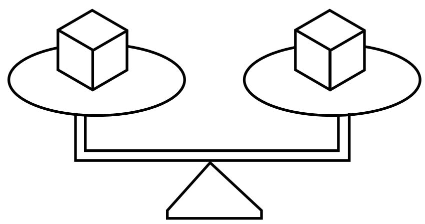
You can also think about density as the amount of stuff packed into a given space. To test your understanding of density, answer the following questions about a very sensitive equal-arm balance (one kind of "scale"). If one side of the balance is heavier than the other, when the balance is released, the heavier side will move down, while the lighter side will move up. (Note: On Earth, mass and weight can be considered the same.)

1) In the pictures below, an object is placed on each of the two trays. Calculate the density of each object. The first one is done for you. $\rho = \frac{m}{v}$

2) Draw arrows to show how the two arms will move when the balance is released. If the arms will not move, write an equals sign (=) between the two trays.

Mass = 1 pound (1 lb.)
Volume = 1 cubic inch (1 in.^{3})

$\rho = \left(1 \ \frac{\text{lb.}}{\text{in.}^3} \right)$

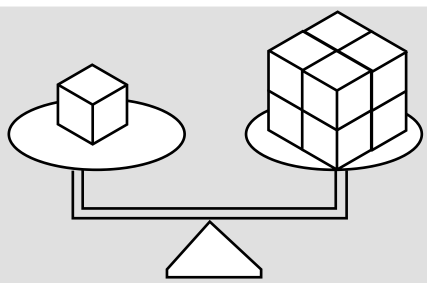


Mass = 1 pound (1 lb.)
Volume = 1 cubic inch (1 in.^{3})

$\rho = \left(1 \ \frac{\text{lb.}}{\text{in.}^3} \right)$

Mass = 1 pound (1 lb.)
Volume = 1 cubic inch (1 in.^{3})

$\rho = \left(— \ \frac{\text{lb.}}{\text{in.}^3} \right)$

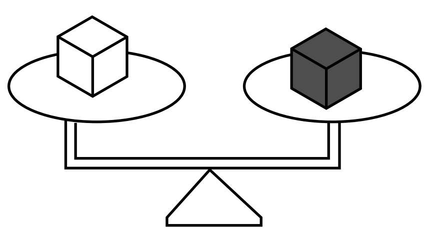


Mass = 8 pounds (1 lb.)
Volume = 8 cubic inches (1 in.^{3})

$\rho = \left(— \ \frac{\text{lb.}}{\text{in.}^3} \right)$

Mass = 1 pound (1 lb.)
Volume = 1 cubic inch (1 in.^{3})

$\rho = \left(— \ \frac{\text{lb.}}{\text{in.}^3} \right)$

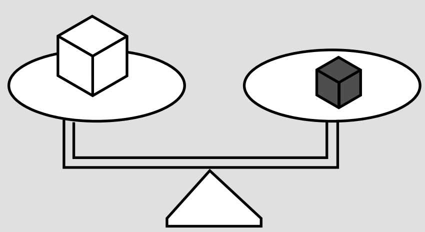


Mass = 2 pounds (1 lb.)
Volume = 1 cubic inch (1 in.^{3})

$\rho = \left(— \ \frac{\text{lb.}}{\text{in.}^3} \right)$

Mass = 1 pound (1 lb.)
Volume = 1 cubic inch (1 in.^{3})

$\rho = \left(— \ \frac{\text{lb.}}{\text{in.}^3} \right)$

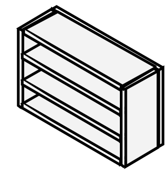


Mass = 1 pound (1 lb.)
Volume = 1/2 cubic inch (1 in.^{3})

$\rho = \left(— \ \frac{\text{lb.}}{\text{in.}^3} \right)$

Find the Volume

To find out what your organizer would weigh if it were made from various materials, you first have to find out the volume of the material in your organizer. If you have already made a list of the parts and their dimensions, use that.



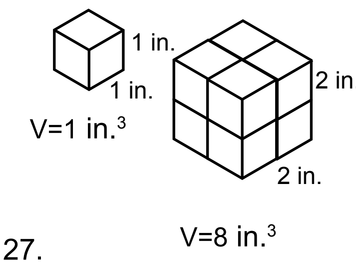
Use a ruler to measure the length *(l)*, width *(w)*, and thickness *(t)* of each piece and find its volume from the equation: $V = l \times w \times t$. Add up the volumes of each piece to get the total volume of the material.

Parts List

Part	Length *(l)*	Width *(w)*	Thickness *(t)*	Volume = $l \times w \times t$

Total Volume = ____________

If your calculations represented the full-scale replica, then you can go on to the next step: calculating weight for each material. But if the measurements were for a scale model, the volume (calculated above) needs to be multiplied by the cube of the scale factor to determine the actual value. For example, as the illustration shows, if the scale factor is 2, the model volume needs to be multiplied by $2^3 = 2 \times 2 \times 2 = 8$ to determine the actual value.



If the scale factor is 3, the volume needs to be multiplied by $3^3 = 3 \times 3 \times 3 = 27$.

1) What will the volume be of all of the materials used to build your proposed organizer? (Show your work below or on a separate sheet of paper.)

Weight with Different Materials

Tables showing the density of different materials can be found on the Internet. You can also measure density by measuring the volume and mass of a sample.

In the table below you will find the density of four common materials. You may want to research a different type of material as well, and add that information in the last column.

1) Multiply the density of the material by the total volume of all parts of the full-scale organizer to find out what it would weigh if built out of that material. Fill in rows two and three of the chart.

Weight *(w)* = Volume *(V)* × Density (ρ) $w = V \times \rho$

Material	**Pine**	**Maple**	**Plastic**	**Aluminum**	**Other**
Density (ρ)	0.0198 lb./in.^{3}	0.0270 lb./in.^{3}	0.0505 lb./in.^{3}	0.0977 lb./in.^{3}	
Volume *(V)*					
Weight *(w)*					
Shipping Parcel Post					
Shipping Priority Mail					

2) For each different material (weight), use the rates from www.usps.com to figure out how much it would cost to ship the box across the United States from Boston, MA (zip code 02214), to Los Angeles, CA (zip code 90014), using Parcel Post and Priority Mail. Assume that you will need to add an additional two pounds for packaging. Fill in rows four and five in the chart above.

3) If you were to double the size of the product, how much more would it weigh? Choose a material and give an example.

4) Someday people will design products for use on the moon. In that case, these calculations will be wrong. What should an engineer do to find the weight of an organizer on the moon?

Decide on a Material

You now have enough information to choose what material should be used to produce your organizer. Discuss it with your teammates. Then write your answers to the following questions:

1) What material did you decide to use?

2) For the material you selected:

How much will your organizer weigh?__________

How much will it cost to ship across country by Parcel Post?_________

How much will it cost to ship across country by Priority Mail?_________

Given the size of your product, how many could you pack per box?___________

3) What were the advantages of the material that you selected?

4) What disadvantages of that material did you consider?

5) What were the trade-offs in your decision?

Read Chapter 8, "The Making of a New Balance Shoe," in the textbook *Engineering the Future.* You will need some of the ideas in this chapter when you design a manufacturing system for your organizer. Use notebook paper to answer the questions at the end of the chapter. Sign, date, and number each page. Insert the pages at this point in your *Engineer's Notebook.*

Develop a Sequence of Manufacturing Processes

How will this product be manufactured? Consider how you fabricated the prototype, and think about how a finished product could be made in a factory. Will you use a batch production system? Will there be parts that have to be made by hand? How would you design a manufacturing plant where 1,000 organizers per hour would be assembled efficiently? Answer the questions on this page on 2–3 sheets of notebook paper.

1 2 3

1) Write a brief description of how you envision your organizer being produced. Be sure to consider how many you want to make and what processes will make the most sense for you to produce large numbers of your organizer efficiently. Number each step in the manufacturing process.

2) Sketch out a process map that shows the steps to produce your organizer in the manufacturing plant. Be sure to label processes such as separating, joining, batch processing, conditioning, and finishing.

3) Draw a system diagram that shows the inputs, processes, and outputs of your manufacturing process.

Conduct a Life Cycle Analysis

To conduct a life cycle analysis, you will need to consider what happens to your organizer from the time the raw materials are taken from the Earth to the time that the discarded organizer is disposed of in a landfill, or is burned in an incinerator.

1) Write a description of each step in the life cycle of your organizer. Number each step and describe the impact of that step on the environment.

2) What will happen to the organizer when it is no longer needed? Can it be recycled? Is it biodegradable (decays and turns into dirt)? Can it be burned safely?

3) List a few ideas for how the organizer could be changed so that it would have the lowest impact on the environment through its production, selling, use, and eventual disposal.

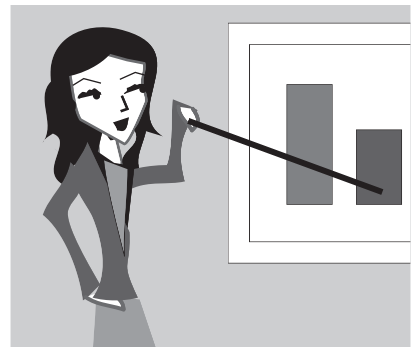
Name ____________________

Initial ____________ Date __________

TASK 1.10 Communicate the Solution

- Describe how you have approached the problem by following the design process.
- Show examples of your work with drawings, notebook work, and task lists.

Now it is time to present what your team has accomplished. If you have designed a product that you believe will save the company, you must convince the Board of Directors that your product is “the best thing since sliced bread.” (Yes, sliced bread is an engineering design!)



Communicating the Cost

If your team has concluded that the product you developed is not quite ready or is not the right solution to their problem, that’s ok. Engineers are not expected to get it right immediately, and it is just as important to know what will not work as it is to know what will. Plan to show the work you’ve done so far, explain what you have learned, and what improvements you could make to enhance your product. Above all, you will have to answer these questions:

- What will it cost to manufacture and distribute the product?
- What will customers pay for the product?
- Will this product save the company?

The steps on the following pages will help you perform a cost analysis so that you can answer these important questions. For each of the following steps, document your work and remember to number, sign, and date each sheet.

What Will It Cost?

Material Costs

List all materials needed to make one organizer and their cost. Include the cost of nails, screws, glue, and tools. It may be easiest to find the cost for producing 100 units, then divide by 100 to find the cost of each unit. Find prices of materials in local stores or on the Internet. List your information sources and show your calculations. Different people on the team can get information on different parts, but each person should assemble the information and show it in his or her notebook.

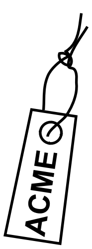
Labor and Overhead Costs

To find the cost of labor, you would need to consider wages for the different types of jobs at a factory, from the workers to the managers. You would also need to add costs for people who package, market, and sell the product. The overhead costs include the cost for building the factory and all of the equipment. Because you do not have enough information to calculate all of these costs, assume that labor and capital costs together will be equal to about three times the cost of the material.

Shipping Costs

The heavier a product is, the more it will cost to ship it to market. Weigh your prototype. If you have built a scale model, weigh and figure out how much the final product will weigh. Then check with the U.S. Mail Service or USPS website to see what it would cost to ship your product in a box to someone who purchased it on the Internet. (If you already did this in Task 1.9, then just enter the information below.)

ACME's Profit



Cost of material		______			
Estimated cost of labor and overhead	+	______			
Total production cost	=	______	→	______	A
Total production cost (A)		______			
Calculated manufacturer's markup (10% of total production cost)	+	______			
Wholesale price (Total production cost plus profit)	=	______	→	______	B
Shipping and handling		______	→	______	C

While this is only an estimate, it will give you an idea of what goes into an actual cost estimate. Write your estimates in the summary table. The additional sheets that you attach will show how you arrived at these answers.

Store's cost = (B+C)	______
Retail price = (2 × store's cost)	______

What Will Customers Pay?

In order to find out whether people in the target group will pay enough money for Acme to make a profit, you will need to go back to some of the people you interviewed before, or others in the same group.

Be sure to bring your prototype. You may want to make up a price tag with the dollar figure that you estimated on the previous page, and add some advertising copy if you wish.

Ask each respondent if they would pay that amount for one of these products, and if they say "Yes," ask them how many they might buy. If they say "No," then ask how much they would be willing to pay in a store for the product. You may also ask what additional features they would like to see for the price you are offering. Record the answers you receive on this page.

It is important to be honest in reporting what people actually say and in drawing your conclusions. You get full credit as an employee whether or not this product turns out to save the company. But you will not keep your job if you are not accurate and honest!

Respondent 1

Respondent 2

Respondent 3

Respondent 4

Respondent 5

Will It Save the Company?

You have now finished testing the prototype. You've checked to see if it meets all of the criteria and constraints of the problem as your team defined it. You've calculated how much money it will cost, and you've shown it to potential customers to see if it meets their needs and whether they would be willing to pay for it. Now it's time to draw conclusions from this work.

Look at the data on the previous pages and write your own conclusions to the following questions. Then compare notes with your teammates and summarize the team conclusions at the bottom of the page.

Your Personal Conclusions

1) Does this design meet the criteria for success and constraints that your team set out to meet? Explain why or why not.

2) How much would Acme Organizer Company need to charge to make a profit? $________
Would customers be willing to pay that much? Explain why or why not.

3) Based on this information, would this design save the company? Explain why or why not.

4) Would you personally recommend

A) Presenting this design and prototype to the company president?
B) Improving the design and presenting that to the company president?
C) Giving up on this design, as it is unlikely to save the company?

Explain your answer here:

Your Team Conclusions

Insert a sheet of notebook paper to summarize your team's conclusions. Explain whether you agree or disagree with your teammates and why.

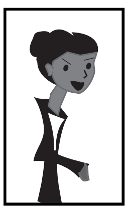
Read Chapter 9, "Like Nature Intended," in the textbook *Engineering the Future.* Saul Griffith recognizes that sometimes the simplest solutions, often inspired by the natural world, may be the most useful. Which of the organizer designs in your class is the best example of this? Use notebook paper to answer the questions at the end of the chapter. Sign, date, and number each page. Insert the pages at this point in your *Engineer's Notebook.*

Presenting Your Product

Engineers are not expected to get it right immediately, and it's just as important to know what will not work as it is to know what will. Plan to show the work you've done so far; explain what you've learned and what steps you will take next. Whether you are demonstrating a product that will solve their problem, or explaining what you've accomplished so far, you want to show your clients that you understand the engineering design process, so they will trust that you know what you're doing. Use the rubric at the end of the next task to make sure you have the requirements for a complete presentation.

Meet with your teammates to create an outline of your presentation, and decide who will describe what part. Be sure to describe the research you've done, as well as the product itself and customer feedback. End with a clear statement that you want your audience to agree with and support.

For example, it may be



This is the product that will save your company. Let's help you put it into production....

or

We've ruled out some possibilities and we have some excellent ideas for how to move forward....

On the next page, you will outline your presentation.

Name ______________________________

Team Presentation

Outline your team's presentation here. List each main part of your presentation and who is responsible for planning and presenting it. Discuss each step as a team to be sure that you all agree with the main point of that section. Insert a separate sheet if necessary.

Your Part of the Presentation

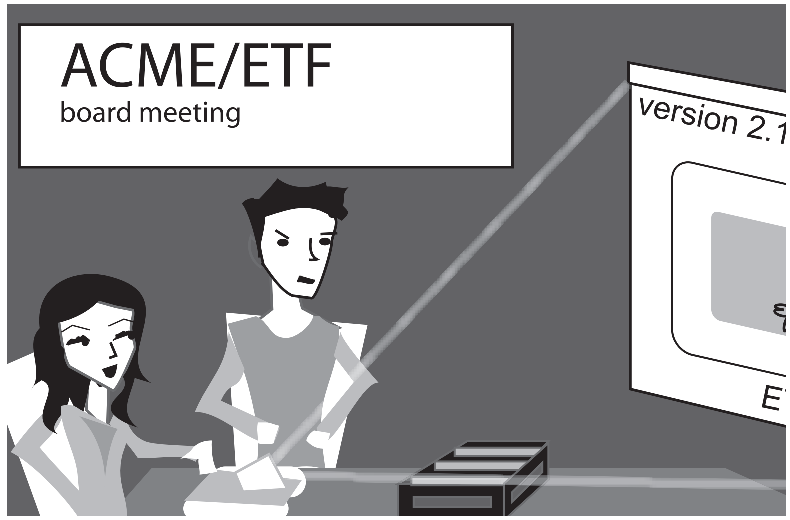
In the space below, summarize the key ideas that you want to be sure to include when you present your part and what drawings or models you want to show to illustrate what you are saying. You may want to put these notes on a card to look at while you are presenting. However, do not write out what you want to say in too much detail. It's boring to listen to a speaker who reads from a prepared speech. Just list the key points as reminders and be sure to point to a drawing or model. When it comes to presentations, a picture really is worth a thousand words!

Initial ______________ Date __________

TASK 1.11 Redesign

- Create a plan for redesign.

Congratulations! You have done a great job designing your first product! Even so, there are probably improvements you could make even now. Be sure that in your final presentation you can identify some improvements you could make to your design.



Plan Your Work

Your teacher may give you the opportunity to redesign your organizer and make another mock-up or prototype. You will want to listen carefully to the other presentations, comments of your classmates about your product, and the reactions of the client to improve your next product.

Write some notes and sketch some new ideas here for your “new and improved” organizer!

Name ______________________________

Rubric for Design the Best Organizer

POINTS	✧✧✧✧	✧✧✧	✧✧	✧
Define the Problem	Problem is clearly defined. **Criteria** and **constraints** for the solution clearly stated.	Good definition of the problem. **Criteria** and **constraints** for solution stated.	Minimal definition of problem. **Criteria** and **constraints** for solution not clear.	Poorly defined problem. **Criteria** and **constraints** for solution not stated.
Research the Problem	Target group is clearly defined. Research data is clearly presented and strongly supports choice of market.	Good definition of target group. Research data is presented and supports choice of market.	Minimal definition of target group. Data is not clearly presented or does not support market choice.	Poorly defined target group. No research data is presented.
Create and Test a Prototype	Carefully completed prototype or scale model that shows care and pride in workmanship. Technical drawings are complete and detailed. Parts list included. Proposed revisions are clearly noted.	Completed prototype or scale model that may have some minor defects in craftsmanship. Drawings are complete. Parts lists are included. Revisions noted.	Partially completed prototype or scale model. Drawings are not complete or detailed. Parts list is not complete. Revisions are not complete.	Minimal prototype or scale model that shows little resemblance to finished product. No drawings, parts list, or revisions.
Communicate the Design	Presentation well organized. High-quality presentation materials are clear and easily understood. All steps of the engineering design process, including proposed revisions, are clearly noted. Presenters showed teamwork and excellent communication skills.	Presentation mostly organized. Most of the presentation materials are clear and easily understood. All steps of the engineering design process identified and some revisions mentioned. Evidence of teamwork within the group. Mostly well-spoken presentation.	Presentation somewhat organized. Somewhat clear presentation but missing important information. Some evidence of teamwork.	Unstructured presentation, very "last minute." Unclear and confusing. No presentation materials or materials that are inadequate to share with audience. No evidence of teamwork and communication very unclear.
Written Report and Project Outline	Clearly organized report with clear writing explaining ideas and project progress at each step.	Mostly organized written report with an explanation of project process at each step.	Written report turned in with some explanation of project process at some steps.	Writing report turned in had minimal information on the project.

Total Points Awarded by Instructor:
Maximum Score 20

Initial ______________ Date ____________