ENGINEERING DESIGN

WHAT FLOATS YOUR BOAT?

A SCIENCE @ HOME ACTIVITY

James E. Richmond Science Center

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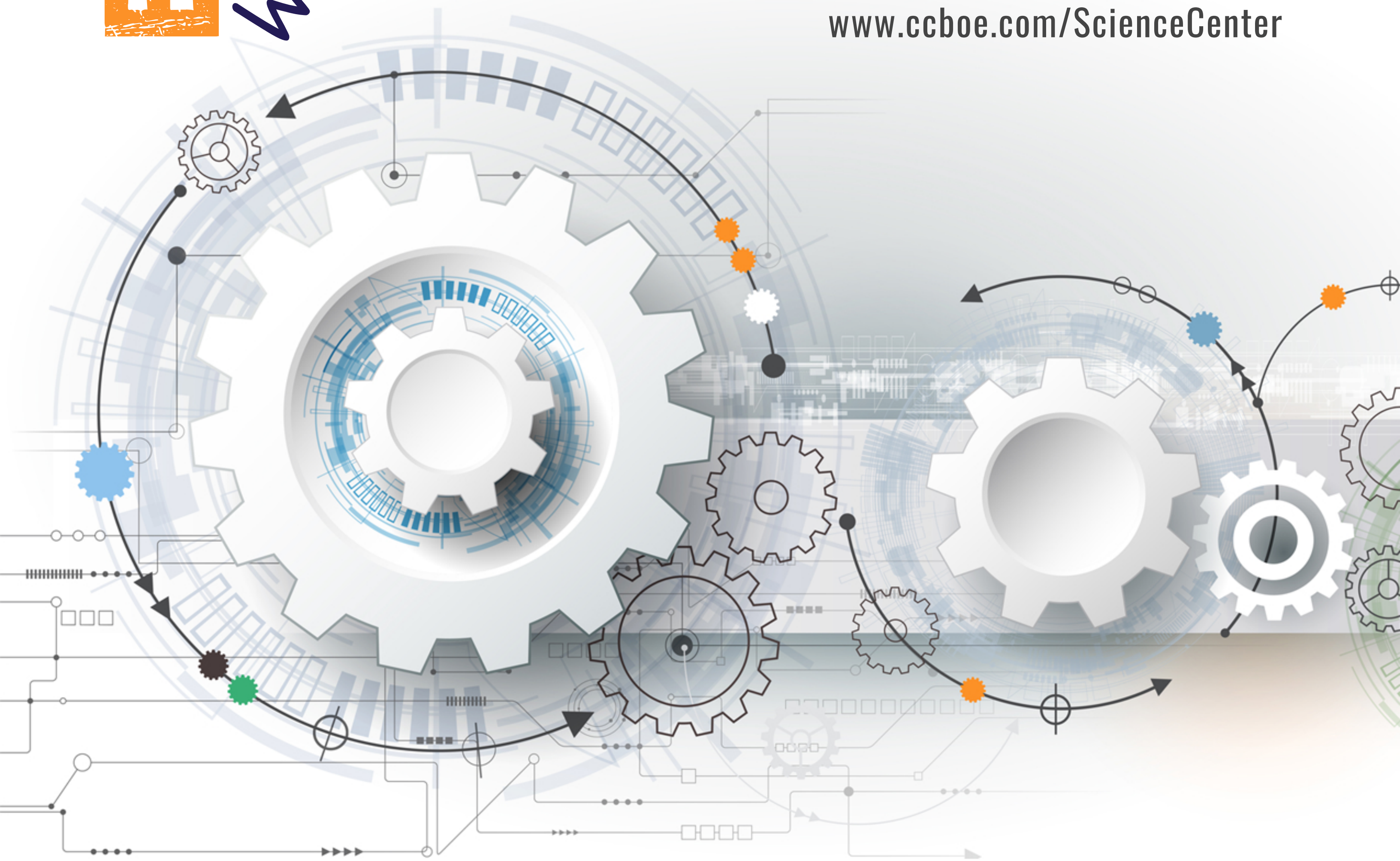


ENGINEERING CHALLENGE

HOW MUCH WEIGHT CAN YOUR BOAT FLOAT?

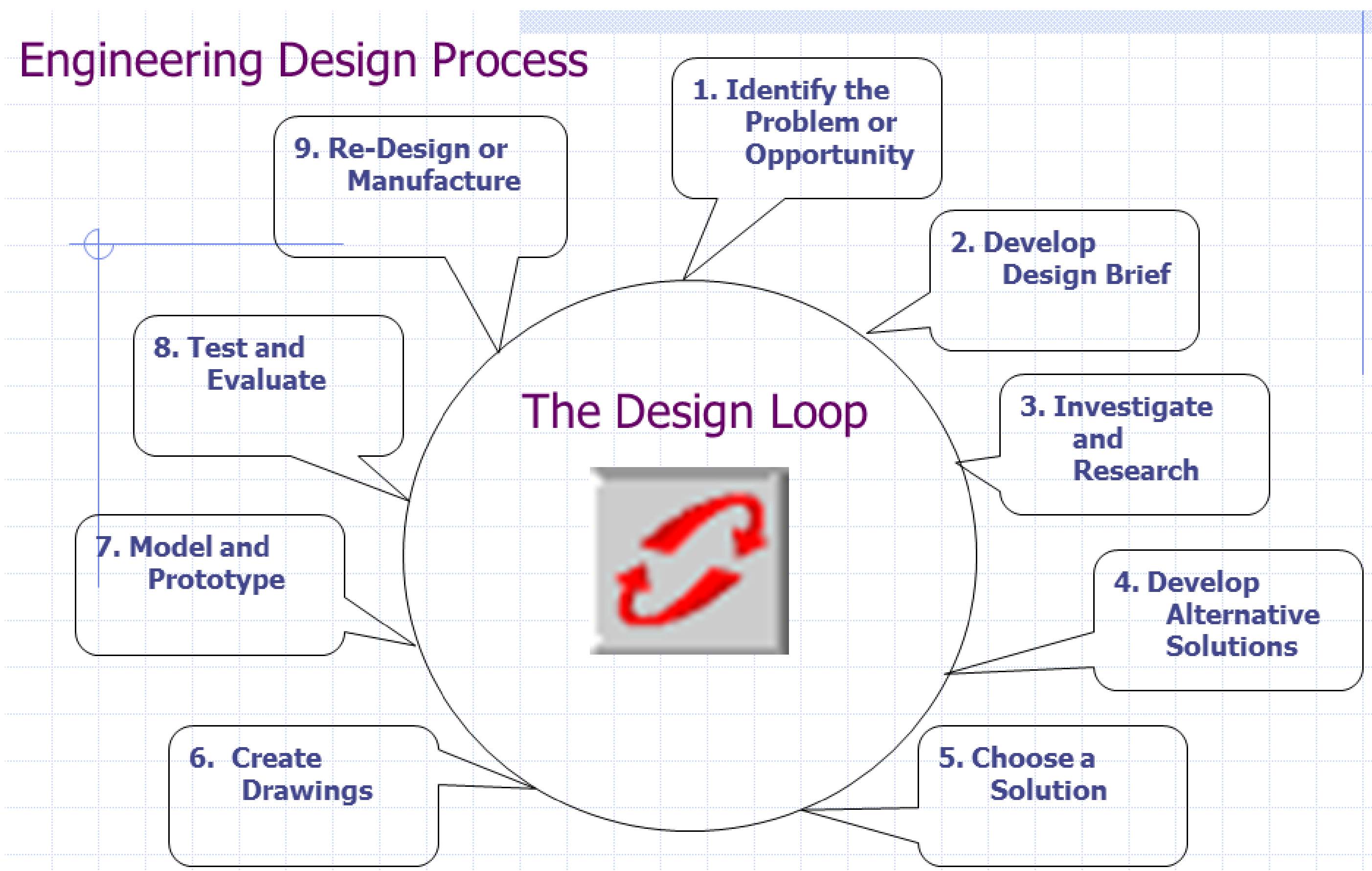
A personal challenge and a fun family competition.

PURPOSE

Engineering challenges are a fun and educational activity to solve a stated task. There is not a single solution or one correct answer for each specific challenge. Rather you are encouraged to try alternative solutions and use the Engineering Design process to meet each challenge for the optimal result.

ENGINEERING DESIGN PROCESS

The **engineering design process** is a series of **steps** that engineers follow to come up with one possible solution to a problem. Often the solution involves **designing** a solution that accomplishes a certain task and/or meets certain criteria. However, one very important aspect of the design process, is the feedback loop. This is used to look at outcomes and then make adjustments to develop a solution that is more successful at meeting the task.



BUOYANCY

Have you ever tossed a rock into a pond or a lake? Did you noticed that it sank immediately?
Did that make you wonder how huge, very heavy steel ships can float while a small very light rock sinks? Every object that you put into water will either float or sink Regardless of size.
Buoyancy is an upward force exerted by a fluid that opposes the weight of an immersed object. It's this buoyant force that determines if an object sinks or floats

DENSITY

Describes how much space an object or substance takes up (its volume) in relation to the mass (weight) of that object or substance. The density of an object is actually what decides whether it sinks or floats. **Density** is calculated by taking the mass of an object and dividing it by the volume of the object.
Mass / Volume = Density

EXAMPLE

- If you had three (3) shoe boxes all the exact same size, they would all have the same volume.
(Height x Width x Length).
- Then you would fill one with Rocks, one with feathers and the last one with Water.
- The heaviest box would have the greatest density (rocks), while the feathers would be the least dense.

19 LBS

1 LB

12 LBS

DISPLACEMENT

Have you ever noticed that when you get into the bathtub, the level of the liquid gets higher? This is known as **displacement**. In the example of a bathtub, the amount of water that is displaced (rises) by your body, is equal to the volume (size) of your body. As you get older and grow you will displace more water. A scientist named Archimedes discovered displacement as he was experimenting with water in his bathtub. Because of this, the idea of displacement is named the **Archimedes Principle**.

Water displacement happens when an object is submerged in a fluid and the fluid is pushed out of the way (or displaced) to make room for the object (Figure 1). The amount of water displaced is directly related to the volume of the object.

Archimedes' Principle is states that, any object, completely or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid that is displaced by the object. This applies to solid, gas and liquid objects.

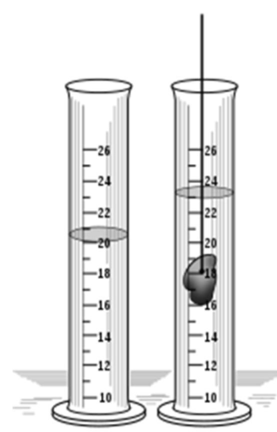
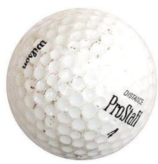


Figure 1

Will it sink or will it float? Mini Challenge

Lets think of two small balls. A ping-pong ball and a golf ball.



Volume = 2.5 cubic inches

Mass (weight) = 0.006 LBS

Volume = 2.5 cubic inches

Mass (weight) = 0.1 LBS

They are similar in volume (size) but their weights are very different, therefore density is different. If you place each in a container of water, since they are similar in size they will each displace (push away) about the same amount of water. Since the weight of the displaced water is more than the weight of the ping-pong ball the “upthrust” will push the ball to the surface and result in what we call floating or being buoyant. However, since the golf ball is much heavier than the water that it displaces there is no “upthrust” and the ball rapidly sinks to the bottom.

DETERMINE WHICH ITEM IS LIGHTEST AND HEAVIEST

Suggested Materials:

- Various size canned goods or other object of your choice
- Deep plastic container to hold water

Procedure:

1. Locate items that you can experiment with that can get wet (make sure you have your parents permission). Dry them off once you are done.
2. Fill the container with water, making sure to leave enough room so when the water is displaced it does not overflow (spill) the container (a bathtub is a great place to do the experiment).
3. Try a canned food. Most cans are similar in volume (size) so they displace the same amount of water.
4. Determine which ones are lighter and which ones are the heaviest (the weight is on the label but doesn’t include the can). A kitchen or postal scale can help you be exact.

Figure 2

5. If you don’t have a scale you can make a balance scale that will compare two items for weight (Figure 2) and then comparing each item you should be able to determine the lightest to the heaviest. (see **Build A Balance Scale** at end of lesson)
6. If unable to use one of these methods you should just estimate by holding each item in the same hand one at a time.
7. Locate other items to test. Similar size objects will give the best results. (a wooden block, a plastic block, a styrofoam block, etc.)

Make your best prediction:

Look at each item and think about its weight. Now predict if you think it will sink or float. Carefully (don't drop) place each item in the container of water and see if it sinks or floats. Use the chart below to record your predictions and results.

		Prediction		Results	
Item	Weight	Float	Sink	Float	Sink

AMOUNT OF BUOYANCY

Although two items may both float, that does not indicate they have the same buoyancy. One item may float with only a small portion above the water, while another item will float with most of it above the surface of the water. We see this in large cargo ships. When a ship is fully loaded, much of the hull is below the water line and once it is unloaded the ship rises.

If the ship weighs less than the maximum volume of water it could push aside (displace), it floats. But it sinks into the water until its weight and the upthrust (weight of the displaced water) exactly balance (equal). The more load you add to a ship, the more it weighs, and the further it will have to sink for the upthrust to balance its weight.

SAFETY TIP

This is why small boats have a capacity rating. If you overload a boat the "freeboard" (the amount of the boats hull above the water) is reduced and could allow water to fill the boat from over the side causing it to sink. Wearing a Personal Flotation Device (PFD—lifejacket) is important because it increases your volume (size) but only adds a very small amount of extra weight, therefore if the boat sinks you will remain afloat (Buoyant).

ENGINEERING CHALLENGE

How much weight can your boat float?

Challenge:

To build a boat using common household materials and hold as much weight as possible, following various constraints.

Materials:

- Aluminum foil (square)
- Standard sheet of paper (8 1/2 x 11)
- Playdough
- Tape
- Scissors
- Pennies (the better the design the more you need)
- Bathtub or sink

Design Constraints:

You may only use 1 type of material for each attempt. Once the boat sinks that is the limit of the weight it held.

Procedures:

1. Using the Aluminum foil construct a boat that will float.
2. Float the boat in your container of water (i.e., Tub)

Test how much weight your boat can hold:

1. Place a single penny in your boat.
2. If the boat is still floating continue adding one penny at a time until the boat sinks.
3. Count the total number of pennies that were held, minus the one that caused your boat to sink.
4. Record this number in the chart below.
5. Make any design notes for helping in the re-design

Construction Material	Floats?	Pennies held	Design Notes
	YES NO		
	YES NO		
	YES NO		
	YES NO		
	YES NO		

TRY THESE VARIATIONS

- Use a single sheet of paper and 6 inches of tape to create a boat and test it using the above procedure.
- Use play dough to create a boat and test it using the above procedure.
- Use your imagination to think of other materials to challenge yourself and others (wax paper, coffee filters, saran wrap, soda straws, popsicle sticks, etc).

WHAT DID YOU LEARN?

Post a picture of your designs by tagging us at James E. Richmond Science Center on Facebook and Twitter. Let us know who had the best design and what made it the best? What did you learn? Post a picture or send to a friend with the most number of pennies held and challenge them to build a boat that can hold more pennies than yours and send you a picture.

HOW ARE A BOAT AND HOT AIR BALLOON ALIKE?

They both depend on Buoyancy to perform their task. That is right, the same force that allows a boat to float is what allows a hot air balloon to fly. This is also why birthday balloons float to the celling, although they do not depend on hot air but rather a specific gas. To learn more about what makes balloons float and directions to construct your own working hot air balloon, make sure you check back next week.

PARENT NOTES

- Water weighs 62.43 LBS per cubic foot or 0.036 LBS per cubic inch
- Salt water 64.1 lbs per cubic foot. (this is why salt water has more upthrust and floating in the ocean is easier.
- In the example of the ping pong ball and the golf ball they each have a volume of about 2.5 cubic inches. Therefore they displace about 0.09 (0,036 x 2.5) LBS of water. Since the Ping Pong ball only weighs 0.006 LBS it floats, while the Golf Ball weighing 0.1 LBS sinks rapidly.
- For questions or to learn more about this topic, please post to our James E. Richmond Science Center Facebook page.

BUILD A BALANCE SCALE

Materials:

- Sturdy Material for balance surface (24 " x 4") Scrap wood works best, but other materials can work.
- Wood dowel (1" x 4") If you don't have a wood dowel you may use another item such as the round block from a set of building blocks or a wooden thread spool.
- Ruler
- Glue that will work on wood
- Pencil

Construction:

1. Measure the Balance surface material length. Draw a line at the mid-point (Figure 3).
2. Put a line of glue on the center line and place the dowel on the glue (Figure 4).
3. Once the line of glue has dried, finish the gluing by adding a line of glue (fillet) along both sides of the dowel (Figure 5).
4. Once the glue has dried you have a working "Balance Scale" (Figure 6).

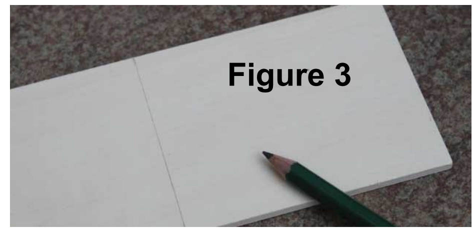


Figure 3

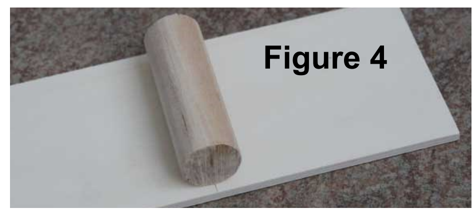


Figure 4

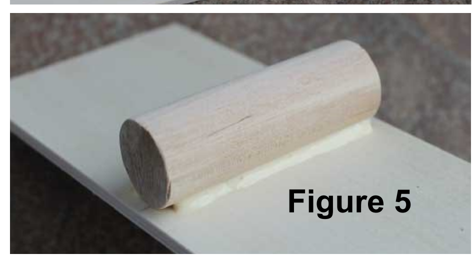


Figure 5

Figure 6

Construction Notes:

- You may make your scale smaller based on your materials and need.
- You may also use other items to build a balance scale. See some examples below and post your solution.