ENGINEERING DESIGN

HOT AIR BALLOON

A SCIENCE @ HOME ACTIVITY

GRADE 9

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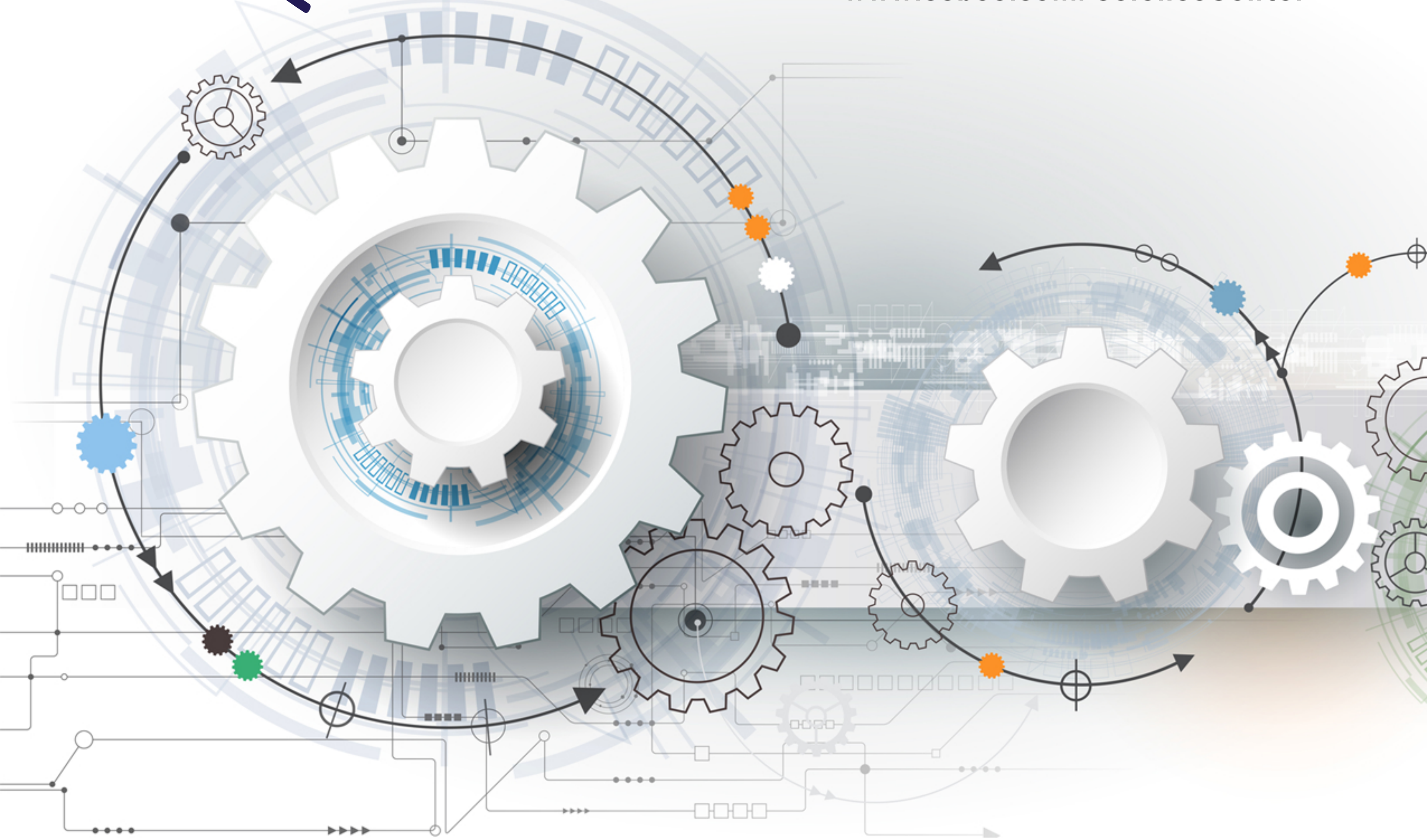


LESSON OVERVIEW FOR PARENTS

How are a boat and a hot air balloon alike?

This lesson will focus on activities designed to generate interest and understanding of the scientific principals that allow a hot air balloon to fly.

Lesson objectives

- To demonstrate that air has the properties of mass and volume
- To demonstrate that heated air expands
- To demonstrate that warm air rises because it is less dense
- To successfully construct a hot air balloon that will float to the celling

Outcomes

- Students should demonstrate an understanding of airs properties of mass and volume
- Students should demonstrate an understanding of the density of air as related to temperature
- Students should be able to demonstrate the lifting force of heated air
- Student will use the engineering design process to build a working hot air balloon

Mini-Labs

There are short activities designed to teach or reinforce scientific concept leading up to the more in-depth Engineering Challenges.

Engineering Challenges

Engineers apply science, technology, engineering, and math (STEM) in order to design solutions to problems. These activities ask students to play the role of an engineer and complete the challenge while considering the design process and using problem-solving skills to overcome obstacles encountered during the challenge.

Project Based Learning

This type of learning is an exciting way to grab student attention and stimulate a need-to-know excitement. This approach to teaching has proven to increase student interest, student learning and retention of concepts.

Resources

Video Review of Buoyancy https://clever.discoveryeducation.com/learn/player/d7f1af56-c322-4a4b-a375-d83ca2c16625

Weekly on-line stem challenge https://www.vivifystem.com/stem-videos

Challenge your student to advanced learning

Ask your student how many standard size helium balloons it would take to lift them off the ground. After they give their best guess, tell them that a standard helium balloon (12 inch diameter) will lift 0.5 oz (14 g). Now calculate the number of balloons needed based on their weight. Hints: 16 oz = 1 pound

Lesson extensions for last week's Buoyancy Lesson

The lesson taught that buoyancy had to do with density and density is the relationship between volume and mass.

If you do not have the materials that are suggested on the materials list, your student can experiment with other substitute materials. Please make sure that you are monitoring the selection and use of any materials.

See "Parent Notes" at end of lesson

ENGINEERING CHALLENGE DIRECTIONS

How are a boat and a hot air balloon alike?

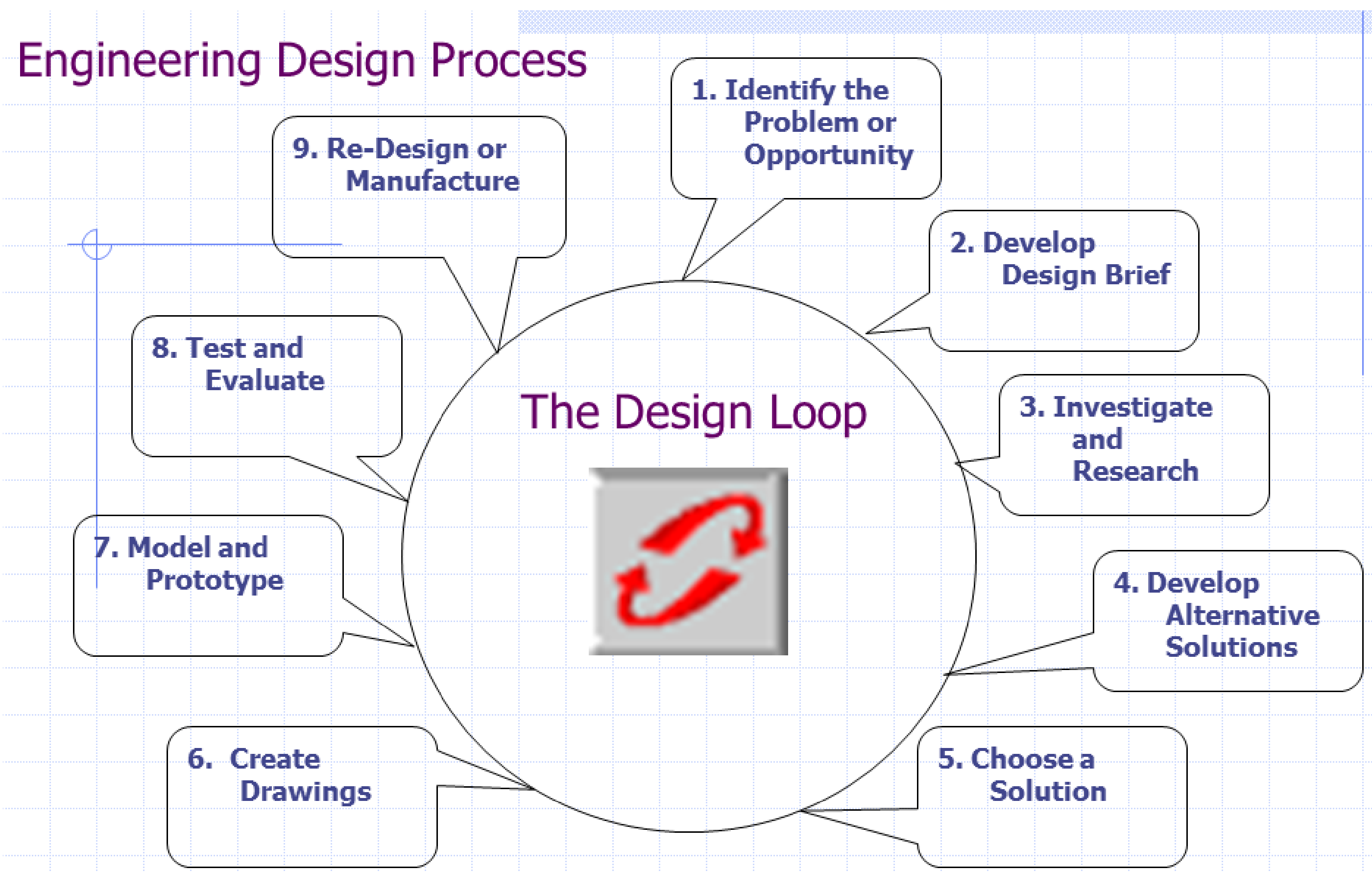
This is both a personal challenge and a fun family project.

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.



LET'S LEARN MORE ABOUT BUOYANCY

Last week we learned about buoyancy in a liquid. Did you know that both Hot Air and Gas Balloons depend on this same force to float (ascend)?

Lets learn more about the principle of "Buoyancy" and how it affects lighter-than-air balloons.

FACTORS THAT INFLUENCE BUOYANCY

DENSITY

Density describes how much space an object or substance takes up (volume) in relation to the mass (weight) of that object. The density of the gas inside the balloon is actually what decides whether it rises or just stays on the ground. Density is calculated by taking the mass of an object and dividing it by the volume of the object. **Mass / Volume = Density**

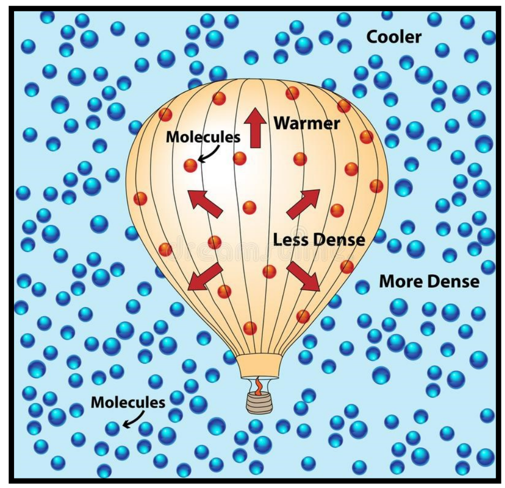


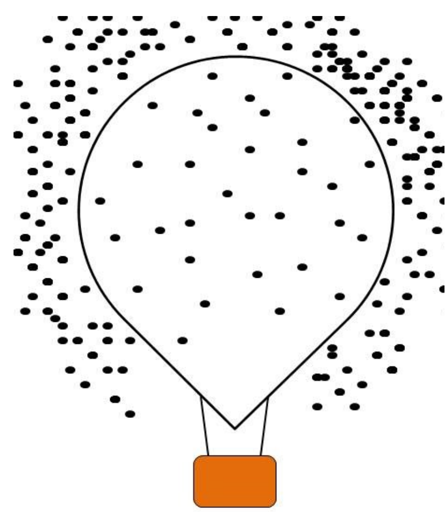
Figure 1

DISPLACEMENT

Air Displacement happens when a balloon is filled with a gas and the air in our atmosphere is pushed out of the way (or displaced) to make room for the gas or heated air (Figure 1). The amount of air displaced is directly related to the volume of the gas inside the balloon.

Archimedes' Principle 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.

In a helium-filled balloon, the buoyant force is created because helium is less dense (lighter) than the air surrounding it. In a hot-air balloon, the lifting force is created by modifying (heating) the temperature of the air inside of the envelope (part of a hot air balloon that holds the hot air), which reduces its density (Figure 2).



The hot air inside the balloon is less dense than the surrounding air, making the balloon rise.

Figure 2

AIR HAS MASS (WEIGHT)

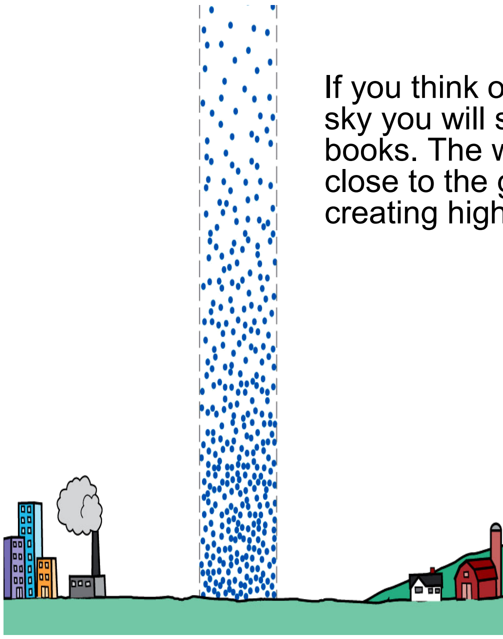
Although most people don't think of air having weight, it does. This weight not only is a factor that determines if a balloon flies, but also has a great impact on our weather. The weight of the air is what causes a difference in air pressure.

WHAT IS AIR PRESSURE?

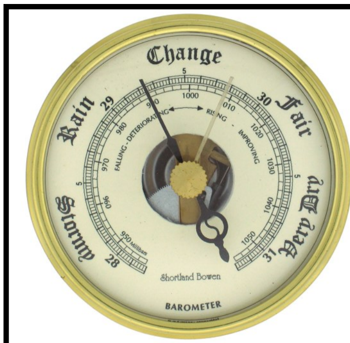
Air Pressure is the weight of air molecules pressing down toward Earth. The pressure of the air molecules changes as you increase altitude, from sea level to high in the atmosphere. The highest pressure is at sea level where the density of the air molecules is the greatest.

MAKE A MODEL TO HELP UNDERSTAND AIR PRESSURE

- Stack 8 books (any size) on a table
- Lift up the top book and feel its weight
- Now lift up the top 2 books and feel their weight
- Repeat this process with the top 3 and then continue with 4, 5, etc.
- What did you notice as you got closer to the table?



If you think of air as a column that extends into the sky you will see the similarity with the stack of books. The weight of the column of air is greatest close to the ground causing the molecules of air to be pushed closer together, creating higher pressure and greater density.



This is a **barometer,** a weather instrument that measures air pressure.

How do all of these factors combine to allow a hot air balloon to fly?

- Hot air is lighter than cool air, because it has less mass per unit of volume.
- A cubic foot of air weighs roughly 28 grams (about an ounce).
- If you heat that air by 100 degrees F, it weighs 21 grams, about 7 grams less.
- Therefore, each cubic foot of air contained in a hot air balloon can lift about 7 grams.
- That's not much, and this is why hot air balloons are so huge -- to lift 1,000 pounds, you need about 65,000 cubic feet of hot air.

Engineering Challenge -
Large 6 Panel Tissue Hot Air Balloon

Construct a hot air balloon using common household materials that will float to the ceiling.

Construction Difficulty: Advanced **Design Constraints:** You may only use the materials listed.

Materials

- 6 pieces of tissue paper (20 x 30)
- Glue stick
- Butcher paper (brown wrapping paper or gift wrap) (20 x 36)
- Paper Clips
- Scissors
- Hair dryer or non flame heat source
- Standard sheet of paper, light card stock, or very thin cardboard

Construction Hints

- Weight is the enemy of flight. Any materials that add weight without allowing additional room for the hot air will make it harder for your balloon to become airborne (fly). Any extra material that can be eliminated without reducing the size of the envelope (the part of a hot air balloon that holds the hot air) should be removed. Keep seams to only 1/2 inch to maximize the volume of the envelope (larger overlapping seams add weight and reduce volume).

Procedure

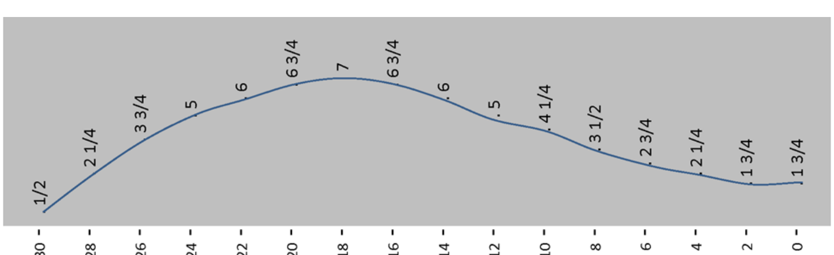
Create the pattern

1. Get a 36 inch piece of butcher paper.
2. Fold the piece of butcher paper lengthwise. Place the fold to the left.
3. Mark zero (0) about 2 inches up from the bottom along the fold
4. Mark the folded edge every 2 inches to 30 inches
5. Starting with the 0 inches mark, make a mark 1 ¾" from the folded edge.
6. Mark the remaining 30 inches as indicated in the chart (Fig 1)
7. Draw smooth curved line to connect the marks (Fig 2).
8. The pattern is now complete.

Inches from the bottom	Inches in from the folded edge
0	1 ¾
2	1 ¾
4	2 ¼
6	2 ¾
8	3 ½
10	4 ¼
12	5
14	6
16	6 ¾
18	7
20	6 ¾
22	6
24	5
26	3 ¾
28	2 ¼
30	½

Fig 1

Fig 2



Making the 6 individual

Gores (panels) that create the balloons envelope

1. Put the 6 sheets of tissue paper in a stack
2. Fold all 6 sheets lengthwise
3. Match the bottom edge of all 6 sheets
4. Place the folded edge into the folded butcher paper pattern
5. Place all 6 sheets of tissue paper into the pattern, make sure that one edge starts at the zero (0) mark you made in the previous step 3.
6. Clamp the folded edge of the butcher paper pattern with the tissue paper inside along the folded edge using paper clips. Make sure that the 6 folded sheets of tissue paper are all the way into the fold of the pattern.
7. Cut out the pattern and the enclosed tissue paper carefully following the outside of the lines (Fig 3).

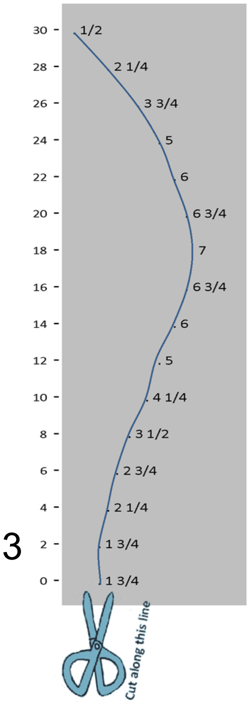


Fig 3

Assembling the Balloon envelope

1. Take panel one off the top of the pile and lay it by itself (Fig 4).

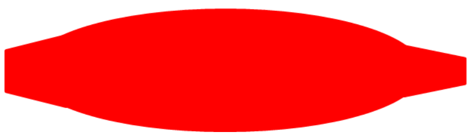


Fig 4

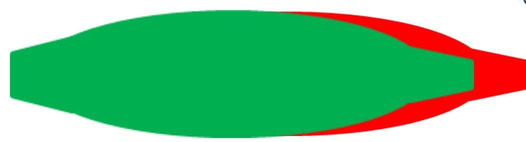
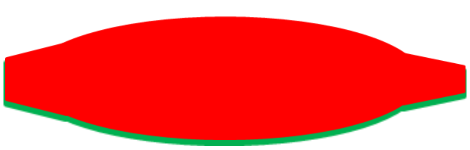


Fig 5

2. Take panel two and lay it on top of panel one. Line up the bottoms, but slide panel two so 1/2" of panel one is showing all the way along one side (Fig 5).

3. Put glue along the edge of panel one and two where the 1/2" of panel one is showing. Fold the 1/2" of panel one onto the glue of panel two. Glue the bottom and top first, then the rest of the side. This will help to keep things lined up while you glue the rest. You may need to make several “relief” cuts to help with the folding (a small cut in the edge you are folding over).

4. Take panel three off of the pile and place it on top of panel two. Line up the bottoms and slide panel three so 1/2" of the unglued side of panel two is showing. This is like step 2. Now glue panel two to panel three the same way you glued panel one to two.



Panel 3 (red)

Panel 2 (green) glued to Panel 1

5. Repeat this process until all six panels are glued together. Be patient and take your time, this part takes the longest time. Going quickly will tear the tissue paper.

6. Turn the whole assembly over. Gently lift what is now the top panel and you should see two seams (four panels) and then the bottom panel. Fold the middle panels in so that the bottom panel can be glued to the top panel making a seam as you did in step 4.

7. Put your hands inside through the bottom and gently work the balloon open. Cut a circle out of the left over tissue paper and cover one side of the circle with glue. With your fist on the inside of the balloon, place the circle over the top of the balloon (sticky side toward your fist) to seal off the top of the balloon. You now have the completed envelope made up of the 6 individual gores (panels).

Bottom Ballast Ring

1. Cut a few ½ inch strips of the paper to glue around the edge of the skirt. Cut off any excess material after you have gone completely around the opening in your balloon (skirt) to eliminate any additional weight. (Fig 6)

Fig 6

2. Put the balloon ring one-inch from the bottom. Fold the bottom of the balloon up over the ring making a one-inch seam. Use glue to hold the seam closed and completely close the seam.
3. Check the balloon for unglued seams and holes. Holes can be patched with a scrap of tissue paper and the glue stick. Open seams simply need to be glued shut.

YOUR BALLOON IS NOW READY TO FLY

Hints
for a Successful Flight

- If you have another set of hands to help you it will make launching easier.
- Hold the top of the bag up so the hoop opening is hanging down
- Set the hair dryer to the high heat setting
- Direct the heat into the opening of the envelope (hoop).
- BE PATIENT— The heating of the air inside your balloon may take a few minutes.
- Continue holding the hoop but release the top. The hot air should keep your balloon floating.
- When you are ready to launch, carefully lift the balloon straight up off of the launcher (heat source) and release it.

Results

How well did your balloon perform?

How much weight do you believe your balloon can lift?

What changes could you make to construct a balloon with more lift (pulling up)?

What was the most difficult step of this construction?

What modifications or adaptations did you make to the design?

How many of these balloons would it take to lift you?

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?

Parent Notes:

- See parent overview
- For questions or to learn more about this topic, please post to our James E. Richmond Science Center Facebook page.