ENGINEERING DESIGN

HOT AIR BALLOON

A SCIENCE @ HOME ACTIVITY

GRADES 7-8

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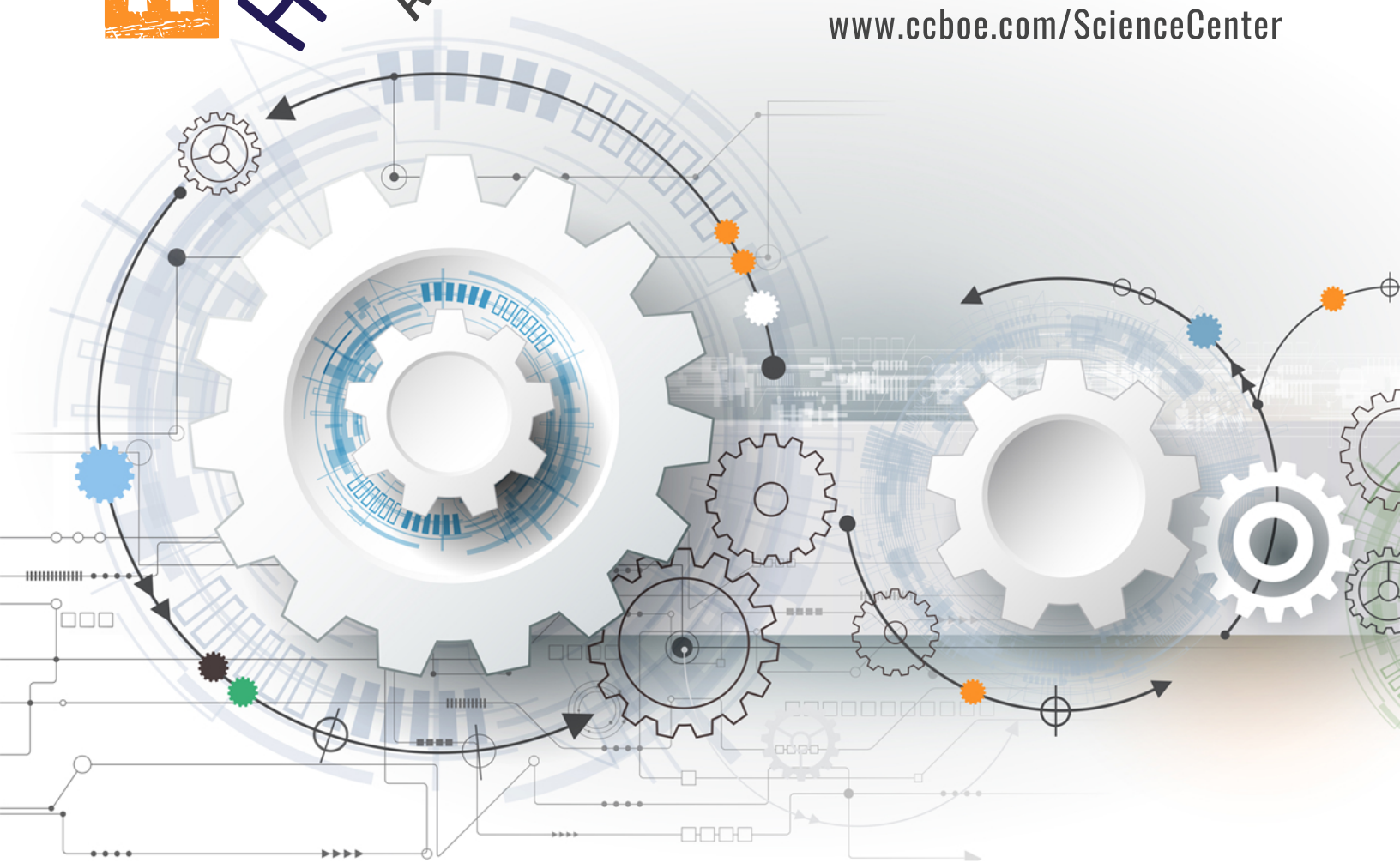


LESSON OVERVIEW FOR PARENTS

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?

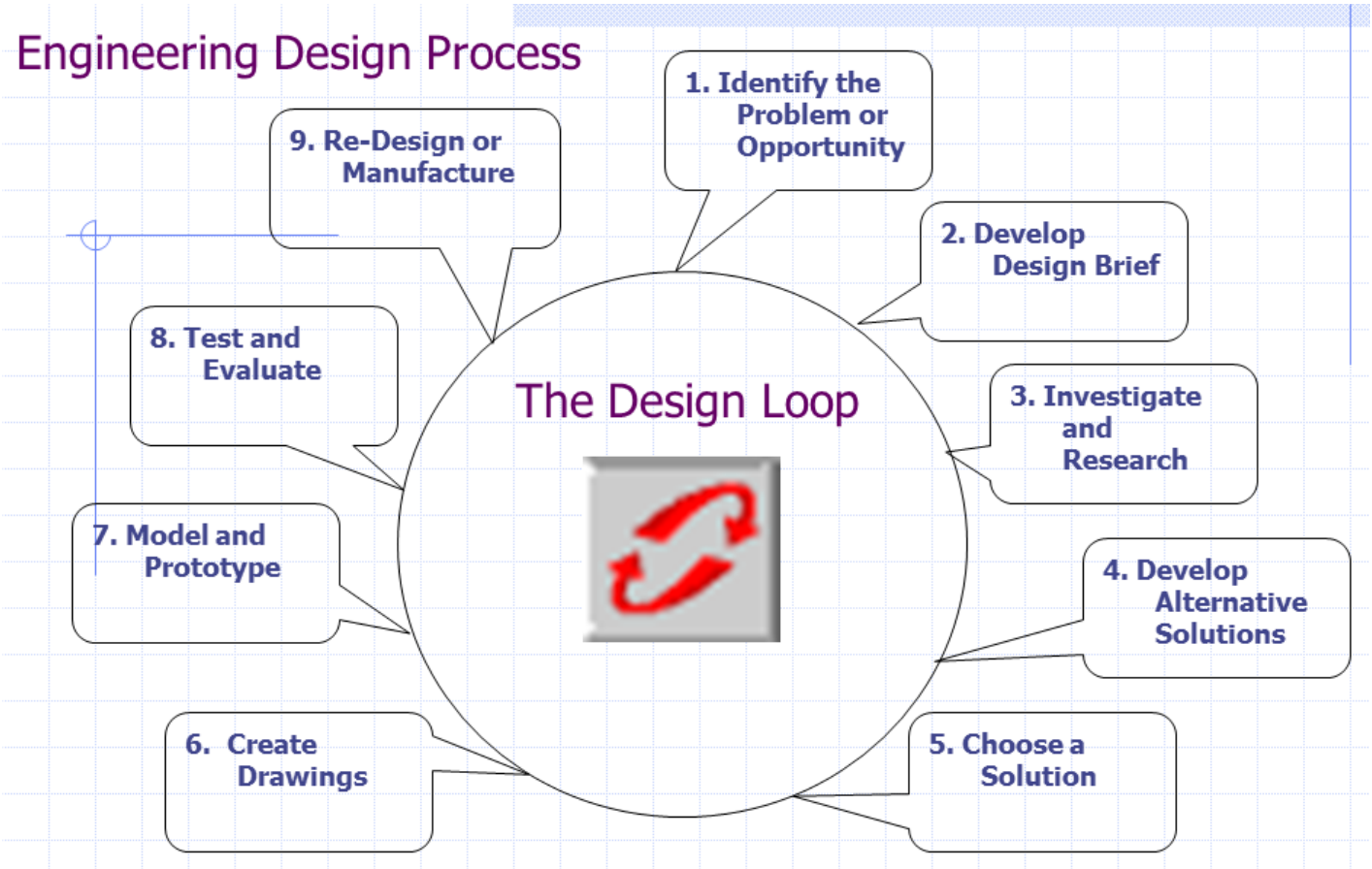
This is both a personal challenge and a fun family project.

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**

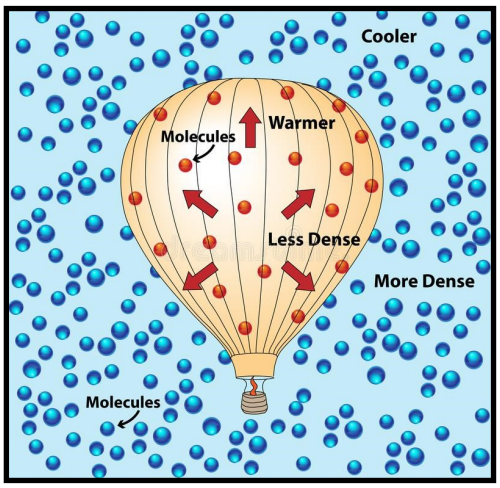


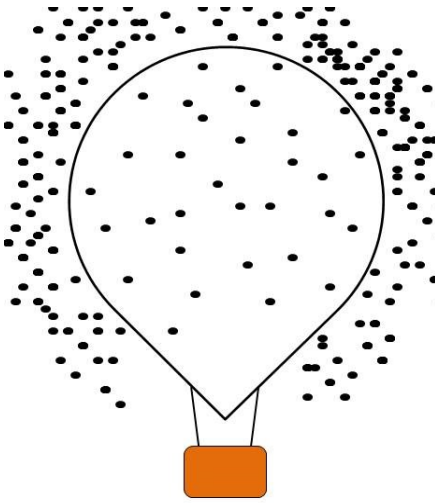
Figure 1

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)

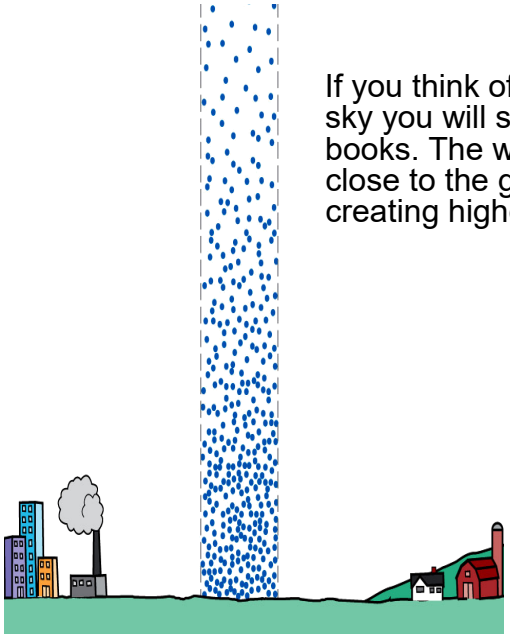
Although most people don't think of air having weight, it does. This weight not only is a factor that determines if a balloon flies, but also has a great impact on our weather. The weight of the air is what causes a difference in air pressure.

WHAT IS AIR PRESSURE?

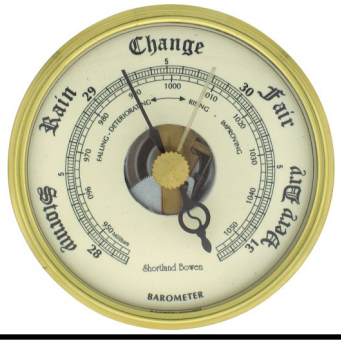
Air Pressure is the weight of air molecules pressing down toward Earth. The pressure of the air molecules changes as you increase altitude, from sea level to high in the atmosphere. The highest pressure is at sea level where the density of the air molecules is the greatest.

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 - Bag Balloon

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

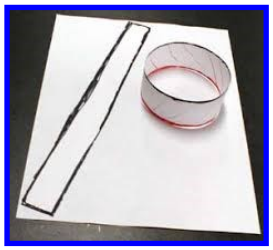
Construction Difficulty: Basic **Design Constraints:** You may only use the materials listed.

Materials

- Plastic bag ("dry cleaners" bag or 5-gallon trash bag) the thinner the better
- Paper clips (used for weight or ballast)
- Hair dryer or non-flame heat source
- Standard sheet of paper or very thin card stock
- Glue
- Tape
- Scissors

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.

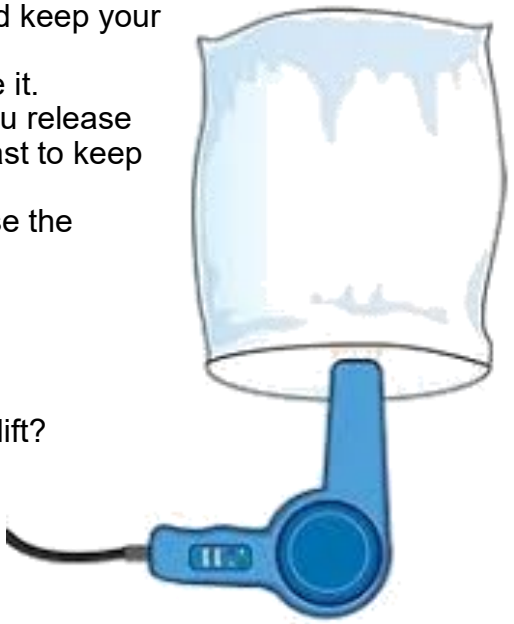


Procedures

- Fully open your bag so the sides are not sticking together
- Cut 3 thin strips of the paper or thin cardboard (about an inch wide)
- Join the strips together (glue is lighter than tape) and connect into a circle about 6 to 8 inches in diameter (a hoop).
- Gather the open end of the bag and attach it to the hoop using glue or tape.

Time to Fly

- 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.
- Once you can feel the balloon pulling up from your hand, release it.
- If the balloon turns so that the hot air is allowed to escape, as you release it, you may need to add a paper clip or more to the hoop as ballast to keep the bottom down.
- If your balloon doesn't fly or doesn't fly as well as you wished, use the design process to make adjustments and try again.



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

Engineering Challenge - Small Tissue Balloon

Construct a hot air balloon using tissue paper that will float to the ceiling.

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

Materials

- 2 pieces of tissue paper (20 x 26) or 4 pieces (10 x 26)
- Glue stick
- Template for top and bottom of balloon
- 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.

Procedures

- Place the two pieces of tissue paper (or 4 if smaller) on top of each other and orient them with the longer distance up. (Figure 1)
- Fold them in half to form a rectangle 26 inches tall x 10 inches wide. (Figure 2)
- Cut out the top and bottom templates (on the next two pages)
- Lay the template on the folded tissue paper (4 thicknesses). Align the apex (triangle) with the top edge of the tissue paper and cut off the exposed tissue paper along the edges of the triangle on the indicated cut lines. (Figure 4)
- Without moving the tissue paper, align the Skirt (bottom of trapezoid) with the bottom edge of the tissue paper. Cut off the exposed tissue paper along the edges of the trapezoid on the indicated cut lines. (Figure 5)

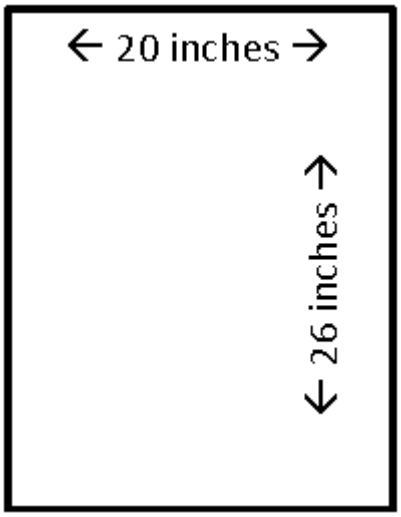


Figure 1

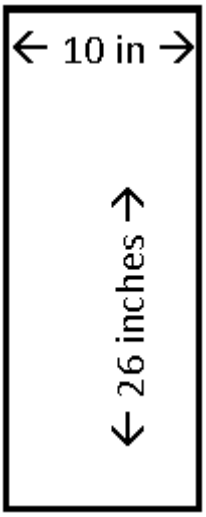


Figure 2

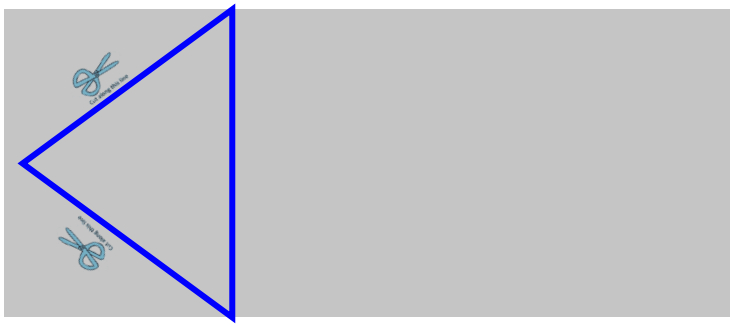


Figure 4

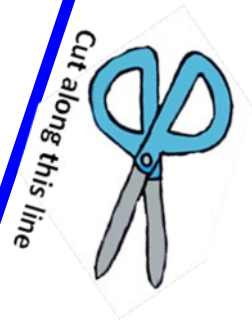
Figure 5

Template for top of balloon

10 inches

10 inches

Template for bottom of balloon



Procedures (Continued)

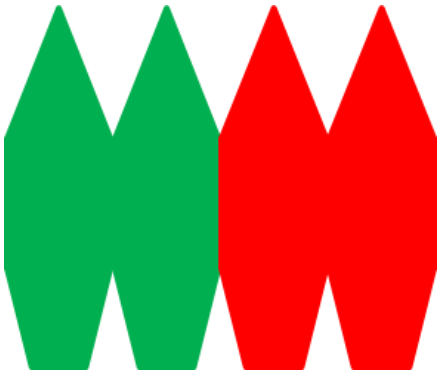
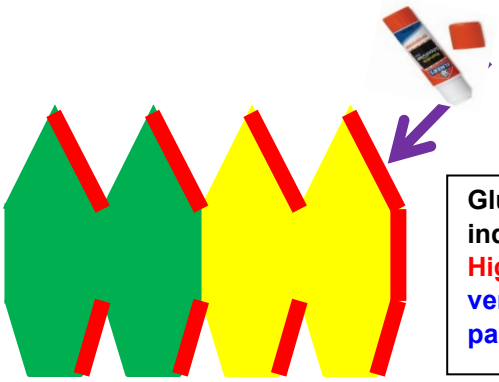


Figure 6

- Open up the paper. You should now have four shapes, two of which are already joined together. (Figure 6)
- Glue all of the edges together as indicated in Figure 7. Try and overlap the glued edges no more than 1/2 inch so the volume of the completed envelope has the greatest amount of volume for the hot air. A greater overlap reduces the volume of you balloon, but does not decrease the weight, which makes it less buoyant.
- Ballast - 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. (Figure 8)
- Check all seams to make sure there are no openings to allow the hot air to escape. If you find a hole you should patch it with a small scrap of tissue paper.
- Once your balloon is ready to fly turn the hair dryer on High heat. Hold the skirt (bottom) of the balloon over the heat source (careful of HOT surfaces) and allow it to fill. You will need to hold the balloon over the heat source until all of the air inside the balloon has been heated (this may take several minutes). You should start to feel the balloon begin to rise. Continue holding it so the air inside gets evenly heated. (Figure 9)
- When ready to launch, carefully lift the balloon straight up off of the launcher (heat source) and release it.



Glue all seams indicated by Highlighted edges. Be very gentle; tissue paper tears very easily!

Figure 7

Figure 8

Hints for a Successful Flight

- Having another set of hands to help you it will make launching easier.
- Hold the top of the envelope 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.

Figure 9

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.

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.