Paper Takes Flight
Teacher Materials

Contents:

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LESSON PLAN

Title: Paper Takes Flight
Grade Level: 4-8
Subject Area: Science and Math
Time Required: Preparation: 1 hour per balloon
Activity: 3 hours

Summary:

Students will construct and fly a hot air balloon

- To learn why hot air balloons fly
- To learn how temperature affects air density
- To learn and/or reinforce metric distance measurement skills
- To observe events and predict outcomes

Objectives:

Students will:

- Build and launch a hot air balloon
- Identify the science principles involved

Materials:

For each balloon:

- 18 sheets Tissue paper (each sheet is 20" x 30")
- 2 glue sticks
- 10” String
- 114”+ of drywall tape

Shared in class:

- Instruction Sheet
- Gore pattern
- Scissors
- 2-3 hair dryers to test inflate
- Fire Extinguisher

Shared at the Launch Site:

- Launch burners
- Repair materials

Safety Instructions:

Use caution when operating the hair dryer - it can get very HOT and may ignite the paper balloon. Have a fire extinguisher available. Use caution when operating a launch burner. Make sure students stand away from the burner when the teacher is heating the balloon. Free flights can carry the balloons for distances and result in safety hazards.

Background:

See Ballooning History section below. Instructions for building other size tissue paper balloons, a video, and other resources are available on our website: www.balloonexplorium.org.

Procedure:

A. Warm Up

1. QUESTIONS FOR STUDENTS (typical sequence)
   - **i.** Why do hot air balloons fly? (Typical response, "Because hot air rises.")
   - **ii.** Why does hot air rise? (Typical response, "Because it's lighter than cold air.")
   - **iii.** Why is hot air lighter than cold air? (Typically no response.)
2. PRELIMINARY ACTIVITY
   - **i.** Draw a circle on the floor 2-3 meters in diameter. See how many students can fit inside the circle. Tell the students they are air molecules. When air molecules are cold they stay very close together, just like the students in the circle. But when air molecules heat up, they start to move around and get further apart. Have the students move at least arm's length apart in all directions. Some students will have to step outside the circle.
   - **ii.** Since all air molecules weigh the same, which is heavier, the number of molecules in the circle when they are cold or the number of molecules in the circle when they are hot?
3. Provide some background on the history of the hot air balloon and the principles which cause hot air to rise.
4. Before construction of the balloon, explain that the tissue paper is very delicate and can be easily punctured or torn. The glue must be applied heavily but carefully. It should be applied in the same direction along the edges of the paper.
5. Students will work in teams of four to six to construct each balloon.

B. Activity

1. Have each team build a balloon using the instructions provided.
2. When completed, hold the balloon by the top and inflate it with a fan or a hand-held hair dryer so you can check it or any tears or loose seams. Make any necessary repairs with glue and left-over tissue paper. (Hint: Tear a piece of paper for a patch, put glue on the patch, and then attach the patch to the balloon surface). Let the repair dry thoroughly. Now you are ready to launch.
3. Launching instructions: If you are doing your own launch - remember that cool, calm weather is best. Free flights can carry the balloons for miles and result in several safety hazards. If you want to build your own launch burner out of a turkey fryer, you can find the instructions on our website at: www.balloonexplorium.org. Have an adult hold the top of the balloon, while the instructor holds the bottom of the balloon about 6 to 8 inches over the stovepipe. After the air is sufficiently heated, the balloon will stand on its own, and you will feel the lifting ability.
4. Have a fire extinguisher available.
5. Invite each student to come forward and grasp the ring using the thumb and forefinger of one hand. After all team members have tested the lift, count down and let the balloon go.
6. Students will time the duration of the flight, and record the data.

C. Wrap-Up

1. Students will compile the data for all the teams and determine the longest and shortest flight and team average. Students may graph the results.

Discussion

When flying a hot air balloon, energy is transferred from the stove to the air in the balloon through heat. The energy of the heat accelerates the motion of the air molecules causing fewer molecules to occupy the same space as do at a lower temperature. With fewer molecules, the hot air has less mass than an equal volume of cold air. Therefore, hot air is less dense than cold air. The greater the difference in the temperature between the air inside the balloon and the surrounding air, the greater the buoyancy. If this buoyant force is greater than the total weight of the balloon and its cargo, the balloon will rise. That's why hot air balloons work best on cool, still days.

Assessment/Evaluation:

Students should be evaluated on their ability to work cooperatively in groups, and the accuracy of mathematical calculations.

Extensions:

1. Have students determine the surface area of the balloon and compare the duration of the flight in relationship to the surface area.
1. Have students pretend they are in charge of picking the animals that will fly in the first balloon. What animals will you pick and why? (K-4)
2. Have students draw what they think the first balloon would have looked like if they had been Etienne and Joseph Montgolfier. (K-4)
3. Have students write a story about what it was like to fly in a Montgolfier balloon. Focus on what it felt like to take off, fly and land and what they saw. (K-4) and (5-8)
4. Discuss the difference between flying in a balloon and flying in an airplane. Include such concepts as steering, runway vs. going straight up, wings and lift, knowing where you are going to land, and basket vs. inside a plane. (5-8)
5. Using the attached timeline, discuss which flights seem most important to you and why. (K-4)
6. Discuss why students think ballooning became so popular in the 1800s in Europe? (K-4)
7. Discuss which gas do you think is the best one to use in a long distance balloon flight and why? (5-8)
8. Explain why a gas balloon rises and falls with changes in outside temperature. (5-8)
9. Discuss the concept of hypoxia and what changes it makes in the body. (5-8)
10. Research the fashions, music and entertainment of the Victorian Age related to balloons.(5-8)
11. Discuss why students think people designed and built special shape balloons? Which is your favorite? (K-4)
12. Name the parts of a balloon and their function. (5-8)
13. Design your own balloon and a pin to go with it. (5-8)
14. Fly the same balloon several times, but hold it over the heat for different periods of time before each flight (60, 75, 90, 105 seconds). The longer the balloon is held over the heat the hotter the air inside the balloon. Measure the duration of each flight. Graph the differences with the "Y" axis as the duration of the flight and the "X" axis as the length of time the balloon was heated.
15. Use your template to make balloons out of different materials (paper bag, newspaper, plastic trash bag*, etc). By making these test balloons all the same size, the air volume will be the same in all balloons. Have the students weigh the balloons. Hold each balloon over the heat source the same length of time and fly them. Better yet, use a digital meat thermometer inserted in the top of the balloon to launch all balloons at the same temp. Be certain to find a thermometer that will measure up to 200 degrees celcius. Use a watch to measure the duration of each flight. Graph the differences with the "Y" axis as the duration and the "X" axis as the material used. Did all the balloons fly? What is the weight of the heaviest balloon that flew?

*Instead of glue, use masking tape to attach gores made of plastic.

Math Integration.

1. Make balloons of different sizes. Weigh each one. Find the volume of each balloon. How does the ratio of weight to volume affect the balloon's flight? How would you graph the results?
   Steps to find the volume of a balloon
   - · Measure the equatorial circumference of each balloon when inflated.
   - · Divide the circumference by pi (3.1416) to get the diameter.
   - · Divide the diameter by 2 to get the radius (r)
   - · To find the balloon's volume cube the radius (r x r x r)
   - · Multiply that number by pi (3.1416)
   - · Multiply that number by 4 and divide by 3

   Formulas used
   Volume of a sphere = (4/3) * pi * r ^3
   Circumference = diameter * pi
   Note - *This process would be exact if your balloon was a perfect sphere, which it is not. However, it will provide you with accurate enough numbers for your experiments.*

2. Where an 8-gore balloon allows repeating patterns of 1, 2, 4 and 8 colors, a 12 gore balloon allows repeating patterns of 1, 2, 3, 4, 6 and 12 colors. What would be the dimensions of the gore pattern for a 12 gore balloon with the same volume as the one in this lesson?

   Answer. The length of the gore remains the same. The width is 75% of the original. The formula is:
   12 * X = 8
   1/12th * 12 * X = 8 * 1/12th
   1 * X = 8/12th
   X = 8/12th
   X = .67
   - or -
   X = 67%

3. This activity is an extension of activities #2 and #3.

   Fact - As you increase the radius/diameter/circumference of a sphere the surface area increases at the square of the factor of the increase and the volume increases at the cube of the increase.

   So, if you increase the circumference of a balloon by 2, the surface area is four times larger (22 or 2x2) and the volume is eight times larger (23 or 2x2x2). Armed with your observations in activity #3, it is now possible to determine the size a balloon would have to be to fly when made out of any given material. Here's how –

   - Find the volume of the balloon made from the template in this lesson plan using the instructions in activity #3. It should be about .35 cubic meters or 350 liters.
   - Weigh the balloon. It should be about 50 to 55 grams or just under 2 ounces.

- Divide the volume in liters by the weight in grams. 350 liters / 50 grams = 7.
- 7 to 1 is the ratio of liters to grams of a balloon that will fly from altitudes of 300 to 400 meters (the Southern Plains States) when heated to a temperature 79 degrees Celsius above the ambient temperature.
- Next we need to know the volume of a balloon with a surface area of 1 square meter (1m2). To find the surface area of a sphere you multiply the square of the radius by 3.1416 and then multiply by 4 or r^2 * pi * 4 . If we work this backwards we find that the radius of a 1m2 sphere is 28cm.
- If we plug the radius of a 1m2 balloon into the formula in activity #3, we find that the volume of a 1m2 balloon is 92 Liters (approx)
- Since we know that the volume increases at the cube of the increase factor while the surface area increases at the square, we can determine the size a balloon would have to be to fly based on the weight of the material used to make it using the following formulae -

  (92 * x**3) / (y * x**2) > 7

  This formula can be further reduced to

  92x / y > 7

  Where

  y = the weight per square meter of the material used.

  X = the factor you have to increase the radius to achieve the necessary volume to weight ratio.

Management Suggestions

1. Build the balloon in the privacy of your own home before you attempt it in class.
2. Building the balloon as outlined in this lesson plan can take as long as 2 hours. Flying the balloons and doing the extended activities will add even more time to the project.
3. A heat gun works well for flying the smaller balloons indoors. However, the best heat source is a turkey fryer burner using a 4' or longer stovepipe. Chances are you or one of your students already has one of these stoves. The stovepipe is readily available at home improvement and hardware stores for less than $5. See www.balloonexplorium.org for directions if you decide to build your own. This is what we use at Paper Takes Flight Launch Day so you don't have to build your own. Because we are placing the throat over a 10" stovepipe the diameter of the throat MUST be at least 12".
4. When launching outside, you may want to have additional adults to help supervise and serve on a "chase crew". This size balloon can easily fly one or two blocks. Under the right conditions it can fly further.
5. Students can decorate the gores with permanent markers if they wish. Be careful though. The moisture from the magic marker can cause the tissue to tear easily.
6. Students can also add pennants to their balloons as decoration but the end of any pennant must not extend below the throat of the balloon so they are out of the way of the burner.
7. Tears in the tissue paper can be mended with scrap pieces of tissue paper and glue sticks. Cut your patch piece to size. Smear glue on the patch piece. Then, apply the patch piece like a piece of tape. Give the patch a few moments to set before inflating again.
8. Share your pictures with the Balloon Explorium. You can e-mail them or mail them to the address on the last page of this lesson plan. We'll post the photos on the Balloon Explorium web site at www.balloonexplorium.org. Please share any comments or suggestions you have and we'll post those too.

Safety Guidelines

1. **TRAFFIC**. Find a wide-open space to launch your balloons and be aware of which direction they will fly. The danger is that it may come down on a busy street or freeway or get caught in power lines.
2. **AIRPLANES**. The 150-centimeter gore balloons as outlined in this lesson seldom fly higher than a house, nor farther than a block. It is recommended that, if you build a balloon larger than the 150-centimeter balloon in this lesson, you launch it at least 3 miles away from and down wind of any airport. If launching a larger balloon within 3 miles of an airport, it is strongly recommended that you notify the airport manager in advance.
3. **TURKEY FRYER BURNER**. When using the burner you should always use a stovepipe. The teacher and another adult should be the one to hold the balloon over the stovepipe. A pair of leather gloves will help you keep from burning your hands during inflation. A burner should never be used indoors.
4. **FIRE**. There is always a slight chance that a balloon might catch on fire. If a balloon does catch on fire let it go and it will rise into the air and burn itself out. DO NOT ATTEMPT TO PUT IT OUT OR YOUR CLOTHES MIGHT CATCH ON FIRE. It would also be a good idea to bring along a small fire extinguisher and keep it close at hand. Or use this opportunity for your local fire station to send out a fireman to watch. Though the fireman isn't really necessary, it enhances your flight day.

BALLOONING VOCABULARY

Aerostat - A lighter than air craft, generally a balloon or airship
Aeronaut – Another name for a balloon pilot
Altimeter – An instrument used to measure altitude
Ammonia – A colorless pungent gas composed of nitrogen and hydrogen
Annonay – The city in France where the Montgolfier brothers designed, built and flew the first hot air balloon
Archimedes Principle – bodies immersed in water or air displace more than their own weight of air, causing them to float
Ballast – Anything heavy carried in an **aerostat** to control altitude. In gas balloons this is usually sand or water
Balloon Federation of America – A national association of balloonists and balloon enthusiasts
Balloon Mail – A special envelope carried in a balloon and then sent through the US mail as a souvenir of a balloon flight
Balloon Pin – special pins used by pilots to commemorate balloon rallies or as a souvenir of their balloon flights
Barometer – An instrument used for measuring atmospheric pressure
Basket – the gondola or the part of the balloon where the pilot and passengers ride
Blast Valve – A control valve attached to the burner. When opened, it causes the burner to ignite.
Burner – A piece of equipment that burns propane gas in order to supply heat to the envelope.
Cables – the steel or Kevlar connections between a balloon envelope and the basket
Car – Another name for a **gondola**, used by early balloonists
Charles – Jacques J.C. Charles was a scientist who designed, built and flew the first **hydrogen** balloon on December 1, 1783
Charlierre – Name given to any gas balloon
Coal Gas – Fuel used in the 19th century to heat homes. It was also used by early balloonist as a lifting gas for balloons
Continental Congress – The first Congress convened by the United States after the American Revolution
Crown – The top of the balloon envelope
Crown Line – A long rope attached to the center of the balloon crown on the outside of the envelope
Deflation – The process of removing the air from an inflated balloon at the conclusion of a flight
De Rozier – Pilatre de Rozier was the pilot who flew the first manned hot air balloon on November 21, 1783
English Channel – A body of water between England and France
Equilibrium – A state reached by a balloon when the weight of the air it displaces is exactly equal to its own weight
Envelope – Name given to the fabric part of a balloon
FR Finish – A fire retardant substance used to coat balloons to prevent fire
Fuel Tank – A large cylinder which holds the propane in the balloon basket
Gay-Lussac's Law – A law of physics discovered by Gay-Lussac and stating that "the volume of any gas bears a simple ratio to that of its constituents"
Gondola – The basket suspended under a balloon
Gordon Bennett Race – The most prestigious gas balloon race in the world
Gore- A section of the fabric sewn together to form a balloon envelope
Helium – A non-flammable, light, inert, colorless gas
Hydrogen – A flammable, colorless, odorless, gaseous chemical element, the lightest of all known substances. Discovery is attributed to the British chemist Henry Cavendish (1731-1810)

Hygrometer – Instrument used to measure relative humidity
Hypoxia – A condition resulting from a decrease if oxygen supplied to the body
Inflation – The process of filling a balloon with air and preparing it to launch
Load Tape – Vertical and horizontal strips of webbing sewn onto the envelop to give the balloon strength and maintain its shape
Magnetic Compass – Instrument used to measure geographical direction by the action of the earth's magnetic field on a bar magnet
Marquis d'Arlandes – co-pilot with **de Rozier** on the first manned hot air balloon flight
Montgolfier – Joseph and Etienne Montgolfier were brothers who invented the first hot air balloon in France in the 1780s
Montgolfiere – name used in most European countries when referring to a hot air balloon
Montgolfier Gas – What the Montogolfier brothers called the "force" which made their balloon fly.
Netting – Cords or ropes which surround the outside of a gas balloon
Parachute – A large cloth shaped like an umbrella used to retard the speed of a body falling from the sky
Phlogiston – another name for **Mongolfier Gas,** technically, a form of burning
Pilot Light – Continuously burning flame used to light the burner
Porosity – the ability of a substance to allow air to pass through it
Propane – Flammable fuel used to fly a balloon, also called LP gas
Pyrometer – An instrument used to measure the temperature in the top of the balloon envelope
Red Line – A long rope attached to the crown of the balloon. When the pilot is ready to land he pulls on this rope to open the top of the balloon and allow the hot air to escape
Rip Line- Another name for the red line
Robert – co-pilot with **Jacque Charles** on the first hydrogen balloon flight
Roziere – name given to combination gas and hot air balloons after the hydrogen/hot air balloon flown by Pilatre de Rozier in 1784. This type of balloon was used in the Brietling Orbiter global flight.
Scoop Skirt – The fabric piece attached to the throat of the balloon which is shaped like a scoop
Side Vent – A slit in the side of a hot air balloon used to maneuver the balloon into a certain position
Skirt – A piece of fabric attached to the throat of the balloon which protects the flame from gusts of wind
Smoke Balloon – Balloons used by entertainers to pull a parachutist into the sky
Spring Top – A type of balloon crown or cap which is held in by small springs
Sulfuric Acid – An oily, colorless liquid used in making dyes, paint etc. It was mixed with iron filings to create a gas for use in balloons.
Throat – The bottom part of a balloon envelope
Vent – An opening in the crown or side of a balloon used to release hot air from the envelope
Vertical Velocity Indicator – An instrument used to tell the pilot how fast the balloon is ascending or descending
Victorian Age - Name given to the era when Victoria was Queen of England (1837 – 1901
Wicker – A type of material used to make balloon basket, usually found in Indonesia

BALLOONING HISTORY

Early Beginnings

The history of ballooning began in Annonay, France, on June 4, 1783, when two brothers, **Joseph and Etienne Montgolfier**, launched an unmanned hot air balloon. The balloon rose to an *altitude* of 6,000 feet and traveled over a mile before landing. The two brothers, while not scientists, were highly educated and interested in science and flight. In 1782, while watching a fire in the fireplace, Joseph became interested in what caused the sparks and smoke to rise. He experimented with making paper balloons and later made a small bag of silk and lighted a fire under the opening at the bottom, causing the bag to rise into the air. The brothers thought the burning created a gas which they called *"Montgolfier gas"* or *"phlogiston"*.

In September of the same year, the Montgolfier brothers demonstrated their wonderful craft for the King and Queen of France and the French Academy of Science. On 19 September 1783 the Aerostat Réveillon carried the world's first airborne passengers - a sheep, a duck and a rooster. These animals were selected for specific reasons. The sheep was believed to have a reasonable approximation of human physiology. The duck, since it flew high, was expected to be unharmed by being lifted aloft. It was included as a control for effects created by the aircraft rather than the altitude. The rooster was included as a further control as it was a bird that did not fly at high altitudes. The safe ascent and descent of the animals proved that it was possible to breathe far above ground, thus paving the way for human flight. According to records kept at the time, the animals returned to earth uninjured and were later adopted by Marie Antoinette as her personal pets.

Although the Montgolfier brothers invented and tested the balloon, it was **Pilatre de Rozier and Marquis d'Arlandes** who made the first flight on November 21, 1783. When King Louis XVI proposed to send a convict up in the first manned balloon, de Rozier objected strenuously. He is reported to have exclaimed "For the honor of France, the first *aeronaut* should be a man of science, not a murderer!" Permission was finally granted and de Rozier and the Montgolfier brothers built a giant *aerostat* 74 feet high and 48 feet in diameter. Around the bottom opening, 15 feet across, was a doughnut-shaped wicker catwalk 3 feet wide. At 1:54 pm on the day of the historic flight, de Rozier and D'Arlandes stepped onto the catwalk and cut the ropes rising into the air to an altitude of 3,000 feet. The flight lasted 25 minutes and covered a little more than 5 miles. The balloons could remain aloft only as long as an on-board fire continued to heat the trapped air. Wood and straw had to be carried for fuel and continually added to the fire. This was a difficult and dangerous process, as well as adding a great deal of weight to the balloon.

At the same time, another Frenchman, Professor **Jacques A.C. Charle**s, was experimenting with *hydrogen*, the lightest known gas. Hydrogen had only been isolated as an element sixteen years before and scientists had some difficulty finding materials which would contain the gas. Charles used a small globe of rubberized silk for his balloon. He designed the bag to tie at the bottom to contain the gas, and to rise and fall using a combination of dropping *ballast* and releasing gas through a crude valve at the top. The design of the first gas balloon was so efficient that it is still in use today with only minor changes. After an initial unmanned test, Professor Charles, accompanied by **Nicholas Robert**, rose high into the air and drifted over Paris for two hours. The flight lasted for over two hours and covered more than 27 miles. This event was witnessed by **Benjamin Franklin** who immediately recognized the potential for uses of balloons in military operations. Because hydrogen is far more buoyant than hot air, the Charliere balloon offered many advantages. In addition, its heights could be controlled by a combination of dropping ballasts to rise and by releasing gas through a crude valve at the top of the bag to descend, a principle still used today.

De Rozier took the concept one step further by designing and flying a combination gas and hot air balloon. The balloon was filled with hydrogen and a small fire was built under the balloon to continue to heat the air. Since hydrogen is highly flammable, the combination proved extremely dangerous and de Rozier and his companion were killed when the balloon exploded and burned. Ironically, with contemporary materials, this design has proven in modern times to be the most efficient for long distance and high altitude balloon flights. The combination gas and hot air balloons are still referred to as *Rozieres.* The Brietling Orbiter and the Spirit of Freedom which made successful global flights, were Rozieres.

Balloons in Entertainment

Ballooning caught on quickly. Between 1783 and 1790, 76 flights were recorded in France alone. In 1784, a huge hot air balloon, built by the Montgolfiers carried a total of seven passengers to a height of three thousand feet over Lyon, France. Events such as these created world-wide interest in ballooning, and soon daring showmen began to stage flights for paying crowds. During this period, the hydrogen balloon replaced the hot air balloon as the aerostat of choice. It was safer, more reliable and had the potential to be used for long distance flights.

Jean-Pierre Blanchard became France's number one *aeronaut.* After several years of *barnstorming* around Europe with his colorful fleet of balloons, Blanchard decided to attempt a crossing of the *English Channel*, the body of water separating England and France. On the afternoon of January 7, 1785, Blanchard and the American physician **John Jeffries** set off for Dover to make the attempt. Jeffries, who had personally financed the project, had every intention of going along on the trip. Blanchard had other ideas and contrived to take off without his backer, he even wore a lead belt so that the balloon would be too heavy for both men. At the last minute Jeffries jumped into the basket and the two ascended into the sky. By mid-channel, the balloon began descending into the water although the two aeronauts had jettisoned almost all their *ballast*, including the clothes they were wearing. Just as they were about to hit the water, Jeffries observed that the *barometer* was falling once again and that they were slowly ascending once more. The crossing ended safely in the forest at Guines. One interesting note on this flight was the first air mail letter which Jeffries carried with him for Benjamin Franklin's grandson from his father. Jefferies hand delivered it five days later.

A few months later, during another attempt to fly across the English Channel, Pilatre de Rozier perished. Unfortunately, he became the first victim of an air accident.

On June 24, 1784, a 13-year-old boy, Edward Warren, became the first American balloonist in a tethered ascent at Baltimore, Maryland.

It was also Blanchard who made the first free balloon flight in the United States in 1793 in Philadelphia. On hand to witness the ascent were **George Washington** and most of the *Continental Congress*. Blanchard's balloon was a *Charliere* of brilliant blue and gold with a spangled blue *gondola* hanging from the *netting.* The *aeronaut* was also dressed in blue with a cocked hat sporting a large white feather. During his 15 minute flight, Blanchard performed some scientific experiments at the request of the new American government. He checked his pulse rate and took the weight of a stone he carried with him. Unfortunately for Blanchard, his flight was less than successful financially and he returned to France, vowing never to fly in America again.

Entrepreneurs throughout Europe took advantage of the ballooning craze, continually contriving new and different ways to outdo the competition and draw the biggest crowds. There were, perhaps, 300-400 *aeronauts* who made a living from ballooning during the late 1700s and throughout the 1800s. Of these, the best known were **Blanchard, Garnerin, James Sadler, Charles Green, Mr. Wise, Mr. Coxwell and the Godard Brothers.** In England, in 1821, Charles Green further popularized ballooning through the use of coal gas, a plentiful and relatively inexpensive source of lifting power. History records that Charles Green made as many as 546 flights in 31 year and died in 1870 at a very advanced age! His numerous flights made ballooning seem almost routine in these early years. In 1836, Green's most famous flight carried him from London, across the English Channel, over France and Belgium to Germany, a distance of 772 kilometers (480 miles).

Perhaps the most outrageous attractions were balloonists jumping from balloons with parachutes and flying with animals! One of the earliest of these dare devils was the flying **Garnerin family**. Garnerin contrived a design for a *parachute* while in a French prison and later tried it out with the help of his wife and niece. His wife became the first woman to jump from a balloon with a parachute. On July 31, 1850, **James Green**, a brother of the famed balloonist **Charles Green**, made the first balloon ascension on horseback! The horse was suspended under the balloon with its legs and head held still. The balloon was inflated and the horse and rider ascended above the crowd at England's Vauxhall Gardens. Both landed safely. Greene was even said to have fed the horse some beans while in the air.

Many women also took to the skies as both balloonists and parachutists. Two of the most famous were **Sophie Blanchard** and **Dolly Shepherd**. Sophie was a part of her husband Jean Pierre's act as he traveled throughout Europe. After he died she became the first woman to fly on her own and made 59 ascents in her balloon. Dolly Shepherd was just 17 when she took up ballooning and parachuting in the early 1900s. Dolly performed all over England, transporting her balloons from event to event by horse and wagon. Her act consisted of a balloon with a trapeze suspended below it. When the balloon rose into the air, Dolly would hold on to the trapeze until the balloon achieved sufficient altitude. Then, she would pull a ripcord, the balloon would collapse, and she would return gently to earth by parachute. Dolly died in 1983 at the age of 96.

Another attraction of the 1800s was the *"smoke balloon"*. These balloons were hot air balloons but did not have a heater or *burner* on board. A parachutist would attach himself or herself to the balloon. Helpers would hold the balloon over a fire until it was sufficiently heated, and, if it didn't catch fire, they would let go and the chutist and balloon would ascend. Once the balloon reached its highest point and *equilibrium* was reached, the parachutist would let go and descend.

Balloons in Science and Government

All these early balloonists were not entertainers, some were interested in experimenting with balloons for serious purposes including scientific experiments, carrying mail and for military uses.

In 1804, **Joseph Louis Gay-Lussac**, a noted French scientist, used balloons to conduct experiments on the Earth's magnetic field. Armed with a *magnetic compass*, a *thermometer*, two *hygrometers*, a *barometer* and two empty wine bottles, Gay-Lussac flew to 23,000 feet over Paris. Barely able to breathe, he uncorked the bottles, filled them with the rarified air and returned to Earth. To his surprise, he discovered that the air at 23,000 feet was exactly the same as the air on the ground. From this he wrote *"Gay-Lussac's Law":* "The volume of any gaseous product bears a simple ratio to that of its constituents".

When Blanchard died in 1809, his wife, Madame Sofie Blanchard, was appointed "official government aeronaut" in France but was killed in a balloon accident ten years later.

During the American Civil War, Thaddeus Lowe commanded a balloon corps with the Union Army. Balloons were used in the Franco-Prussian War (1870-1871) when the French, under siege, sent mail, reports and even people across enemy lines by air. Scientists, also, were beginning to find increased use for balloons as a means for investigating the atmosphere, but lighter-than-air craft had little practical application until they could be controlled and directed.

Early efforts to achieve dirigibility, such as Henri Giffard's 1852 experiment with the steam engine, produced negligible results. The big breakthrough came with the development of a light-weight internal-combustion engine. Using a gasoline engine, Alberto Santos-Dumont piloted an airship around the Eiffel Tower in 1901 and ushered in the age of the dirigible.

The major figure in the development of dirigibles is Count Ferdinand von Zeppelin, whose rigid airships transported passengers over hundreds of miles both before and after World War I. During the war, German airships conducted reconnaissance missions and bombing raids but made only marginal impact on the German war effort. The United States lagged far behind Germany in dirigibles even after the war. Giant airships such as the Graf Zeppelin and the Hindenburg were the pride of Germany. Then, commercial dirigible service came to an abrupt end when the Hindenburg exploded during landing at Lakehurst, New Jersey, on May 6, 1937.

The use of lighter-than-air craft for aerial exploration began before the turn of the century. In 1897, Salomon A. Andree and two companions died during an ill-fated expedition to the North Pole. In 1931, Auguste Piccard made the first stratospheric ascent, reaching almost 15,850 meters (52,000 feet). The development of plastic film balloons together with improved radio and telemetry techniques, led to a series of upper altitude ascents that eventually exceeded 45,720 meters (150,000 feet), the maximum limit of balloon ascents. Such flights yielded valuable data about cosmic rays, the Sun and space.

Balloons in Adventure

In 1859, balloonist **John La Mountain,** with the hope of eventually flying across the Atlantic, tried to reach New York from St Louis, landing in a tree in upstate New York. The following year, British balloonist **Henry Coxwell** and physicist **James Glaisher** made an amazing ascent to 39,000 feet. Both became victims of *hypoxia* and barely made it down alive. **Thaddeus Lowe,** a dashing traveling magician, also hoping to cross the Atlantic, built a giant airship in 1859 called the City of New York. The balloon was built to hold 725,000 cubic feet of gas which he estimated could lift 11 tons, including the 20 foot basket and a lifeboat. He was unable to secure enough gas to make the Atlantic attempt and the advent of the Civil War interrupted any chance he had of trying again.

Early in the 1860s photographer **James Wallace Black** began developing photos taken from balloons piloted by **Samuel King.** The concept became invaluable for use in the American Civil War. However, even before Black began his aerial photography, **Gaspard Felix Tournachon**, better known as **Nadar,** had the idea. Nadar was a French aeronaut and photographer, and a close friend of Jules Verne. Nadar designed a giant balloon called "Le Geant" which stood 196 feet tall and had a capacity of 212,000 cubic feet. The gondola was even more remarkable. It was 13 feet long with a balustraded balcony and was divided into six separate compartments including a bathroom and a darkroom for developing the aerial photos. On October 18, 1863 Nadar flew 400 miles from Paris to Germany. Later, the gondola was exhibited at the Crystal Palace. As far as anyone knows, the aerial photos did not survive but Nadar made a good living with his photo business. Using balloon gondolas, the public could stand behind the gondola and pretend they were on a fantasy balloon flight while Nadar took their photograph.

Ballooning in New Mexico

The first recreational flight in Albuquerque was on July 4, 1882 with **Professor Park Van Tassel**, a local saloon owner, in a balloon called ***The City of Albuquerque***. Van Tassel had originally planned his flight for July 3, but the balloon was fueled with *coal gas*, and the supplies had been depleted by pre-July 4 revelry at the city's downtown saloons. The flight finally got off the ground on July 4 at 6:15 pm. By Van Tassel's own account, he reached an altitude of over 14,000 feet! The flight ended in a corn field near the intersection of Central Avenue and Rio Grande. Van Tassel was so excited by his flight that he subsequently sold his saloon and embarked on a less than successful career as a barnstorming balloonist.

Joseph Blondin and **Roy Stamm** were not barnstormers but were key figures in the ballooning events at the 1907 and 1909 Territorial Fairs. The two collaborated to promise balloon rides at the 1907 fair, but were unable to produce enough gas to inflate the balloon and the project was scrapped. The balloon was put in storage in Roy Stamm's warehouse and was not used again until 1909. New Mexico was actively seeking statehood and **President Howard Taft** was due to visit the 1909 Fair. A dirigible had been commissioned to take off during Taft's visit but it crashed just before the fair. The Fair commission pleaded with Stamm to rescue them with his balloon. Still a little embarrassed by the previous fiasco, Stamm agreed, but the project was kept quiet until the last minute at his request. Fortunately, the Fair committee had provided Blondin with a proper hydrogen generator, consisting of a large wooden tank in which *sulphuric acid* and iron filings were combined to create hydrogen. Over the next few days scores of people were carried aloft on a 1,200 foot tethered rope. The tethered flights were a huge success and the day after the fair Blondin and Stamm took off with enough provisions to last a week or two and an ambitious plan to reach St Louis. The Stamm family has preserved the log and photographs of this remarkable flight of the gas balloon now christened ***Albuquerque.*** The balloon lifted into the air, narrowly avoiding a disastrous collision with the city trolley lines, and headed east toward Tijeras Canyon. It cleared the crest of the Manzano Mountains by 1,000 feet and crossed into the Estancia Valley. In all, the balloon traveled over 900 miles, was shot at by a rancher, reached an altitude of over 12,000 feet and was rescued and returned home by cowboys from the McGillvary ranch near Clines Corners.

Modern Ballooning

It would not be long before the barnstorming days of ballooning and parachuting would be replaced by the newly discovered method of flight called the airplane. It would be many years before competitive and sport ballooning would once again capture the imagination of the world. **Ed Yost**, a long time military balloonist, was experimenting with new types of hot air balloons which he thought would have military and scientific applications. In October, 1960, Yost, then President of **Raven Industries**, flew a prototype of the modern hot air balloon in a test flight in Nebraska. After some changes to the envelope and burner, Yost made another flight above the **Stratobowl** near Rapid City, South Dakota. Yost and Raven thought the military and intelligence industries would be their biggest customers but they were wrong. Raven sold its first sport balloon in 1961 and recreational ballooning took off.

On April 13, 1963, **Ed Yost** and **Don Piccard,** a descendent of the famous Piccard ballooning family, flew a Raven hot air balloon, dubbed ***Channel Champ*** across the English Channel in three hours and 17 minutes, the first balloon crossing of the channel since Blanchard 180 years earlier, and the first crossing by hot air balloon.

History of the Balloon Fiesta

The history of sport ballooning in New Mexico is well known to most Albuquerque residents and to the ballooning community, but it tells the story of how a simple idea can blossom into one of the biggest aviation events in the world. **Sid Cutter** and his brother **Bill** planned a party in 1971 to thank their Cutter Aviation customers. When securing airplanes for their World War I theme proved too costly and complicated, Sid bought a balloon. Sid had a balloon license but had never actually seen a balloon before the party. The balloon was the centerpiece of the party and Bill told everyone he and Sid planned to fly it the next day. They did and the rest, as they say, is history.

In November, 1971, Sid and a few friends, including **Maxie Anderson**, founded the **Albuquerque Aerostat Ascension Association (AAAA**) and bought a Raven RX-6 balloon, naming it *Roadrunner.*

In April, 1972, **KOB Radio** was looking for a unique way to celebrate its 50th anniversary. The idea of a balloon race was the brainchild of Dick McKee, general manager of KOB radio. Balloonists from all over the country were invited to the First Albuquerque Roadrunner Coyote Balloon Race, sanctioned by the Balloon Federation of America. The plan was to have a race that would beat the English record of 19 balloons flying at one time. The goal was 21 balloons but a snow storm in Chicago brought the number down to 13. No one anticipated that over 20,000 people would turn out that day or that the event would become the largest ballooning event in the world-the Albuquerque International Balloon Fiesta. In 2000, AIBF had over 1,000 balloons participate. The number has been reduced to 750 and is stable at that number

The ultimate competitive ballooning event is the prestigious **Gordon Bennett** Cup. Bennett was a wealthy newspaper tycoon who sponsored all kinds of races and events throughout the world. In 1906, Bennett initiated the first world cup balloon race from Tuileries Garden in Paris, France. The race was viewed by over 200,000 people and was won by an American team. The 1907 race from St. Louis, Missouri was attended by over 300,000 spectators. Over the next two decades, the race moved from country to country until it was suspended in 1939 because of World War II. After a near 40 year hiatus, the race once again became THE balloon race to win. Each year, the race moves to the country of the previous year's winner.

The Cultural Context

Man's first successful flights took place in the era of Enlightenment, where scientists and inventors were making great strides at a remarkable pace. Religious beliefs and superstition were a part of daily life for people living in the countryside and outside Europe's large cities. Legend has it that villagers witnessing the first balloon flights were terrified at the site of strange flying objects and even went so far as to attack the invaders with pitchforks. The first flights in 1783 came after the successful democratic revolution in America and just before the French revolution. The French king who witnessed the first flights was later deposed and beheaded by his countrymen.

The romance of flight had an effect on France and on the rest of Europe and within a few years balloon flights had taken place all over the continent, in Australia and in the Americas as well.

Humans being what they are, it was not long before scientists were envisioning how this new way of travel could be used for military applications.

The late 1700s saw great changes in the world. The American and French revolutions brought about a new era of discovery and exploration. The 1800s are known as the *Victorian Age* in England. The era is characterized by a renewed interest in fashion, music, theater and entertainment. The large pleasure garden became a part of everyday life in London and it was here that the early barnstorming balloonists found a home nad an audience. People were curious about how things worked, were hungry for adventure and new experiences. Balloons, for a time, became little more than toys used for entertainment. However, as the 19th century wore on, people became more curious about the world around them and scientists began exploring with balloons and also using the craft for surveillance and transportation in war.

A discussion of barnstormers and entertainers and the advent of sport and competitive ballooning would not be complete without looking at how ballooning influenced culture. The museum has a large collection of ceramics, decorative arts, fine arts, and photography. Commemorative pins, patches, cups, scarves, posters, jackets and t-shirts are all part of contemporary ballooning and hold a prominent place in this exhibit.

Two of the most interesting aspects of the culture of ballooning are the phenomenon of *balloon mail* and *balloon pins.* As early as Blanchard and Jeffries, balloonists delivered the mail. During the *Siege of Paris*, balloons were used to deliver messages from the embattled city to other areas of France. Sport balloonists began the practice of “flying covers” or empty envelopes with special cancellation stamps and signed by the pilot. The covers quickly became collectables and *first day covers*, those issued on the opening day of a multi-day rally, were the most coveted.

Balloon pins are the darlings of balloon aficionados. Each balloon rally has an official pin and most balloonists have a pin of their balloon which is usually given to first-time riders and crew. Pins hold a prominent place in the museum collection.

HOW A BALLOON WORKS

It is important to note that the Montgolfier brothers did not know exactly how their balloon worked. They erroneously assumed it was a smokey gas that made their first hot air balloon fly and referred to it as **Montogolfier Gas or Phlogiston**. Of course, it is well known today that it was the heated air inside the Montgolfier hot air balloon that made it ascend. The heat generated by the fire under the balloon made the air inside the balloon less dense than the air outside, causing it to rise.

When air is heated, the air molecules move faster and faster. They push each other away, causing the air to expand and take up more space. As the air expands, the molecules become more spread out and there are fewer molecules in the same amount of space. So the air in that space weighs less than it did when it was cooler, and it also exerts less pressure on the earth. Cold air molecules are packed closer together, so cold air weighs more and puts more pressure on the earth.

Buoyancy of the Air

The mathematician and philosopher *Archimedes* first quantified the concept of buoyancy:

> *An object immersed in fluid experiences a buoyancy force that is equal in magnitude to the force of gravity on the displaced fluid.*

To understand how balloons rise, it is necessary to understand what happens to the air both inside and outside the balloon. In hot air balloons the air inside the balloon becomes less dense when it is heated by the burner. Since the air inside the balloon is less dense than the outside air, the balloon will begin to rise. It is necessary for the pilot to continually reheat the air since colder air is denser and will cause the balloon to loose altitude. Likewise, a gas balloon is filled with a lighter than air gas such as helium or hydrogen and will rise when the gas displaces the same amount of air outside the balloon. Because of these changes to the air, a gas balloon will get larger as it rises. At some point it is necessary to vent some of the gas through the valve opening to keep the balloon from bursting when it reaches capacity.

Archimedes' Principle applies to bodies immersed in air as well as to bodies in water. Thus, a body which is weighed by means of a spring scale first in air and then in a vacuum will be found to weigh somewhat less in the former case because it is buoyed up by the air about it. The apparent loss of mass of the body when in air, is exactly equal to the mass of the air displaced by it. Since air is very light, this difference in mass is usually extremely small. However, large, hollow bodies, such as dirigibles, actually displace somewhat more than their own weight of air, which explains why they float in air. Since the air is less dense at higher altitudes, a balloon ultimately stops rising at a level where the weight of the air it displaces is exactly equal to its own weight. This is called *equilibrium.*

Over the centuries, balloonists used a variety of gases to fuel their craft. These included *smoke, hot air, hydrogen, coal gas, helium and ammonia.* As we discovered in the first balloons section, the Montgolfiers thought it was smoke that made their balloon rise. Smoke balloons surfaced again in the barnstorming days of the 1800s. These were used simply as a mechanism to transport parachutists into the sky. Once Jacque Charles discovered the existence of hydrogen, it became the most often used lifting gas for many of the sport and scientific balloonists and is still used today in the C*harlierre and Roziere* balloons.

At the turn of the century, coal gas replaced hydrogen as the lifting gas of choice. By this time most cities were using coal gas to heat and light homes and businesses. The gas was plentiful and cheap and easily accessed by tapping into the lines to the underground tanks. Of course, hydrogen and coal gas had one drawback; they were highly flammable. Hydrogen is still used in Europe but helium has replaced hydrogen in the United States. Helium is found exclusively in the oil fields of the southern US and is very expensive. Even though the lifting capacity of helium is 8% less than with hydrogen, the tradeoff of inflammability is worth the difference to some pilots. Ammonia is a relatively new gas for balloons. It, too, is inflammable and much cheaper than helium, but is very dangerous if inhaled.

The Modern Balloon

The Envelope

During the latter half of the eighteenth century, the art of fabric weaving and production of quality paper had improved greatly from earlier times. The early Montgofier balloons were laminated layers of taffeta, silk or paper secured with animal hide glue. The *gores* were attached with rows of buttons. Even when glue was abandoned and they began to sew the gores together, it was the smoke from the choking fires on board the balloon which sealed the seams and held the air inside the envelope.

When Professor Charles began work on his hydrogen balloon, he faced the problem encountered by scientists who were experimenting with this new element. Because it was so light, it was nearly impossible to contain it inside any known container. Fortunately for Charles, a recently discovered substance called rubber, presented possibilities. He was able to coat the balloon fabric with rubber dissolved in turpentine. After drying, the gores were sewn together and re-coated to ensure a tight, non-porous envelope. Today's envelopes use nylon, polyester or other light weight fabrics which are coated to reduce porosity and endure higher temperatures. The gores are still sewn together just as they were in the 1780s.

The modern hot air balloon *envelope* is usually constructed of light weight fabrics coated with both water repellant and fire resistant finishes which also retards *porosity*. Because of the FR (fire resistant) finish, if the balloon is accidentally touched by the burner flame, it will melt rather than catch fire. The envelope is made up of long sections or *gores*, sewn together and reinforced with nylon webbing called *load tapes*. Attached to the load tapes at the *throat* or the bottom of the envelope are long steel or Kevlar *cables* which attach the envelope to the *basket or gondola*. The envelope consists of the gores, a *crown or cap* at the very top of the balloon and a *skirt* which attaches to the throat. There are usually several ropes attached to the cap both inside and outside to control the balloon. The outside rope is called the *crown line* and is used by a crew person to stabilize the balloon during cold inflation. It is usually long enough that it can be attached to the basket once the balloon is fully inflated. Balloons travel horizontally with the wind, but can be controlled vertically in several ways. Since it is hot air inside the balloon that makes it rise, it is the release of hot air that makes it descend. One of the ropes attached to the inside of the cap opens and closes *a vent* in the cap. By using this vent the pilot releases hot air to make the air in the envelope cooler and cause it to descend. Caps in balloons vary in design by manufacturer but are usually of three kinds, the *parachute*, the *spring top* or, in older balloons, the *side vent.* As the name implies, a side vent is a slit in the side of the envelope rather than at the top. In commercial balloons a side vent is often installed as a maneuvering vent so the balloon can be turned in the air to show off banners and company names.

Another part of the envelope is called the *skirt*. Most, but not all, balloons have a fabric skirt attached at the throat of the balloon. These have different shapes and are made of different fabrics. Some are round and some are shaped like a *scoop.* The scoop skirt is placed on the ground during inflation to maximize the flow of air and speed up inflation. The Scoop, and sometimes other skirts are often made of a fire retardant fabric like *nomex.*

The pilot uses a rope to land the balloon by dumping the hot air completely out of the top of the balloon. This may be a separate rope called a *rip line* or *red line* or it may be part of the vent rope. When the pilot has committed to a landing, he or she pulls the red line and dumps hot air, bringing the balloon to a complete stop and ultimately, *deflation.* The two diagrams attached show two different styles of balloons, one with a parachute top and one with a side vent.

The Gondola

Most modern hot air balloon baskets are made of *wicker* or *rattan.* The basket houses the *propane fuel tanks*, the *flight instruments* and the *burner.* Some balloons also carry fire extinguishers and helmets. Instruments include an *altimeter* which indicates the altitude when in flight, *a vertical velocity indicator* to measure rates of ascent and descent *and a pyrometer* to measure the temperature in the top of the balloon. The burner, or heater, generates a hot flame by burning propane stored as liquid in the fuel tanks. When the pilot opens the *blast valve* on the burner, liquid passes through the vaporizing coils and is burned as it emerges from the nozzles in the burner. Each burner has a *pilot light* which is lighted by the pilot before beginning hot inflation and remains lit throughout the flight. Pilot and passengers ride inside the gondola. Occasionally, you may still see a balloon with a metal or fiberglass basket, but there are few of these still flying. Wicker is sturdy, flexible and lightweight and will “give” on landing, helping to prevent injury or damage.

Paper Takes Flight - making your tissue paper balloon

The balloon is made of seven "gores" of tissue paper. Two and one half sheets of tissue paper will make one gore. Each gore can be unique using different colors of tissue paper, or make gores all one color. Use your imagination! Gores can be decorated with scraps of tissue, but be careful not to add too much weight or the balloon will not fly well.

Gores will be glued together, leaving openings at the top and bottom. A string will be attached to the top, and dry wall tape attached at the bottom to create the throat, allowing for inflation.

Instructions:

1. Glue short ends of 2 ½ sheets together to make one large rectangle approximately 75” long and 20” wide. Repeat 6 more times, making a total of 7 rectangles. Some will be left over, so save the pieces for repairs.
2. Using the pattern provided cut out 7 gores from the rectangles built in step 1. It is possible to stack all seven rectangles and cut all at one time.
3. Select two gores. Lay one on top of the other, allowing a ½" margin to show on the bottom gore (figure 1).
4. Apply a line of glue to the ½" margin of the bottom gore #1 (figure 2). Fold this ½" over the edge of panel #2 as you go along (figure 3). Apply the glue stick heavily and press firmly together.
5. Place gore #3 on top of gore #2, allowing a ½" margin to show on gore #2 on the unglued side. Repeat gluing as in previous step.
6. Glue up the remaining 4 gores using the above method (accordion fashion). Join free edges of gore #1 and gore #7, joining all gores (figure 4). This will make a circle when opened.
7. During and after gluing, carefully separate all folds to keep them from sticking together. This is important!
8. Tie off the top of the balloon with string, about 1" back from the top to close hole in top of balloon. Leave a loop in string for holding balloon up while inflating (figure 5).
9. Your drywall tape has already been stapled together to form a ring for a 12” throat. Do not make this ring smaller as it needs to be this size to launch properly.
10. Open hole in bottom of balloon and shape balloon panels to fit by making tucks and gluing together. Place ring inside opening and fold paper over it about 1", gluing into place (figure 6).
11. Let balloon dry thoroughly. You can inflate with a fan or hair dryer to check for holes, loose edges, etc. Make necessary repairs with glue and paper or tape. A fan or hair dryer is not sufficient to launch the balloon. For heating tips visit our website at www.balloonexplorium.org .

YOUR BALLOON IS NOW READY FOR LAUNCHING!
WARNING!
Please be careful and do not launch in the proximity to power lines.

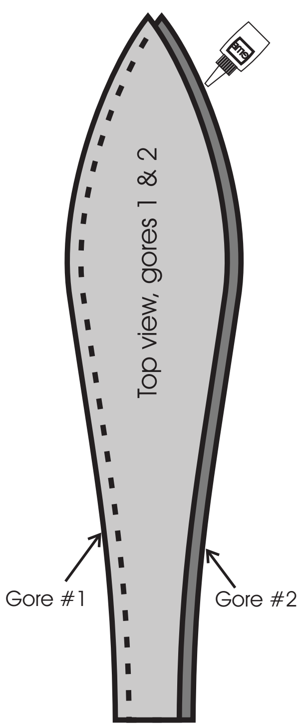


Figure 1

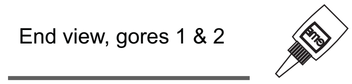


Figure 2

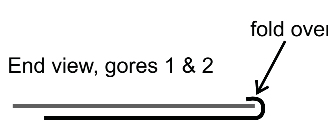


Figure 3

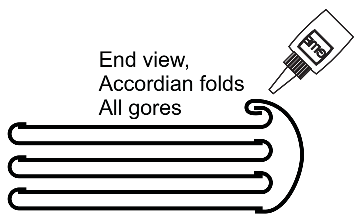


Figure 4

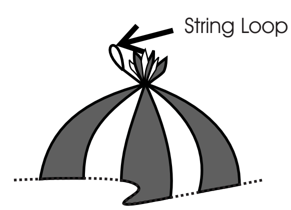


Figure 5

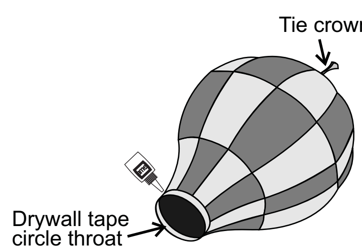
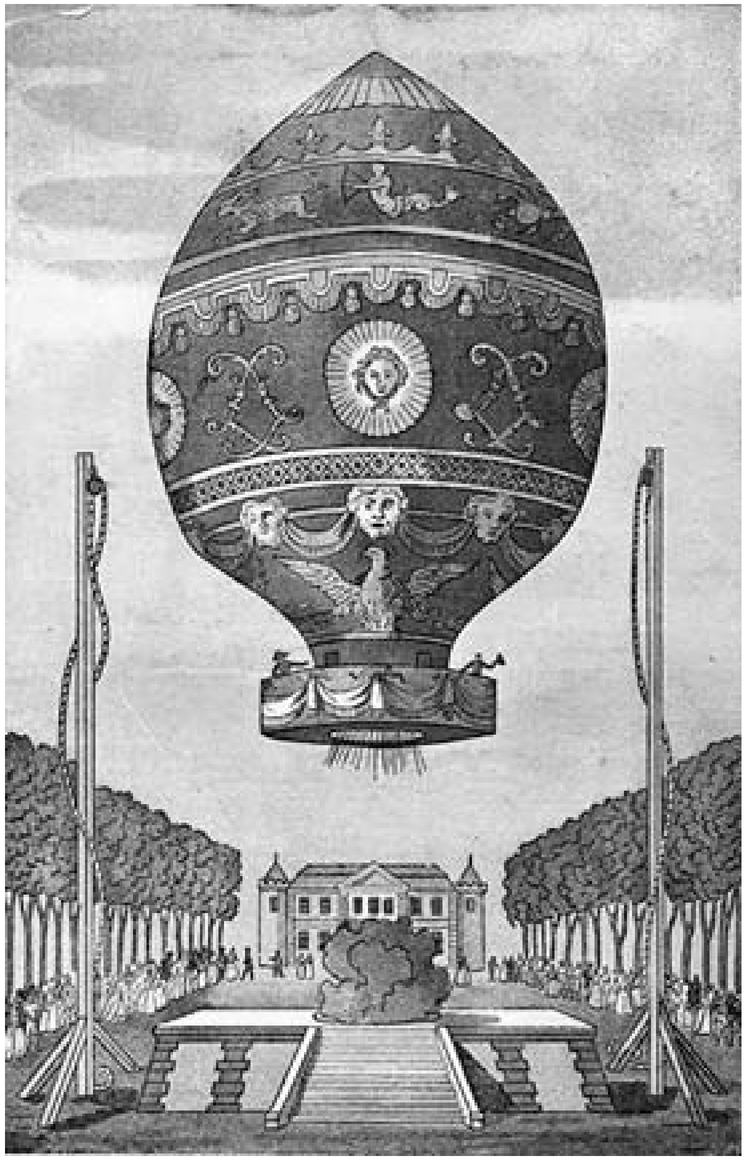


Figure 6

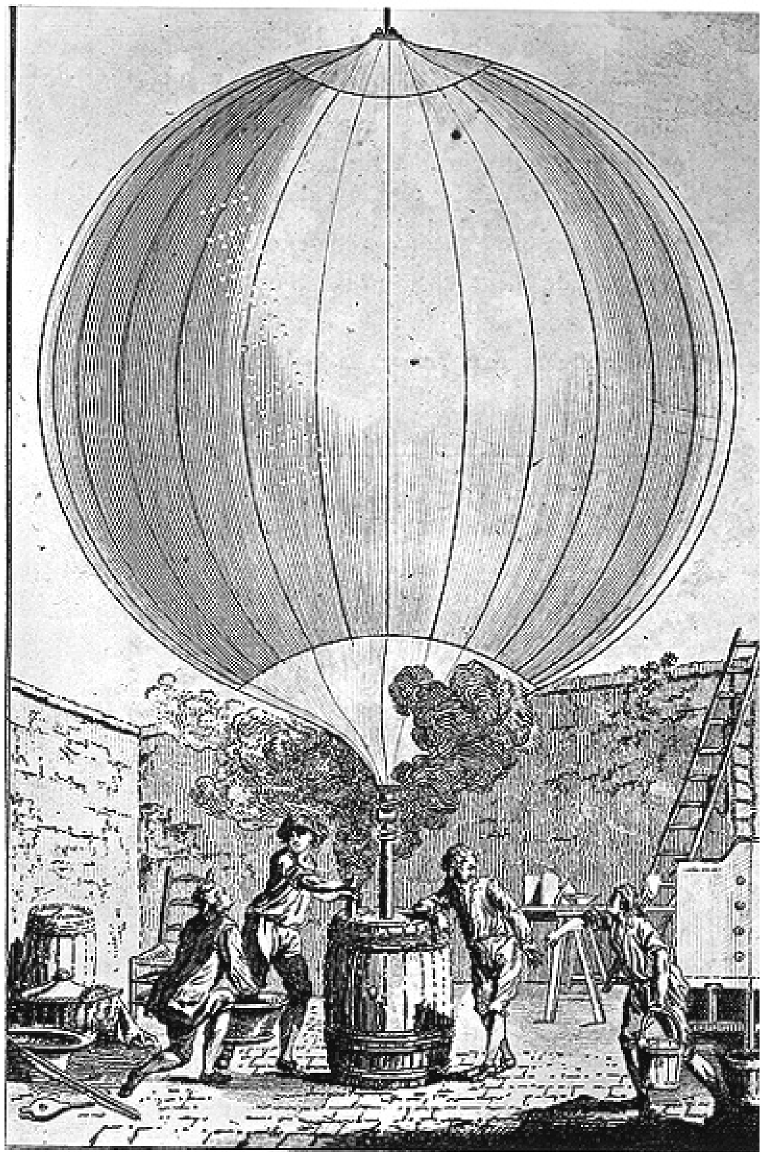
GRAPHICS & ILLUSTRATIONS

A. First Manned Hot Air Balloon Flight in 1783
B. First Gas (Hydrogen) Balloon in 1783
C. Balloon flown across English Channel in 1785
D. Balloon ascent at Cremorne Gardens in London by Walter Greaves in 1872

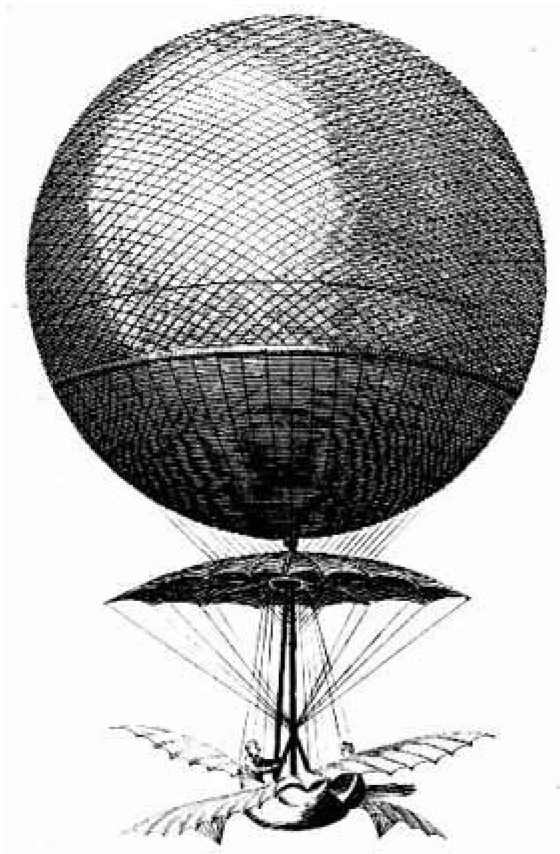
Diagrams of hot air balloon systems, tanks and burners
Along with other resources can be found at our website:
www.balloonexplorium.org



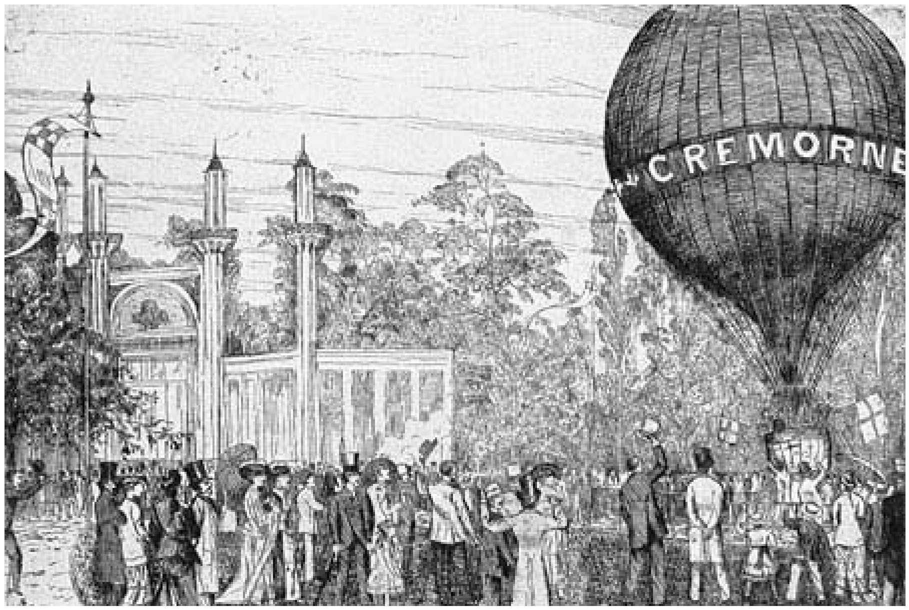
The first manned balloon flight piloted by Pilatre de Rozier and Marquis d'Arlandes on November 21, 1783 in Annonay, France. The hot air balloon was designed and built by Joseph and Etienne Montgolfier



The first hydrogen balloon flown by Jacque J. C. Charles and Nicholas Robert
on December 1, 1783



Balloon flown by Jean Pierre Blanchard and John Jeffries across the English Channel in 1785



Drawing of a balloon ascent at Cremorne Gardens in London by Walter Greaves in 1872

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