Science Experiment Manual

A collection of 167 quick and inexpensive science activities guaranteed to rocket launch your brain into a higher state of Ah-HA!

Developed by a real scientist and university educator

"Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world."

-- Albert Einstein

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Supercharged Science

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Special Note: All experiments are to be completed at your own risk. You are responsible your own safety, as well as the safety of those around you. If you are not sure about an experiment, don't do it or get help from an experienced adult (someone with a successful track record of doing whatever it is you want to do). In all seriousness, be safe, have fun, and if you run into any problems that stump both you *and* those you consult, let us know. The rest of you guys… Stay indoors when it rains!

Chapter 1: Air Pressure & Aeronautics

There's air surrounding us everywhere, all at the same pressure of 14.7 pounds per square inch (psi). You feel the same force on your skin whether you're on the ceiling or the floor, under the bed or in the shower.

An interesting thing happens when you change a pocket of air pressure - things start to move. This difference in pressure causes movement that creates winds, tornadoes, airplanes to fly, and some of the experiments we're about to do in this chapter.

An important thing to remember is that **higher pressure always pushes** stuff around. While lower pressure does not "pull," we think of higher pressure as a "push".

Another interesting phenomenon occurs with fast-moving air particles. When air moves quickly, it doesn't have time to push on a nearby surface, such as an airplane wing. The air just zooms by, barely having time to touch the surface. These air particles are really in a rush. Think of very busy people driving fast in their cars. They are so busy doing other things and driving fast to get somewhere that they don't have time to just sit and relax.

Air pressure works the same way. When air zooms by a surface (like an airplane wing), the fast air has no time to just sit there and push on the surface, so not much air weight gets put on the surface. Less weight means less force on the area. You can think of "pressure" as force on a given area or surface. Therefore, a less or *lower* pressure region occurs wherever there is fast air movement.

There's a reason airplane wings are rounded on top and flat on the bottom. The rounded top wing surface makes the air rush by faster than if it were flat. When you put your thumb over the end of a gardening hose, the water comes out faster when you decrease the size of the opening. The same thing happens to the air above the wing: the wind rushing by the wing has less space now that the wing is curved, so it zips over the wing *faster*, and creates a lower pressure area than the air at the bottom of the wing.

Air Pressure Experiment 1. 1: Soda Can Trick

DVD: Aeronautics, track 1

CD: Aeronautics, track 2

Materials: About 25 straws, two empty soda cans (not included)

Lay a row of straws parallel to each other on a smooth tabletop. Place two empty soda cans on the straws about an inch apart. Lower your nose to the cans and blow *hard* through the space between the two cans. Clink! They should roll toward each other and touch!

Why does this happen? When air moves, the air pressure decreases. This creates a lower air pressure pocket right between the cans relative to the surrounding air. Because higher pressure *pushes*, the cans clink together. Just remember – whenever there's a difference in pressure, *the higher pressure pushes.*

Air Pressure Experiment 1.2: Fountain Bottle

DVD: Aeronautics, track 2

CD: Aeronautics, track 2

Materials: small lump of clay, water, a straw, and one empty 2-liter soda bottle (not included)

Fill a 2-liter soda water bottle full of water and seal it with a lump of clay wrapped around a long straw so that the straw is secured to the mouth of the bottle. (The straw should be partly submerged in the water.) Blow hard into the straw. Splash!

What happened? As you blow air into the bottle, the air pressure increases inside the bottle. This higher pressure pushes on the water, which gets forced up and out the straw (and up your nose!).

Air Pressure Experiment 1.3: Squished Balloon

DVD: Aeronautics, track 3

CD: Aeronautics, track 2

Materials: a balloon, one empty glass jar (not included), and scrap of paper towel (not included), matches (not included), and an adult

Blow up a balloon so that it is just a bit larger than the opening of the jar and can't be easily shoved in. With an adult, light the small wad of paper towel on fire and drop it into the jar. Place the balloon on top. When the fire goes out, lift the balloon. The jar goes with it!

What's going on? Fire eats air, or in more scientific terms, the air gets used up by the flame and lowers the air pressure inside the jar. The surrounding air outside the jar is now at a higher pressure than the air inside the jar and it pushes the balloon into the jar. Remember: *Higher pressure pushes!*

Air Pressure Experiment 1.4: Sneaky Bottles

DVD: Aeronautics, track 4

CD: Aeronautics, track 2

Materials: two balloons, one tack, and two empty water bottles (not included)

Poke a balloon into a water bottle and stretch the balloon's neck covering the mouth of the bottle from the inside. Repeat with the other bottle. Using the tack, poke several small holes in the bottom of one of the water bottles. Putting your mouth to the neck of each bottle, try to inflate the balloons.

What's going on? This experiment illustrates that air really does take up space! You can't inflate the balloon inside the bottle without the holes, because it's already full of air. When you blow into the bottle with the holes, air is allowed to leak out making room for the balloon to inflate. With the intact bottle, you run into trouble because there's nowhere for the air already inside the bottle to go when you attempt to inflate the balloon.

A cool twist on this activity is to drill a larger hole in the bottle (say, large enough to be covered up by your thumb) and inflate the balloon inside the bottle with hole open, then plug up the hole with your thumb. The balloon will remain inflated even though its neck is not tied! Where is the higher pressure region now?

Air Pressure Experiment 1.5: Streaming Water

DVD: Aeronautics, track 5

CD: Aeronautics, track 2

Materials: A tack, and a plastic water bottle with cap (not included), and bathtub (not included)

Fill the bathtub and climb in. Grab your water bottle and tack and poke several holes into the lower half the water bottle. Fill the bottle with water and cap it. Lift the bottle above the water level in the tub and untwist the cap. Water should come streaming out. Close the cap and the water streams should stop. Open the cap and when the water streams out again, can you "pinch" two streams together using your fingers?

What's happening? First, you're getting clean. Second, you're playing with pressure again. Watch the water level when you uncap the bottle. As the water streams out, the water level in the bottle moves downward. Notice how the space for air increases in the top of the bottle as the water line moves down. (The air comes in through the mouth of the bottle.) When you cap on the bottle, there's no place for air to enter the bottle. The water line wants to move down, but since there's no incoming air to equalize the pressure, the flow of water through the holes stops. Technically speaking, there's a small decrease in pressure in the air pocket in the top of the bottle and therefore the air outside the bottle has a higher pressure that keeps the water in the bottle. *Higher pressure pushes!*

Air Pressure Experiment 1.6: Magic Water Glass Trick

DVD: Aeronautics, track 6

CD: Aeronautics, track 2

Materials: a glass (not included), and an index card large enough to completely cover the mouth of the glass

Fill a glass one-third with water. Cover the mouth with an index card and over a sink invert the glass while holding the card in place. Remove your hand from the card. Voila! Because *atmospheric* air pressure is pushing on all sides of both the glass and the card, the card defies gravity and “sticks” to the bottom of the glass. Recall that higher pressure *pushes and when* you have a difference in pressure, things move. This same pressure difference causes storms, winds, and the index card to stay in place.

Where's the pressure difference in this trick? At the opening of the glass. The water inside the glass weighs a pound at best, and, depending on the size of the opening of the glass, the air pressure is exerting 15-30 pounds upward on the bottom of the card. Guess who wins? Tip, when you get good at this experiment, try doing it over a friend's head!

Air Pressure Experiment 1.7: Air Takes Space

DVD: Aeronautics, track 7

CD: Aeronautics, track 2

Materials: 12" flexible tubing, two clear plastic cups, bathtub (not included)

Part I: Fill the tub and climb in. Plunge one cup underwater so it fills completely with water. While the cup is underwater, point its mouth downward. Insert one end of the tubing into the cup and blow hard into the other end. The water is forced out of the cup!

Part II: While still in the tub, invert one cup (mouth downwards) and plunge it into the tub so that air gets trapped inside the cup. Place the second cup in the water so it fills with water. Invert the water-filled cup while underwater and position it above the first cup so when you tilt the first cup to release the air bubbles, they get trapped inside the second cup. Here you see that air takes space, because in both variations of this experiment the air forced the water out of the cups.

What’s happening? You’re playing with one of the first methods of underwater breathing developed for scuba divers hundreds of years ago. Back then, scientists would invert a very large clear, bell-shaped jar over a diver standing on a platform, then lower the whole thing into the water. Everyone thought this was a great idea, until the diver ran out of breathable air!

Air Pressure Experiment 1.8: Ping Pong Funnel

DVD: Aeronautics, track 8

CD: Aeronautics, track 2

Materials: A funnel and a ping pong ball

Insert a ping pong ball into a funnel. Place the stem of the funnel between your lips and tilt your head back so ball stays inside. Blow a strong, long stream of air into the funnel.

Hey! How come the ball doesn't fly out of the funnel? As you blow into the funnel, the air under the ball moves faster than the other air surrounding the ball, which generates an area of lower air pressure. The pressure under the ball is therefore lower than the surrounding air which is, by comparison, at a higher pressure. This higher pressure pushes the ball back into the funnel, no matter how hard you blow or which way you hold the funnel. The harder you blow, the more stuck the ball becomes. Cool.

Air Pressure Experiment 1.9: Hot Air Balloons

DVD: Aeronautics, track 9

CD: Aeronautics, track 2

Materials: A lightweight plastic garbage bag, duct or masking tape (not included), a hand-held hair dryer (not included)

About 400 years ago, Leonardo da Vinci wanted to fly… so he studied the only flying things around at that time: birds and insects. Then he did what any normal kid would do—he drew pictures of flying machines!

Centuries later, a toy company found his drawing for an ornithopter, a machine that flew by flapping its wings (unlike an airplane, which has non-moving wings). The problem (and secret to the toy's popularity) was that with its wing-flapping design, the ornithopter could not be steered and was unpredictable: It zoomed, dipped, rolled, and looped through the sky. Sick bags, anyone?

Hot air balloons that took people into the air first lifted off the ground in the 1780s, shortly after Leonardo da Vinci's plans for the ornithopter took flight. While limited seating and steering were still major problems to overcome, let's get a feeling for what our scientific forefathers experienced as we make a balloon that can soar high into the morning sky.

Shake out a garbage bag to its maximum capacity. Using duct or masking tape, reduce the opening until it is almost-closed leaving only a small hole the size of the hair dryer nozzle. Use the hair dryer to inflate the bag, heating the air inside, but make sure you don't melt the bag!

When the air is at its *warmest*, release your hold on the bag while at the same time you switch off the hair dryer. The bag should float upwards and stay there for a while.

Troubleshooting: This experiment works best on *cold, windless* mornings. If it's windy outside, try a cool room. The greater the temperature difference between the hot air inside the garbage bag versus the cold, still air, the faster the bag rises. The only other thing to watch for is that you've taped the mouth of the garbage bag securely so the hot air doesn't seep out. Be sure the opening you leave is only the diameter of your hair dryer's nozzle.

Air Pressure Experiment 1.10: Genie in a Bottle

DVD: Aeronautics, track 10

CD: Aeronautics, track 2

Materials (not included): Two identical tall glasses, hot water, cold water, red and blue food dye, and an index card larger enough to cover the opening of the glasses

While this isn't actually an air-pressure experiment but more of an activity in density, really, it's still a great visual demonstration of why Hot Air Balloons rise on cold mornings.

Imagine a glass of hot water and a glass of cold water sitting on a table, side by side. Now imagine you have a way to count the number of water molecules in each glass. Which glass has more water molecules?

The glass of cold water has *way* more molecules… but why? The cold water is more dense than the hot water. Warmer stuff tends to rise because it's less dense than colder stuff and that's why the hot air balloon in experiment 1.10 floated up to the sky.

Clouds form as warm air carrying moisture rises within cooler air. As the warm, wet air rises, it cools and begins to condense, releasing energy that keeps the air warmer than its surroundings. Therefore, it continues to rise. Sometimes, in places like Florida, this process continues long enough for thunderclouds to form. Let's do an experiment to better visualize this idea.

Fill two identical water glasses to the brim: one with hot water, the other with cold water. Put a few drops of blue dye in the cold water, a few drops of red dye in the hot water. Place the index card over the mouth of the *cold* water and invert the glass over the glass of hot water. Line up the openings of both glasses, and *slowly* remove the card.

Troubleshooting: Always invert the cold glass over the hot glass using an index card to hold the cold water in until you've aligned both glasses. You can also substitute soda bottles for water glasses and slide a washer between the two bottles to decrease the flow rate between the bottles so the effect lasts longer.

Air Pressure Experiment 1.11: Squished Soda Can

DVD: Aeronautics, track 11

CD: Aeronautics, track 2

Materials (not included): An empty soda can, water, a pan, a bowl, tongs, and a grown-up assistant

An average can of soda at room temperature measures 55 psi before you ever crack it open. (In comparison, most car tires run on 35 psi, so that gives you an idea how much pressure there is inside the can!)

If you heat a can of soda, you'll run the pressure over 80 psi before the can ruptures, soaking the interior of your house with its sugary contents. Still, you will have learned something worthwhile: adding energy (heat) to a system (can of soda) causes a pressure increase. It also causes a volume increase (kaboom!).

How about trying a safer variation of this experiment using water, an *open* can, and implosion instead of explosion?

Prepare an ice bath by putting about ½" of ice water in a shallow dish. With an adult, place a few tablespoons of water in an empty soda or beer can and place the can upright in a skillet on the stove. When the can emits a think trickle of steam, grab the can with tongs and quickly invert it into the ice dish. CRACK!

The air in the can was heated and expanded. When you cool it quickly by taking it off the stove and placing it in the ice water, the air cools down inside and shrinks, creating a lower pressure inside the can. Because the surrounding air outside of the can is now higher, it pushes on all sides of the can and crushes it.

Troubleshooting: The trick to making this work is that the can needs to be full of hot *steam*, which is why you only want to use a tablespoon or two of water in the bottom of the can. It's alright if a bit of water is still at the bottom of the can when you flip it into the ice bath. In fact, there should be some water remaining or you'll superheat the steam and eventually melt the can. You want enough water in the ice bath to completely submerge the top of the can.

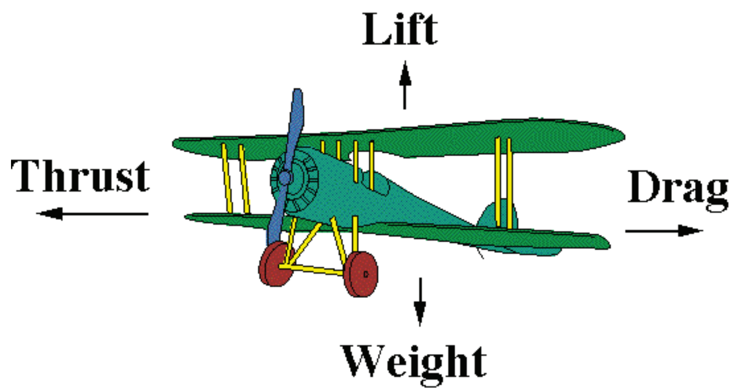
Always use tongs when handling the heated can and make sure you completely submerge the top of the can in the icy water. The water needs to seal the hole in the top of the can so the steam doesn't escape. Be prepared for a good, loud *CRACK!* when you get it right.

Aeronautics Experiment 1.12: Flying Paper Machines

DVD: Aeronautics, tracks 13-19 or watch the video online:
http://www.superchargedscience.com/paperairplanes.wmv

CD: Aeronautics, track 2

Materials: Sheet of paper, pencil (not included), and a hair dryer (not included)

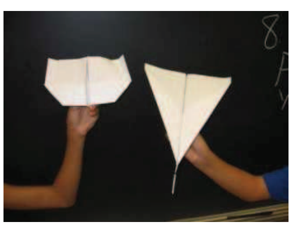


Every flying thing, whether it's an airplane, spacecraft, soccer ball, or flying kid, experiences four aerodynamic forces: lift, weight, thrust, and drag. An airplane uses a propeller or jet engine to generate thrust. The wings create lift. The smooth, pencil-thin shape minimizes drag. And the molecules that make up the airplane attribute to the weight.

Think of a time when you were riding in a fast-moving car. Imagine rolling down the window and sticking out your hand, palm down. The wind slips over your hand. Suppose you turn your palm to face the horizon. In which position do you think you would feel more force against your hand?

When designing airplanes, engineers pay attention to details, such as the position of two important points: the *center of gravity* and the *center of pressure* (also called the *center of lift*). On an airplane, if the center of gravity and center of pressure points are reversed, the aircraft's flight is unstable and it will somersault into chaos. The same is true for rockets and missiles!

There are several different flying paper machine designs you can build right now. Pop in the DVD or watch the video online and start building! After you have your model, come back and we'll explore the finer details tweaking, trimming, and finding the lift points on your airplane.



Let's find the center of gravity on your airplane. Grab your flying machine and sharpened pencil. You can find the 'center of gravity' by balancing your airplane on the tip of a pencil. Label this point "CG" for Center of Gravity.

Find the Center of Pressure (CP) by doing the opposite: Using a blow-dryer set to low-heat so you don't scorch your airplane, blast a jet of air up toward the ceiling. Put your airplane in the air jet and, using a pencil tip on the top side of your plane, find the point at which the airplane balances while in the airstream. Label this point "CP" for Center of Pressure. (Which one is closest to the nose?)

Besides paying attention to the CG and CP points, aeronautical engineers need to figure out the static and dynamic stability of an airplane, which is a complicated way of determining whether it will fly straight or oscillate out of control during flight. Think of a real airplane and pretend you've got one balanced on your finger. Where does it balance? Airplanes typically balance around the wings (the CG point). Ever wonder why the engines are at the front of small airplanes? The engine is the heaviest part of the plane, and engineers use this weight for balance, because the tail (elevator) is actually an upside-down wing that pushes the tail section *down* during flight.

How does an airplane remain stable during flight? Positive stability means that the airplane is designed so that if the pilot jams on the controls during straight and level flight (in other words, pitch up hard), and then let go, the airplane will more or less return to straight and level flight.

Here's how that works: When the airplane's nose suddenly pitches up, the wind speed over the wings slows and decreases the lift on the plane. This causes the nose to tip downwards and the wind to rush over the wings again, creating more lift. This cycle eventually dampens out and soon the airplane is flying level again.

If, however, you have a negative stability (meaning that your CG is aft of or behind the CP), when the airplane suddenly pitches up, one of several things may happen, all of which require sick bags and a parachute. One of the worst cycles is this: When a tail-heavy plane noses down, the speed over the wings increases and provides more lift but only briefly, because a tail-heavy plane will keep its nose up until the wind speed slows so much that the winds stall. Lift is no longer generated by wind flowing over the wings, because there is no wind, and the airplane "falls" a distance until the air flows back over the wings. This generates a lot of lift very quickly until the tail section tilts the nose back up. The cycle continues to worsen each time with greater "fall" distances" that place huge structural forces on the fuselage or body of the plane until you jump ship.

The great news is that many of the problematic circumstances and situations related to flying were figured out a long time ago by two amazing people: the Wright brothers. The Wright brothers also took an airfoil (a fancy word for "airplane wing"), turned it sideways, and rotated it around quickly to produce the first real propeller that could generate an efficient amount of thrust to fly an aircraft. Before the Wright brothers perfected the airfoil, people had been using the same "screw" design created by Archimedes in 250 BC.

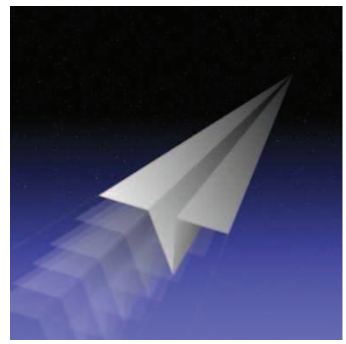
This twist in the propeller was such a superior design that modern propellers are only 5% more efficient than those created a hundred years ago by the two brilliant Wright brothers.

Aeronautics Troubleshooting Guide

DVD: Aeronautics , track 14

We've included several flying designs for you to test, including: stunt planes, fast jets, hang gliders, and a one that, mathematically-speaking, isn't even supposed to fly.

The trick to any paper airplane, be it dart, stunt, or glider, is in the *tweaking*. In order to turn a disappointing nose-diver into a stellar barrel-roller, you'll need to pay close attention to your dihedral angle (angle the wings make with the horizon) and elevator angle (pinching up or down to the tail section). Here's how we do it:



- Throw your airplane. Notice if you threw it hard, medium, or easy. Try modifying the throw to see which one works better for this particular airplane design. Stunt planes tend to work better with an easy throw and jets zoom with a fast throw.

- Now make the wing dihedral neutral (level with the horizon). Pinch up on the elevators a *tiny* bit and give it another like the throw that worked best last time.

- If the plane nose dives sharply, give it more of a pinch up on the elevators. If it nosed up first, then pitched down and crashed, you've got too much 'up elevator' in the back. What happens when you pinch one elevator up and one down?

- If the airplane still won't fly correctly, then check your symmetry. Are your wings exactly the same size and shape? When you fold your airplane, do the wings sit right on top of each other? Most airplanes don't like being asymmetrical, and it'll show up when you try to fly.

If you're crazy for airplanes, we've got several more at this link
Enjoy!

http://www.superchargedscience.com/paperairplanes.wmv

Aeronautics Experiment 1.13: Rigid Flyers

DVD: Aeronautics, track 12, or visit this link on our website:
http://www.superchargedscience.com/airplanes1.wmv

CD: Aeronautics, track 2

Materials: A small cardboard or Balsa wood flyer

Punch out the parts on the flyer, separate all the parts, and detach the metal nose-tip if included. Grab just the wing section and throw it as if you were attempting to make them fly on their own. Did you see how fast it somersaults?

Now attach the wings to the body and give it a good throw. Did the somersaults get faster or slower? The body should give the wings a bit more stability, but we need more stabilizers to keep our passengers from getting sick.

Add the elevator (horizontal tail part). Now throw it, but when you do, give it a twist to one side. Can you get it to "skid" in the air? Did the somersaults stop? Now we need to do something about that skidding problem (called 'yawing' in airplane-speak).

If you're using a balsa wood flyer, here are two additional variations you can test:

First, add the rudder (vertical tail piece). Throw it again, and notice what initially happens. It will probably pitch up, stall, and fall out of the sky to the ground.

NOTE: When flying, a 'stall' doesn't have anything to do with the engine, but rather it means the airflow over the wings isn't sufficient to keep the airplane flying.

Next place a fingertip on the underside of the body. Where does the plane balance now? Where is most of the weight? If you've left off the nose weight, you know now what you need to do! Add the nose-clips to balance your weight and give it a good, hard throw! Your plane should soar across the room. If not, you'll need to do a bit more tweaking with the design as described above.

Aeronautics Experiment 1.14: Ring Thing

DVD: Aeronautics, track 20 or watch the video on our website:
http://www.superchargedscience.com/airplanes2.wmv

CD: Aeronautics, track 2

Materials: Index card, straw, scissors (not included), tape (not included)

Cut an index card into thirds lengthwise. Loop one strip into a circle and tape the ends together. Place the two remaining strips together end-to-end and tape, then loop them into a large circle and tape in place. Place a piece of tape across one end of the straw and gently secure one ring to the tape. Repeat on the other end with remaining ring. Make sure the two rings are concentric (you can see through both like a telescope). Now throw it, small-end-first!

Why can this thing fly? It doesn't even LOOK like a plane! When I teach at the university, this is the plane that mathematically *isn't* supposed to be able to fly! There are endless variations to this project—you can change the number of loops and the size of loops, you can tape two of these together, or you can make a whole pyramid of them. Just be sure to have *fun!*

Aeronautics Experiment 1.15: Helicopters

DVD: Aeronautics, track 21 or watch this video online:
http://www.superchargedscience.com/airplanes4.wmv

CD: Aeronautics, track 2

Materials: A paperclip, a thin strip of paper, and scissors (not included)

The directions are a bit more complicated than usual, so watch the video online or on your DVD. This project is pretty bullet-proof—to fly the helicopters, all you need to do is drop them! Speaking of which, you can also notch the tip end and add a slingshot.

Aeronautics Experiment 1.16: Butterfly Cups

DVD: Aeronautics, track 22 or watch this video on our website:
http://www.superchargedscience.com/airplanes3.wmv

CD: Aeronautics, track 2

Materials: Two paper cups, 5 to 7 rubber bands, and tape (not included)

Tape two paper cups together, bottom-to-bottom. Chain together six rubber bands. Loop one end of the rubber band chain over your thumb and hold your arm out horizontally straight, palm up. Drape the remainder of the chain along your arm. Place the taped cups at the free end of the rubber band chain near your shoulder and slowly wind the rubber bands around the middle section of the cups. When you wind near the end, stop, stretch the chain back toward your elbow, make sure the rubber band comes from the underside of the cups. Now release the cups. The cups should rotate quickly and take air, then gracefully descend down for a light landing.

Why does THAT thing fly? The Butterflying Cups experiment is one of my favorites to use when teaching university-level fluid mechanics, because it is quite a complex task to demonstrate and analyze the aerodynamic lift. The easiest explanation is that lift is generated by the rotation of the cups. How and why the vortex generates lift is much more complex, but remember that as the air velocity increases, the pressure decreases. And remember… higher pressure regions always *push*.

You can try further experiments with your butterfly cups: Try reversing the rotation direction, spin the cups in a cloud of fog or smoke while your video-tape their flight, performing the same experiment underwater (add small particles to the water so you can see the lines of flow!), change the size of the cups, and change the number of cups.

Bonus Experiments!

We've got even MORE science for you! These experiments are not on the DVDs, CDs, and we didn't include the parts for them. They are just pure science ideas for you to test. Have fun!

Air Pressure Experiment: Diaper Wind Bag Cut an eight-foot section of the diaper genie bag and knot one of the ends. Hold the other end open, take a deep breath, and blow. How many breaths does it take for you to fill up the entire bag with air? Try this now…

After you know how many breaths it takes, do you think you can fill the bag with only ONE breath? The answer is YES! Hold the bag about eight inches from the face and blow long and steady into the bag. As soon as you run out of air, close the end of the bag and slide your hand along the length (toward the knotted end) until you have an inflated blimp.

Troubleshooting: If the bag tears open, use *packing tape* to mend it.

What's going on? When you blow air past your lips, a pocket of lower air pressure forms in front of your face. The stronger you blow, the lower the air pressure pocket. The air *surrounding* this lower pressure region is now at a *higher* pressure than the surrounding air, which causes things to shift and move. When you blow into the bag (keeping the bag a few inches from your face), you build a lower pressure area at the mouth of the bag, and the surrounding air rushes forward and into the bag.

Teaching Tip: Kids have a tendency to shove the bag right up to their face and blow, cutting off the air flow from the surrounding air into the bag. When they figure out this experiment and perform it correctly, this is one of those *oooh-ahhh* experiments that will leave your kids with eyes as big as dinner plates.

Substitution Tip: If you can't locate a diaper genie, you can string together plastic sheets from garbage bags, using lightweight tape to secure the seams. You'll need to make a 8-12" diameter by eight-foot long tube and close one end. When kids get their eight-foot bag inflated in just one breath, ask them: "Did you really have that much air in your lungs?"

Air Pressure Experiment: Plumber Magic Take two clean old-fashioned, red rubber-and-wood-stick toilet plungers and stick them together (you may need to wet the rims first). Try to separate them. Why is it so hard? When you rammed them together, air was forced out of the cavity that the insides make when pushed together, leaving you with a lower air pressure pocket inside, compared to the surrounding air pressure—14.7 (psi)—outside the plungers. Higher pressure, always pushing, keeps the plungers together.

Air Pressure Experiment: Magic Egg Trick Remove the shell from a hard-boiled egg and use a bottle with a neck large enough that the egg can be squeezed through without squashing it. Old fashioned milk bottles work great. Light a match and toss it in the empty bottle, then quickly set the egg (small-end down) on the mouth of the bottle. The air gets eaten up by the flame, thus lowering the air pressure inside the bottle. The higher pressure (now outside the bottle) pushes on the egg and pops it in. To remove the egg from the bottle, turn the bottle upside down and wiggle the egg until the small end is pointing toward the mouth of the bottle. Blow hard into the mouth of the bottle and the egg should pop right back out.

Air Pressure Experiment: Rebellious Paper Wad Take an empty water or soda bottle and lay it down horizontally on a table. Carefully set a small wadded up ball of paper towel in the mouth of the bottle—the ball should be about half the size of the opening. Can you blow hard enough to get the paper to go into the bottle? Why is this so impossible?!? HINT: You're trying to force more air into the bottle, but there's no room for the air already inside to go except back out the mouth of the bottle, taking the paper ball with it.

Air Pressure Experiment: Flying Papers Hold a regular sheet of paper to your bottom lip and blow hard across the sheet. (You may have to play a bit to find the exact location.) The paper flies up! This happens for the same reason airplanes can fly. As you blow across the top of the sheet, you lower the air pressure because the air is moving faster Therefore, the pressure on the underside of the sheet is now higher, and… Higher air pressure pushes the sheet upwards.

Air Pressure Experiment: Kissing Balloons Blow up two balloons. Attach a piece of string to each balloon. Have each hand hold one string so that the balloons are at nose-level, 6 inches apart. Blow hard between the balloons and watch them move! The air pressure is lowered as you blow between the balloons. The air surrounding the balloons is now at a higher pressure, which pushes the balloons together.

Aeronautics Experiment: Parachutes Attach a piece of dental floss or thin string to opposite corners of a tissue. Repeat for the other diagonal. Attach several different lightweight items, such as a small stick, a small pebble, etc… to the string and drop from a height. Practice dropping these from the balcony and see which falls slowest.

Aeronautics Experiment: Super-fast Parachute Grab a plastic grocery bag and tie the handles together with string. Add a weight to the string and toss the whole thing over the balcony. Instant fun!

Aeronautics Experiment: Free Form Machines

Make an obstacle course to further challenge your inventors. Design your course to include airplane banking, list and dive maneuvers, and more. By setting a goal (longest time aloft, furthest distance traveled, into the basketball hoop…), you'll encourage the kids to think about their design, test their ideas, and really zero in on which "tweak" has which effect on the airplane performance. Here are a few ideas to get you started:

- Hit a target balloon (if you're daring, you can arm the paper airplanes with toothpicks taped to the nose to pop the balloons)
- Go over and under a suspended length of string
- Make it through a hula hoop suspended vertically or horizontally
- Carry a jelly bean passenger safely across a set distance
- Dangle large paper airplanes made from 11x17-inch paper from the ceiling for a "dogfight" and earn points if you tag one. (Construction Tip: You can tape two 8.5x11-inch sheets of paper together to make an 11x17-inch sheet.)
- Shoot through a basketball hoop, and dive into a basket.

Air Pressure & Aeronautics Review

(Answer key can be found at the end of this guide.)

1. Higher pressure does which? (a) pushes (b) pulls (c) decreases temperature (d) meows (e) causes winds, storms, and airplanes to fly

2. The tips on the edge of a paper airplane wing provide more lift by: (a) flapping a lot (b) destroying wingtip vortices that kill lift (c) getting stuck in a tree more easily (d) decreasing speed

3. In the ping pong ball and funnel experiment, the ball stayed in the funnel was because: (a) you couldn't blow hard enough (b) you glued it into the funnel (c) the ball had a hole in it (d) the fast blowing caused a low-pressure region around the ball, causing the surrounding atmospheric pressure to be a higher pressure, thus pushing the ball into the funnel

4. In the sneaky bottle experiment, which of the two bottles was the balloon able to inflate in? (a) the one with a hole (b) the one with no holes (c) the one the kid fit inside

5. If your plane takes a nose dive, you should try (a) changing the elevators by pinching the edges (b) change the dihedral angle (c) change how you throw it (d) all of the above

6. What are the four forces that act on every airplane in flight?

______________ ______________ ______________ ______________

7. Draw a quick sketch of your paper airplane when it has positive dihedral:

8. Label these parts on your sketch for Question 7: fuselage, elevators, rudder, and wings.

9. Why does the index card stay in place when you invert the cup of water in the magic water glass trick?

10. When the balloon was squished into the jam jar with the snuffed candle, where was the higher pressure?

11. Why does the water stop streaming out of the bottle when you put the cap on in the streaming water experiment? Why does the water come out if you squeeze the capped bottle?

12. How can you make the fountain bottle shoot even higher?

13. If you were designing your own “Flying Paper Machine Kit”, what would be inside the box?

14. What’s the *one thing* you need to remember about higher pressure?

"MORE THAN ANYTHING ELSE THE SENSATION IS ONE OF PERFECT PEACE MINGLED WITH AN EXCITEMENT THAT STRAINS EVERY NERVE TO THE UTMOST, IF YOU CAN CONCEIVE OF SUCH A COMBINATION."

WILBUR WRIGHT
(LEFT)

"THE EXHILARATION OF FLYING IS TOO KEEN,
THE PLEASURE TOO GREAT,
FOR IT TO BE NEGLECTED AS A SPORT."

ORVILLE WRIGHT
(RIGHT)

Specialized Aeronautics Projects: Kites

Kites are airplanes on a string. They use both high and low pressure to gain altitude and soar skyward. Not all kites need tails—the tail section helps stabilize an otherwise unstable kite design by adding a bit of weight near the bottom. While kites need to be lightweight, the framework needs to be strong, as they can withstand winds greater than 70 mph at higher altitudes.

To launch a kite, you can start with it on the ground and simply start running, hold it in your hands and toss it behind you as you run, or have someone hold it for you and toss it up as you start to run with the string. The best launch method depends on the kind of kite you're working with.

BUILDING TIPS:

The directions for building these kites are a lot easier to understand when you watch the DVD than they are to assimilate as written instructions. Therefore, we've supplied a basic overview to building kites in this chapter. You'll find the instructional video on our website at: *http://www.superchargedscience.com/ktas38590.wmv*

FLYING TIPS:

Before flight, hold your kite where the main line attaches to the bridle (the part that attaches to the string spool). Adjust the strings so that the kite hangs about 30 degrees into the wind. Use your fingers on the bridle on a windy day to find the "magic spot" or the place where your kite picks right up and flies best.

Moving the bridle forward makes the kite fly higher in smooth winds and moving it backward helps it fly in gusty winds. If your kite fails to rise, try a windier spot or a shorter tail.

If it flies then quickly crashes, you may need to shorten your bridle or change the angle. If your kite spins around and around while flying, add more tail length.

Kite Experiment 2.1: Bat Kite

DVD: Aeronautics, track 23 or watch the video online:
http://www.superchargedscience.com/media/kite1.wmv

CD: Aeronautics, track 3

Materials: An 11"x17" sheet of paper, 10 feet of string, two donut stickers (also known as page reinforcement stickers), a stapler (not included), and a short straw

This kite is basically a paper airplane on a string. It's fast and easy to make. And the directions are really confusing, so feel free to watch the video online or on your DVD.

Take an 11x17-inch sheet of paper and fold it in half so it now becomes 8 ½ x 11 inches. Curl one corner tip to the center fold, 2 inches from the same end. Do the same with the other side, and secure the fold with a staple. Two inches below the staple, punch a hole near the center fold and attach donut stickers (to keep string from tearing through the paper). Attach a good length of string and run! This kite works with little-to-no wind. *Just run!*

Note: To make a string handle, cut a straw in half and thread one of the pieces onto the end of the string, looping the free end back onto the main line. Wind the excess string around the straw.

Teaching Tip*:* When we teach kids how to make this kite, we punch holes both on both sides of the staple and ask the kids which hole works best.

Why does this kite fly? This kite soars because you're holding the kite at the correct angle to the wind. The wind flows both over and under the kite, and with this shape, the air flying over the kite is traveling a bit faster than the wind under the kite. Recall that higher speeds mean lower pressure. The underside of the kite now has a relatively higher pressure, thus pushing the kite upwards into the sky.

Can I add string to any paper airplane and make it into a kite? Anytime someone asks us a question like this, we respond with a very enthusiastic: "I don't know. Try it!" Then we offer enough tools for the job with a smile. We want kids experimenting with new ideas (even if we're not entirely sure if they will work). Success is not our top goal when we do science here at Supercharged Science. We focus on "learning by doing" instead. So go ahead, roll up your sleeves, test out your ideas, and prepared to learn.

Troubleshooting: The bat kite needs very little wind to fly – in fact, most kids get their kites airborne just by running. Depending on where the staple is located, you can place your string forward or aft of (behind) the staple. Encourage kids to test and find their own answer, but our recommendation is to shoot for the aft hole 3.5 inches from the nose and the staple 1.5 inches from the nose. This kite is very forgiving about measurements.

Kite Experiment 2.2: Tetrahedral Kite

DVD: Aeronautics, track 24
http://www.superchargedscience.com/media/kite2.wmv

CD: Aeronautics, track 3

Materials: Six straws, one sheet of tissue paper, string, crepe paper streamers, glue sticks (not included), scissors (not included), and tape (not included)

Thread three naked straws (straws with the wrapper removed) onto a length of string and tie it off to make a stiff triangle. Thread two more straws onto a string and attach to a different corner of the triangle, making a 2D diamond shape.

Thread one straw onto a string and attach one end to each diamond apex, pulling your shape into a 3D tetrahedral triangle or pyramid shape.

Cover two adjacent sides with tissue paper and use glue sticks to fold the tissue around the straws and back onto itself. Then attach a bridle string along the tissue fold. Add a crepe paper streamer for a tail and you're ready to fly! Tip: You can also make four tetrahedral shapes and stack them into one giant pyramid!

Kite Experiment 2.3: Dragon Kite

DVD: Aeronautics, track 26

CD: Aeronautics, track 3

Materials: Wire coat hanger or thin plastic dowel, string, straw, plastic garbage bags, tape (not included), and scissors (not included)

Bend a very thin wire coat hanger into a D-shape. Tape a covering of a trimmed plastic garbage bag for a kite skin. Along the straight side of the D, tape a ten-foot pieced-together section of garbage bag the same width as the D for the tail. Attach a bridle of string to the top and bottom of the coat hanger section, and add a main kite line to the bridle. This kite works best in an area with a lot of wind, such as the beach. Try making a larger version with a fifty foot tail!

Kite Experiment 2.4: Diamond Kite

DVD: Aeronautics, track 25

CD: Aeronautics, track 3

Materials: Two 36" dowels or plastic balloon sticks, string, plastic garbage bags, crepe paper streamers, tape (not included), and scissors (not included)

If you can find balloon sticks (white plastic stiff tubes about 3 feet long), use them. They're inexpensive, lightweight, and easy to work with. Otherwise, use wood dowels from a hardware store or 36" bamboo gardening stakes from a nursery. Make a lowercase T-shape with two sticks, crossing one stick one-third the way down from the top, and lash them together with string or tape.

Outline the diamond-shape by attaching thin string around the ends of the dowels clockwise. Use a garbage bag for the kite skin by trimming the plastic bag with an inch of excess outside the kite outline, fold the trimmed plastic over the kite string and tape it along the edge.

Attach crepe paper streamers for a tail. Then attach a bridle to the kite by tying one string to the top and bottom of the vertical dowel, and other string to both ends of the horizontal dowel. Tie the main kite string line (the one with attached to the spool) around both bridles. You'll need to play with the string lengths to adjust the angle that the kite makes with the wind.

To make the large red kite in the photo (right), simply make the diamond kite as described above, with these modifications:

Use 6 foot lengths of bamboo for a 6x6 foot kite or 9 foot lengths for a 9x9 foot kite. You can find these poles for the spars at your hardware store. Use rip-stop nylon from a fabric store for the skin and a sewing machine to attach the skin to the spars where you are instructed to use tape above. Tip: Place the sewing machine in the center of the room as you will need space to maneuver the kite around the needle as you work. The tail for this large kite should be 25-40 feet long.

Instead of string, use nylon cord with a tensile strength of *at least* 500 pounds and tie the end onto the bumper of a truck—unless you want to be lifted off the ground! We have successfully made a 12 foot version of this kite, which requires about a mile of string takes hours to pull it in. If you love to fly, this is the ultimate project!

Kite Experiment 2.5: Sled Kite

DVD: Aeronautics, track 27

CD: Aeronautics, track 3

Materials: Two 24 inch wood dowels (or two 24 inch long plastic balloon sticks), four donut stickers (also known as page reinforcement stickers), string, plastic garbage bags, tape (not included), scissors (not included)

Cut a garbage bag into a rectangle 24 inches high and 30 inches long. Snip the corner of the upper right side as follows:

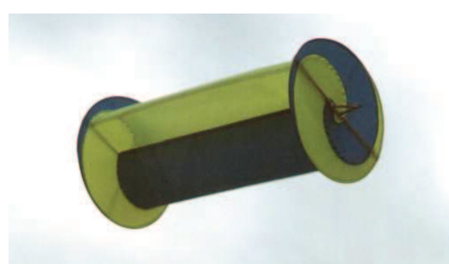
From the upper right corner, measure 9 inches to the left and mark with a dot (the dot will be on an edge). From the corner again, measure down 7.5 inches and make another dot (again, on an edge). Connect the dots and cut along a line. Cut the left upper corner to match. Tip: You can easily do this by folding the bag in half and follow the cut you just made.

Snip the lower bottom corners the same way. From the lower right corner, measure over 9 inches to the left and mark with a dot, then measure 16.5 inches up from the corner and mark with another dot. Connect the dots and cut along the line. Do the same for the left side. Shape the top straight edge of your kite by cutting a shallow curve (like the neckline of a T-shirt) for better airflow.

Your kite should look like a rectangle with a triangle attached to either side, pointing out. At those points, punch a hole and reinforce it with donut hole savers. Attach six feet of string with double knots at each hole, then knot the ends together. Spread your kite out flat. Line up your dowels where the rectangle edges meet the triangle edges, one for each side and tape them in place. Add a spool of string and you are ready to go!

Kite Experiment 2.6: Rotor Kite

DVD: Aeronautics, track 28
http://www.superchargedscience.com/media/kite3.wmv



CD: Aeronautics, track 3

Materials: Two straws, a long length of string (20 feet or more), duct tape, two foam plates(at least 4 inches in diameter, one 6x4-inch clean foam meat tray, hot glue gun (optional), and scissors

Rotor kites (often called UFO kites) are one of those unusual kites that require more complex aerodynamics in order to fly. This particular kite flies only when rotating. Make sure you have *lots* of wind for this kite by either visiting the beach or tying it to your bicycle.

Cut the curved sides off the short ends and cut the tray lengthwise to make two vanes. Measure the length of your vanes and add three inches to the measurement—this is the straw length you need. Tip: You can tape together several smaller straws to make one long straw.

Important: Puzzle-fit your meat tray back into its original shape. Note that there's a lip that runs all the way around the tray. Take ONE vane and flip it over, still keeping the cut sides together. Now your rotor should have one lip facing up, the other facing down. Slide your extended straw between the cut sides of the vane and hot glue it into place. Tip: Use duct tape to hold it together securely.

Poke a hole in the center of two foam plates. Slide one foam plate onto the straw and hot glue it in place next to the vane. Do the same for both sides.

Thread a line through the straw and tie it back onto itself, leaving enough room for the rotor to spin freely in the wind. Attach the main kite line and go find a place with *lot* of wind, like at the beach! *Running around isn't enough to get this kite in the air!*

Troubleshooting: this kite is *very* picky about wind speed. Make sure the string doesn't rub on the plates during flight. You can use hollow gardening stakes, empty ballpoint pen tubes taped together into a long straw, or composite tubes instead of the straws described above. Fishing line or nylon string works for kite line as well.

To see this kite working in a close-up range, get an indoor fan and set it on high speed while you hold your kite string close to the knot in the bridle. Hold your kite in the airstream until it rotates freely. Depending on where you live, you can drive your car on a country road or ride your bike to generate more wind speed than just running.

Bonus Idea! Butterflying Cups

Here's a flying machine that's closely related to the Rotor kite, but requires only two cups and a few rubber bands to work (no wind):

http://www.superchargedscience.com/airplanes3.wmv

Kite Experiments Worksheet

(Answer key is found at the end of this manual.)

1. Kites need string so: (a) they don't get lost (b) to hold them at the correct angle to the wind (c) so you can pull the kite in when you're done (d) all the above

2. Kites can be in the shape of which ones? (a) box (b) pyramid (c) diamond (d) hippos

3. Which part of the kite is the most adjustable? (a) the kite skin (b) the tail (c) the bridle (d) the frame

4. Which kite is collapsible and easy to carry? (a) sled (b) dragon (c) bat (d) rotor (e) tetrahedral (f) diamond

5. If your kite crashes to the ground, what two things can you try changing?

6. How do you get your kite to spin in circles?

7. How much wind does the Rotor kite need? (a) a day at the beach could work (b) zero (c) winds like a hurricane (d) running ought to do it

8. What do you do if your kite doesn't lift off the ground? (a) run faster (b) find a windier spot (c) let go of the kite (d) stop stepping on it (e) all of the above

9. Where is the higher pressure area on the kite during flight? (a) the topside (b) the underside (c) the tail (d) nowhere

10. What is the frame for on a kite? (a) to keep the kite in the right shape (b) to provide weight in the right places (c) so it can break (d) so you have something to attach the bridle to

11. Which kite works with the least amount of wind?

12. How can you modify the diamond kite so will lift you off the ground? Sketch out a picture with measurements.

13 (a) For Question 12, what will you make the kite skin out of?

(b) How about the frame?

"ALL OUR KNOWLEDGE HAS ITS ORIGINS
IN OUR PERCEPTIONS."

LEONARDO DA VINCI

Specialized Aeronautics Projects: Rockets

Rockets shoot skyward with massive amounts of thrust, produced by chemical reaction or air pressure. Scientists create the thrust force by shoving a lot of gas (either air itself, or the gas left over from the combustion of a propellant) out small exit nozzles.

According to the universal laws of motion, for every action, there is equal and opposite reaction. If flames shoot out of the rocket downwards, the rocket itself will soar upwards. It's the same thing if you blow up a balloon and let it go—the air inside the balloon goes to the left, and the balloon zips off to the right (at least, initially, until the balloon neck turns into a thrust-vectored nozzle, but don't be concerned about that just now).

A rocket has a few parts different from an airplane. One of the main differences is the absence of wings. Rockets utilize fins, which help steer the rocket, while airplanes use wings to generate lift. Rocket fins are more like the rudder of an airplane than the wings.

Another difference is the how rockets get their speed. Airplanes generate thrust from a rotating blade, whereas rockets get their movement by squeezing down a high-energy gaseous flow and squeezing it out a tiny exit hole.

If you've ever used a garden hose, you already know how to make the water stream out faster by placing your thumb over the end of the hose. You're decreasing the amount of area the water has to exit the hose, but there's still the same amount of water flowing out, so the water compensates by increasing its velocity. This is the secret to converging rocket nozzles—squeeze the flow down and out a small exit hole to increase velocity.

There comes a point, however, when you can't get any more speed out of the gas, no matter how much you squeeze it down. This is called "choking" the flow. When you get to this point, the gas is traveling at the speed of sound (around 700 mph, or Mach 1). Scientists found that if they gradually un-squeeze the flow in this choked state, the flow speed actually *continues* to increase. This is how we get rockets to move at supersonic speeds or above Mach 1.

The image (right) is a real picture of an aircraft as it breaks the sound barrier. This aircraft is passing the speed at which sounds travel. The white cloud you see in the photo is related to the shock waves that are forming around the craft as it moves into supersonic speeds. Because the aircraft is moving through air, which is a gas, the gas can compress and results in a shock wave. You can think of a shock wave as big pressure front. In this photo, the pressure is condensing water vapor in the air, hence the cloud. There are lots of things on earth that break the sound barrier – bullets and bullwhips, for example. The loud crack from a whip is the tip zipping faster than the speed of sound.

The rockets we're about to build get their thrust by generating enough pressure and releasing that pressure *very* quickly. You will generate pressure both by pumping and by chemical reaction, which generates gaseous products. Let's get started!

Rocketry Experiment 3.1: Paper Blow-Gun Rockets

DVD: Aeronautics, track 29

CD: Aeronautics, track 4

Materials: Two straws each in two different sizes, two sheets of paper, index cards, scissors (not included), tape (not included), and a hot glue gun (not included)

Additional optional materials: Air compressor or air tank, spray-nozzle, and metal tubing that fits just inside the larger straws

Make a very long straw by joining two straws with tape. Roll an 8½x11-inch sheet of paper into a long tube and tape it shut. Cut triangle fins out of the index card and hot glue to the base end of the rocket.

Construction Tip: Younger kids can roll the paper around a dowel to help.

To make the nosecone, cut a circle out of paper. You can trace the inner diameter of masking tape roll to get a good circle. To make a flat circle into a 3D cone, begin to cut the circle in half, but stop cutting when you get to the center. Slide one flap over the other to form a nose for your rocket and tape it shut. Pile a lot of glue inside the cone insert the long straw and wait to for it to dry. Slip the straw inside the tube and seal the nosecone to the rocket body.

When dry, blow into your straw to check for leaks. It should be impossible to blow through. If you have a leak, go back and fix it now. Otherwise, slip a metal tube slightly larger than the straw over the straw and blow hard. Tip: Check a hardware store for the metal tube.

What's going on? This rocket uses air pressure to launch itself skyward. When you blow hard, you create a higher pressure region behind the rocket. *Higher pressure always pushes*, so off it goes!

Optional, super Cool idea: If you have an air tank or compressor handy, the nozzle from it to blast these rockets hundred of feet in the air!

Repair Tip: If your straws come loose, simply cut the rocket body just below the nosecone and rebuild the straw-cone assembly, fastening it in place when dry.

Rocketry Experiment 3.2: Water Rockets

DVD: Aeronautics, track 30

CD: Aeronautics, track 4

Materials: Car tire valve… and these items are not included for safety reasons: empty 2-liter soda bottle, razor blade, bike pump), vice, drill, water

Modify an empty soda bottle into a rocket that launches from your hand! **Important: DO NOT USE water bottles** as they will burst. You MUST use a bottle that was made to hold contents under pressure.

Clamp the soda bottle cap in a vice. Using a razorblade, strip threads from the cap until you can untwist the cap completely from the bottle with one wrist movement. You'll have to cut off approximately one full turn of threads from open end, which will make it easier to get the cap off quickly without allowing too much air pressure to leak out. It also makes this experiment more dangerous and prone to accidents as now the cap will comes off a lot easier. Be careful!

Drill a hole that matches the size of the car tire valve into the center of the cap, again using the vice to hold it still. A ½-inch spade bit works best. Next insert the valve through cap so when it's screwed on, you can easily pressurize the bottle with a bicycle pump. To the bottle, add water , screw on the valve-cap, and pump up the pressure using the bicycle pump or air compressor until the bottle feels rock-solid.

NOTE: Bottles tend to burst above 70 psi and after extended use, so replace the bottles after 7-10 shots. As they get banged around on landing, they start forming fissures that lead to bursting under pressure. If you are using an air compressor rather than a bicycle pump, be sure to keep your air compressor set to a maximum of 70 psi.

ALWAYS USE SAFETY GOGGLES or a FACE SHIELD!

Be sure to transport the charged bottle with the **valve-side down**, in case the valve tears free from the bottle.

Hold the bottle bottoms-up at an angle, grasp the cap, and begin to untwist *slowly*… until the water begins to drip out and leaks like a faucet. Now untwist the cap fully in one motion, and the bottle will fly a hundred feet or more, leaving you drenched and awed. Make sure you've got about a football field-sized launch area.

What's happening? This rocket uses HIGH pressure to soar skyward. Think of a balloon; when you release the end of a balloon, the air inside the balloon travels one direction and the balloon zooms in the opposite direction (initially, anyway). The Water Rocket shoots water in one direction (toward you) and launches in the other (away from you).

Why is there water in the rocket? Can I launch without water? The water is in there to provide you with both a visual of what's going on (when the water leaks out, you know it's time to untwist the cap FAST), as well as giving you a time-delay to get the cap off. Try launching it without water (just pressurize the bottle) and see if you're fast enough to launch it.

Troubleshooting: The first time kids do this experiment, they are often so surprised it works that they drop the bottle on the ground OR they grasp it so tight that they forget to let the rocket go. With practice, you will be able to launch them consistently skyward.

Rocketry Experiment 3.3: Seltzer Rockets

DVD: Aeronautics, track 31 or watch the video on our website:
http://www.superchargedscience.com/rocketry.wmv

CD: Aeronautics, track 4

Materials: Effervescent tablets, canister with tight-fitting snap-on lid (you can use Fuji (not Kodak) film canisters), and water

Place an effervescent tablet in a canister (you may need to break it into pieces) and fill the canister part way with water. Working quickly, cap the canister and invert it on the sidewalk. Stand back… POP! Through experimentation, you'll find there is an optimal water level for maximum height. If you work fast, you can get about four launches from one tablet. What happens if you try two tablets at once?

What's going on? The tablets contain sodium bicarbonate (baking soda) and citric acid (a solid form of vinegar). What happens when you mix together vinegar and baking soda? It fizzes all over the place, doesn't it? Note that this reaction takes place because the vinegar (acetic acid) is in a liquid state. Notice how the effervescent tablets contain both chemicals, but they don't react until you get them wet.

The reaction of baking soda and vinegar is deceptively simple: what appears to be one reaction is actually two, happening in quick succession. The first reaction takes the vinegar and baking soda (sodium bicarbonate) and forms carbonic acid. But carbonic acid is really unstable (meaning that it falls apart easily), and it breaks into water and carbon dioxide as soon as it forms. This means that the gas bubbles are carbon dioxide, since carbon dioxide needs to be at -109^{o}F to become a solid. The gas bubbles escape from the liquid (called effervescence), leaving water behind with a bit of sodium acetate in the water. By the way, carbon dioxide goes straight from a solid to a gas (called sublimation) at temperatures above -109^{o}F.

So, to recap: The chemical reaction of sodium bicarbonate and citric acid generates carbon dioxide gas bubbles (the same molecule you burp after chugging an entire soda), and those bubbles foam up and out of the canister. When you cap it, there's no room for the bubbles to go. They build up pressure, and more pressure, and more pressure… until POP! There's so much pressure that the lid can't stay on the canister any longer and it flies off.

Important question: *Does more water, tablets, or air space give you a higher flight?*

Variations: Add foam fins and a foam nose (try a hobby or craft shop), hot glued into place. Foam doesn't mind getting wet, but paper does. Put the fins on at an angle and watch the seltzer rocket spin as it flies skyward. You can also tip the rocket on its side and add wheels for a rocket car, stack rockets, for a multi-staging project, or strap three rockets together with tape and launch them at the same time! You can also try different containers using corks instead of lids.

More Variations: What other chemicals do you have around that also produces a gas during the chemical reaction? Chalk and vinegar, baking soda, baking powder, hydrogen peroxide, isopropyl alcohol, lemon juice, orange juice, and so on.

Rocketry Experiment 3.4: Slingshot Rockets

DVD: Aeronautics, track 32

CD: Aeronautics, track 4

Materials: A foam tube, foam sheet, film canister, paper clip, and 5 to 8 rubber bands, scissors (not included), and hot glue gun (not included)… and optional, but nice to have: duct tape

Punch a small hole in the bottom of a black Kodak film canister. Chain 5 rubber bands together and push one end of the rubber band chain through the hole from the outside, catching it with a paper clip on the inside like a cotter pin so it can't slip back through the opening.

Hot glue the canister into one end of a 6-inch piece of ¾-inch foam pipe insulation. Check the hardware store for this insulation, which comes in 6 foot. Tape the circumference of the pipe with a few wraps of duct tape. The rubber bands should be hanging out of the foam pipe.

Cut out triangular fins from a foam sheet and attach with hot glue to the opposite end. To launch, hook the rubber band over your thumb, pull back, and release!

Bonus Experiments! We've got even MORE science project for you! These experiments are not on the DVDs, CDs, and we didn't include the parts for them. They are just pure science ideas for you to test. Have fun!

Rocketry Experiment: Puff Rockets Grab a clean, empty shampoo or lotion bottle. Make sure the bottle you choose gives you a good puff of air out the top cap when you squeeze it. You'll also need two straws, one slightly smaller than the other. And a small piece of foam.

Insert the smaller straw into the hole in the cap. If you have trouble, ream out the hole or just take off the cap and seal the connection with a lump of clay or a lot of hot glue. Insert a small bit of foam into one end of the larger straw. Slide the larger straw (your rocket) onto the smaller straw (your launcher). Squeeze the bottle hard! POOF!

Which bottles work best? Does straw length matter? In our testing, we had one rocket that cleared 25 feet! You can watch us build this project on our web site: *http://www.superchargedscience.com/rocket.wmv*

Rocketry Experiment: Micro Paper Rockets Spiral-wrap a thin strip of paper around and along the length of a wood pencil and use tape to secure. You can alternately use a naked straw instead of making your own rocket body from paper, but then you'll need a slightly smaller launch tube straw.

Hot glue triangular fins made from an index card to one end. Fold the opposite end over twice and secure the fold with a ring of tape to make a nose for the rocket. Insert straw into the rocket body and blow hard!

Rocketry Experiment: Multi-Staging Balloon Rockets Tie a length of string through a room, having at least twenty feet of clear length. Thread two straws onto the string before securing the end. Punch the bottoms out of two foam coffee cups and tape them parallel to the threaded straws. Blow up balloons while they are inside the cups, so they extend out either end.

When blowing up the second balloon, sandwich the 'not-yet-tied' end of the first inflated balloon *between* the second inflated balloon surface and the inside surface of the cup. Hold the second balloon's end with a clothespin or your fingers, and release!

The space shuttle passes through the sound barrier during ascent.

Rocketry Review

(Answer key can be found at the back of this guide.)

1. If you inflate a balloon (don't tie the end), which direction does the air in the balloon and the balloon itself travel? (a) both the same way (b) in opposite directions (c) nothing happens

2. When you drop an effervescent tablet into water, what happens? (a) bubbles foam up (b) it burps (c) carbon dioxide gas is released (d) it produces a chemical reaction that can propel a rocket skyward

3. Puff Rockets use which of the following propellants? (a) air pressure (b) chemical reactions (c) both (d) neither

4. The most dangerous parts of the Water Rocket experiment is are: (a) working with high pressure (b) that you've stripped out the threads that normally secure the cap in place, and now it's easier to accidentally release the rocket and shoot someone's eyeballs out (c) reusing the bottles over and over causes fissures and cracks to form in the bottle, increasing the chances of bursting if you don't replace the bottle after every 7-10 launches (d) all of the above and more

5. The most important things to remember when launching water rockets are: (a) safety goggles or face shield (b) 70 psi maximum air pressure (c) always hold the valve-side down when holding the bottle (d) only use soda bottles that are build to hold pressure (e) never water bottles, juice bottles, sports drink bottles, or any others that don't say *pssssst!* when you first open them

6. To get the multi-staging rockets to work correctly, where does the trigger need to be? (a) inside the first balloon (b) on the string (c) in the straw (d) squished between the first balloon and the cup

7. How does a Slingshot Rocket work? Where does the thrust come from?

8. If your Blow Gun Rocket straw rips loose, what can you do to quickly repair it without rebuilding the entire rocket?

"I HAVE LEARNED TO USE THE WORD 'IMPOSSIBLE' WITH THE GREATEST CAUTION."

WERNHER VON BRAUN