SCIENTIFIC DISCREPANT EVENTS:

PROPERTIES OF AIR

42 LESSON PLANS COMPLETE WITH DIAGRAMS

SYNONYMOUS EDUCATION

TABLE OF CONTENTS

Air Occupying Space

Air Exerting Pressure

Air Expansion by Heat

Air Containing Oxygen

Air Has Weight

Technological Application

Air Compressibility/Density of Material

Transferability of Pressure

Aerodynamics

#1: THE AIR CATCHER

Materials:

- a medium plastic garbage bag
- one plastic sandwich bag per student

Procedure

1. Take the medium size garbage bag, open its mouth and ask the students: "What is in the bag"? (Anticipated answer: "Nothing").
2. Move the bag with two hands back and forth (like wanting to catch a bug in the bag), then quickly close the mouth of the bag with a twisting motion.
3. Ask the students: "What do I have in the bag now"?
4. Distribute the sandwich bags to the students and let them try to catch air in their own seats, without blowing into the bag.

Explanation

Air is found everywhere. The plastic bags may be filled with air above the table, under the table, behind the door, or anywhere else with the same air. The bags can also be inflated by blowing in them, but then the bags would contain exhaled air, which has a higher percentage of carbon dioxide (CO_2) and more water vapour.

When the filled bag is slammed between the two plasm of the hands it will burst with a loud pop. This explosion is caused by the sudden expansion of the air rushing out of the torn plastic bag.

An example of this is a popping balloon.

Questions

1. What was filing the bags?
2. Can we catch air under the bench or behind the door?
3. Is the air the same everywhere?
4. How else can we fill the bag?
5. Would the material in the bag be the same if we blew in it?
6. How can we keep the bag inflated?
7. What would happen if we hit the inflated small plastic bag with the palm of the other hand?

#2: THE BOTTLE AND THE BAG

Materials:

- 1-2 plastic sandwich bags
- 1-2 large wide-mouthed glass jars (pickle jars)
- masking or transparent adhesive tape

Procedure

1. Invert the bag over the mouth of the jar, blow a little air in the bag such that it stays inflated over the jar.
2. Tape the bag airtight against the jar.
3. Now ask one of the students to push the bag into the jar without tearing it. It won't work! *(see Sketch A)*
4. Place another plastic bag inside another wide-mouthed jar (or use the same bag and jar) and let the edge of the bag hang over the jar rim.
5. Tape it airtight against the jar and let a student try to take the bag out of the jar without tearing it. It won't work! *(see Sketch B)*

Explanation

It is the air occupying the space in the jar which kept the bag from going inside after it had been taped airtight against the jar. In trying to push the bag in, the pressure increased (because the volume decreased) and this held the bag out.

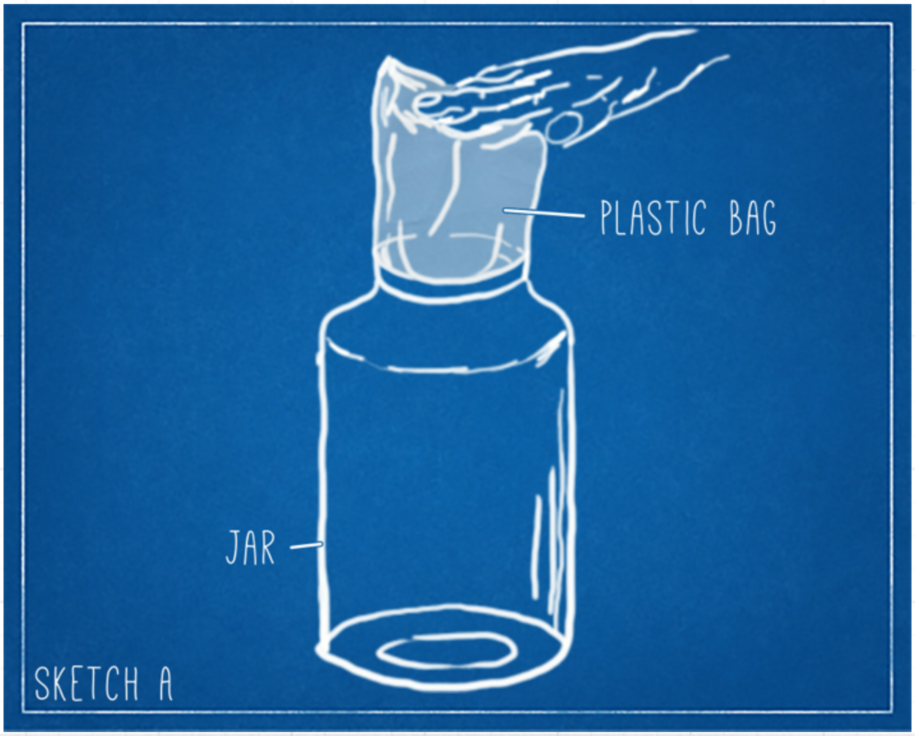
When trying to take the bag out of the jar, air pressure inside the jar decreased (because the volume increased) and this kept the bag inside. The outside air pressure kept the bag inside the jar.

We encounter the first situation often when we try to fold up a plastic air mattress or inflatable plastic toy.

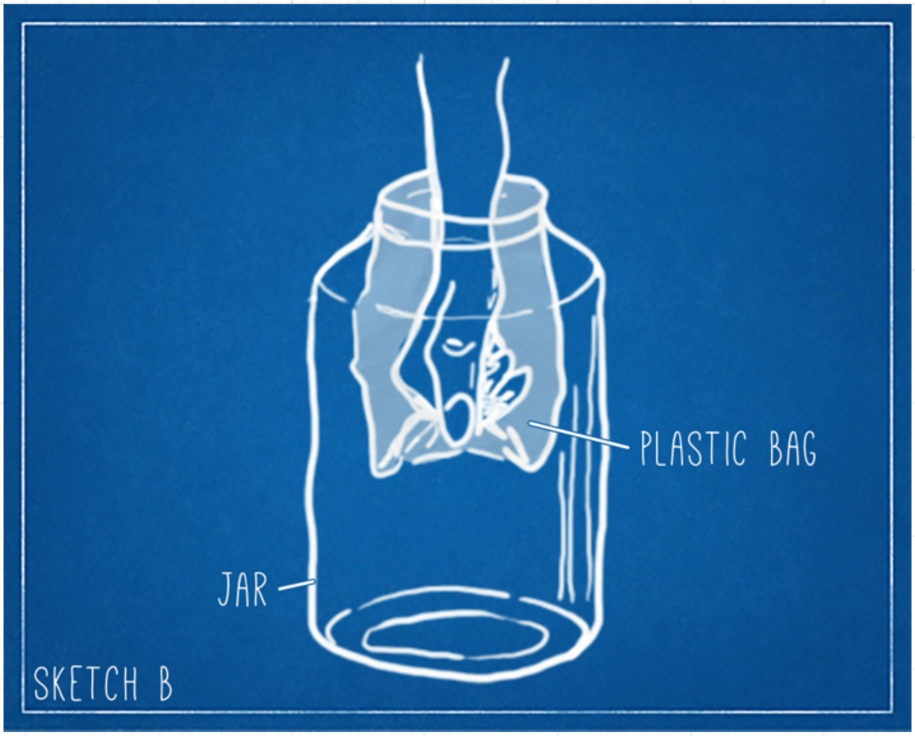
Questions

1. Before putting the plastic bag on the jar, ask: "What is inside the jar? Inside the plastic bag?"
2. What is holding the bag out of the jar? (when trying to push it in)
3. What is holding the bag inside the jar? (when trying to take it out)
4. How could we get the bag inside the jar without making a hole in it?

THE PROPERTIES OF AIR: AIR OCCUPYING SPACE



Try to push the bag into the jar (without tearing it). It won't work!



Try pulling the bag out of the jar (without tearing it). It won't work!

#3: POURING AIR UNDER WATER

Materials:

- 2 glass or transparent plastic cups
- a large transparent container (a small aquarium would do)

Procedure

1. Fill the plastic or glass container about 3/4 full with water.
2. Hold one cup in each hand upside down and push them under water.
3. Fill one of the cups with water by holding it slanted and thus releasing the air bubbles. Do not leave any bubbles.

Now we have one cup filled with water in the one hand and one cup with air in the other (still under water).

4. Push the cup with air a little lower than the other and pour the air in the other cup by slowly slanting it. Catch the air bubbles *(see Sketch)*.

We can repeat this by *pouring* from one cup to the other.

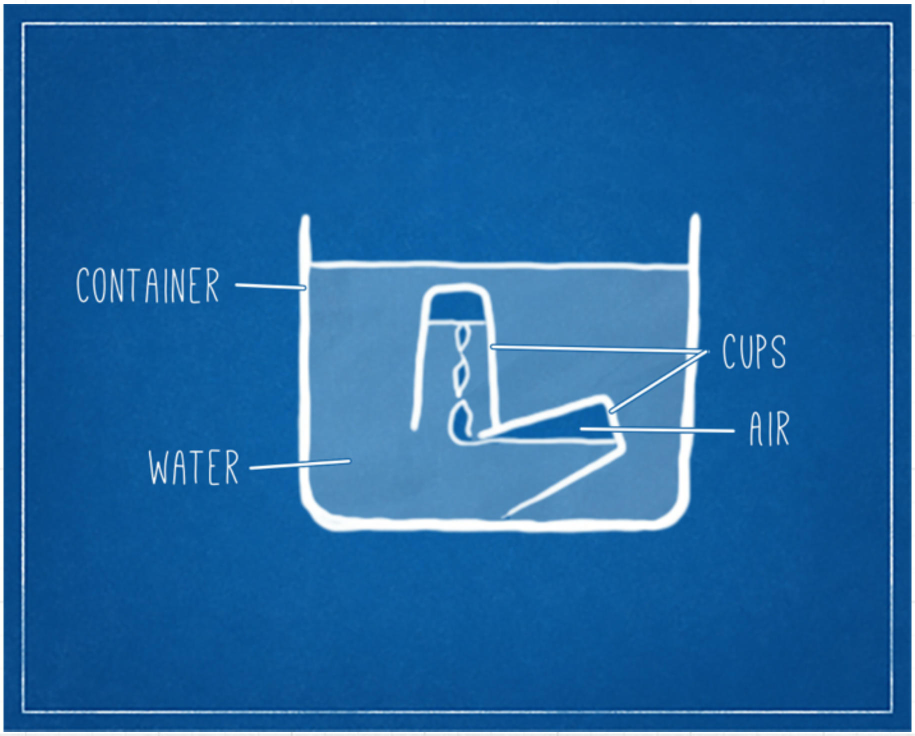
Explanation

Air **occupies space**, including the space in the cups. At the time the cups were immersed under water, they were filled with air. That is why the water could not enter the cups. By holding one cup slanted the air bubbles were free to escape and thus the water could take its place. Air is much lighter in weight than water and that is why air bubbles rise and not sink in water. The water-filled cup can be held above the water level without letting the water run out because atmospheric pressure is pushing on the water surface.

Questions

1. Before immersing the cups, ask: "What is in the cups?" (anticipated answer: "Nothing").
2. At the time of immersing the inverted cups, ask: "Why doesn't the water enter the cups?"
3. Why do the bubbles rise and not sink?
4. Can the cup with water be held partly above the water level without letting the water run out of the cup?

THE PROPERTIES OF AIR: AIR OCCUPYING SPACE



Pour the air out into the other cup by slowly slanting it and catch the air bubbles.

#4: KEEPING PAPER DRY UNDER WATER

Materials:

- a dry glass or transparent plastic cup
- a large beaker or transparent plastic container (large enough to fit a person's hand)

Procedure

1. Fill the large container about 2/3 full with water.
2. Crumple a piece of dry paper and squeeze it in to the bottom of the glass or plastic cup.
3. Invert the glass (making sure the crumpled paper stays up in the cup) and immerse it completely under water, holding it as vertical as possible.
4. Take the cup back out of the water and let the water drip off (do not shake off!).
5. Take the crumpled paper out of the cup with a dry hand and let the students feel and check whether it is dry or not. If done correctly, it will be dry.

Explanation

Air is **space occupying**. The glass is filled with air, no matter whether it is right side up or upside down. Besides there being crumpled paper in the cup there was also air in the cup. This is why the water could not enter the cup during the immersion process. Therefore the paper stayed completely dry.

Applications of this characteristic of air can be found when people have to work under water. Air is then pumped in and around the are where the people are working, enclosed by a watertight wall.

Questions

1. Before inserting the crumpled paper, ask: "What is in the cup?" (Anticipated answer: "Nothing").
2. Before immersing the glass under water, ask: "What else, besides the paper, is in the cup?"
3. While immersing the cup, ask: "Why doesn't the water enter the cup?"
4. Why does the paper have to be crumpled?

#5: THE EMPTY BOX CANDLE SNUFFER

Precaution(s):
• be careful not to burn yourself during this demonstration
• know where the nearest fire extinguisher is and hot to use it

Materials:

• one empty shoebox • a birthday candle and matches • masking tape

Procedure

1. Show the open shoe box to the students and ask: "What is in the box?" (Anticipated answer: "Nothing").
2. Make a small hole in the side of the long end of the box (about 1/2 cm in diameter) at the same height from the bottom as the candle length, and tape the top to the box.
3. Light the candle and place it about 5 cm away from the box, in front of the hole *(see Sketch)*.
4. Hit the box top with a sudden tap with the open hand (make sure that the hole is in line with the candle flame).

The snuffing of the candle may be shown again by repeating #3 and #4.

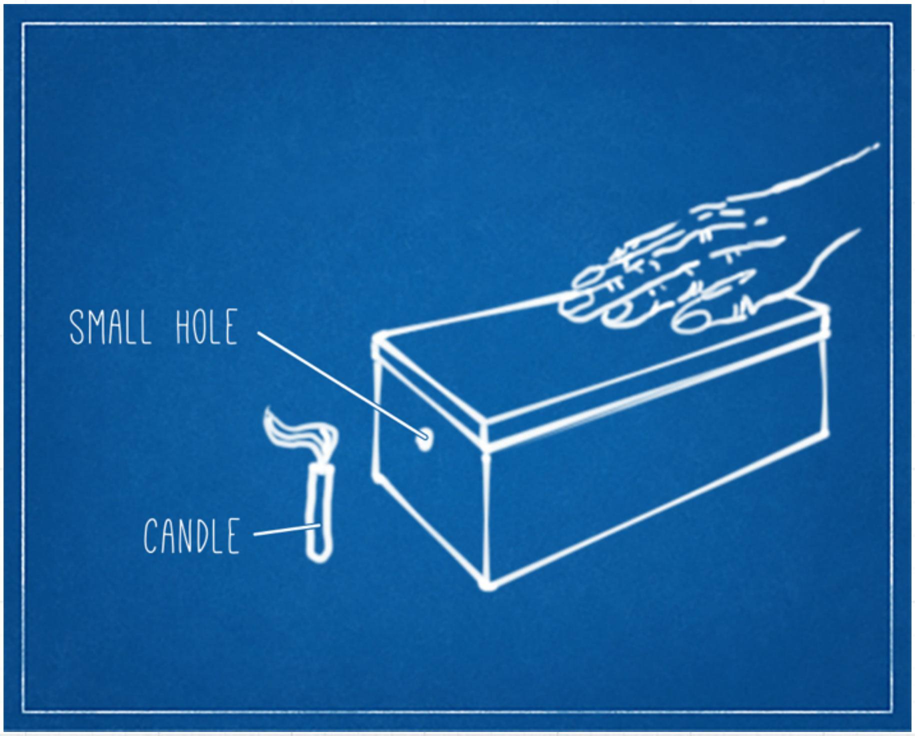
Explanation

The shoe box is **occupied with air** and by tapping the top of it the air was forced through the little hole, blowing the candle flame out, just like when we pucker up our lips to blow out a candle. By tapping the box, the volume of it suddenly becomes smaller for a short moment and this action forces the air out. Pushing the box in gently is like blowing very lightly against the flame.

This demonstration shows that air is **occupying all the space** around us, also in an 'empty' box.

Questions

1. What was blowing the candle flame out?
2. What did the tap do to the volume of the box?
3. How far can you hold the candle from the box and still blow it out?
4. What would happen to the flame if you pushed the box top in gently instead of giving it a sharp tap?



Tap the box top while the small hole is in line with the candle flame.

#6: THE REFUSING FUNNEL

Materials:

- 2 identical glass or plastic funnels with a narrow stem
- 1 two-hole stopper and 1 one-hole stopper
- two identical empty jars or bottles

Procedure

1. Set up the funnels with the stoppers on the bottles, as shown in *Sketches A* and *B*. Do not tell that one of the stoppers has two holes.
2. Fill the funnels with water. In one the water will run through (two-hole stopper) and in the other the water will stay in the funnel.
3. Take the bottle with the two-hole stopper by the neck and casually put your forefinger on the open hole and put water into the funnel.
4. Take the bottle with the one-hole stopper, squeeze the stopper open and the water will run through.

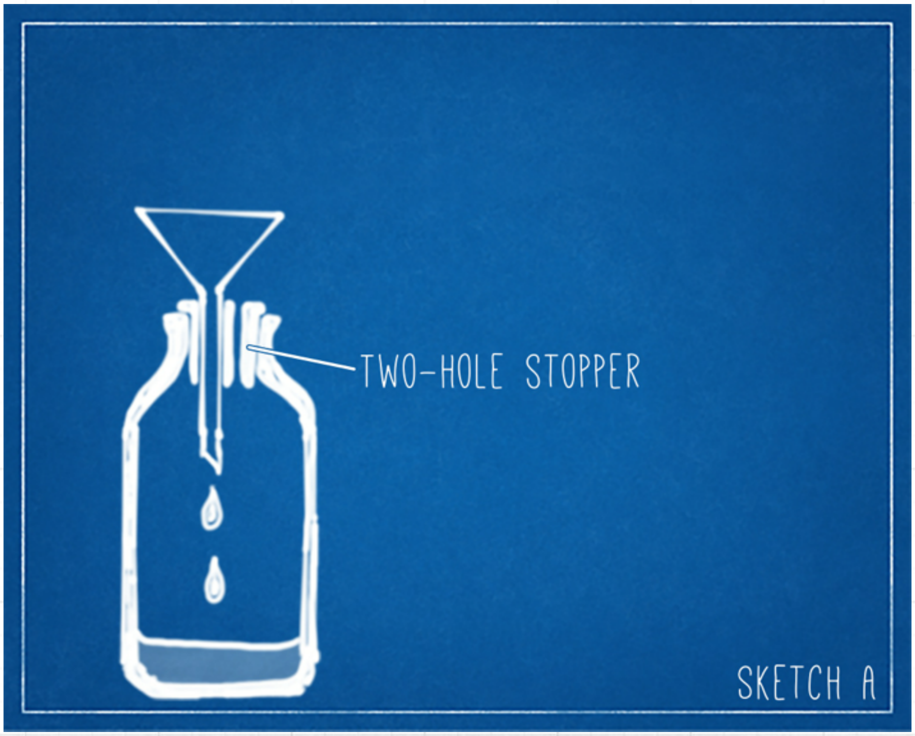
Explanation

The bottles were filled with air in the first place. In the bottle with the two-hole stopper the air can escape through the second hole and the water will run through. But in the bottle with the one-hole stopper, there is no way for the air to escape and this will hold back the water.

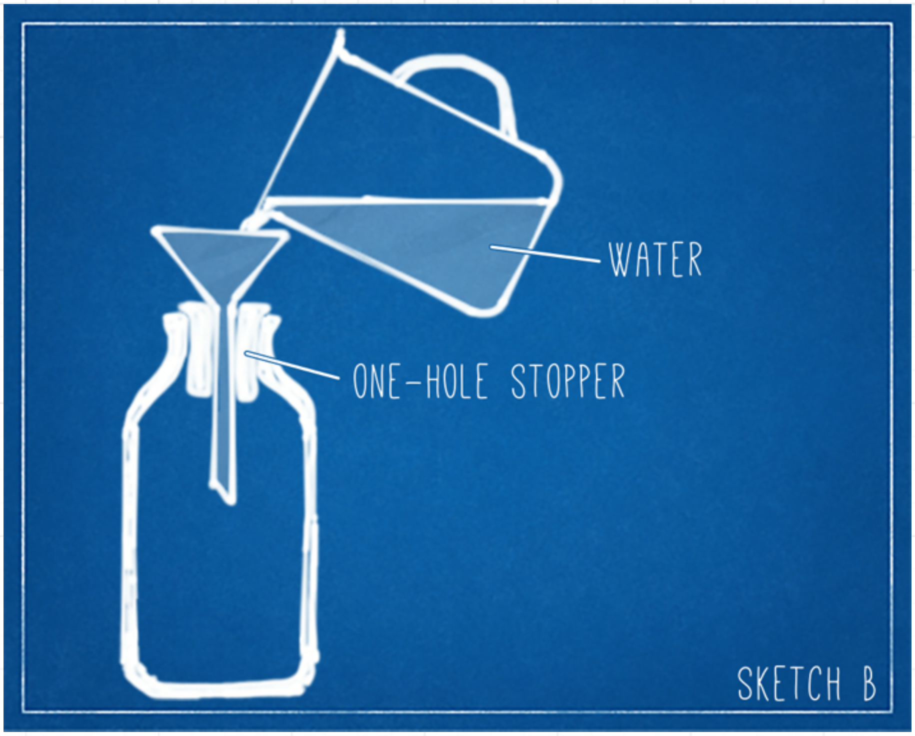
An example of this phenomenon we find when trying to fill a perfume bottle with water or other liquid, or any narrow mouthed bottle with water by holding it under a large stream of water from the tap. There is only one passage way for the water to come in and for air to go out. In other words, the air is blocking the way for the liquid to come in.

Questions

1. Before pouring the water, ask: "What is in the bottle?"
2. Why is the water only running through in one bottle?
3. What is holding back the flow of the water?
4. Before doing Step 4, ask: "How can we let the water run through this funnel?"



Set up the two bottles and funnels as shown above and below and fill the funnels with water.



#7: THE INVERTED GLASS OF WATER

Materials:

- a transparent glass or plastic cup
- a paper card (slightly larger than the mouth of the cup)

Procedure

1. Fill the cup between halfway and fully with water.
2. Place the paper card on the cup *(see Sketch A)*.
3. Put one hand on top of the card and invert the cup holding the card in place. Do this over a sink or large container to catch any water drippings. Also, make sure that the hand holding the card is dry.
4. Take the hand that was holding the card away slowly *(see Sketch B)*.

Explanation

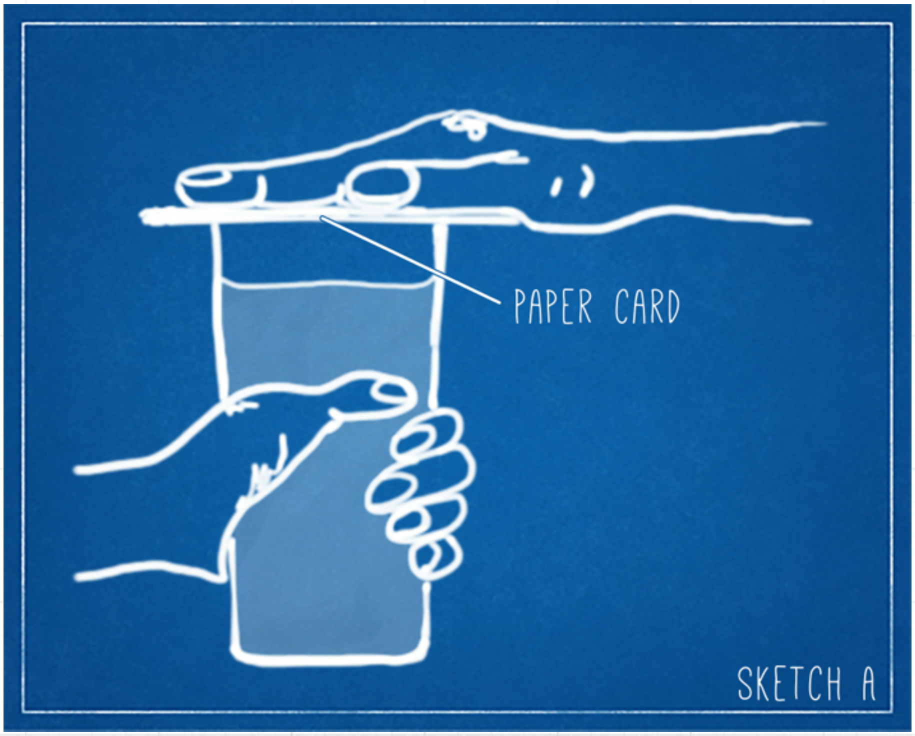
When the cup is completely filled with water, there is no air left in the cup and thus no air pressure. The inverted cup can therefore hold the water up because the **atmospheric pressure** is working against the underside of the cup.

In case of a partially filled cup of water, we can explain it as follows: During the process of inverting, some of the water is dripping out. This increases the volume of the air pocket without increasing the amount of air, thus decreasing the pressure of the air pocket above the water. Again, the atmospheric pressure is therefore larger and holds the water inside the cup.

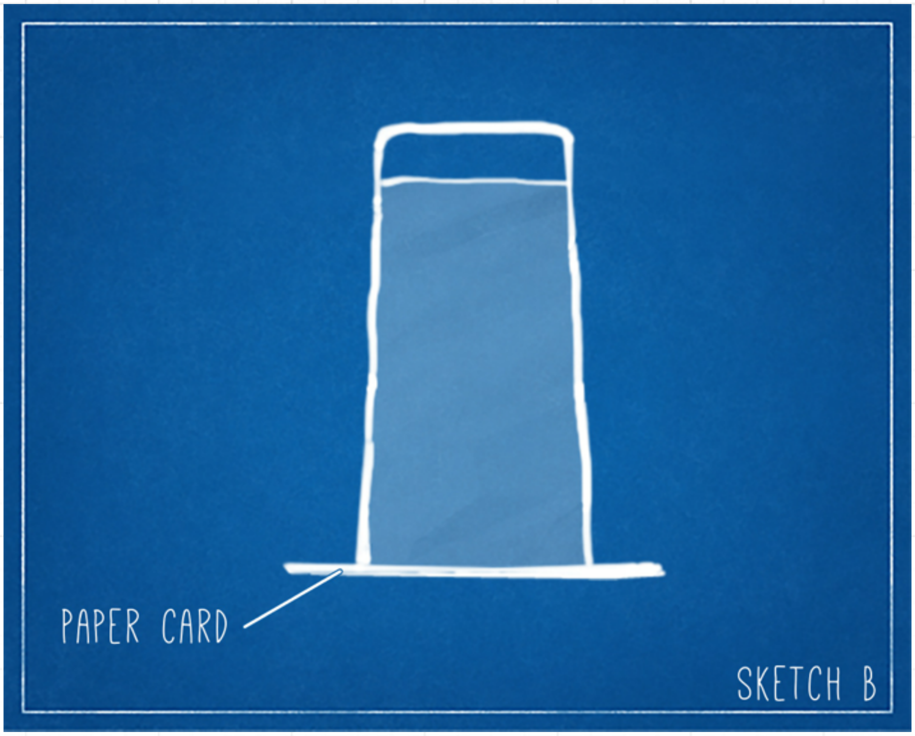
Alcohol and oil will also be held up inside the inverted cup but a carbonated soft drink will not. This is because the carbon dioxide exerts pressure from inside the glass above the liquid, preventing a partial vacuum from forming.

Questions

1. Why does the paper have to be rather stiff?
2. Why do we have to make sure that the hand holding the card on the cup is dry? What will a wet hand do?
3. What is keeping the water in the inverted cup?
4. Can we hold the cup slanted without letting the water pour out?
5. Will we be able to do the same thing with other liquids? (e.g. alcohol, oil, carbonated soft drinks, etc.?)



Put one hand on top of the cup and card, applying some pressure to keep it in place.



When you remove your hand from the card, the card and water in the cup should stay in place.

#8: THE STRAW DRINKING RACE

Materials:

- 2 identical drinking straws: one punctured with a few needle holes over the whole length
- 2 small cups and some carbonated beverage

Procedure

1. Fill the two small cups halfway with carbonated beverage (or water) and place straws in the cups (one will have holes poked in it but do not mention this).
2. Ask two students to come up and comment: "Who can win the straw drinking race?"
3. Let them start drinking through the straws on the count of three.
4. Give another pair of students a turn to race. The one who has the straw with holes will always lose.

Explanation

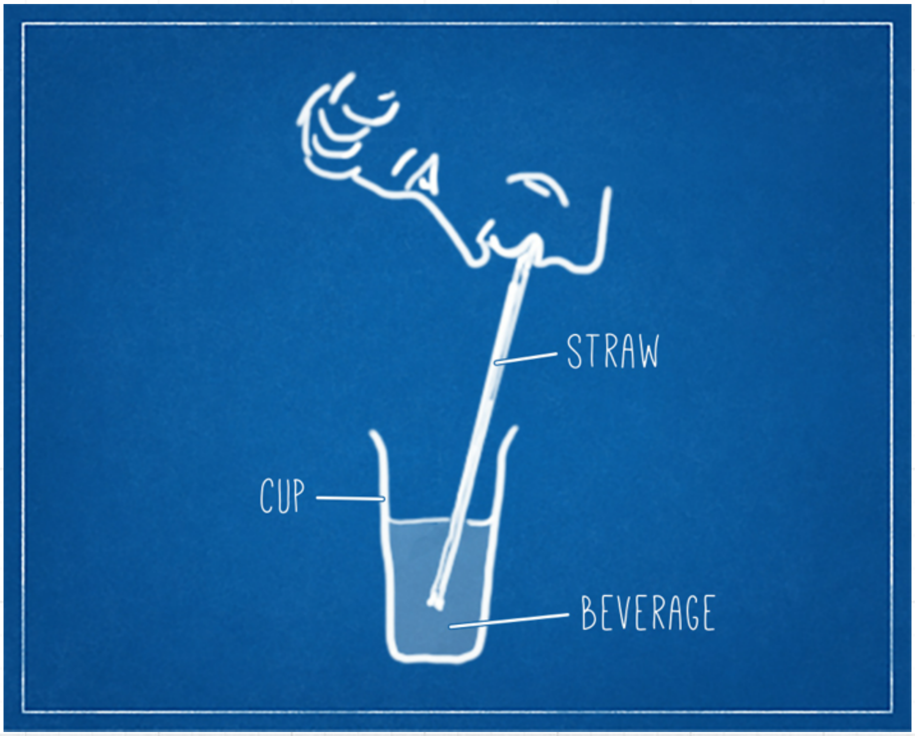
By sucking we are creating a partial vacuum or a lower pressure in the straw above the liquid that we drink. The higher pressure in the atmospheric air pushes the liquid up the straw and into our mouth.

The student with the leaky straw sucks in air and thus cannot create a vacuum above the liquid, so the liquid is not pushed up.

If there were no air pressure in the atmosphere, we would not be able to suck liquids through a straw. If the mouth of an astronaut was connected to a straw through his or her spacesuit to an open cup with liquid on the moon surface, the astronaut would not be able to drink the liquid by sucking through the straw because there is no pressure on the liquid surface that will push it up the straw (videos of this can be found on *YouTube*).

Questions

1. What makes the liquid go up the straw when we drink?
2. Why is it so hard to drink through a leaky straw?
3. What do we actually create when we suck through a straw?
4. Would we be able to drink through a straw if there was no air pressure around us?
5. Would an astronaut in space or on the moon be able to drink liquid through a straw?



Students will enjoy the challenge of racing their friends in the (rigged) Straw Drinking Race!

#9: THE UPWARDS FALLING TEST TUBE

Materials:

- 2 test tubes, one just fitting into the other
- a little coloured water

Procedure

1. Fill the larger test tube half way with coloured water.
2. Let the smaller test tube float on the water. Push it a little further in so the water will overflow.
3. Now invert both test tubes over a small container to catch the dripping water and hold only the larger test tube. You may need to push the smaller tube up to start the motion *(see Sketch)*.

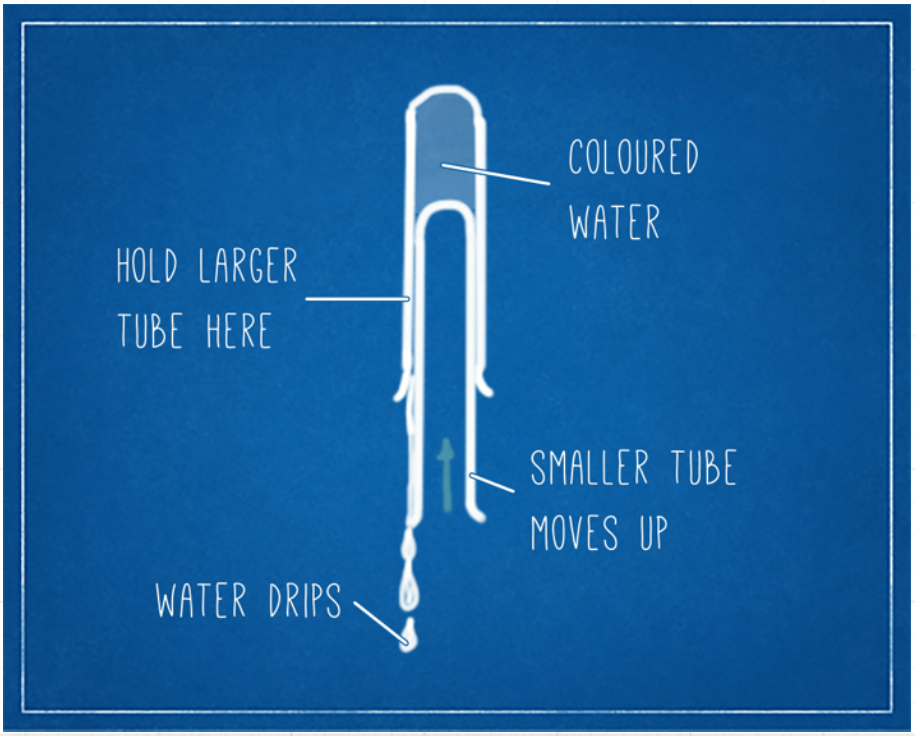
Explanation

The smaller test tube has to be pushed a little further into the larger one until the water overflows so that no air will be left between the two test tubes. After inverting the set of test tubes, the water is dripping out, **decreasing the volume of the water**. Since there is no air above the smaller tube, the outside air pressure is pushing it up.

The total force upwards is 1 kg per cm^2. For a test tube with about a 1.2 cm diameter this upward force is around 1 kg. This event of 'falling up' will not succeed with two test tubes that have a large difference in diameter because the air will be able to replace the dripping water and thus equalize the pressure above and under the smaller test tube.

Questions

1. What happened to the volume of the water after inverting?
2. What made the smaller test tube move upwards?
3. What would be the total force pushing the test tube upwards?
4. Would this 'falling upwards' also succeed with a much smaller test tube floating on the water of a much larger test tube and then inverting it? Why or why not?
5. Would this event work on the surface of the moon?
6. Would this event work in a pressurized satellite around the earth?



The inset test tube moves upwards, giving students a moment of intrigue.

#10: THE MYSTERIOUSLY RISING WATER (PART I)

Precaution(s):
- wear proper safety clothing, including goggles and an apron or lab coat (no loose-fitting clothes)
- ensure rubber tubing for burners are free of rips and tears
- know where the nearest fire extinguisher is and how to use it

Materials:

- 1 small beaker (100 mL) and 1 large beaker (400 mL)
- 1 hot plate or burner and stand
- boiling chips and food colouring

Procedure

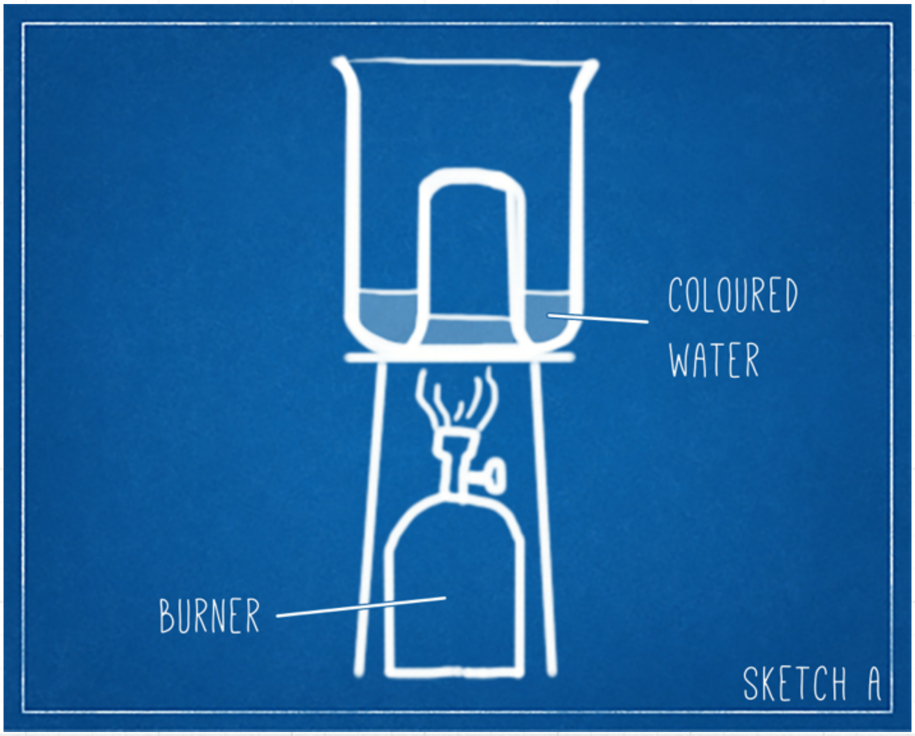
1. Put about 110 mL of water in the large beaker, a few drops of food colouring and a few boiling chips.
2. Heat this beaker and the water to a boil while the small beaker is placed upside-down inside the larger beaker *(see Sketch A)*.
3. Let the water boil for at least one full minute, taking care that the small beaker does not tip over.
4. Take the two beakers off the fire and let them cool to room temperature. Observe the water level in the small beaker *(see Sketch B)*.

Explanation

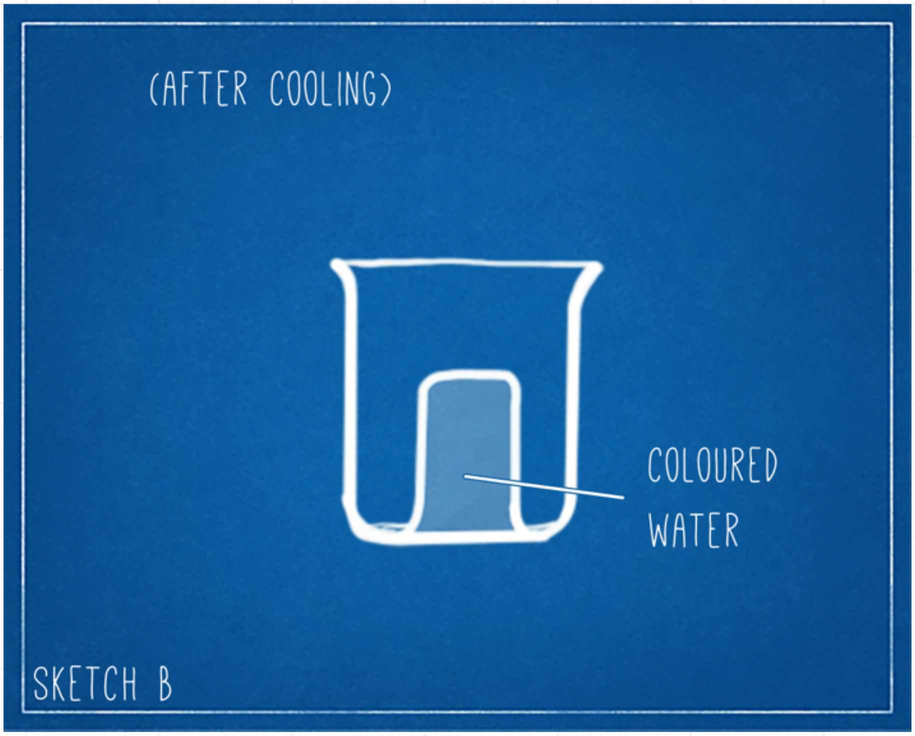
By boiling the water, it is changing from a liquid state into a gaseous or vapour state. This water vapour is also formed under the inverted beaker and it replaces the air under this beaker. The longer we let the water boil, the more air will be replaced by water vapour. The cooling process makes this water vapour condense and turn back into water, reducing the pressure inside the small beaker. The water is therefore pushed up inside the inverted beaker by the higher atmospheric pressure. By letting a few drops of cold water drip on the inverted beaker, the cooling process is sped up and will cause the water to rise faster.

Questions

1. What is inside the inverted small beaker before the heating?
2. What happens to the water when we boil it?
3. Why does the small beaker keep bobbing up and down?
4. What do the bubbles consist of?
5. Why does the water level rise in the small beaker?
6. What would happen if, after the heating, we put a few drops of cold water on the small inverted beaker?



Heat the water to a boil while the small beaker is upside-down inside the large beaker.



Observe the water level in the small beaker after you remove the heat source.

#11: THE MYSTERIOUSLY RISING WATER (PART II)

Precaution(s):
• wear proper safety clothing, including goggles and an apron or lab coat (no loose-fitting clothes)
• ensure rubber tubing for burners are free of rips and tears
• know where the nearest fire extinguisher is and how to use it

Materials:

• 1 test tube and 1 test tube holder
• 1 large beaker (400 mL) or other water container
• 1 Bunsen or alcohol burner and food colouring

Procedure

1. Fill the large beaker with cold water and some drops of food colouring.
2. Put a little water in the test tube (about 3 mL) and boil it *(see Sketch A)*.
3. After the water has been boiling vigorously for about 10 seconds, invert this test tube immediately in the coloured water, making sure that the test tube mouth stays under water *(see Sketch B)*.

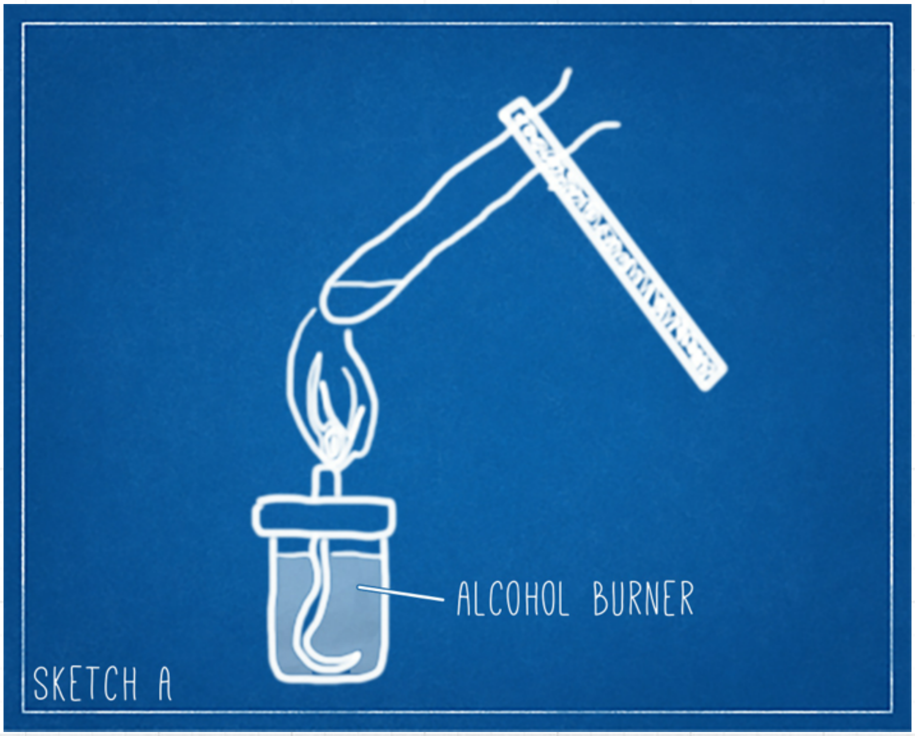
Explanation

Before the heating, the test tube was filled with a little water and the rest was air. Water vapour was produced by boiling the water and this water vapour pushed out the air in the test tube (vigorous boiling of the water). After inverting the test tube in the coloured cool water, the hot water from the test tube poured out into the large container, the test tube cooled off, and the water vapour condensed. This decreased the pressure inside the test tube and the water was pushed up the tube by the existing **atmospheric air pressure**.

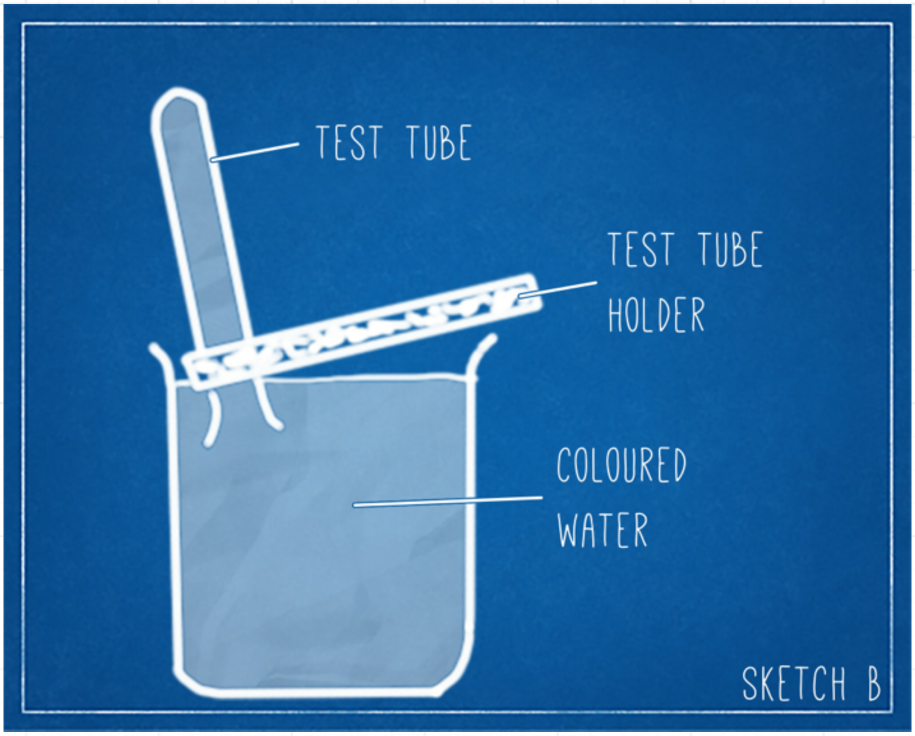
We encounter this kind of event in daily life sometimes when, after boiling water or soup in a pan with a well fitting top, cooling the pan afterwards and trying to open the cover we find the cover to be sticking to the pan.

Questions

1. What is in the test tube besides the water before heating?
2. What is in the test tube during the heating?
3. What happens during inverting of the test tube in the coloured water?
4. What does water do when it is boiled?
5. What does water vapour do when it is cooled?
6. How did the temperature of the test tube change when it was inverted?
7. Why did the coloured water rise in the inverted test tube?



Boil a small amount of water in the test tube.



Invert the boiled water test tube into the coloured water.

#12: THE COLLAPSING CAN

Precaution(s):
• wear proper safety clothing, including goggles and an apron or lab coat (no loose-fitting clothes)
• ensure rubber tubing for burners are free of rips and tears
• know where the nearest fire extinguisher is and how to use it

Materials:

• 1 empty gallon (or 4-5 L) can, or any other tin can that can be closed off airtight
• a hotplate or burner and tripod

Procedure

1. Put about 20 ml of water in the can (just enough to cover the bottom) and heat it over the hot plate or burner.
2. Let the water boil vigorously for about 2 minutes (vapors should come out of the can).
3. Take the can with the boiling water off the heat (don't burn your fingers!) and immediately close off the cap very tightly.
4. Let it stand upright on the table and cool off to room temperature. For faster results, cool with a wet towel *(see Sketch)*.

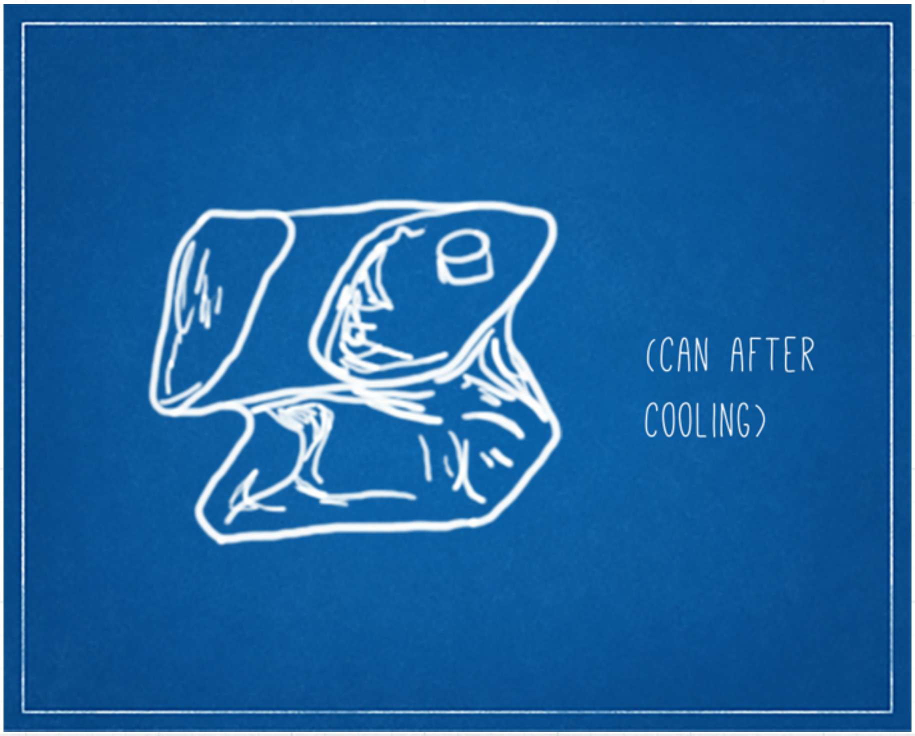
Explanation

Before heating, the can was filled with water and air. By boiling the water, it changes states, from liquid to gaseous state (water vapor). The water vapour or steam pushed the air that was inside of the can out. In closing off the can with an airtight cap, we are actually trapping the air out of the can; that is, we are preventing it from going back into the can. The cooling **condenses** the water vapour back to water. All the vapour which took up the interior space of the can before is now turned into a few drops of water, which takes up much less space. This causes the pressure to drop and the atmospheric pressure to push on the can, crushing it.

The total force working on the outside of the can is the total of the can's surface area in cm^2 multiplied by 1 kg.

Questions

1. What was in the can besides water?
2. What happens when water is boiled?
3. What will the air in the can do when a lot of water vapour is formed?
5. What would happen if we did not close the can very tightly?
6. What is the total force that is working on the outside of the can?



As the can cools, it will crush before your students' eyes!

#13: THE BALLOON IN THE FLASK

Precaution(s):
• wear proper safety clothing, including goggles and an apron or lab coat (no loose-fitting clothes)
• ensure rubber tubing for burners are free of rips and tears
• know where the nearest fire extinguisher is and how to use it

Materials:

• an Erlenmeyer flask (150 - 200 mL)
• a round balloon with a large mouth (not inflated)
• a hotplate or burner and stand

Procedure

1. Put a little water (about 20 mL) in the flask and heat it to a boil. Use a few boiling chips.
2. Let the water boil vigorously for at least one full minute.
3. Take the flask off the fire and immediately place the mouth of the balloon over the flask's mouth *(see Sketch A)*. Be careful not to burn yourself.
4. Let cool slowly at room temperature. The ballon will be sucked into the flask *(see Sketch B)*.

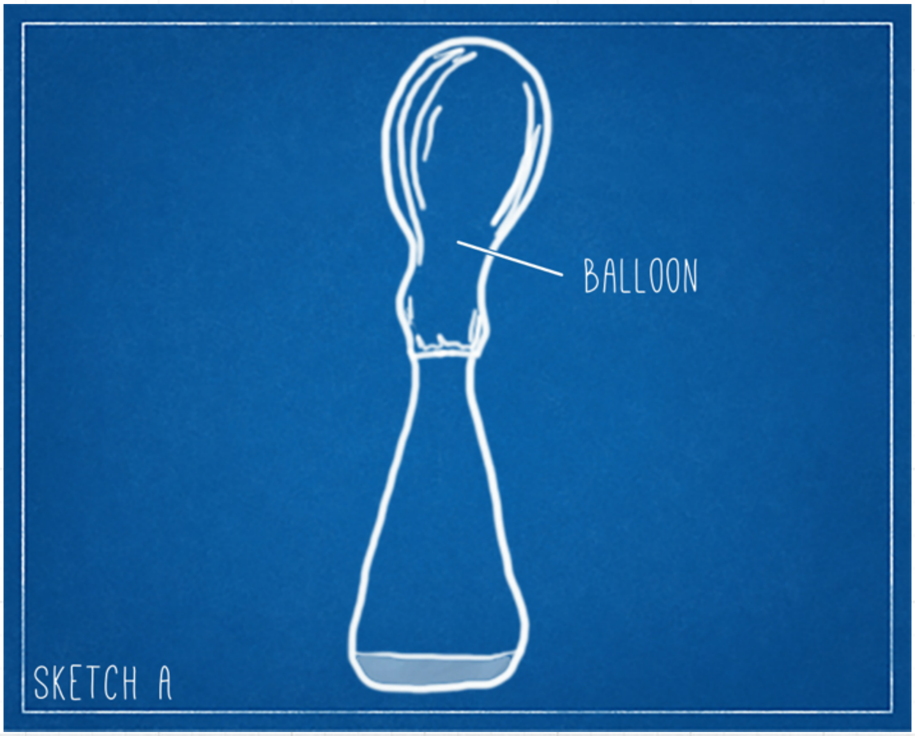
Explanation

By boiling the water in the flask, it was changed from a liquid state into a vapour state. Water vapour or steam is formed and this pushes the air that was originally present in the flask out of the flask. The longer we let the water boil, the less air will be left in the flask. After the flask is closed off with the balloon, the air cannot get back into the flask. The cooling of the flask will slowly **condense** the water vapour and thus create a **partial vacuum** in the flask. This will cause the sucking in of the balloon and the **atmospheric air pressure** will further blow up the balloon inside the flask.

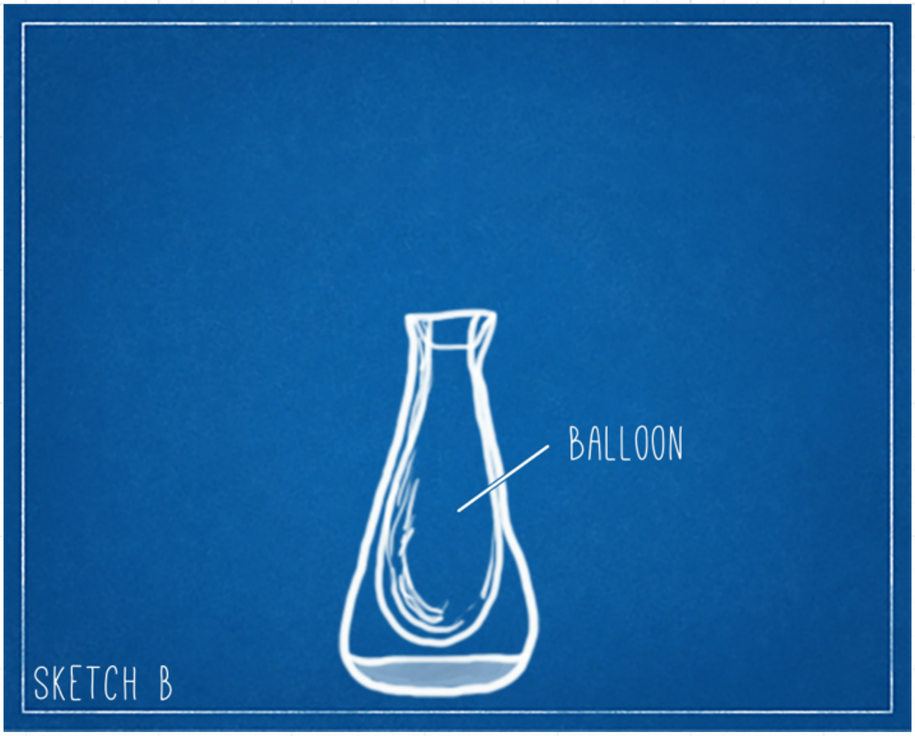
During the cooling of the flask and the sucking in of the balloon, care has to be taken that the balloon's mouth is not pinched closed (this will prevent the whole balloon from getting into the flask and only part will go in or probably burst).

Questions

1. What is in the flask besides the water?
2. What is water doing if we boil it?
3. What is the steam doing to the air in the flask?
4. Why did the balloon go inside the flask?
5. Why did the ballon continue to expand inside the flask?



Immediately place the balloon over the flask's mouth after bringing the water to a boil.



As the water cools, the balloon will be sucked into the flask.

#14: FOUNTAIN IN A FLASK

Precaution(s):
- wear proper safety clothing, including goggles and an apron or lab coat (no loose-fitting clothes)
- ensure rubber tubing for burners are free of rips and tears
- know where the nearest fire extinguisher is and how to use it

Materials:

- 1 round or flat-bottomed flask (400 mL) and holder
- boiling chips
- a glass tube drawn at one end in a one-hole stopper
- a hotplate or burner and stand
- a beaker (500 mL)
- rubber tubing

Procedure

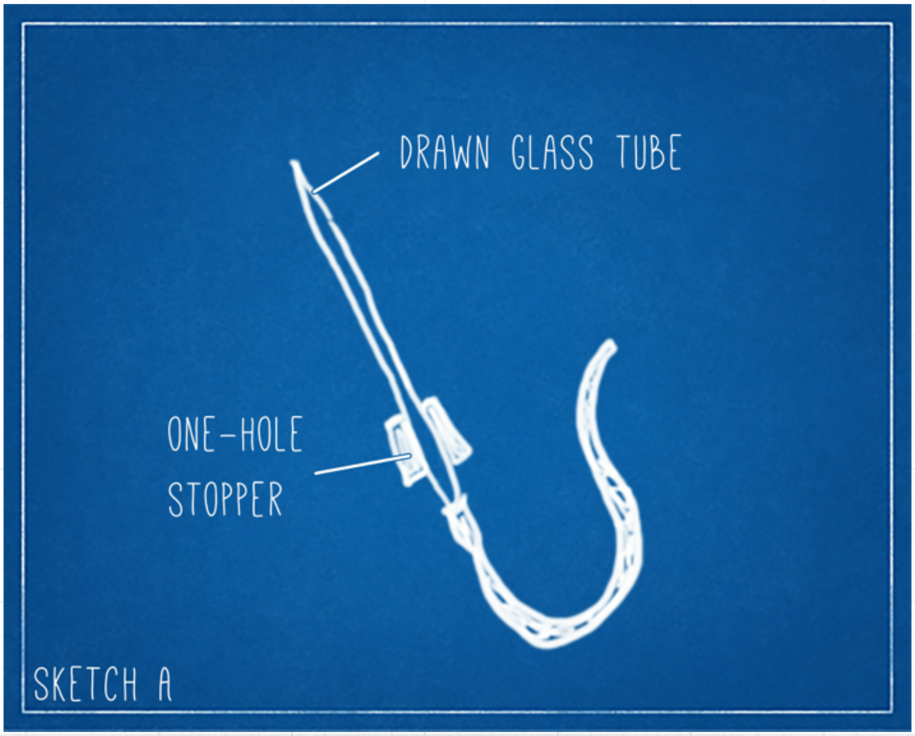
1. Put about 30 mL of water in the flask and heat it over the fire.
2. Let it boil for at least one full minute.
3. Get ready with the glass tube, stopper and rubber tubing to close off the flask *(see Sketch A)*.
4. Hold the flask by the flask holder, take it off the fire, and insert the stopper with the drawn tube on the flask.
5. Immediately invert the stoppered flask and dip the end of the rubber tubing into the coloured water in the beaker *(see Sketch B)*.

Explanation

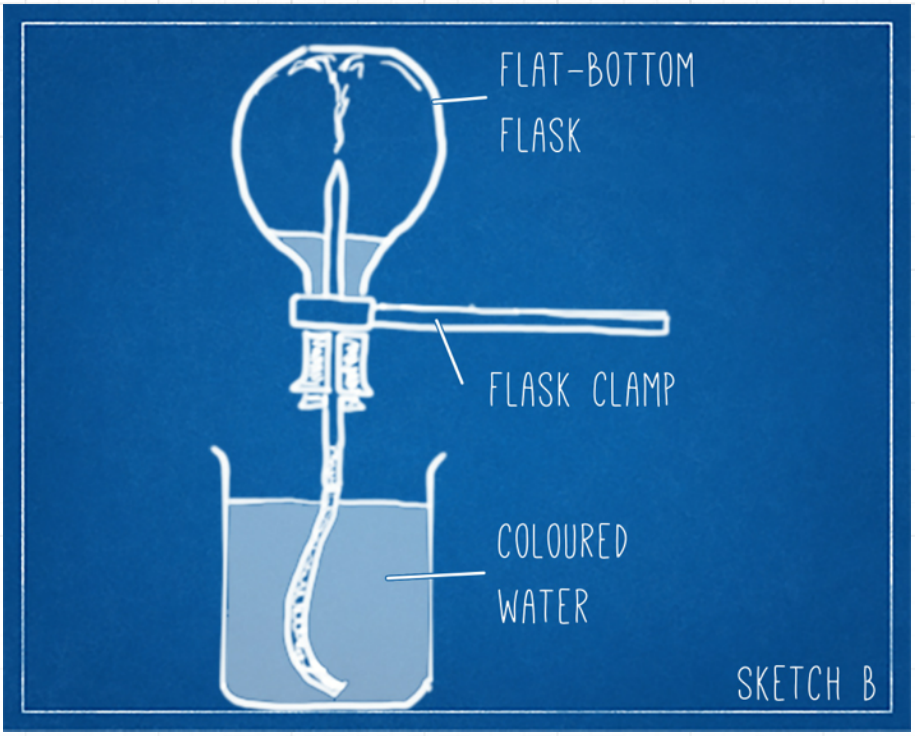
Boiling the water produced water vapour in the flask and this caused the air to be pushed out. By closing the flask off with the stopper the air was trapped out. The cooling of the flask after inverting caused the water vapour to condense slowly and to **contract**, with a decrease of pressure as a result. The water is therefore sucked up the tube slowly. As soon as the cool water hits the bottom of the flask it cools off much faster and the water vapour condenses much faster, creating a sudden partial vacuum, sucking up the water vigorously. Bromothymol Blue in the beaker and acid in the flask gives colour change.

Questions

1. Why is water needed in the flask?
2. Would the water also be drawn up if the flask was heated without any water in it?
3. What caused the water to go up the tube?
4. Why did the water go up the tube so slowly in the beginning? And why did it suddenly speed up after the water hit the flask?



The glass tube, stopper and rubber tubing.



Invert the stoppered flask and submerge the rubber tubing into the beaker's water.

#15: THE STICKING CUP OF WATER

Materials:

- a petri dish or other shallow dish with a smooth rim
- a smooth surface, ceiling or underside of a table

Procedure

1. Fill the petri dish full to the brim with water.
2. Bring the dish to the smooth surface. Push it against the surface making sure that there are no air bubbles left in it.
3. At this point, make sure that the dish will stick to the surface then ask a student to hold it up or pretend as if you need to get something and leave the dish hanging.
4. If you have a student holding it, give them permission to let go off the dish.

Explanation

By filling the dish completely full with water there is no air left, thus there is no air pressure working down on the dish. The only force working down on the dish is **gravity**, therefore the weight of the dish plus the water. The force holding the dish against the surface is equal to the air pressure of 1 kg per cm^2 of dish surface area. A dish with a 3 cm radius will have a force of about 27 kg holding it up minus the weight of the water and the dish itself. Once the dish is sticking to the surface, it will stay up for quite a long time until some water evaporates and air seeps into the dish.

The water, in this case, acted as a seal preventing the air from coming into the dish. An application of this principle is when we wet suction cups with water to make them stick better to smooth surfaces.

Questions

1. Why do we need a smooth surface?
2. Why does the dish stick to the surface?
3. How much force is holding the dish up?
4. How heavy a dish can we stick to the surface?
5. How long will the dish keep sticking to the surface?

#16: THE BIONIC FINGER (PART I)

Materials:

- 1 heavy rubber plunger (the kind used to unplug a sink)
- a stool or chair with a smooth seat

Procedure

1. Make a small hole in the plunger with a scissor's point.
2. Show the students the plunger and ask: "What is under the plunger when I place it on the table?" (Anticipated answer: "Nothing").
3. Ask one of the students to come up and put his/her cheek close to the hole in the plunger.
4. Push the plunder in. Air rushes out and blows against the cheek. **Air occupies space!** *(see Sketch A)*.
5. Show the students the plunger on top of a stool.
6. Tell them that you possess a bionic finger and that you can hold down the plunger against the stool with one finger.
7. Push down on the plunger and hold it down with one finger covering the hole (a wet finger will work better). Ask a student to come up and pull the plunger up *(see Sketch B)*.

The whole stool will stick to the plunger and be lifted!

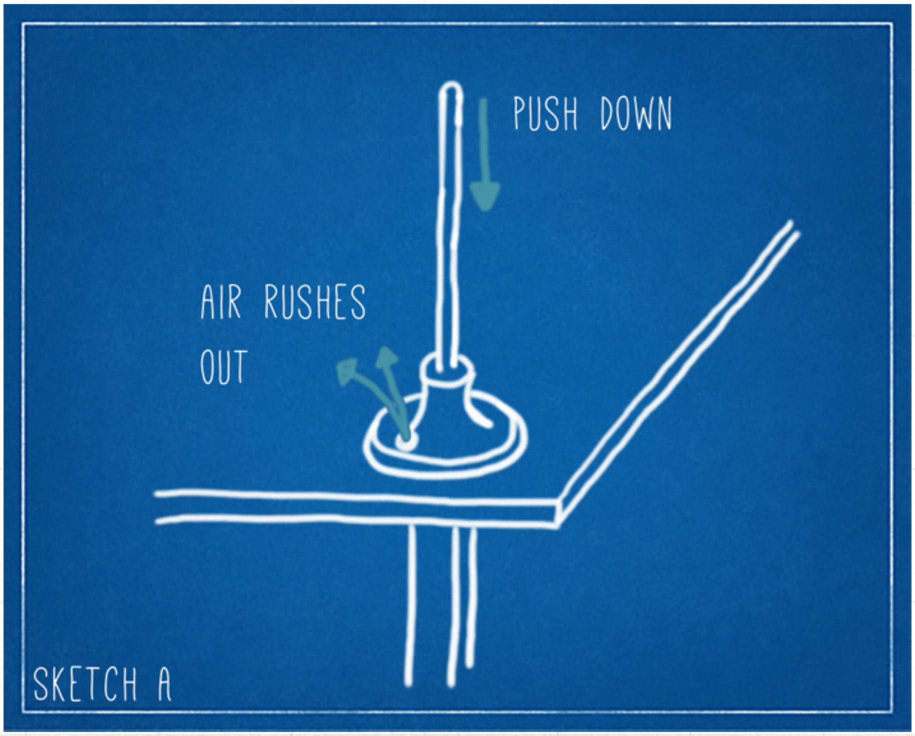
Explanation

There was air under the plunger and it rushed out when it was pushed in. When holding the plunger down with one finger, the hole was covered and this prevented the air from coming back in under the plunger, causing a lower pressure under it. A moist finger works better to plug the hole because water acts as a seal.

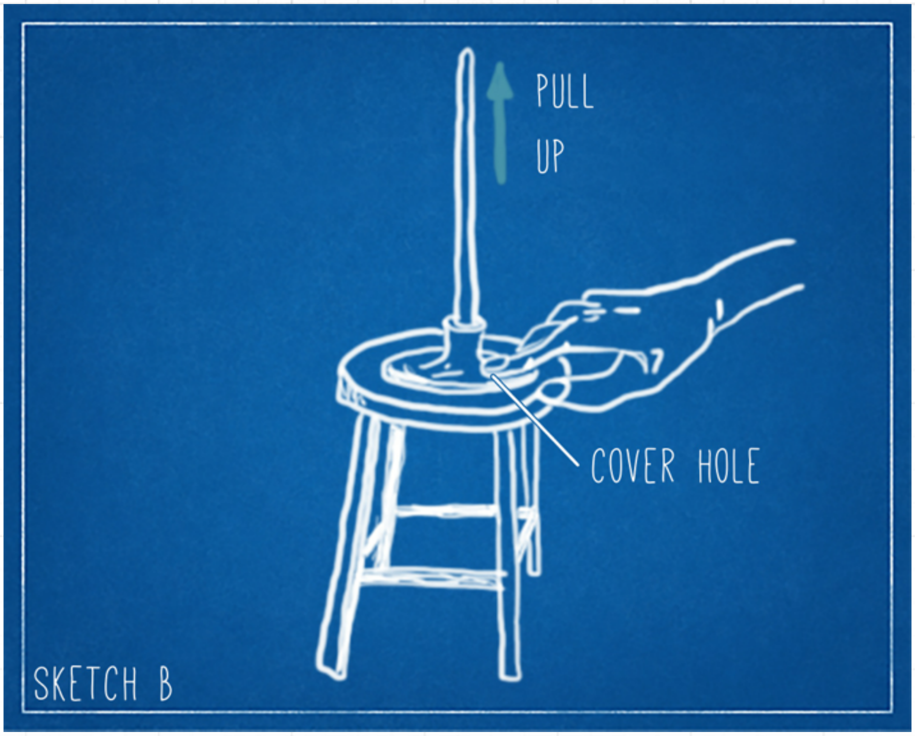
The force acting down on the plunger is equal to the surface area of the plunger multiplied by 1 kg (about 75 kg for a plunger with a 10 cm diameter).

Questions

1. What was under the plunger?
2. What was helping my finger to keep the plunger down?
3. How much force is pressing down on the plunger?
4. How heavy can the stool be and still be lifted up?



The student can feel air rushing out, an example that air occupies space.



Remarkably, one finger is enough to cause the plunger to be firmly affixed to the stool.

#17: THE BIONIC FINGERS (PART II)

Materials:

• 2 heavy plungers (the kind used to unplug a sink), one of them with a small hole in it

Procedure

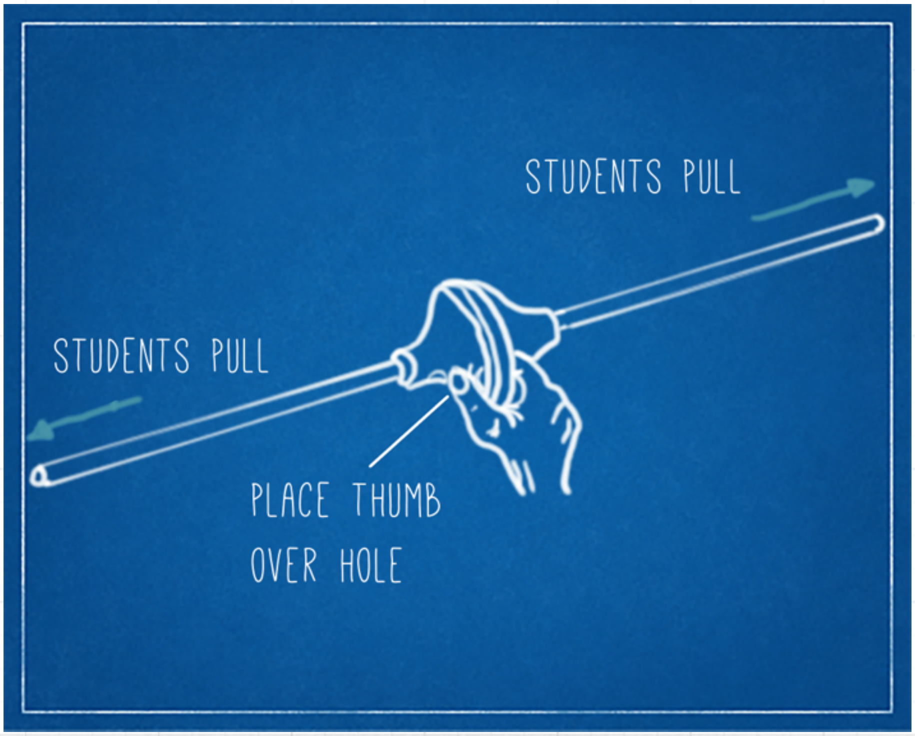
1. Ask two students to come up and push the two plungers against each other.
2. Ask them now to pull them apart (can be easily done).
3. Tell the students now that you have bionic fingers to keep the two plungers together.
4. Let the students push the two plungers together again and this time hold the plungers with thumb and forefinger, making sure that you cover the hole with your thumb (a wet finger works better) *(see Sketch)*.
5. Now let the students try to pull the plungers apart (most likely the wooden handle will come off first!)

Explanation

The plungers were quite easy to separate before holding them together because there was a hole in one of them, allowing the air to come inside between the two plungers. By covering the hole the air was prevented from coming in (water on the finger acts as a seal) and when the students tried to pull them apart the volume increased between the plungers, thus decreasing the pressure. It was again the atmospheric air pressure that was holding the two plungers together. The total force that was holding them together can be calculated from the total surface area of the two circles multiplied by 1 kg (about 150 kg for plungers with a 10 cm diameter). A similar experiment was done with large steel half-spheres and horses pulling on each side (Google: Magdeburg spheres).

Questions

1. Why was it so easy to pull the plungers apart before I held them?
2. What did actually hold the plungers together?
3. Did I have to hold the plungers in a special way?
4. How much force was keeping the two plungers together?
5. Would larger or smaller plungers stick together better?



By simply covering the hole with your thumb and forefinger, students will find it impossible to pull the plungers apart.

#18: STOP THE LEAK

Materials:

- an empty can or plastic bottle
- a one-hole stopper fitting the neck of the can or bottle

Procedure

1. Punch a hole in the side near the bottom of the can or bottle with a small nail.
2. Fill the can or bottle with water and show the leaking container.
3. Ask: "How can I stop the leak without getting my finger wet?"
4. Put the one-hole stopper on the can or bottle and cover the hole with one finger. The leak is stopped!
5. Release your finger from the stopper. The leak will start again *(see Sketch)*.

Explanation

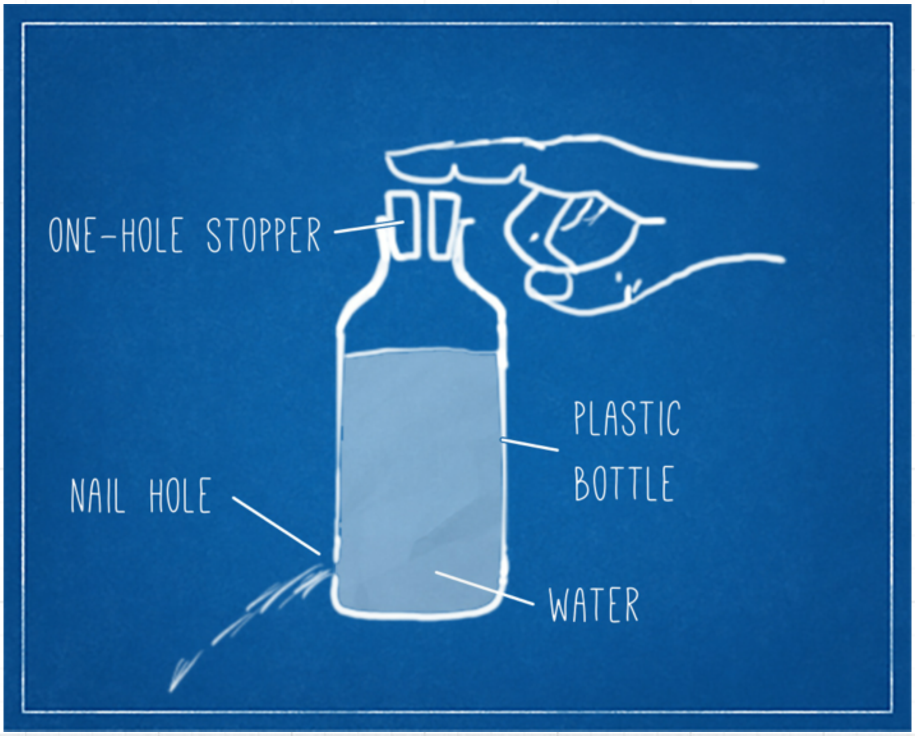
The water does not stop flowing immediately after covering the stopper, but it still keeps draining out of the can for a while. This increases the volume of the air pocket above the water. The amount of air stays the same because air is prevented from coming into the hole in the stopper. The increase in volume causes a decrease in pressure (Boyle's Law). The outside atmospheric air pressure pushes against the water and prevents it from flowing out.

This is why we always punch two holes in a can of evaporated milk in order to pour the milk out. Also, on a metal can of frying oil, it is usually recommended to punch a hole in a corner opposite the pouring spout. This hole will allow air to enter the can while oil pours out. It will promote a smooth flowing oil out of the can. The same can be done with cartons of juice at home, too!

Questions

1. Why did the water stop flowing out of the can?
2. How could we stop the leak without the one-hole stopper?
3. Does the water stop flowing immediately after the hole is covered?
4. How does the air pressure inside the can compare with the atmospheric pressure after the water stops flowing?
5. What is it that we prevent from entering the can by covering the hole?

THE PROPERTIES OF AIR: AIR EXERTING PRESSURE



Covering the hole in the stopper causes the water to stop leaking from the nail hole.

#19: THE PERPETUAL FOUNTAIN

Materials:

- 1 medium-size jar
- 2 large bottles
- 1 two-hole stopper fitting the jar
- 2 glass tubes (the longer one drawn to a point at one end)
- 2 lengths of rubber tubing (about 30 cm)

Procedure

1. Push the two pieces of glass tubing through the two-hole stopper such that the one with the point extends farther than the other *(see Sketch)*.
2. Connect the two lengths of rubber tubing to the glass tubes.
3. Fill one of the two large bottles full with cold water and set up the flask and the two bottles as shown in the *Sketch* (hold the jar).
4. Pour about 100 mL of water in the jar and insert the stopper tightly.
5. Invert this jar, making sure that the two rubber tubes stay in the two bottles (the end of the tube in the bottle with water should stay under water at all times).

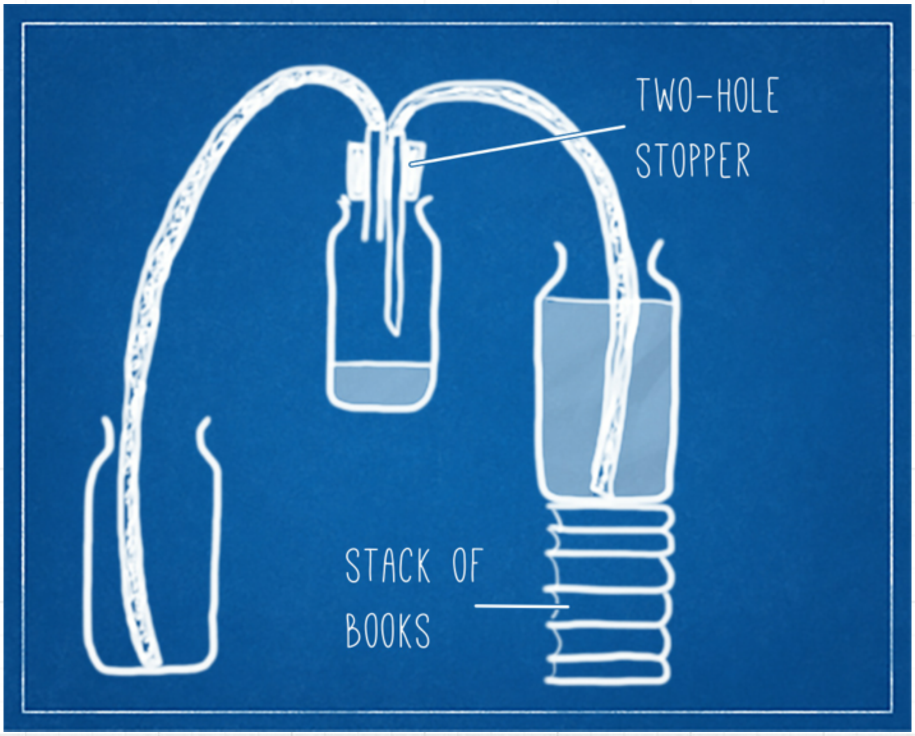
Explanation

The water in the jar was needed to 'prime' the siphoning action. Immediately after inverting the jar, the water ran down and out into the empty bottle. This caused an increase in volume of the air pocket above the water in the jar, thus decreasing the pressure. This lower pressure caused the sucking up of the water from the water-filled bottle. In other words, the atmospheric air pressure is pushing the water up into the jar. The larger the difference in height of the water levels in the two bottles the stronger the flow of water. As soon as the water levels are the same height in both bottles the water flow will stop. This is the same principle of a siphon.

Questions

1. What was the first thing that happened after inverting the jar?
2. What happened to the volume of the air pocket about the water in the jar as the water poured in the empty bottle?
3. Why was the water drawn up into the jar?
4. Why does the water-filled bottle have to stand higher than the other?
5. How can we make the fountain flow harder or slower?

THE PROPERTIES OF AIR: AIR EXERTING PRESSURE



#20: TRANSFER WATER WITH A STRAW

Materials:

- 1 drinking straw for each group of three students
- 2 small cups for each group of three students

Procedure

1. Divide the class into groups of three students.
2. Provide each group with one straw and two cups.
3. Let one student hold a water-filled cup, another an empty cup, and the third will transfer the water from one cup into the other.
4. Ask the students how they can do this without tilting the cups.
5. Demonstrate how the water can be held in the straw:
   - dip the straw vertically in the water-filled cup
   - hold forefinger against the top end of the straw and lift
   - move straw with the water in it over the empty cup and release finger: water drips out!

Explanation

By closing off the top end of the straw with our finger, we prevent air from coming in. Some water will drip out of the lower end of the straw, enlarging the volume of the air pocket above the water and thus creating a lower pressure inside the straw. The outside atmospheric pressure is holding the water up in the straw. When the finger is released, air is allowed to enter and the pressure is equalized.

Questions

1. How can we transfer the water without tilting the cups?
2. How can we hold water in the straw without sucking through it?
3. What holds the water in the straw when your forefinger is closing off the top end of the straw?
4. What happens if we try to hold the water in the straw and not close the top end tightly?
5. What is prevented from coming in the straw at the end where our finger is pressing?
6. What is holding the water back if we close the top end of the straw with our finger before immersing it in the water?

#21: THE WATERTIGHT CLOTH

Materials:

- a drinking glass
- a piece of cheesecloth (or any other thin cloth) large enough to cover the mouth of the glass

Procedure

1. Fill the glass between halfway to fully with water.
2. Wet the cloth under the tap and show students that water will flow easily through the cloth.
3. Place the cloth now over the mouth of the glass and push the fringes against the side of the glass.
4. Hold the fringes with one hand against the glass. With the other hand, hold the bottom part of the glass without holding the cloth. Invert the glass!
5. Let go go the first hand. The cloth and water will stay up in the glass!

Explanation

The cloth needed to be wet with water so that it could adhere to the sides of the glass (adhesive forces between water & cloth and water & glass). During the process of inverting, some water poured out because the cloth is porous, but this caused an increase in the air pocket volume above the water, which in turn reduced the pressure inside the glass. This demonstration can also be used to show the cohesive forces between the water molecules, as a film of water molecules is forced in the little pores of the cloth.

Questions

1. Why would this not work with a dry cloth?
2. Why does the wet cloth cling to the sides of the glass?
3. Why does some water flow out of the glass in the beginning?
4. Why does the water stop flowing out?
5. What is keeping the water and the cloth up?
6. Can we hold the class slanted or sideways without letting the water flow out?
7. What shape does the cloth take when we hold the glass vertically upside down?

#22: THE CUPS AND THE BALLOON

Materials:

- a round ballon that is not inflated
- 2 small plastic or glass cups with a smooth rim

Procedure

1. Blow up the balloon about one-third of the way.
2. Tell the students that you will hold the two cups against the sides of the balloon and blow it up further.
3. Hold one cup in each hand, hold the cups against opposite sides of the balloon (while the balloon is in your mouth) and blow further until about twice the size.
4. Let go of the two cups. They should stick to the balloon. If not, moisten the cup rims. Hold the balloon in one hand by its mouth.
5. Show students that the cups are not glued to the balloon by releasing the air slowly out of the balloon. The cups will fall off as the balloon gets smaller.

Explanation

Because of the increase in curvature (or actually a flattening of it) from A to B, the volume in the cups increased, thus causing the pressure to decrease. The air pressure inside the balloon had nothing to do with the sticking of the cups to the balloon.

Questions

1. Why did the cups stick to the balloon?
2. Did the air pressure in the balloon have anything to do with it?
3. How does the volume of the cups change from stage A to stage B?
5. What does the pressure inside the cups have to be to stick to the balloon compared to the atmospheric pressure (in stage B)?
6. How much larger does the balloon have to be in stage B compared to stage A for the cups to stick to it?

#23: INFLATE A BALLOON BY SUCKING

Materials

- an empty glass jar with a fitting two-hole stopper
- 2 lengths of glass tubing (one with a 90° bend)
- a small balloon and tape (or a rubber band)

Procedure

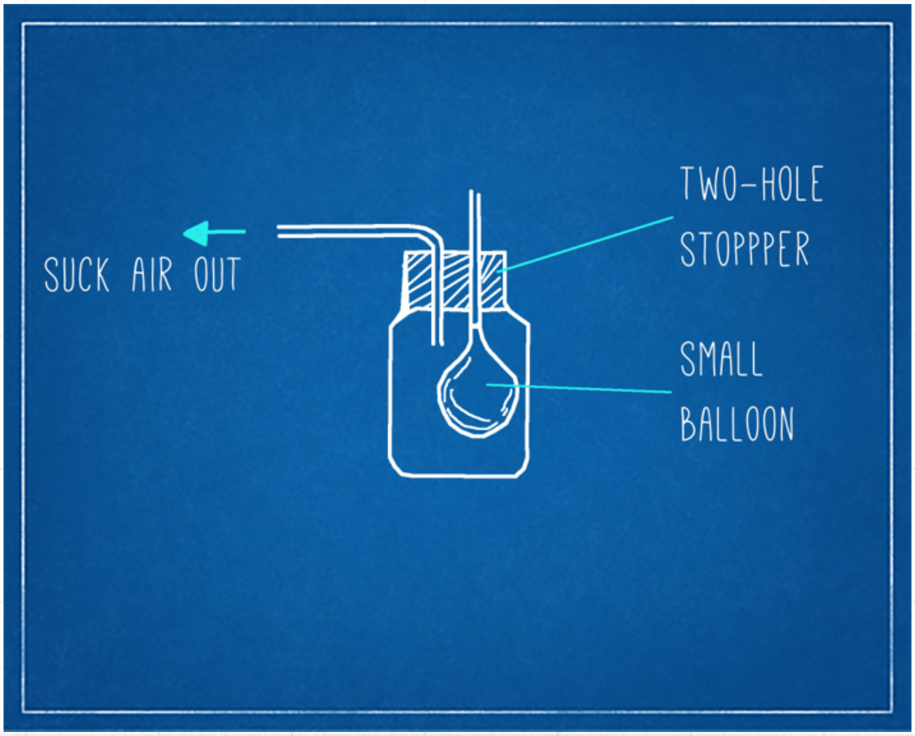
1. Insert the glass tubing into the stopper and tie or tape the small balloon to the end of the straight tube.
2. Place the stopper with the tubing and the balloon over the jar, insert tightly, and set up the equipment as shown in the *Sketch*.
3. Suck through the bent glass tube until the balloon is inflated and close off the end of the bent tube with your finger (prevent the air from getting back into the jar).

Explanation

By sucking through the bent tube, the pressure inside the jar is decreased and the atmospheric air pressure is inflating the balloon. By placing the finger over the end of the bent tube, the air is prevented from reentering the jar. A lower pressure inside the jar (outside the balloon) is now maintained, which causes the balloon to stay inflated even with an open mouth. Another way to inflate the balloon is to blow through the straight tube and, by putting a finger over the bent tube, it can be kept inflated. This way, during inflation the pressure inside the jar is higher than the atmospheric pressure.

Questions

1. What was I doing to inflate the balloon?
2. How does the pressure inside the jar compare to the pressure outside of the jar during balloon inflation?
3. Why doesn't the balloon deflate? (finger over end of bent tube).
4. How else can the balloon be inflated?
5. What would happen if I blew through the bent tube?
6. How does the pressure inside the jar compare to that of outside during inflation of the balloon by blowing through the straight tube?



Sucking the air out of the container will cause the balloon to inflate.

#24: THE HEAVY NEWSPAPER

Materials

- 1 or 2 full sheets of an ordinary newspaper
- a stick of pine wood that measures 0.3 cm x 3 cm x 75 cm *or* 1/4” x 1” x 2” (an old ruler is excellent)

Procedure

1. Place the stick on a table with a smooth surface and let it protrude over the edge about 8 cm.
2. Ask: "What will happen if I hit this protruding end of the stick?" (Anticipated answer: “The stick will fly up").
3. Strike it and let the students catch the flying stick.
4. Place the stick back on the table as you did in Step 1 and cover it with the newspaper, flush with the edge of the table.
5. Ask: "What do you think will happen now if I hit it again?" (Anticipated answer: "The paper will fly up" or “The paper will tear").
6. Smooth down the paper with your left hand and strike the protruding end of the stick with your right hand (a sudden sharp blow with the edge of the palm). The stick breaks!
7. By pulling the stick out another 8 cm after breaking, the cycle of smoothing the paper and breaking (Step 6) may be repeated.

Explanation

By smoothing the paper down there was almost no air under it but a whole column of air exists above the paper, pushing it down on the paper with the atmospheric pressure. This is about 1 kg/ cm^2 (nearly 15 pounds per sq. in.). The total weight or force pushing down on a 60 x 80 cm (20" x 30") piece of paper is roughly: 60 x 80 x 1 kg = 4800 kg (20 x 30 x 15 pounds = 9000 pounds), which is close to the weight of two large SUVs! It is therefore impossible to lift the paper with the thin stick!

Questions

1. What did I do with my left hand?
2. Why was it necessary to smooth the paper before hitting?
3. What would happen if the protruding end of the stick was slowly pushed down instead?
4. How much weight was actually holding the stick down?

#25: THE MAGIC BEAKER

Precaution(s):
- be careful not to burn yourself during this demonstration
- know where the nearest fire extinguisher is and how to use it

Materials

- a small jar (50 mL) or a small wine glass
- matches
- a piece of paper

Procedure

1. Show that the jar or wine glass is empty by inverting it.
2. Crumple a small piece of paper.
3. Strike a match and start burning the paper.
4. Place the burning paper in the jar or wine glass and immediately press the jar against your forehead or against the palm of your hand (please keep the flame away from your skin and do not burn yourself!). Keep pressing until the fire is out and you feel a suction.
5. When you feel a suction inside the jar, slowly let go of it. It will stay stuck against your forehead or palm.

Explanation

Although you showed the students that there was "nothing" in the jar by holding it upside down, naturally there was air in it. By placing the burning piece of paper in the jar, the air inside the jar was heated and expanded. The expansion made the air rush out of the jar and when pressed against the forehead or palm of the hand, the jar was closed off from the outside air. This caused the flame to go out because there was no more oxygen to feed the burning process. The extinguishing of the flame caused the air inside the jar to cool off and contract. The pressure inside the jar was therefore getting smaller than the atmospheric pressure outside of the beaker. This higher air pressure kept the jar against the forehead or palm. In other words, a **partial vacuum** was created inside the jar which kept the jar stuck against the skin surface.

Questions

1. What was inside the jar or glass before burning the paper?
2. Why did the flame inside the jar go out?
3. What does the heat of the flame do to the air inside the jar?
4. What was left inside the jar after the flame went out?
5. What made the jar or glass stick to the forehead or palm?

#26: THE EGG AND THE MILK BOTTLE

Precaution(s):
- be careful not to burn yourself during this demonstration
- know where the nearest fire extinguisher is and how to use it
- wear proper safety clothing, including goggles and an apron or lab coat (no loose-fitting clothes)

Materials

- one hard-boiled egg
- one empty glass milk bottle

Procedure

1. Peel the shell off the hard-boiled egg and place the egg on the mouth of the milk bottle.
2. Ask: "What will happen if I put a burning piece of paper in the bottle and place the egg back on the bottle?" (Anticipated answer: "The fire goes out", "The bottom of the egg will turn black", "The bottle might crack", etc.).
3. Burn a small piece of paper, lift the egg up, put the burning piece of paper in the bottle, and place the egg immediately back on the bottle's mouth. The egg will vibrate and then be sucked into the bottle.
4. Ask: "How can we get the egg out of the bottle without cutting it up?".
5. To get the egg out of the bottle whole: Invert the bottle and let the egg fall into the bottle neck, blow a short spurt of air up into the inverted bottle and catch the falling egg.

Explanation

The burning paper is heating the air in the bottle and expanding it and this is why the egg was vibrating before it was sucked into the bottle. Some of the air slipped under the egg and out of the bottle and thus there was less air pressure in the bottle. An added cause for decreasing the pressure inside the bottle is that the burning of the paper took away the oxygen of the remaining air, turning it into CO_2 and water vapour. The latter condensed against the cold bottle. Another way to get the egg out is to warm the bottle while the egg sits in the bottle neck.

Questions

1. Why did the egg get pushed inside the bottle?
2. What did the burning paper do to the air inside the bottle?
3. What did the egg do before it went into the bottle? (Observe!)
4. Is there another way to get the egg out whole?

#27: THE TWO BOTTLES IN LOVE

Precaution(s):
• be careful not to burn yourself during this demonstration
• know where the nearest fire extinguisher is and how to use it

Materials

• 2 identical bottles with thick, smooth rims (like medicine bottles)
• a piece of filter paper or blotting paper
• matches

Procedure

1. Soak the filter paper in water and place it over one of the bottles.
2. Twist a small piece of paper and make sure that it will fit through the mouth of the other bottle.
3. Ignite the twisted piece of paper, put it in the open bottle and immediately cover this bottle with the filter paper-covered bottle.
4. Press the top bottle for a few seconds longer on the lower side until the flame of the burning paper is completely extinguished.
5. Now lift the two bottles up by holding on to the top bottle only.
6. Hold both bottles, invert the set, and let go of the lower bottle.

Explanation

The burning paper heated up the air in the open bottle, which caused the air to expand. Thus, some of the air in the bottle escaped. By covering this bottle immediately with the other bottle the escaped air was trapped outside. The air pressure outside the bottles is keeping the set pressed together. The moist filter paper functions as a seal between the two bottles making them almost airtight. Without this filter paper, the air would seep between the two bottles and the experiment would not work. The two bottles will stick together as long as the pressure inside is lower than the atmospheric pressure. Slowly, air will seep in through the filter paper and as soon as the air pressure inside and outside the bottles is equalized, the bottles will come apart.

Questions

1. What did the burning paper do to the air in the bottle?
2. Why did the filter paper have to be soaked in water?
3. Why did the two bottles stick to each other?
4. Would the bottles stick to each other without the filter paper? Why?
5. How long will the two bottles stick to each other?

#28: THE INVERTED PAPER BAG BALANCE

Precaution(s):
- be careful not to burn yourself during this demonstration
- know where the nearest fire extinguisher is and how to use it

Materials

- 2 small identical paper bags
- 2 short lengths of thread
- 2 drinking straws
- tape
- a straight pin
- matches

Procedure

1. Open the two small paper bags, invert, and attach the thread to the center of the bottom with a piece of tape.
2. Hang the two bags upside down on the ends of one of the straws and balance this on a pin attached to the other straw as shown in the *Sketch*. Make sure that the straws move freely around the pin.
3. Let one of the students hold the vertical straw. Strike a match and hold the flame under one of the bags, being careful not to set the bag on fire.This bag moves up.
4. Take the flame away and the equilibrium is restored (both bags will be in balance again).
5. Hold a flame under the other bag and this side will now move up.

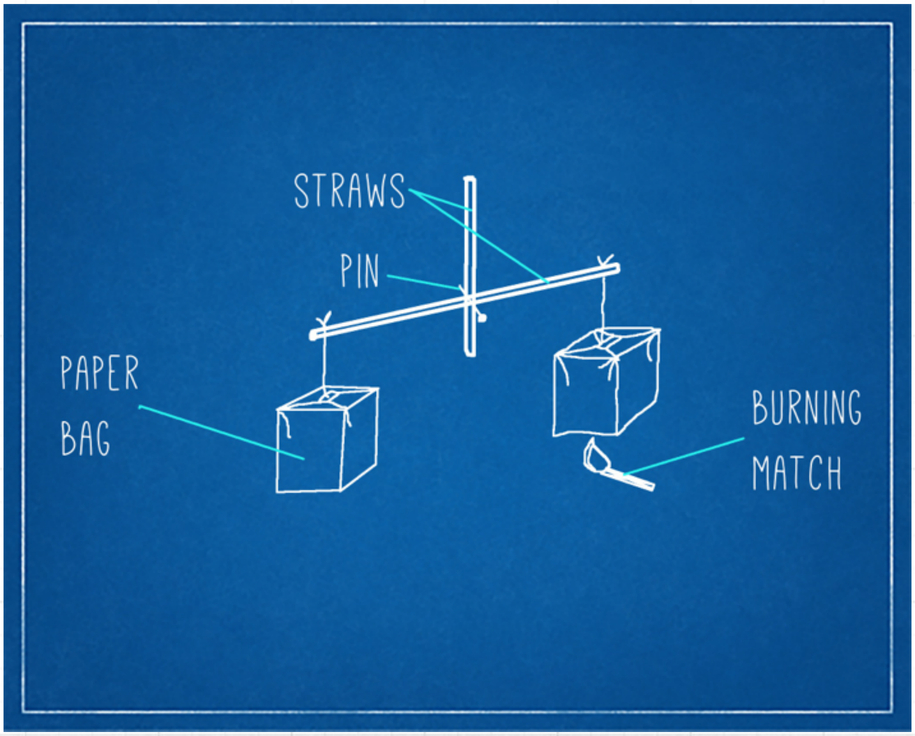
Explanation

The flame under the bag heats up the air in the bag and expands it. This leaves less and lighter air in the bag. This lighter air pushes against the bag's underside and the bag moves up. When we take the flame away, the warm air cools down and slowly the balance of the two bags is restored.

This principle of making air lighter by heating is applied in **hot air balloons**. Air inside the balloon is heated, it expands and becomes lighter, and the balloon is pushed up by the lighter air (compared to the surrounding atmospheric air). The larger the balloon, the larger the force upward and thus the more weight it can lift.

Questions

1. What is in the bags?
2. What is air doing if it is heated?
3. Why did the heated bag move up?
4. What happened after the flame was taken away from under the bag?
5. In which direction does heated air move?



A simple experiment to prove that hot air rises.

#29: SQUEEZE THE GLASS BOTTLE

Materials

- an empty glass bottle
- a small beaker
- a grease pencil
- glass tubing (about 30 cm) in a fitting one-hole stopper
- water and food colouring
- masking tape or a small rubber band

Procedure

1. Colour a few millimetres of water with food colouring in the beaker.
2. Dip the end of the glass tubing in the coloured water and close the other end off with a finger. Take the tube out of the water, hold the tube horizontal and let the water drop ride in the tube until close to the stopper. Close off the end again with a finger.
3. Place the stopper in the bottle neck and insert tightly (the water drop will move some).
4. Mark off the position of the water drop with a grease pencil, masking tape, or a rubber band.
5. Hold the bottle in both hands. What happens to the water drop?
6. Let the bottle stand on the table. What happens to the water drop?

Explanation

The 'empty' bottle is, of course, filled with air. In closing off the bottle with the stopper and tube, the water drop was pushed upwards by the air. It is because of the presence of air inside the bottle that the water drop in the tube cannot slide down by itself. It is actually held up in the tube by the air.

By holding the bottle in our hands, our body heat is warming up the bottle, which in turn warms the air. The air expands and pushes the water drop up the tube. By cooling the bottle with cool water and blowing the water drop can be made to move down the tube.

Questions

1. What is in the bottle?
2. Why does the water drop not slide down into the bottle?
3. Why does the water drop move up when inserting the stopper?
4. What made the water drop move up when the bottle was held?
5. How can we get the water drop to move down the tube?

#30: THE PAPER MERRY-GO-ROUND

Precaution(s):
• be careful not to burn yourself during this demonstration
• know where the nearest fire extinguisher is and how to use it

Materials

• two 5” x 8” paper cards
• matches
• scissors
• a needle or pin
• masking tape
• a pencil
• candle

Procedure

1. Draw a spiral on the paper card of about 1 cm width and cut out the spiral with scissors following the line *(see Sketch A)*.
2. Tape the needle or pin to the pencil or straw.
3. Balance the paper spiral on the needle point and hold it about 10 cm above the lit candle or lamp. The spiral turns!

Other types of merry-go-rounds can be made from paper cards or light paper (construction). See Sketch B and Sketch C.

Explanation

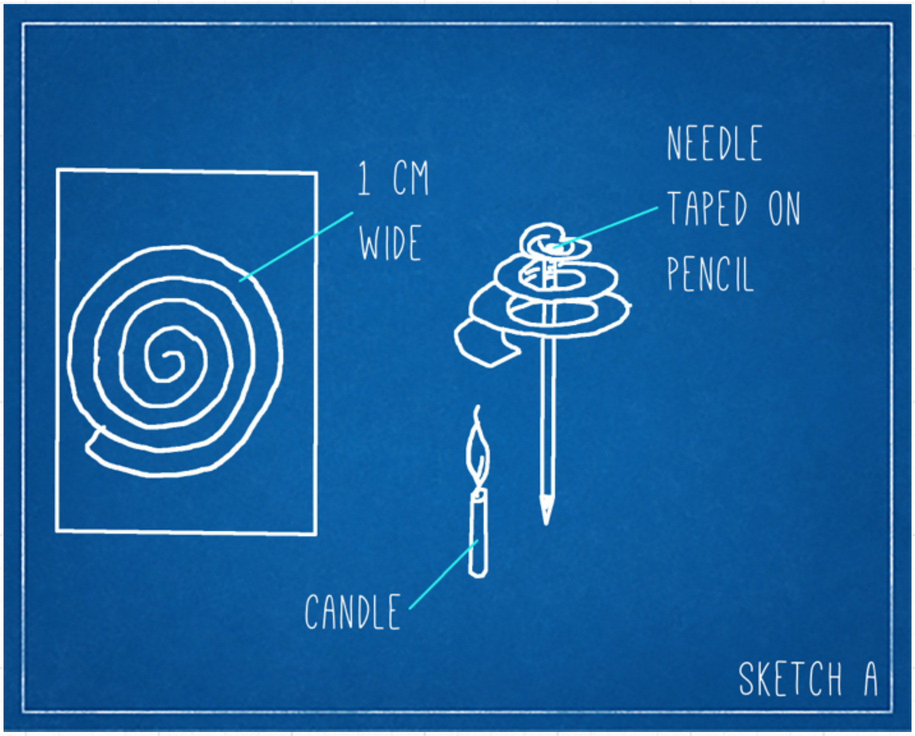
The lamp or burning candle was the source of heat which heated the air. **Hot air takes up a larger volume than cold air** and is therefore lighter in weight. Thus, **hot air rises** and by holding the paper spiral in this stream of air it flows along the spiral and makes it turn.

Examples that are based on this same principle are windmills, which only turn when there is wind blowing. The air stream here, however, is flowing in a horizontal direction. The air stream which was moving the paper spiral moved in a vertical direction. Other paper cut-outs are drawn in *Sketch B* and *Sketch C*, which will also spin in a stream of air.

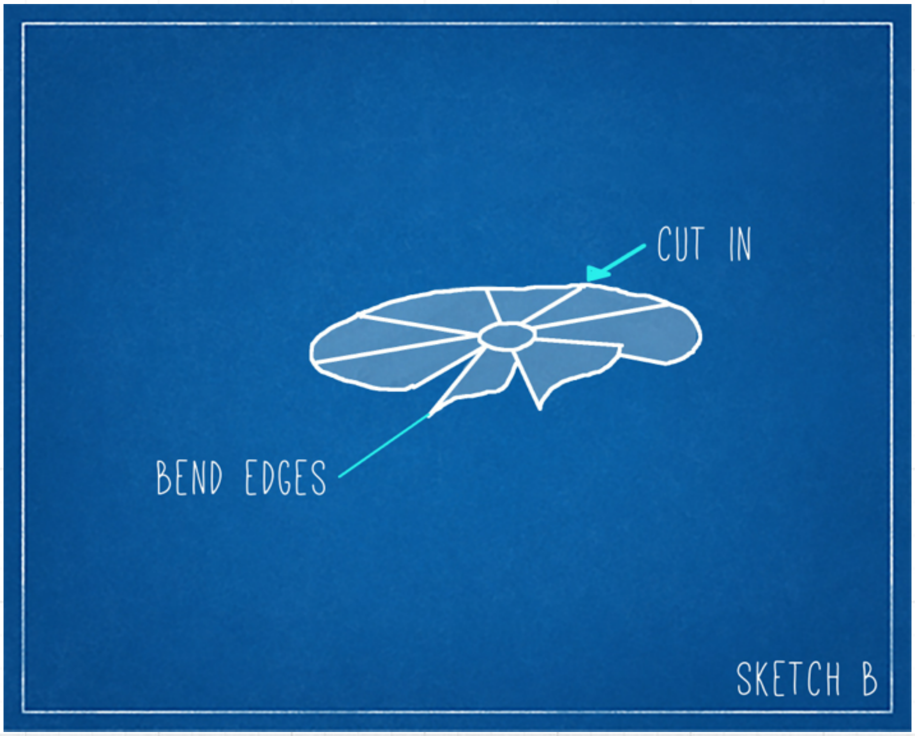
The needle point is the center point of rotation and it serves as a near frictionless set up for the rotation of the object. A very slow moving airflow would therefore be detectable.

Questions

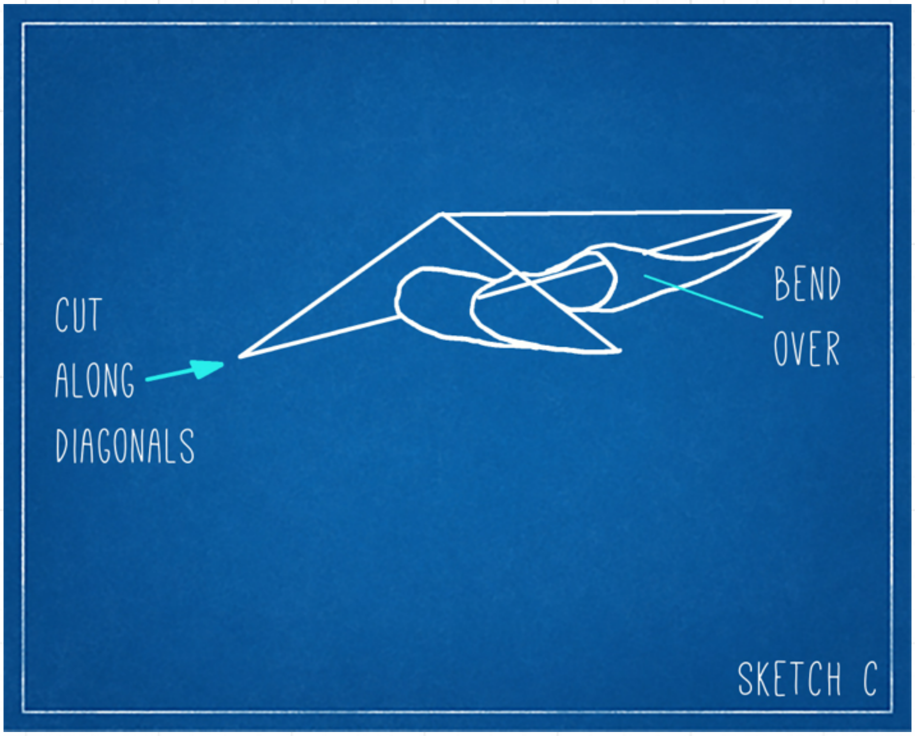
1. What does the burning candle do to the air?
2. What will heated air do?
3. What does a windmill need to turn?
4. Why did the spiral turn?
5. Can we make other paper cut-outs that will spin?



Using simple materials, you can create a merry-go-round that shows that hot air rises.



Creating merry-go-rounds is simple.



#31: THE DANCING PENNY

Materials

- 1 empty bottle with a narrow neck (perhaps a water bottle)
- 1 large beaker or container with warm water
- a penny, dime or other small coin

Procedure

1. Moisten the opening of the bottle and place the coin flat on the bottle mouth.
2. Fill the large beaker with hot water (not steaming so that it might look like cold water). If possible, fill the container before doing the demonstration.
3. Immerse the penny-covered bottle in the water and observe the dancing coin.

Explanation

The bottle was filled with air before covering it with the coin. The moisture on the opening of the bottle functions as a seal between the inside and outside of the bottle. When the bottle is placed in the hot water, the air inside the bottle is heated and this causes the air inside the bottle to expand. The only way it can escape from the bottle is through the opening, and thus it has to lift the coin. The coin falls back, more air expands, and lifts up the coin again. When this sequence of events happens quickly, a vibration of the coin is caused.

Without the moisture on the opening of the bottle, the coin does not seal off the air, so that the escaping air from inside the bottle could just seep under the coin out into the open without lifting the coin. The coin would not vibrate.

Questions

1. What was in the bottle before covering it with the coin?
2. What kind of water was in the beaker?
3. What was the moisture on the bottle opening necessary for?
4. Why did the coin go up and down/vibrate?
5. Would it also vibrate without moisture on the opening of the bottle?

#32: THE LIVE BALLOON

Materials

- a small balloon that has not been inflated before
- a large bottle with a narrow neck (perhaps a water bottle)
- a large beaker or container for hot water

Procedure

1. Show the bottle to the students and ask: "What is in the bottle" (Anticipated answer: "Nothing").
2. Place the small balloon over the mouth of the 'empty' bottle and let it hang limp against the side of the bottle *(see Sketch A)*.
3. Fill the container with hot water (not steaming hot). If possible, do not show students that it is hot water.
4. Immerse the bottle with the balloon on it in the hot water. The balloon will slowly fill with the expanding air *(see Sketch B)*.

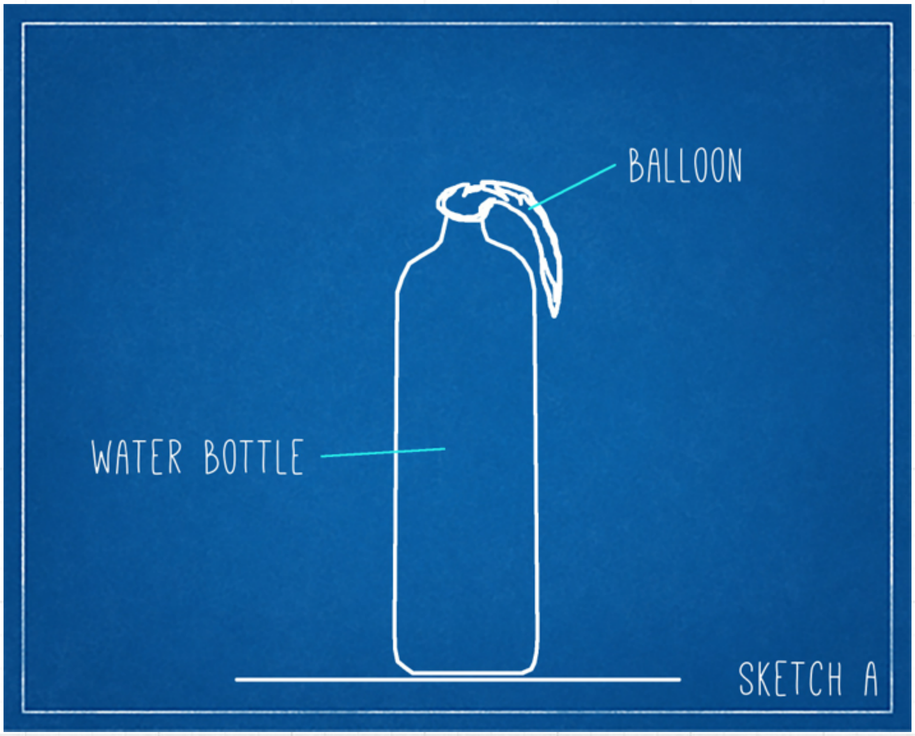
Explanation

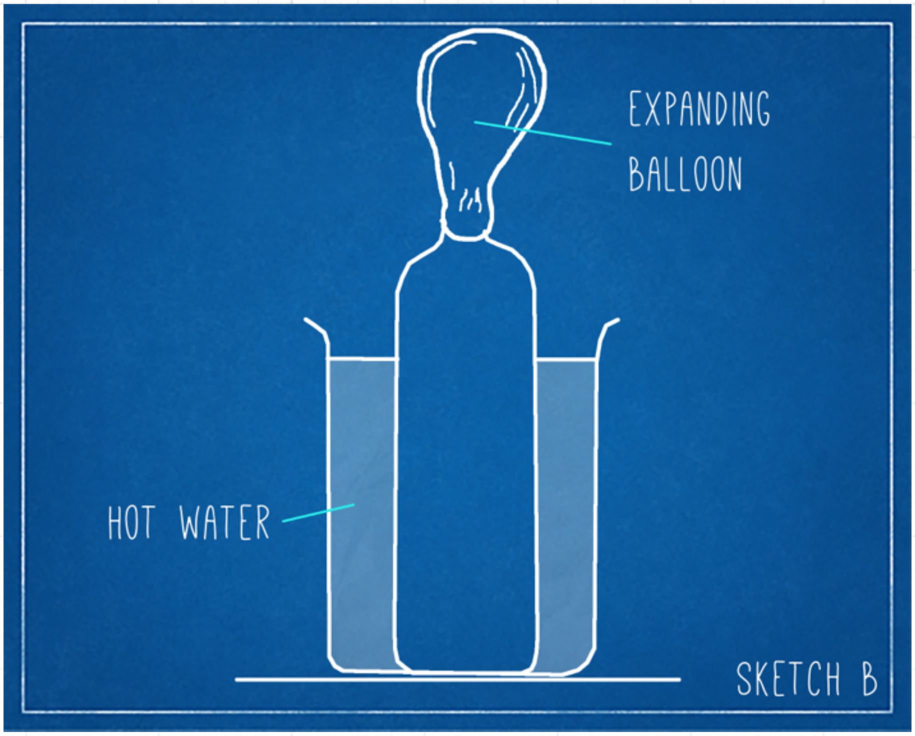
The bottle was filled with air at the moment that the balloon was put over it. The immersion of the bottle in the hot water heated the air inside the bottle, making the air expand and fill the balloon. The larger the bottle, the more air will expand, and the quicker the balloon will inflate. Taking the bottle out of the warm water and leaving it to stand on the table will cool it off and contract the air. This will deflate the balloon again. The amount of air is not changing, whether it is hot or cool, as no outside air was allowed in or out of the bottle. It is just the volume of air that is changing.

Questions

1. Why did the balloon inflate itself?
2. What kind of water do you think was in the large container?
3. How can we deflate the balloon without taking it off the bottle?
4. What does air do when it is heated?
5. Is there more or less air in the warm bottle compared to the cold one?

THE PROPERTIES OF AIR: AIR EXPANSION BY HEAT





#33: WHAT CAUSES THE WATER TO RISE? (PART I)

Precaution(s):
• be careful not to burn yourself during this demonstration
• know where the nearest fire extinguisher is and how to use it

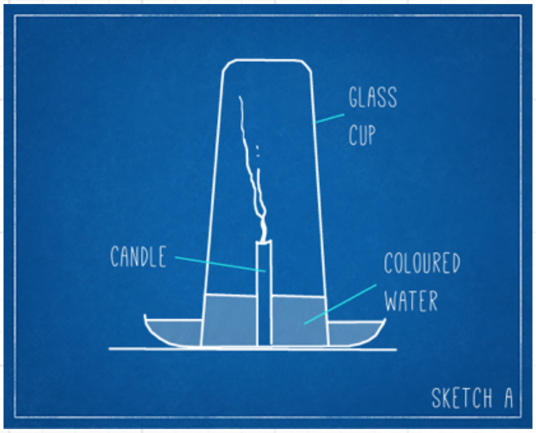
Materials

• 3 identical saucers or one large flat tray
• three identical glass cups
• matches
• 6 small birthday candles

Procedure

1. Attach one, two, and three candles to the center of each saucer or at different spots of the tray (in the case of using a flat tray).
2. Fill each saucer with at least ¾ cup of water.
3. Light all six candles and wait until they all burn evenly.
4. Place the three cups at the same time (have a student help you) over the candles on the saucer *(see Sketch)*.

Explanation

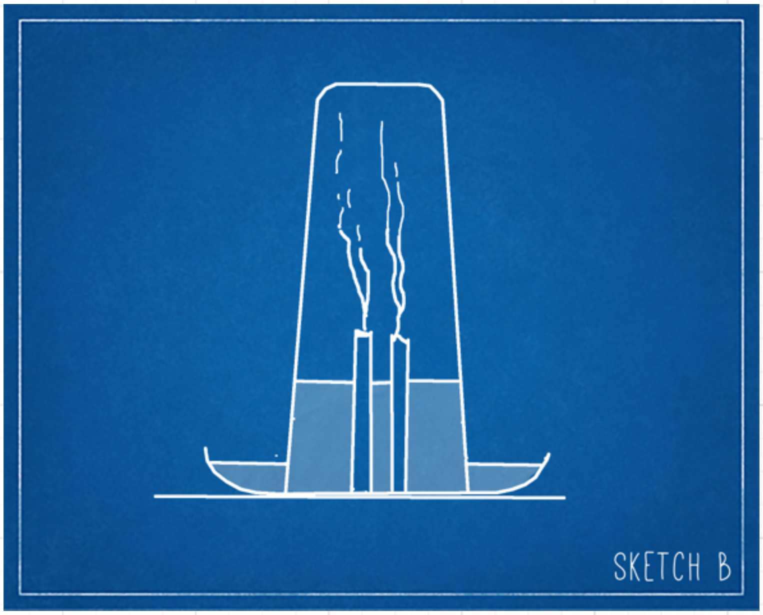


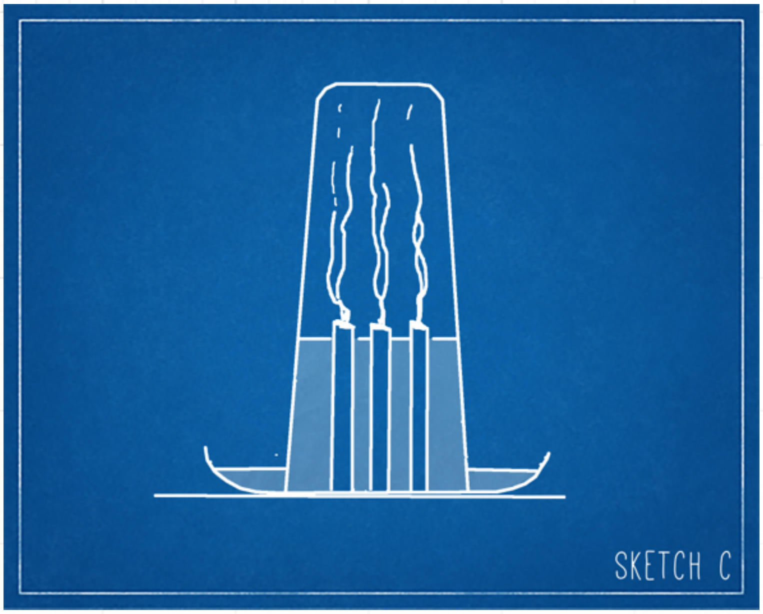
In all three cases the saucers, cups, and candles were identical. This meant that these variables did not influence the rising of the water level. The only variable that changed or manipulated was the number of candles, and thus the amount of heat. This was the main factor causing the air under the cup to expand just before it hit the water, thus under Cup C the trapped air was the least and exerted the lowest pressure. This is the reason why the water is pushed up the highest in Cup C.

Most students will think that the three candles will burn more oxygen, which is not the case. The use of oxygen for the burning process also helped in decreasing the pressure under the cups, but the amount of oxygen was the same for all three cases.

Questions

1. Under which cup does the water level rise highest?
2. Why did we take identical saucers, cups, and candles?
3. Do we need to pour the same amount of water in the saucers?
4. Which variable is manipulated or changed in comparing A, B, and C?
5. Above which saucer did heat develop most?
6. Was the amount of air trapped under the cups the same for all three?
7. Why did the water level rise highest in Cup C?





#34: WHAT CAUSES THE WATER TO RISE? (PART II)

Precaution(s):
• be careful not to burn yourself during this demonstration
• know where the nearest fire extinguisher is and how to use it

Materials

• a small saucer
• a coin
• a glass cup
• a birthday candle or wooden match

Procedure

1. Attach the candle in the center of the saucer with a drop of melted wax *(see Sketch A)*, **OR**, if no candle is available, break the short end of a couple of matches halfway and place them vertically in the saucer using a coin as a weight to support them *(see Sketch B)*.
2. Fill the saucer with about half a cup of water.
3. Light the candle or the two matches and cover it immediately with the inverted cup. Observe the water level!

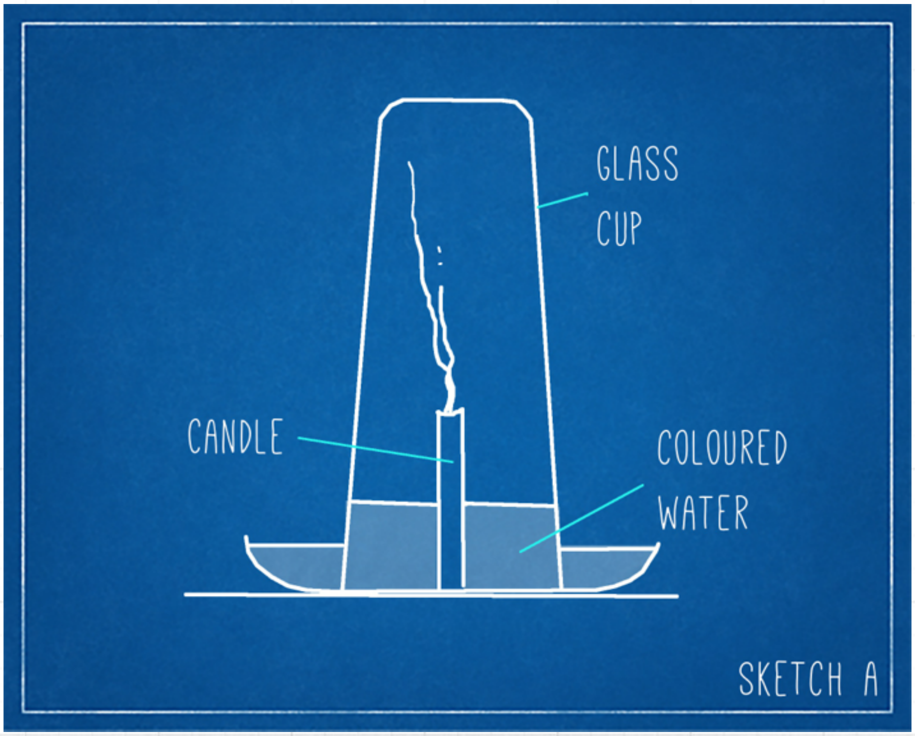
Explanation

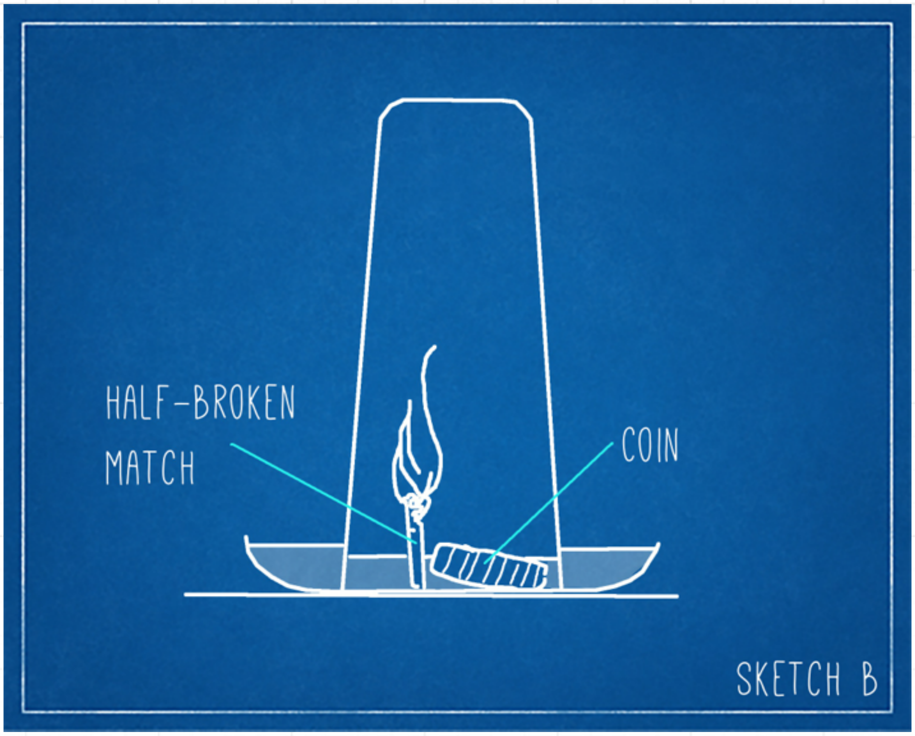
The burning of the candle needs oxygen and is therefore taking away all the oxygen under the cup. The flame is extinguished as soon as all the oxygen is used up. As the space under the cup does not contain any oxygen anymore, it is exerting less pressure compared to the atmospheric air. The water is therefore pushed into the space under the cup.

Another major factor contributing to the decrease of pressure inside the cup is the fact that the heat of the flame expanded the air under the cup just before it hit the water. At that moment air escaped from under the cup. After the flame extinguished, the remaining air cooled off and contracted and, in doing so, sucked up the water.

Questions

1. Why did the water level under the cup rise?
2. What does the candle need in order for it to burn?
3. Did the water level under the cup rise immediately after covering?
4. What did the heat of the flame do to the air under the cup?
5. Would the burning of two or three candles bring up the water level under the cup to the same height?
6. How would the size of the cup influence the rising of the water level? How can we set up experiments to test this?


GLASS
CUP
CANDLE
COLOURED
WATER
SKETCH A


HALF-BROKEN
MATCH
COIN
SKETCH B

#35: THE CANDLE UNDER THE JAR

Precaution(s):
• be careful not to burn yourself during this demonstration
• know where the nearest fire extinguisher is and how to use it

Materials

• 3 or more jars in different sizes

• 3 or more birthday candles (depending on the number of jars used)

• a large clock or stopwatches used for timing the burning candles

Procedure

1. Divide the class in small groups of three to six students.
2. Give each group one jar, one candle, and matches.
3. Make sure that the students can see the large clock or that each group of students have a watch for timing.
4. Ask the groups to measure the burning time of the candle under the jar. Start timing as soon as the jar is put over the candle and stop timing when smoke appears from the wick. Repeat several times, making sure to replenish the air in the jar.
5. Compare size (volume) of jar with the burning times. Plot on a graph.

Explanation

Air (actually oxygen in the air–about 20%) is needed to sustain the burning of the candle. After the first burning, the jar has no more oxygen. All the oxygen is replaced by carbon dioxide and water vapour, which can be seen condensing on the cold inside surface of the jar. Before doing a next timing of the burning candle, the air or oxygen in the jar has to be replenished. This can be done by pushing crumpled paper in and out of the jar several times. A straight line relationship exists between the volume of the jar and the burning time of the candle when the data are graphed.

Questions

1. Why do we measure the burning time more than once?
2. What should we do to the gas in the jar before repeating the measure of the burning time of the candle?
3. What do you think the burning time of the candle would be if we did not replenish the air in the jar after the first reading?
4. Why did the candle stop burning under the jar?
5. How can we measure the volume of the jar?
6. What is the relationship between size or volume of the jar and the burning time of the candle?

#36: THE WATER-ATTRACTING STEEL WOOL

Materials

- 2 graduated cylinders or two tall glasses
- 2 shallow dishes or trays
- a small paper card (index)
- a small piece of steel wool

Procedure

1. Fill both shallow dishes with water.
2. Place the steel wool close to the bottom of one of the cylinders or tall glasses *(see Sketch A)*.
3. Wet this steel wool thoroughly by pouring some water in the cylinder.
4. Fill the cylinder one quarter full with water, cover it with a small paper card, place it upside down in the dish, and take the card out from under the inverted cylinder.
5. If the water level inside the cylinder is too high in relation to the water level in the dish, adjust the level by letting an air bubble into the cylinder (holding it slightly slanted) *(see Sketch B)*.
6. Repeat steps 4 and 5 with the other cylinder without the steel wool.
7. Place them side by side and leave them overnight. Observe the water level.

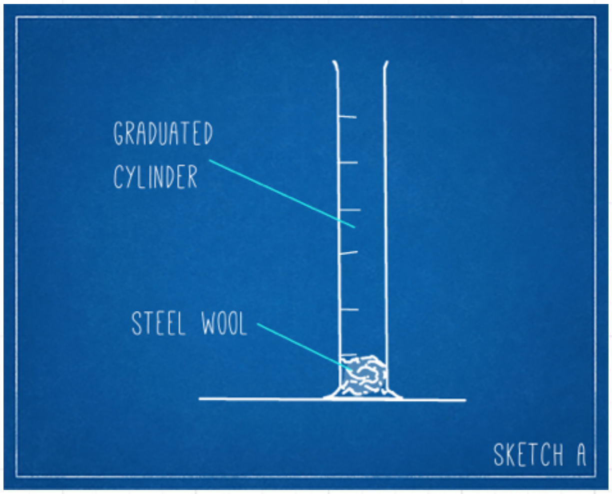
Explanation

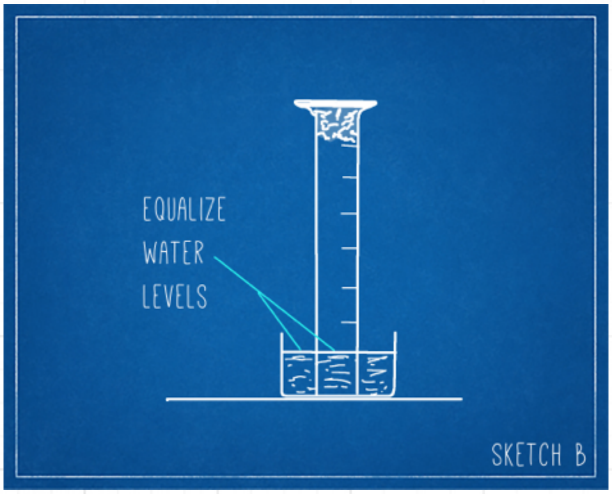
The steel wool in the cylinder reacted with the oxygen in the air forming iron rust (Fe_20_3). When all the oxygen under the cylinder has reacted with the iron, the water level should have risen about one-fifth of the volume, since 20% of the air consists of oxygen. Having taken away the oxygen under the cylinder, the pressure of the remaining air is decreased, forming a partial vacuum and sucking the water level higher up.

Magnesium ribbon or a chunk of white phosphorus may be used in place of the steel wool to bind the oxygen out of the air.

Questions

1. Why did the water level under the cylinder with the steel wool rise?
2. Did the steel wool change colour? What happened to it?
3. What part of the volume in the cylinder did the water level rise?
4. What other chemical can we use in place of the steel wool?


GRADUATED
CYLINDER
STEEL WOOL
SKETCH A


EQUALIZE
WATER
LEVELS
SKETCH B


- OVERNIGHT -
SKETCH C

#37: THE BALANCING BALLOONS

Materials

- 2 drinking straws
- 2 identical deflated balloons
- 3 pins or needles
- 2 pieces of thread

Procedure

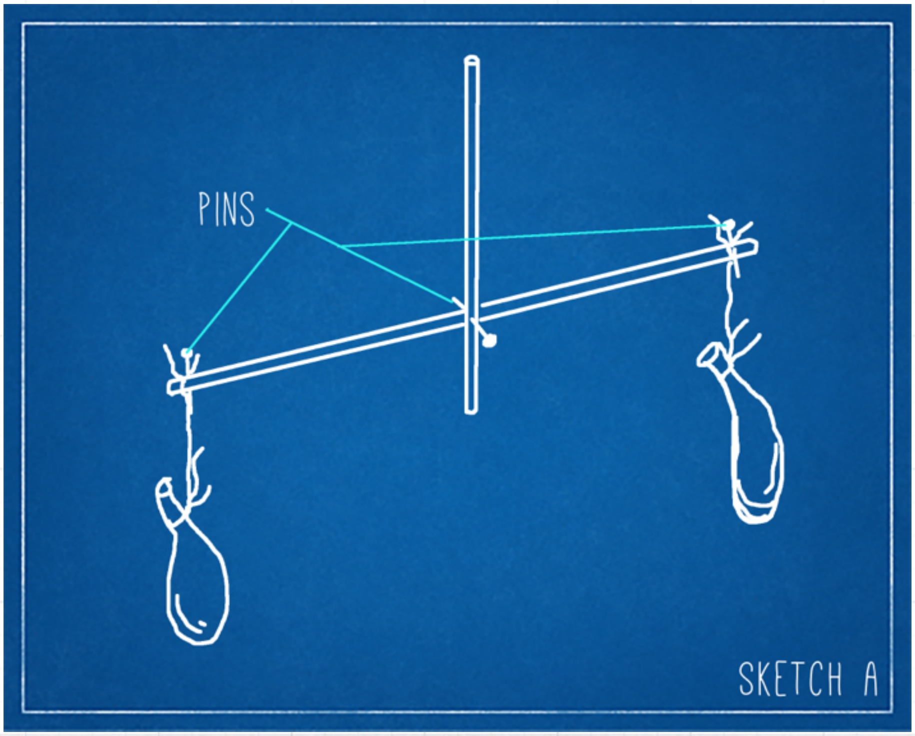
1. Tie a piece of thread to each of the two balloons and tie the threads to the two ends of one of the straws.
2. Balance this straw on your finger horizontally, push a pin through the straw where it is balancing, and attach it to the other straw *(see Sketch A)*.
3. Make sure that the straws are moving freely around the needle. Balance the horizontal straw then push a pin through at the spot where the threads are attached to prevent them from sliding.
4. Make sure that the two deflated balloons are in perfect balance. Blow air in one of them and tie a knot in the mouth. The balance will tip down at the end of the inflated balloon *(see Sketch B)*.

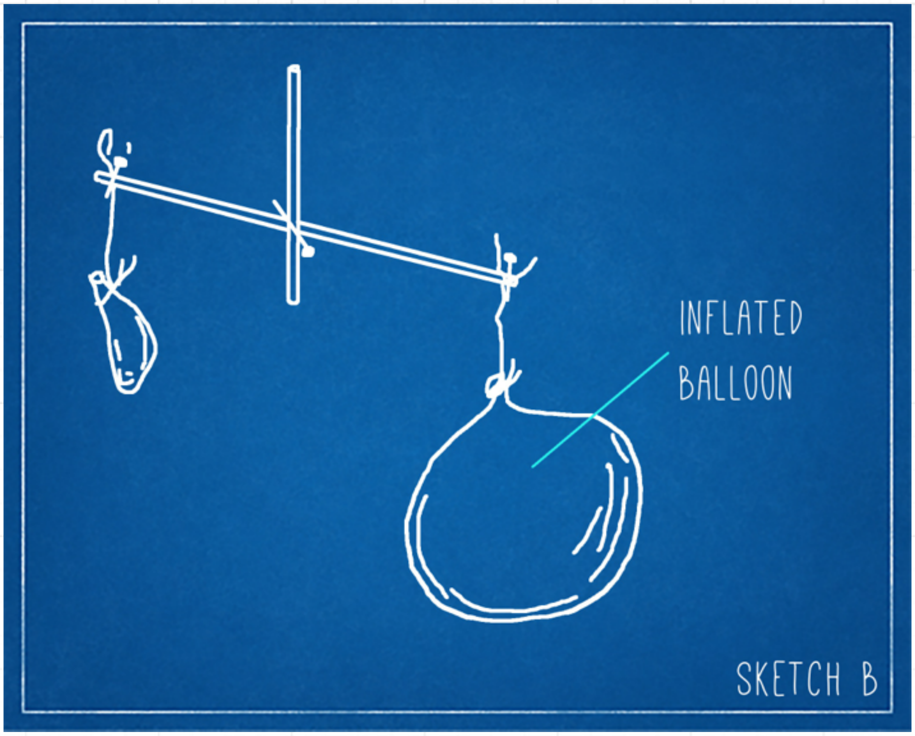
Explanation

The straw balance may be adjusted by moving the threads further or closer to the end of the straw. In order to keep these attached threads from sliding, we need the pins. The air that was blown in the balloon was exhaled air, which contains some water vapour that we will neglect for the purposes of this experiment. By inflating the other balloon, the balance should be in equilibrium again.

Questions

1. What is inside the deflated balloons?
2. What kind of air was blown in one of the balloons?
3. What could happen if no pins were placed on the ends of the horizontal straw where the threads were attached?
4. What does the balance indicate after inflating one balloon?
5. What would you expect the balance would do if the other balloon was also inflated?
6. How else could we show that air has weight?


PINS
SKETCH A


INFLATED
BALLOON
SKETCH B

#38: THE BALL THAT GAINS WEIGHT

Materials

- a basketball or volleyball with a valve
- a hand pump to pump up the ball with
- a technical scale or balance to weigh the ball

Procedure

1. Place a rather soft basketball or volleyball on the pan of the technical scale and measure the weight.
2. Connect the hand pump to the ball and pump ten strokes of air into the ball.
3. Disconnect the pump and read off the weight of the ball. How much did the ball gain in weight?
4. Repeat steps 2 and 3 and have students predict what the gain in weight would be after 5, 10, 15, 20, and 25 strokes of the pump.

Explanation

This demonstration shows that **air has weight**. By adding air to the ball, it increases in weight. The same number of pump strokes should result in the same gain in weight. Half the number of pump strokes gives half the gain in weight. The number of pump strokes is therefore directly proportional to the increase in weight. If the data were plotted on a graph, a straight line relationship would be obtained between the number of pump strokes and the weight of the ball. Whether a ball, air mattress, or airtight bottle is pumped, the increase in weight should be the same, provided that the same pump is being used and the same number of strokes applied.

Questions

1. What made the ball gain weight?
2. What can we say about the relationship between the number of pump strokes and the gain in weight of the ball?
3. How can we make the ball lose weight?
4. How much would a beach ball gain in weight when pumped with 5, 10, or 15 strokes of the same hand pump?
5. Would an airtight bottle gain weight if air were pumped into it?

#39: THE PLASTIC BAG AIR LIFT

Materials

- 20 - 25 medium-size plastic garbage bags
- 2 identical flat top tables

Procedure

1. Ask as many students as possible to stand around one of the tables (without being too crowded) and give them each a plastic bag.
2. Let them spread the bags out on the table and hold the bag's mouth in their hands to get set to blow air in them. Make sure that all students are ready to blow air into the bags with their hands and fingers away from the table top.
3. Ask two or four other students to lift the other identical table, turn it upside down, and place it slowly on the first table (be sure no students' heads are hit by the table!).
4. Ask one or two students to climb up and sit on top of the set of tables.
5. Let the students standing now blow air in the plastic bags all together on the count of three.

Explanation

By blowing in the plastic bags, air is being compressed. This compressed air is exerting pressure underneath the inverted table causing the table to rise. This principle is being applied when pumping tires of a bicycle or automobile, or compressing air in air lifts at car repair shops. Tire pressures are twice or four times as high as the atmospheric pressure, and in air lifts these pressures go as high as 20 to 50 atmospheres.

Questions

1. Did you expect a heavy weight like that to be lifted by air?
2. What made the table top rise?
3. How did the pressure of the air inside the plastic bags compare to the outside atmospheric air pressure?
4. Where do we find applications of this principle?

#40: THE OBEDIENT DIVER

Materials

- a milk bottle or other container
- a large beaker
- a medium-size test tube
- large balloon
- a medicine dropper
- wooden match

Procedure

1. Fill the beaker with water. Fill the dropper half-way with water and test it in the beaker (it should just float. Add more or remove some to make it sink or float).
2. Fill the bottle to the brim with water and tie a deflated balloon flap on the bottle opening (do this after you transferred the dropper from the beaker into the bottle).
3. Put your finger on the stretched balloon and control the sinking or floating of the dropper by putting pressure on it *(see Sketch A)*.
4. Ask the students to say "up" or "down" or "stop" and make the dropper respond on their command!

A broken off wooden match head in a water-filled test tube can be similarly controlled by pressure of the thumb *(see Sketch B)*.

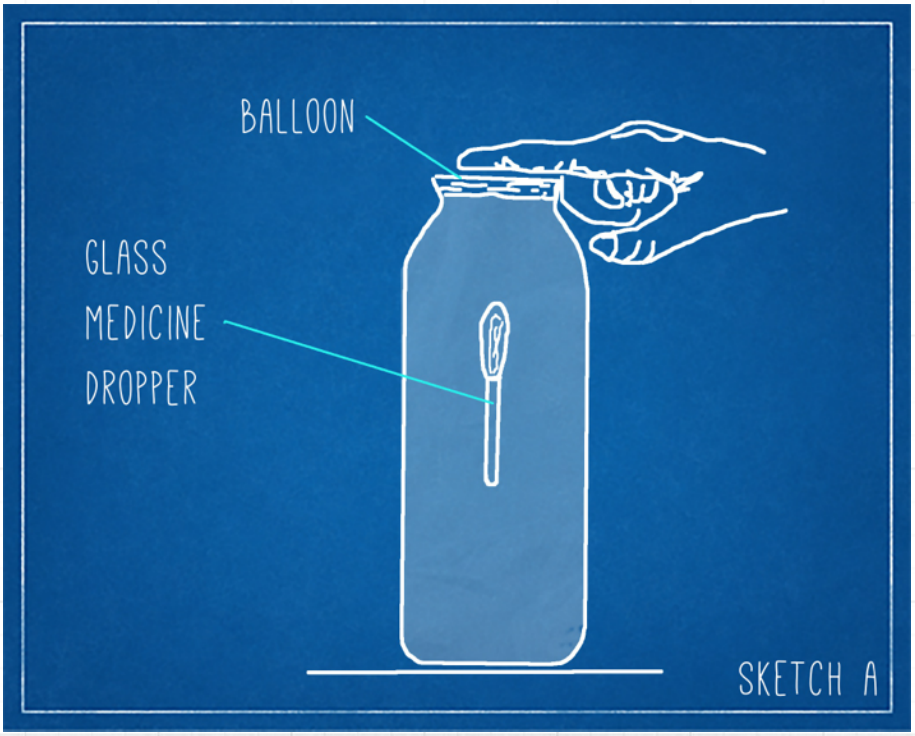
Explanation

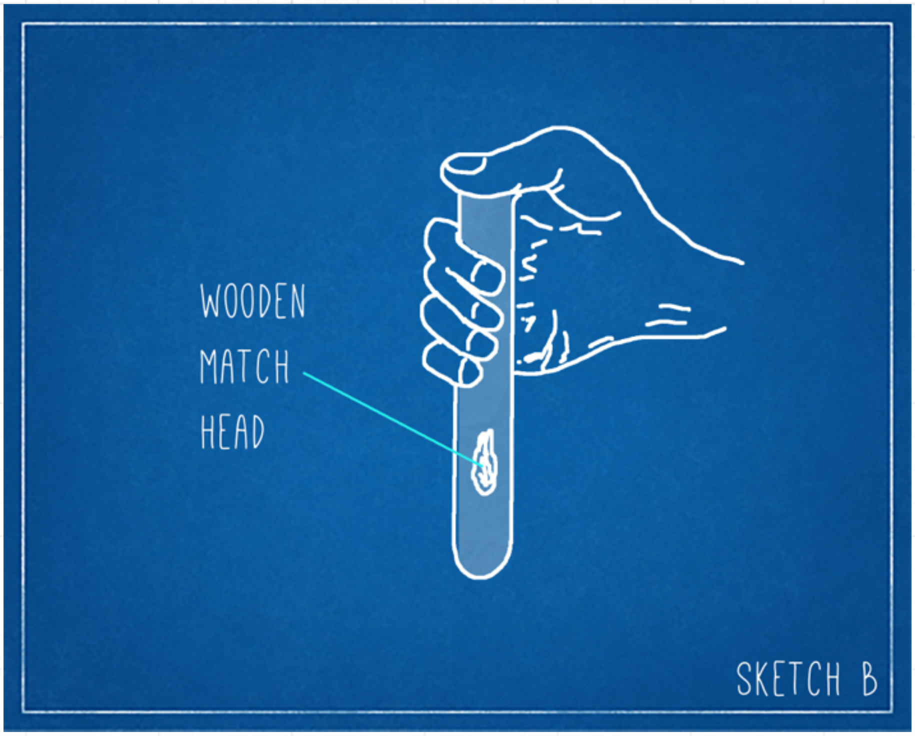
By putting pressure on the stretched balloon with a finger (or the thumb on the test tube), the air inside the dropper (or inside the wood fibers of the match) get compressed, the water level rises and the whole dropper gets heavier and sinks. By releasing the pressure, the water is pushed out again, the dropper gets lighter and floats. This principle is applied in submarines, where water is pumped in to submerge or pumped out to surface. This demonstration is also suitable to initiate inquiry on *sinking and floating* or on *density*.

Questions

1. What made the dropper or the match head sink? Float?
2. What did the water level inside the dropper do when it dove down?
3. Did the air inside the dropper increase or decrease in volume during the diving? During the floating?
4. Is water or air more compressible?

THE PROPERTIES OF AIR: AIR COMPRESSIBILITY/DENSITY OF MATERIAL





#41: TURN A LITTLE WATER INTO A LOT OF LEMONADE

Materials

- 2 identical one gallon (4 L) tin cans
- a glass funnel
- 2 two-hole stoppers to fit the opening of the cans
- food colouring
- glass tubing
- rubber tubing

Procedure

1. Fit the glass and rubber tubing and the glass funnel in the two-hole stoppers, as shown in *Sketch A*.
2. Fill Can A about ¾ full of water. Add food colouring for lemonade effect. Pour about 100 mL of water in Can B.
3. Make sure that the stoppers are pressed tightly in the can openings. Now you are ready for the demonstration. Do not reveal the construction of the tubes inside the cans–students should only see the things outlined in *Sketch B*.
4. Pour some water in the funnel and say: "I am turning a little water into a lot of lemonade. Can you find out what the structure of the glass tubes inside the cans have to be to make it work like this?"
5. Have students work in groups and have each group come up with their hypothesis and explanation.

Explanation

With the correct structure in *Sketch A*, after pouring some water into the funnel, the water level in Can B rises, increasing the pressure of the air above the water, also increasing the air pressure in Can A. This will push down the water level and push the water up in the long tube. The water drips into the funnel and the cycle is repeated again. The flow of water will stop as soon as either the water level in Can A gets lower than the opening of the long tube or the water level in Can B reaches the opening of the short tube.

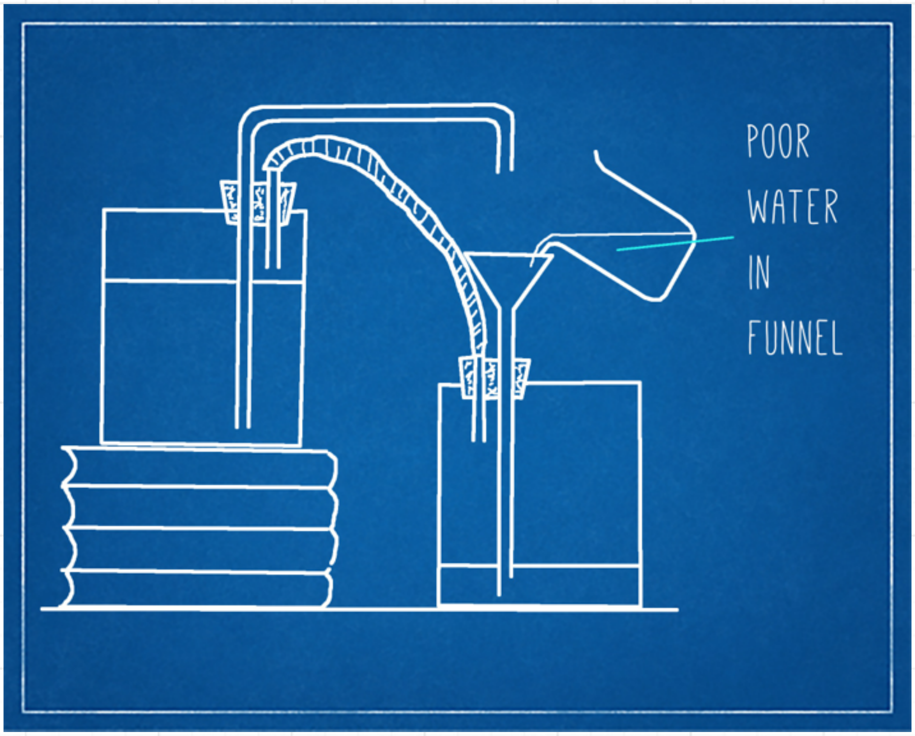
Questions

Before seeing the inside of the structure

1. Did you observe any water flowing from Can B to Can A?
2. What would cause the water to flow from Can A?
3. What would adding water to the funnel do to the water level in Can B?
4. Do either of the two tubes in Can B have to extend into the water level or not, or both? What about Can A?

After seeing the correct inside structure

5. What would happen if the funnel did not extend into the water?
6. What would happen if the glass tube in Can B also extended into the water?
7. What would happen if the long tube in Can A did not extend into the water?
8. What would happen if both tubes in Can A extended into the water?



#42: MAKING AN AIR RING SHOOTER

Precaution(s):
- take great care when handling chemicals
- wear proper safety clothing, including goggles and an apron or lab coat
- read all MSDS sheets prior to handling any chemical
- know where the nearest eye wash station is and how to use it

Materials

- a medium-size cardboard box
- 2 small petrie dishes
- concentrated ammonia
- a heavy polyethylene sheet to cover one end of the box with
- concentrated hydrochloric acid
- 4 long heavy rubber bands
- a rubber stopper

Procedure

1. Cut a circular hole of about 15 cm diameter in the bottom of the box and flip the flaps of the open side inwards.
2. Staple the long rubber bands to the four corners of the side with the hole, and staple the other end of the bands to the rubber stopper.
3. Cover the open end of the box rather loosely with the polyethylene sheet and tape the edge of the sheet tightly against the box.
4. Push the rubber stopper against the center of the sheet, wrap the sheet around the stopper, and tie it with a small thick rubber band.
5. Now the air shooter is ready. Have someone hold a paper or cloth sheet about 10 meters away and shoot air rings at the sheet by holding the box, aiming the circular hole at the sheet, pulling the rubber stopper and releasing it suddenly *(see Sketch)*.

The air shooter can also be used to produce smoke rings:

1. Tape two small petrie dishes next to each other inside the box.
2. Place a few drops of conc. ammonia (HC3) in one and a few drops of conc. hydrochloric acid (HCl) in the other dish.

Explanation

The circular opening in the box made it possible for the air to form rings that can move through the stationary air much faster and farther. Other shapes of the opening in the box would hamper this natural travel of fluids. The smoke was formed by the gases and vapors of ammonia and hydrochloric acid: $NH_3 + HCl = NH_4Cl$, forming ammonium chloride, which is a solid (smoke consist of finely divided solid particles in a gas).

Questions

1. What makes it possible to blow at the paper sheet from 10 m away?
2. Would a square to triangular opening have the same effect?
3. What shape would the air "ring" have?
4. What did the smoke consist of?