

Atmospheric (Air) Pressure Experiments

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This is a compilation of experiments on pressure exerted by air or atmosphere surrounding our planet. The atmosphere exerts pressure on each and every place on the earth. This pressure can be understood from hydrostatic frame of reference (resulting from mass of the air being pulled by the earth gravity) or molecular frame of reference (resulting from composite bombardment of air molecules). According to this pressure, every square inch area of the earth at sea level is carrying a weight of 14.7 pounds or air is exerting a force of 14.7 pounds on every square inch of the earth area. The atmospheric pressure decreases with height as the air becomes thinner with altitude.

These simple experiments range from very simple to somewhat more involved scientific techniques. Many do not need sophisticated apparatus and many of them can be performed even by middle and high school students. The principle involved in most of them is related to creating a partial vacuum so that the surrounding air would respond to this decrease in pressure. The partial vacuum is created by expelling air physically, removing oxygen of air chemically through combustion or replacing air with steam (water vapors condense on cooling) in a closed set up. The experiments are listed below.

1. Inverted Water Bottle

Equipment/Apparatus/Material: A narrow mouth 6-8 inches tall bottle, a sheet of paper, water

Procedure: Fill a glass bottle with water to the brim. Place a sheet of an ordinary paper on the top with no air bubbles in between paper and water. Invert the bottle gently giving support to the paper with palm. Remove palm and if done with care the paper should hold weight of water in the bottle. Air pressure from outside is supporting the weight and holding paper in place. Newspaper and oily sheets of paper will not work. Please do not do this in the living room of the house. The experiment can also be done with a volumetric flask.

2. Manometer

Equipment/Apparatus/Material: A large size U-tube (manometer), rubber stopper, rubber tubing, a gas/air supply source, colored water solution

Procedure: A U-tube (manometer) should be with one side open and the other side closed but having an opening on the side for connecting rubber/plastic tubing. This piece of equipment is available from most lab apparatus vendors.

Fill the tube halfway with colored water, liquid level in both arms will be same as both sides are open to the atmosphere. Connect a source of gas or air to the side opening. Let a little bit gas or air in to see water level rise 2-3 inches on the open side (would be lower on the side gas is connected). The difference in meniscus levels in both arms give us the pressure of the gas/air that was let in.

Close the open end tight with a rubber stopper and disconnect the manometer from gas/air source

keeping side opening exposed. The liquid levels in both arms will stay about where they were when gas/air was let in. Liquid levels will not be same in both arms, instead it will be higher on stopper side. The liquid levels in arms of the manometer do not go back to same height because this time air pressure is acting only on one side, i.e. the opening side. If we remove the rubber stopper, then water levels will equalize. Similar principle is used in mercury barometer to measure atmospheric pressure at a given location.

Other instructions for making a manometer at www.science-house.org/student/bw/flight/manometer.html

3. Suction Cups

Equipment/Apparatus/Material: Suction Cups: Suction cups or Magdeburg hemispheres

Procedure: Squeeze suction cups or Magdeburg hemispheres (regular/miniature) and then try to separate them apart. After the air is squeezed out, separation need extra force depending on intensity of vacuum and seal between the parts for outside air is pressing on the cups. Pressing suction cups against hard and smooth surfaces would give the same experience. Use of suction cups to lift glass panes is an example of this application.

4. Siphoning Tube

Equipment/Apparatus/Material: A 3-4 inch long glass tubing bent in V shape, container/beaker, water

Procedure: Fill tubing with water. Block one end tight with finger tip. No water would come out from the open end of the tubing when it is inverted. With one end closed, air pressure at the open end will support weight of water. When closed end is dipped in a container full of water and tip is removed, water will be siphoned out depending on the length of dipping end in water. When tubing full of water is inverted in the container, it creates a vacuum at the bend and air pressure on the water in the container pushes the fluid upward through the tubing producing siphoning effect.

5. Differential Pressure Bottle

Equipment/Apparatus/Material: A 1000 mL bottle with two holes (one at the top and the other at the bottom, available from Cenco and other vendors), balloon, rubber stopper, water

Procedure: Attach a balloon to the neck of the bottle and plug the bottom hole with the stopper. Remove the stopper and inflate the balloon in the flask (balloon cannot be inflated when hole is closed). Replace the stopper. Fill the bottle with water and remove the stopper, water gushes out as a geyser because of air pressure.

6. Metal Cans

Equipment/Apparatus/Material: A 1 gallon metal can with a screw in cap top (like kerosene or other fluid storage can, empty and clean) or empty soda cans, heating assembly, water, big container with ice cold water, tongs (for soda cans)

Procedure: Put 2-3 cups of water in the can. Boil the water in the can and keep heating for few minutes so steam replaces air in the can. Put the can lid tight and dip the can in ice-cold water immediately. The can will get squeezed because of air pushing the sides in as trapped steam condenses in the can creating a partial vacuum. The same experiment can also be performed by using empty soda cans. Put about a half cup of water and bring water to boil in the can. Keep heating for a little while to flush out air. Then immediately put it upside down

in ice-water mixture. If done correctly, the can will get deformed as if it were beaten with a wooden mallet.

7. Ping Pong Balls

Equipment/Apparatus/Material: Two ping pong balls, sewing threads, suspension stand

Procedure: Suspend the ping pong balls with threads from a rod of the suspension stand. Threads should go through holes that can be made in the balls. Keep about 14 to 12 inch space between the balls. If we blow between the balls, instead of flying apart the balls will cling together. As per Bernoulli's principle, air set in motion on blowing creates a decrease in pressure. Thus the air pressure from surrounding air pushes the balls closer. The same experiment can be done with metal spheres instead of ping pong balls, but a blower would do a better job to set air in between spheres in motion.

8. Candle and Water Trough

Equipment, Apparatus/Material: A shallow pneumatic water trough, candle (used for birthday cakes will work fine), matchbox, tall glass cylinder, water

Procedure: Stick a small candle in the center of water trough. Fill the trough about half with water and light the candle. Let it burn for a few moments. Then invert the tall glass cylinder over the burning candle. The candle will burn for few seconds and then will go out. When the candle extinguishes, water level in the inverted cylinder would rise (theoretically equal to approximately $1/5^{\text{th}}$ of volume of air enclosed in the cylinder, i.e. equal to 20% oxygen present in the air). Here the oxygen in the cylinder was used up in combustion of candle thus creating a partial vacuum in the cylinder, so the air pressure from surrounding air pushes water in the cylinder.

9. Candle and Egg

Equipment/Apparatus/Material: A 24-30 oz glass bottle with narrow mouth (in which an ordinary hard boiled would fit snugly), candle, matchbox

Procedure: Stick a small candle in the pointed end of the egg. Light the candle and hold the egg under the mouth of the inverted glass bottle with candle burning inside the bottle. The egg should make a tight seal with bottle mouth. The candle will burn for a few seconds and would then go out. As it goes out the egg will be pushed inside the bottle because of the outside air pressure. It works on the same principle as in experiment number 8. The burning candle uses up the oxygen from air inside the glass bottle creating vacuum. Thus the outside air pressure slides the egg in the bottle.

10. Boiling water

Equipment/Apparatus/Material: A 500-mL flat bottom flask, heating assembly, a rubber stopper, water, container with ice cold water

Procedure: Take a 500-mL flat bottom flask and fill it about half with water. Bring water to boil and let it boil for 3-4 minutes to flush out air replacing air with steam. Close the flask mouth with a tight rubber stopper entrapping steam inside. Let it cool down completely. May be next day invert the flask over a ring stand. Pour cold water over flask bottom, water would be boiling at room temperature. Because the flask inside is cut off from outside air and its pressure, water boils under reduced pressure (partial vacuum) created by condensing water vapors when cold water was poured over the bottom. When water is open to air, it has to be heated to normal boiling temperature before it boils (100 deg C). However, under reduced air pressure it does not

have to be heated to high temperature to bring it boil. Use of pressure cookers at higher elevations because of water boiling at temperatures lower than normal boiling point signifies air pressure is lower than normal at mountain tops.

The author would be happy to help to give these demonstrations. He is also willing to perform these demonstrations wherever it is possible depending on location and schedule.

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