BERNOULLI'S PRINCIPLE

PROBLEM PRESENTATION / EXPLORATION

A. Set up three stations with the following challenges.

1. Suspend two apples, or ping pong balls, about 3 cm apart from a horizontal support.

   INSTRUCTIONS: What do you expect will happen to the apples when you blow in between them? Do it and observe what happens.

2. Take a 3 x 5 index card and draw two lines each 1 inch in from the end. This will produce a 3 x 3 square and two 3 x 1 in rectangles. Fold the two one inch flaps at right angles to the card Place the card on the table so that it is resting on its folded edges.

   INSTRUCTIONS: Predict what will happen when you blow air through a straw at the card. Do it and observe what happens.

3. Light a candle and set it on the table. Direct a funnel at the center of the candle flame and blow the candle out. Blow through the narrow end.

   INSTRUCTIONS: Predict what will happen when you blow through the funnel at the candle flame. Do it and observe what happens.

B. At each station students will not be able to accomplish what appears to be the common sense outcome.

1. At the first station the apples will move closer together instead of farther away.
2. At the second station the center of the card will bend downward and the card will not flip over.
3. At the third station not only will the flame not go out but it will actually be drawn back toward the center of the funnel.

CLASS RESPONSE / CONCEPT INVENTION

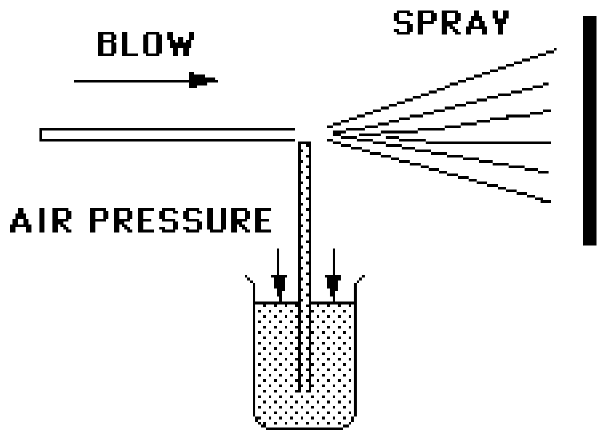
A. Fluid Motion and Pressure

1. In each of the above examples the key ingredient was the presence of a moving fluid. The fluid common to these three examples was air, however, we will see that other fluids also demonstrate the strange properties we encountered above.
2. The next time you take a shower make some observations about the shower curtain. Before the shower head is turned on the curtain is hanging vertically. But when the fast moving water is moving past the inside surface of the curtain what does it do? The curtain moves inward. Why? From our lesson on air pressure we know that when the curtain was handing vertically that there was the same pressure on one side as there was on the other side. Also from the lesson on air pressure we know that when pressure is lowered there is an unbalanced force and something must move in response to the unbalanced condition. On which side of the curtain is there lower pressure when the shower is running?
3. Situations similar to the shower curtain caused Daniel Bernoulli to propose that there is a relationship between the speed of a moving fluid and the pressure it creates.
4. Most people think that the atmospheric pressure is very high in a tornado. Actually, the opposite is true. Even though the winds are blowing fiercely, the pressure within the tornado is much lower than normal moving air on a nice spring day. From this we might suspect that Bernoulli's Principle states that as the speed of the fluid increases the pressure in the fluid decreases.

5. What if we could measure the pressure being exerted by a moving fluid? We would be in a position to see if Bernoulli was correct in his observations.
6.. We have all seen streams where water was gently moving along in the stream. Suddenly the stream narrowed. What happened to the velocity of the water passing through the more narrow portion of the stream? The water must speed up in the constricted region if the flow is to be continuous. Did the pressure exerted by the water decrease as predicted by Bernoulli?

C. Experimenting with a homemade atomizer

1. What do carburetors and perfume atomizers have in common? Almost everything except the liquid involved.
2. How does a perfume atomizer work? You squeeze the bulb and force air over the opening to a tube that is reaching down into the liquid perfume.
3. The fast moving air moves across this opening, lowers the pressure. The atmospheric pressure pushes down on the surface of the liquid perfume which pushes the perfume up the tube where it is mixed with the fast moving air. The liquid is broken into many small particles (atomized) and sprays out into the room.



4. The basic atomizer
   a.) Put about 300 mL water in a 400 mL beaker and add some food coloring.
   b.) Cut a plastic straw with a knife or scissors but leave a slight hinge connecting the two pieces. Bend the one half at a 90° angle.
   c.) Lower the vertical portion into the water. Blow through the open end of the horizontal part of the straw.
   d.) Aim the atomizer at a piece of white paper a few centimeters away. Observe what happens.
   e.) If you have difficulty getting it to spray, cut the straw through thoroughly and try moving the horizontal part slightly with respect to the vertical straw.
5. If you blow harder one time than another, what effect will it have?
   a.) Lengthen the vertical portion of the setup by using the entire length of another straw.
   b.) Blow with different intensities and see if you can detect any difference in how far up the liquid rises in the vertical straw. Did the times when you blew hardest, which would mean that the air was moving faster across the top, result in the liquid rising higher?
   c.) Does this match with what Bernoulli said? [Faster moving air lowers the pressure more at the top of the straw so that the atmospheric pressure can push the liquid up higher.]
6. We saw that as the water in a stream was constricted that the water flowed faster through the constriction.
   a.) Examine an eye dropper. If you blow through it, the air will be

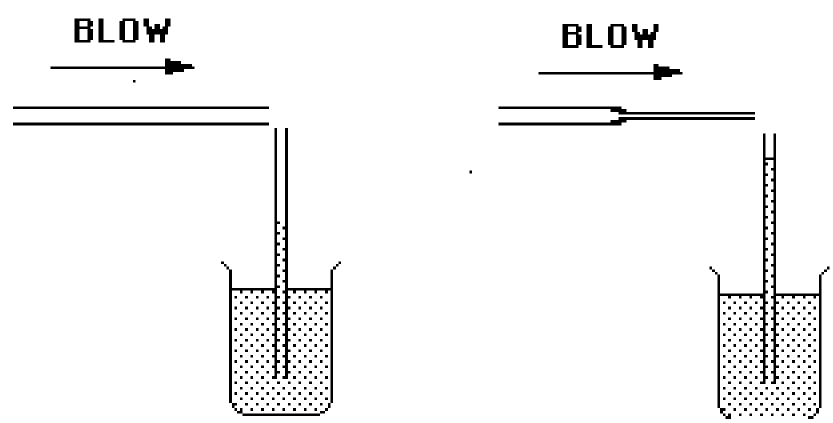
moving faster through the narrow point that it is moving through the barrel of the dropper.

b.) Rather than using a commercial eye dropper lets make one. Simply take a piece of glass tubing and heat it up in a Bunsen burner flame or a propane torch flame. After a short time the glass will start to sag in your hands. Take it out of the flame and pull on both ends of the tubing. It will stretch and be constricted in the middle. With a file score and break the constricted tubing in the middle. You now have two long needle nosed eye droppers. Adjust the length of the dropper so that the opening of the small end is only about one fourth as big as the diameter of the original tubing.

c.) Cut another piece of tubing, that has not been heated, to the same length as your needle nosed dropper.

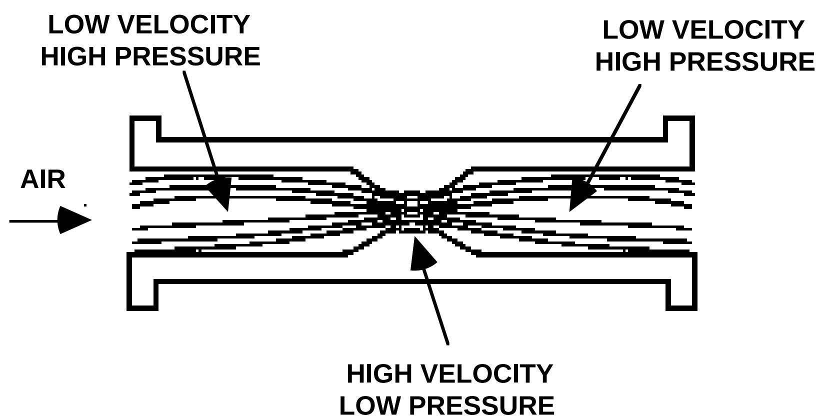
d.) We now can blow into these two droppers with the same amount of breath and feel confident that the air rushing out of the needle nosed dropper will be moving faster when it comes out than the air coming out of the normal piece of glass tubing.

e.) This time we can compare how high the water climbs in the vertical tube of the atomizer when the speed of the moving air is different.

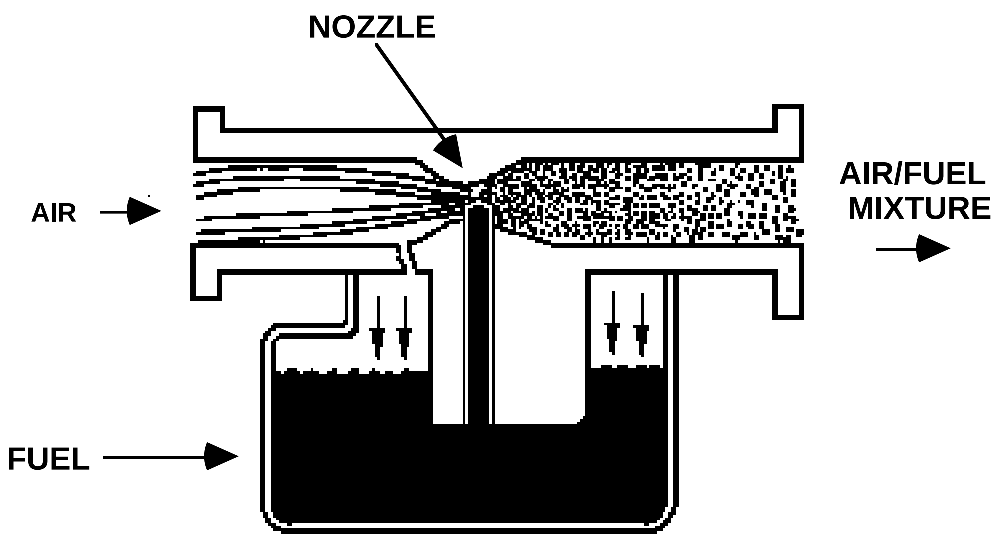


D. The Venturi tube in a carburetor

1. Using the Bernoulli principle the diagram below should be easy to understand.



2. This type of configuration is referred to as a Venturi tube. The portion of the tube where the fluid is moving the fastest is where the pressure is the lowest.
3. A simple sketch of a portion of a carburetor employs the idea of both the atomizer and the Venturi tube.



4. As the air enters the line on the left it has low velocity and high pressure. As it comes to the restricted part the velocity increases and the pressure decreases. This is the position at which the nozzle coming from the fuel bowl is attached to the air line. This lower pressure allows the fuel to be pushed up the nozzle and enter the air flow. On the other side of the restriction the velocity lowers and the pressure increases.

E. Using the Bernoulli principle to explain the opening discrepant events
1. Blowing in between the two apples that were hanging down vertical speeded the air flow on the side of the apple facing the center. This lowered the pressure on this side and the apples. Because the air pressure on the side furthest from the center did not change, the apples moved toward the center.
2. Blowing air underneath the index card lower the pressure on the under side and the card sagged. It could not be tipped over by blowing unless someone tried blowing of the top of the card. This might work. Since the pressure on the top of the card is lower providing enough air might turn it upside down.
3. No matter how strongly you blow through the funnel the candle flame will not

go out. In fact it is actually drawn toward the funnel instead of being blown the other way. How does Bernoulli explain this? The air you blow in has a tendency to flow along the inside surface of the funnel. Almost none of your breath travels down the center of the funnel. This rapidly moving air rushes along the sides and creates a low pressure area in the center. Since the pressure on the other side of the flame is higher than this newly created low pressure area, air moves toward the funnel making the flame to flicker toward the mouth of the funnel.

CONCEPT EXTENSION

A. Floating a hard boiled egg
  1. Hard boiled eggs normally sink when placed in water. Place one in a tall narrow glass.
  2. CHALLENGE: How can you lift the egg up to the surface without turning the glass upside down. You many not reach in with your hand or any tool to grab it and raise it to the surface.
  3. If there are no forthcoming suggestions from the students, tell them that all they need is water.
  4. Move the glass and egg under a water tap. Turn the water on and adjust the flow to be steady. (You need to test out what flow you need before giving this challenge to the students.)
  5. Hold the vial with the glass and egg under the water stream. The water must fall directly on top of the egg. Mysteriously the egg will rise to the water surface!
  6. Ask the students what will happen if the water stream suddenly stopped?
  7. Have students explain what is going on here. [Bernoulli's Principle says that the fast moving fluid (water in this case) cause lower pressure. At the correct flow of the stream of water there will be a pressure above the ball low enough so that the upward force of the overflowing water will cause the egg to rise to the surface. A sudden stop of the water flow will make the egg sink.]

B. Ping pong balls and funnels
  1. Place a long-stem funnel next to a ping pong ball. "I bet you can't pick up the ball with the funnel without sucking through it. You may not touch the ball with your hands or any other tools. The funnel must at all times remain above the table."
  2. Someone will surely figure out that instead of sucking air up through the funnel they need to blow air out through the funnel, especially since this is in a Bernoulli's Principle lesson.
  3. Pick up the funnel and place it over the ball and blow through the stem while picking up the funnel. The ball will come with it.
  4. As we saw when trying to blow out the candle flame through the funnel, there is a region of lower pressure in the center of the funnel. Since this is over the top of the ball the pressure is lower here that underneath. If you have enough wind you can point the funnel at all different directions and it won't come out of the funnel. Even pointing straight upward and blowing as hard as you can won't dislodge the ball from the funnel.

C. Ping pong balls and wine glasses
  1. You will need two identical wine glasses (plastic are safer) and a ping pong ball (The old party trick books say you can use a hard boiled egg, but I have never had very good luck with the egg.)
  2. CHALLENGE: Place the two wine glasses about 3 cm apart. Its a good idea to tape them down or at least have someone hold them down. Challenge a student to move the ball from one glass to the other without touching the ping pong ball with your hands.
  3. After awhile you can demonstrate that it is possible. Blow a short and hard puff of air into the far side of the wine glass holding the ball. Magically, it leaps from one wine glass to the other wine glass.

4. Blowing obliquely over the top surface of the ball does two things. It lowers the pressure on the top edge of the ball. It also directs the flowing air to the far side which bounces off the far wall of the glass down to the bottom and upward carrying the ball. Because the pressure is lower on the top of the ball, it jumps out of the glass. The harder you blow the farther apart the glasses may be positioned. [Try it; it really works!]

D. One more funnel trick

1. You will need a funnel and a coin. Hold the funnel upright and place the coin inside the funnel.
2. CHALLENGE: Try to turn the coin over by blowing into the wide mouth end of the funnel.
3. It will be almost impossible to blow the coin over without covering the spout with a finger. When the spout is covered, it is very easy to flip the coin.
4. With the spout uncovered, some of the air passes through the small spaces between the coin and the side of the funnel, tending to equalize the pressure below and above the coin. When the spout is covered air cannot get out below the coin, and more is blown across the top of the coin. According to the Bernoulli principle, the moving air above the coin has less pressure than the still air below, and tends to lift the coin slightly. Then the air catching below it flips it over.

E. The spool and the card

1. Take an ordinary index card and hold it up close to the mouth and blow against it. The card will float off toward the ground. Blow through the opening of a spool at the card. This card too will float off toward the ground.
2. Now Push a straight pin through the center of the card. With the card resting flat against the spool make sure that the pin is loosely hanging in to the hole.
3. With your finger on the pin and card raise the spool/card to your mouth and blow hard. Have students predict what will happen. When you blow hard and let go of the card with your finger the card will stick against the spool. You may aim it upward, outward, or even downward and the card will float at the surface of the spool. Of course when you run out of air to exhale, the card will fall to the ground.
4. Have students reason through this one.
5. By blowing in the hole of the spool the air is moving fast when it comes out the other end. It moves over the surface closer to the spool at this rapid pace. According to Bernoulli the pressure on this side of the card will be higher than on the other side of the card. The normal air pressure will then hold the card to the spool as long as the fast moving air is moving over the surface of the card.
6. The reason that the straight pin is needed is to keep the card from moving horizontally away from the source of the steady stream of air.

F. Some questions to ponder

1. When high-speed trains pass each other, they must slow down or their windows will be broken. Why? Will the windows be pushed into the train or sucked out. If you are standing near a high-speed train, will you be pulled toward or pushed away from the tracks? [The fast moving air between them lowers the pressure so much that windows will be pushed outward by the normal air pressure inside the train which is now so much higher than the low pressure outside the train.]
2. Are insects squashed directly on the windshield of fast moving cars, or do they rupture in the air and then splatter on the windshield? [As the air is accelerated up over the hood and windshield the pressure becomes so low that the bugs actually rupture because the pressure on their insides is greater than the lower pressure they are feeling on their outsides.]