MIND TREKKERS
Ping-pong Cannon Lesson Plan

Amount of time Demo takes: set-up 5-10 min, demo 2:00 min

Materials:
1. Ping-pong cannon
2. Ping-pong balls (40mm)
3. Empty aluminum pop cans
4. Clear packing tape
5. Alcohol/wipes
6. Razor/box cutter
7. Safety goggles and ear protection
8. Hanging curtain or other setup to catch the can and ball
9. Magdeburg Hemispheres (2)

Set up instructions:
1. Set up cannon tube on a long level table. Ensure that the firing end (the one lacking a vacuum pump hookup) is facing away from the spectating area and preferably not aimed at a solid wall. (The ping pong ball will not survive a collision with the wall. Curtains or a hanging sheet work best for catching the ball.)
2. Put on safety glasses and ear protection during the demonstration
3. Have the supplies set out and readily available for the demonstrations throughout the day.
4. Specific instructions for loading and firing cannon are listed in instructional procedures.

SAFETY!
1. Always be sure that the firing end of the cannon is pointed away from the spectating area, and will not be firing into any other populated areas. It is also recommended that the cannon not fire at a solid wall, since that will surely destroy the ball. Drop a tarp/sheet a ways away, instead.
2. It is recommended you wear safety goggles, just in case.
4. Give a heads-up to any spectators, as well as passersby/other demonstrators that you will be firing the ping pong cannon - it will be a loud, somewhat startling “bang.” A countdown is recommended.

Lesson’s big idea
The main idea behind the ping pong cannon is the power of air pressure. When we create the vacuum inside the tube (ie, remove all air), there is no pressure. Puncturing the tape allows the air to rush back in, air will attempt to fill a vacuum traveling at the speed of sound. This propagation (motion) is limited by the volume you are filling and its cross sectional area.

Instructional Procedure
1. Acquire a second demonstrator/helper.
2. Set the cannon tube on a level table. Ensure that the firing end (the one lacking a vacuum pump hookup) is facing away from the spectating area.
3. Seal the firing end with clear packing tape, ensuring that there are no air bubbles. Any bubble leading out of the circular opening can cause the vacuum to be weakened, and the demo will fail.
4. Loosely attach an empty can to the firing end with small strips of tape.
5. Gently set the ping pong ball just within the vacuum end.
6. Seal the vacuum end with clear packing tape, again ensuring that there are no air pockets leading to the edges.
7. Attach the vacuum hose to the valve on the tube. Start the vacuum pump by plugging it in; run for 20-30 seconds, or until the tape looks like it is being ‘sucked into’ the tube. The tape will be very taut.
8. Quickly turn off the vacuum pump (perhaps have a helper do this), turn the red lever to seal the vacuum and almost immediately...
9. ...declare that you are “FIRING!”
10. Puncture the tape. BANG.
11. Retrieve the wreckage, show it to the crowd, and celebrate.

**Why it works:**
The ping-pong cannon works using a very basic principle: that atmospheric pressure is extremely strong. At all times, there are approximately 14.7 pounds pushing on every square inch of every single object. We don’t notice this in our day-to-day goings-on because (A) we are large and (B) we do not live in a vacuum. There are other forces of greater concern, like gravity. When we put the ball into the tube and remove all the air, the inside of the tube is a pressure-less vacuum. Nothing is happening to the ball.

Puncturing the tape breaks the seal of the vacuum. This is why it is so important that the tape be smoothly applied at both ends; if there are wrinkles or air bubbles, the pump will suck in air from the outside, making the vacuum weak and the experiment uneventful. Allowing the air back in suddenly causes a huge rush of atmospheric pressure on the back of the ball. The ball is projected forward almost instantly, accelerated to nearly 500 mph depending on the strength of the vacuum. By the time it reaches the end of the tube, it has enough velocity to (hopefully) blast through the pop can.

Knowing all of this, we can explain the basic principles to the spectators after having set up the cannon with the tape and can.

**Assessment**
1. What do you think will happen when I puncture the tape and let the air back in?

**Addition: Magdeburg Hemisphere**
1. Take the two hemispheres and push them together.
2. Challenge a spectator to pull the hemispheres apart by grasping the handles and pulling straight outward.

**How it works:**
When the hemispheres are pressed together air is forced out of the interior creating at least a partial vacuum. This seals together the hemispheres with a remarkable force. When air is removed from the interior of the hemispheres, there is no longer any force pushing outward and the atmospheric pressure outside dominates, pushing the hemispheres together and keeping them from being easily separated.
Conclusion
In short, the ping-pong cannon is a great demonstration of the sheer force that air can have. By sealing off the ends of the tube and sucking out all the air, we create a vacuum - no pressure on the ping pong ball. When the air is allowed to re-enter the tube, the pressure is so great that the ball is literally shot out, destroying the can at nearly 500 miles per hour!

Clean Up
Clean up between demonstrations if needed. When completely finished gather all materials listed for this demonstration and make sure everything is accounted for. If something was used up, broken or damaged, let someone know so it can get replaced or fixed.

1. Set aside the destroyed can and ping pong ball
2. Remove all tape from both ends of the tube. Clean the ends thoroughly with rubbing alcohol, ensuring that as much adhesive as possible is removed.
3. Place Magdeburg Hemispheres in plastic bags to prevent drying out.

National Standards:
K-12 Content Standard B, Physical Science

References:
http://stokes.byu.edu/pingpong.htm
http://www.mcdaniel.edu/news_2281.htm
http://en.wikipedia.org/wiki/Atmospheric_pressure

Ping Pong Cannon lesson plan bullet points:
- The main idea behind the ping pong cannon is simply the power of air pressure. When we create the vacuum inside the tube (ie, remove all air), there is no pressure. Puncturing the tape allows the air to rush back in, exerting huge force upon the ping pong ball.
- When the air is allowed to re-enter the tube, the pressure is so great that the ball is literally shot out, destroying the can at nearly 500 miles per hour!