

VACUUM CANNON!

A Demonstration of the Power of Atmospheric Pressure

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ONE day, while messing around with some PVC pipe, I noticed that the bore of the pipe had about the same size diameter as that of a Ping-Pong ball. I then mused on the vacuum-powered systems that banks use to service their drive-through lanes, and an idea occurred to me. I decided to hook a vacuum cleaner up to the T of a PVC pipe—and the vacuum cannon was born!

The cannon provides a very engaging way to show students one of the variety of ways that propulsion can be achieved. It uses differences in pressure created by a shop vac to launch a projectile. Some systems achieve propulsion with the thrust of a rocket engine. In other systems, such as other types of cannons, an explosive charge pushes an object through a barrel. Through teacher demonstration of the vacuum cannon, students learn how concepts related to atmospheric pressure can also provide a power source.

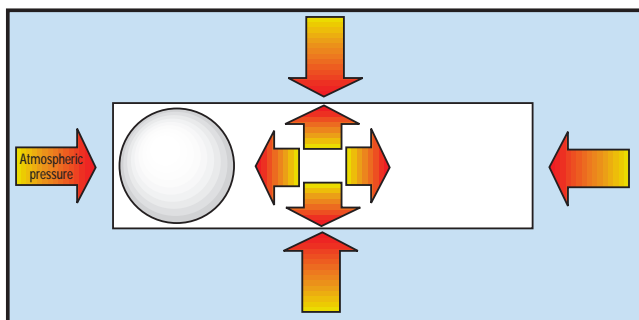


Fig. 1—Atmospheric pressure inside and outside a PVC pipe



The completed vacuum cannon

Objectives

After completing this activity students will be able to:

- apply systems thinking concepts to diagram the inputs, processes, outputs, and feedback necessary for operation of a vacuum cannon;

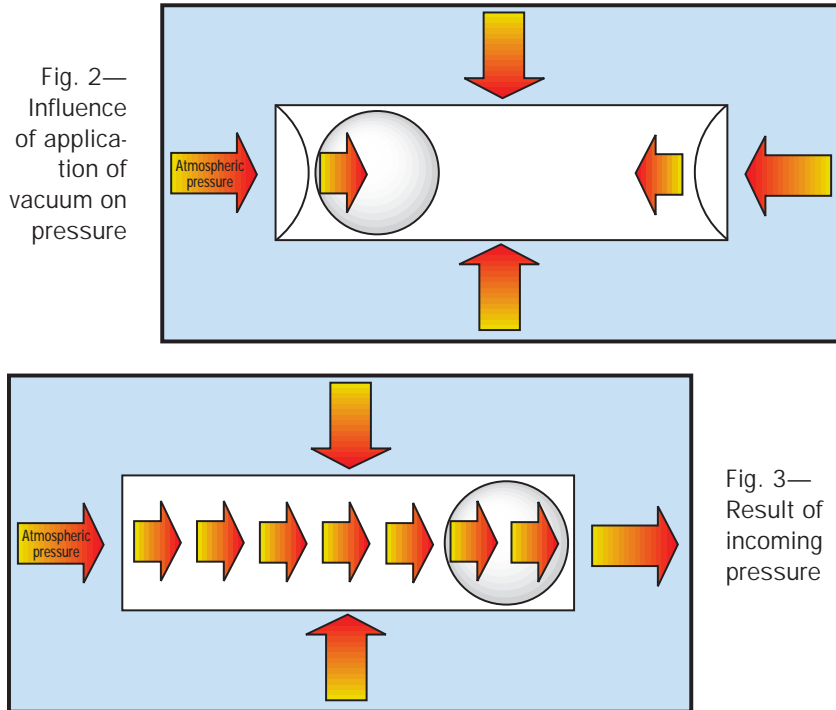
- describe how a projectile moves through a vacuum; and

- describe how a vacuum cannon operates through the application of concepts related to differences in atmospheric pressure.

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difference in pressure can then serve as a source of propulsion for an object. With the projectile sealed in the pipe, what will happen if the seal on one end of the pipe is broken? Figure 3 shows that the force of the incoming pressure will push the Ping-Pong ball out of the tube. From this concept, you can construct a simple vacuum cannon using little more than a piece of paper, a Ping-Pong ball as a projectile, some PVC pipe, a PVC “T”, and a shop vacuum.

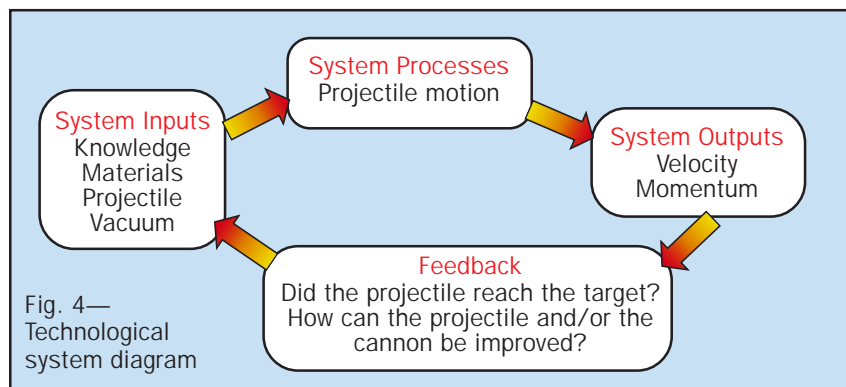
Systems thinking

All technological systems can be described on a systems model. Technology systems include inputs, outputs, processes, and feedback. The vacuum cannon also works well as a vehicle for helping students understand these concepts. The inputs of this system can be described using the diagram in Fig. 4.

Vacuum propulsion

How does this technology work? The Earth’s atmosphere consists of a large mass of gasses. We can apply this concept to create a device that will move an object.

Figure 1 illustrates that atmospheric pressure is equal on both the inside and the outside of a PVC pipe. Yet, if you use a vacuum to produce a difference in pressure (Fig. 2), the wrap that is on the ends of the pipe will begin to buckle inward due to the difference in pressure. This



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Construction Details—Cannon

1. Construct the vacuum cannon using PVC pipe as shown in Fig. 5. Make sure the bore of the PVC pipe is smooth and free of obstructions. Test the bore of the pipe with a Ping-Pong ball. The ball should move freely, with only a minimal gap between the ball and the inside diameter of the PVC pipe.

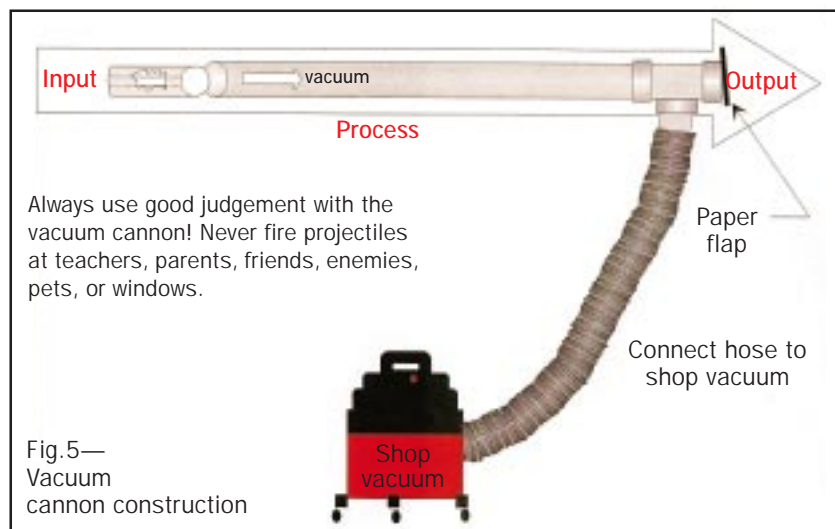
2. Attach the pipe to the shop vacuum. You can either attach the hose with a hose adapter or simply tape the parts together with duct tape. For best performance, make sure all fittings are well sealed.

3. Turn on the shop vac. Note that this will produce a vacuum on both ends of the pipe. Next, cover the end of the pipe closest to the vacuum hose with a flap of paper. The vacuum inside the pipe should hold the paper in place.

4. Place a Ping-Pong ball inside the open end of the cannon. The Ping-Pong ball should be pulled through the tube at a high velocity. When the Ping-Pong ball hits the paper it will either bounce back into the tube and into the hose or it will push through the paper flap and perhaps travel a few yards.

5. Next, modify a Ping-Pong ball by adding mass (such as pennies or washers) to the nose of the inside of the ball. How does additional mass affect the performance of the Ping-Pong ball?

6. Finally, the teacher can allow students to design their own projectiles for testing inside the vacuum cannon. What characteristics should the optimum projectile have?



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Math Extension

1. Let students experiment by adding different types and weights of mass to the Ping-Pong ball projectile. Have students collect the data then chart the results in the space provided below.

2. Have students calculate the velocity at which the object moves through the barrel.

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Tools and Materials

PVC Pipe
PVC Pipe "T"
Ping-Pong ball
Shop vacuum
Shop vacuum hose
Shop vacuum adapter
Duct tape
Pennies or metal washers
Pipe wrap
Hot-glue gun
Hot-glue sticks
Tape
Miscellaneous construction materials

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Student-Designed Construction Details—Projectile



Loading the vacuum cannon

Be sure to make your projectiles using safe materials. I constructed a projectile using foam pipe wrap, a Ping-Pong ball, a piece of PVC pipe, tape, and some pennies.

Basically the assembly has a mass of 6-8 pennies hot

glued behind a Ping-Pong ball, with the ball and pennies then glued to the pipe and pipe wrap. I then taped the entire projectile to help hold it together under the strain of bouncing off of block walls, the ground, plastic soda bottle targets, and so forth.

You may want to experiment with varying your projectile's length, but in general I recommend a total length of about twice the diameter of the pipe that you use. You may also want to experiment with the amount of mass that you add to the projectile.



Sample finished projectile

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Safety Procedures

1. Never fire a projectile without teacher supervision.
2. Never fire a projectile at a classmate.
3. Wear eye protection at all times.
4. Never attempt to catch a projectile after it has been fired.
5. Design all projectiles with safety in mind. Use soft materials in the construction of all projectiles. Projectiles should not contain any loose parts that could break apart during a launch.

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Questions (part 1)

1. In systems thinking, a technological product contains inputs, processes, outputs, and feedback. Describe in detail the inputs, process, outputs, and feedback of the vacuum cannon. Include diagrams that illustrate the concepts related to systems thinking.

2. How does the vacuum cannon operate through the application of a difference in atmospheric pressure? Draw a diagram and describe the process in detail.

3. How does the mass affect the performance of the projectile in a vacuum cannon? Why might a heavier mass perform better than a lighter mass?

4. How does the fit of a projectile in the barrel of the cannon affect its performance? What will happen if the projectile is too loose? What will happen if the projectile fits too tightly? Draw a diagram and explain in detail.

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Questions (part 2)

5. Design and document the construction of your own projectile for the vacuum cannon. What characteristics should the projectile have to successfully launch, while not posing a safety hazard? What characteristics should the projectile have to obtain the best possible performance regarding distance achieved in a launch?

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Vocabulary

System

Inputs

Outputs

Process

Feedback

Propulsion

Vacuum

Pressure

Atmospheric differences

Projectile

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Web Resources

www.towson.edu/physics/demo/fluid/2b30.html

www.xinventions.com

www.corin.com/bill/paintball/aircannon/

www.frii.com/~bsimon/backyard.html

<http://jersey.uoregon.edu/vlab/Cannon/>

Print Resources

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