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Citation: The Physics Teacher **47**, 252 (2009); doi: 10.1119/1.3098217
View online: http://dx.doi.org/10.1119/1.3098217
View Table of Contents: http://aapt.scitation.org/toc/pte/47/4
Published by the American Association of Physics Teachers

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Plastic Syringe Vacuum Cannon

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While working for Keio Academy of New York,[1] I attended the 2003 and 2004 AAPT Summer Meetings. While I saw many interesting experiments at these meetings, I was particularly impressed with the Ping-Pong Vacuum Cannon[2] demonstrated by PIRA.[3] I was so taken with the cannon that I constructed my own upon returning to Japan.

At first, I made a Ping-Pong cannon of acrylic pipe. Using two light sensors, I found the exit velocity of a Ping-Pong ball to be about 280 m/s when launched from a 3-m pipe. This value was comparable to the values obtained by others who have experimented with the cannon.[4-7]

When I demonstrated the apparatus at Yokohama Physics Circle, its performance won the applause of all the participants. However, I was disappointed to hear one participant whisper that he felt it would be a little too big to demonstrate in his class. That motivated me to develop a small vacuum cannon that could be used in a variety of settings.

My first cannon consisted of a 30-ml plastic syringe (i.d. 23 mm), #6 cork test-tube stopper (maximum diameter 22.5 mm) (Fig. 1), and a thin plate that served as an air-tight seal. After cutting off both ends of the syringe, I inserted the cork in the syringe and placed a thin rubber plate over one end. The pressure inside the syringe was then reduced by rapidly removing the piston (Fig. 2).

Fig. 1. Syringe, cork stopper, and sealing plate.

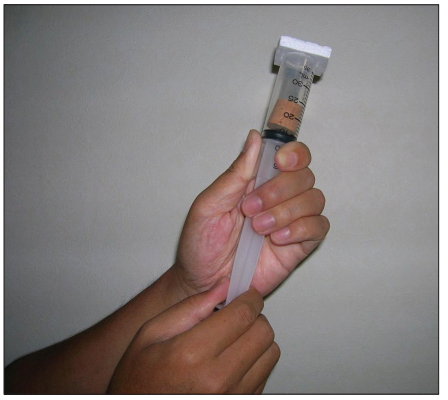

Fig. 2. Removing piston to launch cork.

In theory, the cork should have been pushed out of the syringe by the air rushing into the evacuated tube. Instead, the rubber plate interfered with the motion of the cork. Even a very thin 1-mm rubber plate caused the cork to rebound. I needed to find a lighter plate to serve as a seal.

A student's suggestion solved the problem. As luck would have it, he was using a hard Styrofoam (beadboard) plate as an air-tight seal in another physics experiment and I thought it might serve as a low-mass cap for the cannon. With the hard Styrofoam plate as a seal, the cork was launched with vigor (ordinary light Styrofoam does not provide a satisfactory seal)!

I then experimented with a 140-ml plastic syringe (i.d. 37 mm) and a #12 cork test-tube stopper (maximum diameter 36.5 mm). I found that considerably more force was required to remove the plunger from larger syringes, with no significant increase in exit velocity.

Next, I recorded the launch of a #6 cork test-tube stopper on video. Based on an analysis of the video, the velocity of the cork was found to be 15 m/s. While the exit velocity obtained with the syringe cannon is nowhere near that achieved with its much larger acrylic counterpart, the smaller cannon does demonstrate the effects of unbalanced air pressure in a clear and engaging manner.

DOI: 10.1119/1.3098217

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PACS codes: 01.50.My, 51.00.00