[Iowa Science Teachers Journal](https://scholarworks.uni.edu/istj)

Volume 13 | Number 1 Article 2

1976

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Introduction

Having had success using a student constructed catapult last year in my physics classes in demonstrating the principles and mathematics of projectile motion, I was ready to repeat the experience, when a student reminded me of a cannon I made when I was younger.

Construction of the cannon is outlined in Figure 1 (drawn by student Ed Isenberg) and the materials required are listed below:

1. Five pop cans
2. One tennis ball
3. One roll of tape (masking or rubber)
4. One can of lighter fluid
5. One punch

To operate the cannon, the cannoneer injects about 5 cc of lighter fluid into a small hole at the bottom of the cannon, swings the cannon in an arc to vaporize the fuel, loads the cannon with a tennis ball, aims the cannon, and ignites the vaporized liquid to fire the cannon, preferably using a piezoelectric starter available from Edmund Scientific Company or a local electric supply company. Care should be taken to emphasize the following safety precautions:

1. The cannon should be wrapped with at least two layers of tape to prevent splitting.
2. The persons holding the cannon should wear asbestos gloves (Fig. 2).
3. Cotton should be placed in the ears of the cannoneers.
4. Only lighter fluid should be used as a fuel.
5. The cannon should only be fired outdoors in an open field.
6. Safety glasses should be worn.
7. The cannon should only be fired during classtime with instructor permission.

Figure 1.

Instructional Procedure

After completing instruction in trajectory theory in my physics classes, each class went outside to demonstrate the cannon. A launch site was selected in a nearby field and each student was assigned a specific task such as timer, range measurer, protractor angle measurer, recorder and cannon launcher. The instructor served as consultant and range officer. Measurements were taken and related to the following types of launch.

Figure 2.

Vertical Trajectory

To study vertical trajectory, the cannon was fired vertically (Fig. 3). Total flight time was measured by three observers with stop watches and the average flight time was recorded. Discussions were held on how the vertical height (h) of the trajectory and the launch velocity (v_L) could be computed from the following sample data.

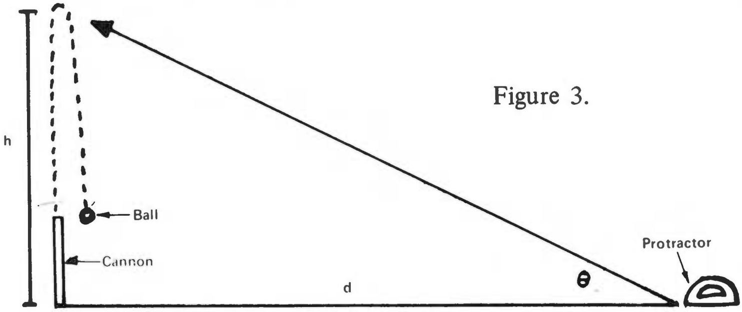

Figure 3.

Sample data: Average flight time is six seconds.

$$h = 1/2\, gt^2 \qquad (1)$$
$$h = 1/2\, (32\ ft/sec^2)\ (3\ sec)^2 \qquad (2)$$
$$h = 144\ ft \qquad (3)$$

$$v_L = gt \qquad (4)$$
$$v_L = (32\ ft/sec^2)\,(3\ sec) \qquad (5)$$
$$v_L = 96\ ft/sec \qquad (6)$$

It was also discussed as to how a double check on trajectory height could be made if an observer stood at a known distance (d) from the launch site and measured the angular height (θ) of the trajectory with a protractor (Fig. 3). Computations were as follows:

Sample data: θ is 55° at a distance of 100 ft.

$$\tan\theta = \frac{h}{d} \qquad (7)$$
$$h = (100)\,(\tan 55^\circ) \qquad (8)$$
$$h = 142.8\ ft \qquad (9)$$

Horizontal Trajectory

It was shown that a projectile fired at a vertical height of four feet (Fig. 4) takes 1/2 second to strike the ground regardless of launch velocity and that launch velocity (v_L) can be independently checked again by measuring the range (r) and using the following computations.

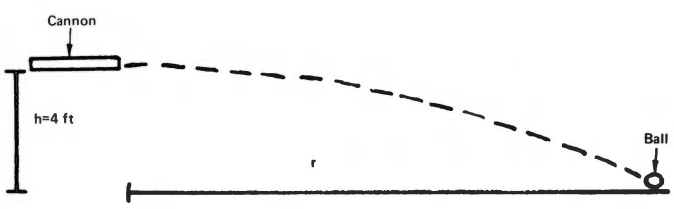

Figure 4.

Sample data: Horizontal range (r) is 48 ft.

$$v_L = \frac{r}{t} \qquad (10)$$

$$v_L = \frac{48 \text{ ft}}{1/2 \text{ sec}} \qquad (11)$$

$$v_L = 96 \text{ ft/sec} - 66 \text{ mph} \qquad (12)$$

Angular Trajectory

It was pointed out that additional information concerning predictions of the range (r) could be made for angular launches (Fig. 5). Having established the launch velocity (v_L) to within 10% accuracy, the cannon could be fired at various angles and the range (r) predicted by making the following computations.

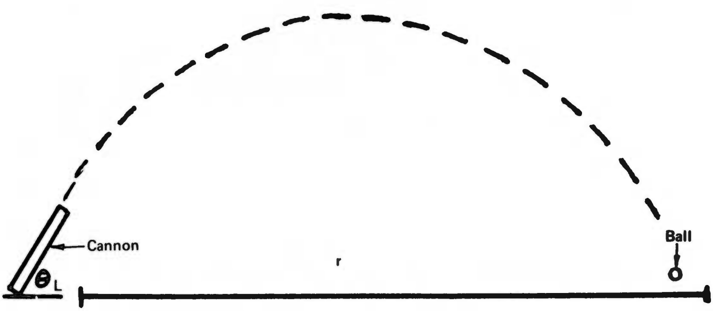

Figure 5.

Sample data: Launch angle (θ_L) is 45°.

$$r = \frac{(2)(v_L)^2}{g} (\sin \theta_L)(\cos \theta_L) \qquad (13)$$

$$r = \frac{(96 \text{ ft/sec})^2}{32 \text{ ft/sec}^2} \cdot (2)(\sin 45^\circ)^2 \qquad (14)$$

$$r = 288 \text{ ft} \qquad (15)$$

After spending two days in the field and one follow-up day in class, I presented the students with the following rules for an upcoming Can-On-Can Cannon Contest:

CONTEST RULES

1. Three categories of cannons could be entered:
   a. Four-can cannons
   b. Five-can cannons
   c. Unlimited – different number and kinds
2. Only lighter fluid would be used as fuel.
3. Projectiles were to consist of standard Lawn Tennis Association tennis balls.
4. Winning entries would be those cannons with the greatest firing range.
5. Ignition dates were two weeks after the contest announcement.

Discussion

During the two weeks assigned for cannon construction, the class responded enthusiastically and it was soon discovered that many of the ninety students had their own pet theories concerning cannon design. Fifteen cannons were constructed in the five physics classes.

Some students put the ignition hole in the very bottom of the cannon while others decided on location of the hole in the side. Some cut off the entire top of the bottom can assuming that an entirely open chamber was necessary for maximum thrust, while others perferred just the tab opening. Some placed the tennis ball in the top can while others designed theirs so that the ball rested toward the middle of the chamber. Some students, in the unlimited class, made the top can out of the tennis ball can so that three projectiles could be stored in the end of the cannon. We had one design which included two cannons side-by-side which propelled two balls with a single ignition. The ultimate in the unlimited class was "Big Bertha" consisting of 13, three-pound coffee cans, using a taped smaller can as the projectile. Four girls succeeded in launching this projectile an unbelievable 245 feet.

The variety of designs was exceeded only by the number of mechanical and thermal expansion theories created by students to explain why some designs had further ranges than others. Ranges of 250 feet were consistently attained by the cannons fired at 45-degree launches. Since these firings, we have made a launcher which holds the cannon while exposing only the firing hole. The piezoelectric starter fits into this hole and this greatly reduces the incidence of slightly burned fingers which resulted from earlier firings using matches. Actual ranges attained, fell short of theory by 5 to 10%. This led nicely into a discussion of air resistance which varies as the square of the launch velocity.

Conclusion

By using this simple, inexpensive cannon, many fundamental principles of projectile theory were demonstrated and tested. In addition to teaching the fundamentals of projectile physics, the physics of design was also introduced. As a result of this activity, the Cannon Design Contest is an annual event and the Science Club at Central High School has started a Cannon Corp that fires cannons, minus projectiles, at football games. Most teachers and students will get caught up with the challenge of cannon design theory and get a taste of physics in action through application of sound physical principles.

Editorial note: The ISTJ Reviewing Board cautions teachers to recognize the potential hazards involved in this activity which, if properly supervised, dramatically and successfully demonstrates the principles of projectile physics. Correspondence with the author indicates that the cannons discussed in this article were fired a total of 50 times over a two-year period without serious mishap, the only injuries sustained were slightly burned fingers prior to the use of the piezoelectric starter. The hazards faced in this article are similar to those confronted in amateur rocketry.

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Quickies

Joe Moore of the ISTJ Reviewing Board and Science Consultant for the Muscatine-Scott County School System has suggested that the ISTJ devote a portion of the journal to brief notes concerning ideas that facilitate classroom science instruction. We will give the suggestion a try.

If you have discovered or tried something in your classroom that has made your instruction more effective or easier, share it with other science educators by typing a brief note and sending it to Editor, ISTJ, Biology Department, University of Northern Iowa, Cedar Falls, Iowa 50613. Be sure to include your name and school system so that proper credits may be given in the journal if your idea is accepted for publication. Ideas for any level of instruction are appropriate. Come on you science teachers get those cards and letters rolling in.