

The Design and Testing of a Catapult

Eers²

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Executive Summary:

The catapult, an ancient design that was created by primitive engineers, was used effectively during war to break down nearly indestructible walls. Using the specifications that were given a catapult was designed and built to solve the problem of hitting a target with a golf ball from three meters away. Using engineering techniques and cost effective ideas, a design was created that is visually appealing and inexpensive to construct. This design was placed through many extreme tests during and after the prototype testing. A final design was attained, which will be competitive with alternative designs.

Introduction:

In deciding the type of design that was needed for this project many ideas were drawn out on paper. Many feasible designs were considered. The problem was to design a catapult that would launch a fifty-gram golf ball a distance of three meters. The catapult had to fit in the volume of a 1.5' X 1.5' X 1.5' box. The design also had to maximize accuracy for it had to hit a target that was placed on the ground at the end of its trajectory three meters away. Safety was considered in the designing as well as durability and adjustability.

Using AutoCAD the sketches were developed into a clean and understandable blueprint for production. Next the workshop was used to create a rough prototype to test during the prototype-testing period. Placing second to last at the competition, there was much improvement that needed to be done to the prototype to earn more respectable scores. The revisions were completed and the final catapult met all expectations and specifications.

Methodology:

Initial Ideas

The initial stage of the catapult design was done just as all engineering projects should start out; a team of engineers exchanged possible ideas. Ideas concerning the catapult were discussed and recorded in the log book. It was decided the base would be at a maximum allotted measurement so that during the arm movement, the catapult would stay planted firmly on the ground. On the matter of the actual launching the device, there were some differences. Ideas ranged from counterweights to tourniquet cords to metal springs. All ideas were taken into consideration, but after some discussion, it was decided that a metal spring or coil would prove to be the most effective way of having a consistent force applied to the actual trajectory object, thus there would be a lack of inconsistency applied to the catapult and safety would be observed. Next, there was the idea of stop bars, actual attachments of the arm, what material the arm and catapult would be made from, and how the entire catapult would be constructed.

Taking into consideration the actual aspects of the competition, a general idea was ascertained for arm position and where and how it would be attached. The arm would measure a little over the maximum height standard, if the arm were to be standing upright, and it would be attached back to an eyehook. The arm (consisting of $\frac{3}{4}$ inch PVC pipe) would be attached to a tennis ball, which was halved, for the trajectory. Inside the halved tennis ball would be glued a halved racquetball so that during acceleration of the arm, there would be no interference from any of the screws or bolts with the golf ball. The arm would be braced in place by two equilateral triangles, and a dowel rod would be used as the stop bar. From here, the building process could begin, and trials could be observed.

Actual Building Process of Prototype

The base was cut from a piece of plywood, which remained the same from the initial idea. The decision was made that the catapult arm would be held up and braced by four pieces of wood, forming two triangles on opposite sides of the base. This design would maximize the idea of strength in a triangle and proved to be most effective. The triangles were formed by cutting angles into the ends of two by fours with a power saw. Next, the arm was established. A last minute change was made on the actual material of the arm; instead of normal PVC pipe, much thicker electrical PVC pipe would be used. A hole was drilled at the top and bottom (for the cup and attached eyehook), and the halved tennis ball and racquetball were placed into position. A two-part epoxy was used to glue the racquetball into place; the entire cup with a golf ball inside was wrapped in rubber bands so that the inner cup would not move and was left to dry over night.

The triangle braces were attached to the base, and holes were drilled so that the arm and its axis could be positioned. The axis about which the arm rotated was a $\frac{1}{2}$ "X18" metal threaded dowel rod. The axis and arm were placed into point and attached to the spring via an eye-hook.

The required force needed to project the ball the required distance was attained by placing blocks at the back of the board, stacked, to add height to the position of the second eye hook. The spring was then attached to the arm's eye-hook and to the backboards.

Last, the position of the stop rod was determined. Trials showed where the general area of the stop rod should be, and after screwing the dowel rod into position it was time for actual trials.

The trials revealed that the spring proved highly ineffective in applying enough force to project the golf ball. The spring was often sporadic and unsafe. Bungee cords were purchased and replaced the springs. During secondary trials the bungee proved more effective than the spring and was kept for the final product. All that was left thereafter was the actual competition trial.

Final Revisions and Product

After the outcome of the first major test trial, it was decided that the catapult would have to undergo some major changes. Stability and consistency were two major issues that needed corrected. In addition, the revisions made to the prototype would serve as the final product, thus aesthetic value and safety needed to be taken into consideration. The base of the final version stayed the same. The triangle braces were used as well; however they were strengthened by the addition of dowel rods between them for support. The axis and arm were the two areas where adjustments had to be made. The axis had an addition of nuts to maintain the consistency of where the arm would be positioned, so that during acceleration, the arm would not move out of position. The arm had numerous holes drilled into it so that, depending on where the golf ball hit on target, the cup could be adjusted to reach the target.

In the final design where the arm pivots on the copper bushing was inserted to reduce friction and make the arm move more smoothly. Areas where sharp ends were apparent were sanded or covered to make sure that any personnel would not be harmed by brushing up against, using, or simply being around the catapult. The edges were beveled to add visual appeal and a smooth edge to avoid any splinters or other injuries. Rather than plywood the final base was cut from a poplar board, giving the catapult added weight and stability. The final product was made of a higher quality wood, and stained to be marketable and aesthetically pleasing.

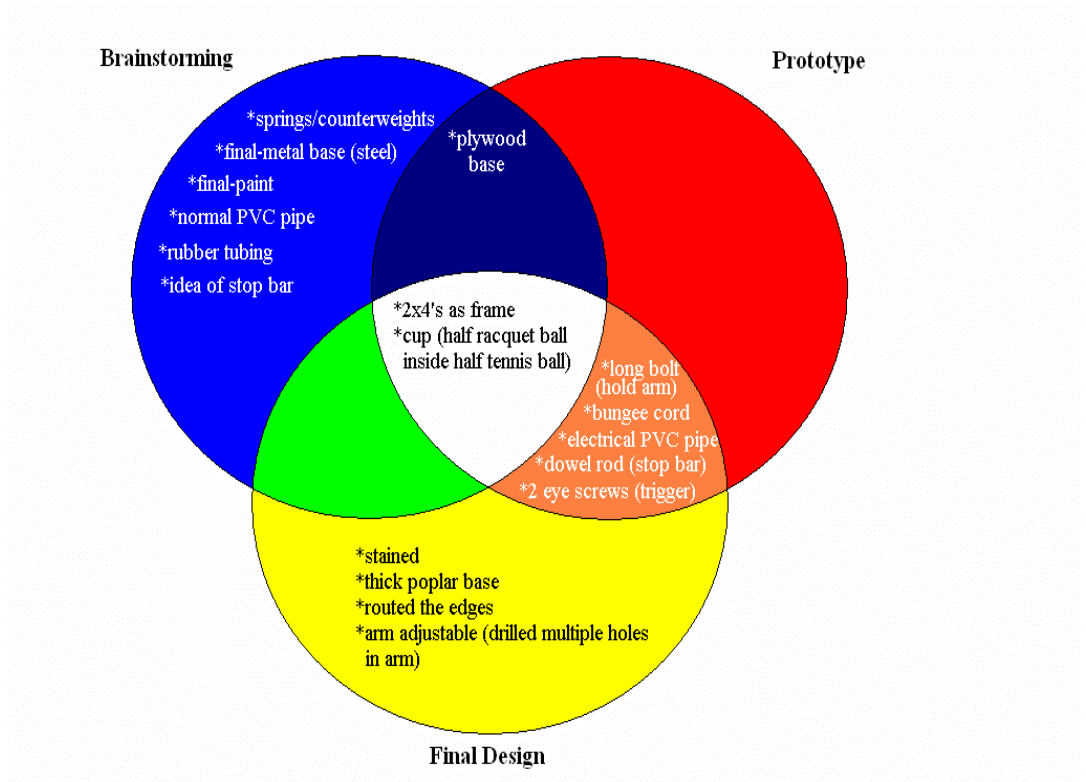


Figure 1: Summary of Design Cycle

Figure 1 is a Venn diagram that visually represents the design process. The blue circle represents the brainstorming phase, the red circle represents the prototype phase, and the yellow circle represents the final design. The white area in the middle shows the characteristics that remained constant throughout the design process.

	Oct. 24	Oct. 27	Oct.29	Oct. 31	Nov. 6	Nov. 7	Nov. 12	Nov.13	Nov. 14	Dec. 4
Brainstorming										
Design Prototype										
Build Prototype										
Test Prototype										
Prototype Test Day										
Redesign Catapult										
Build Final Product										
Test Final Product										
Oral Report										
Design Fair										

Figure 2: Summary of Time Spent

Figure 2 is a Gantt chart that demonstrates the time spent on the project. The grey areas represent the subject of the project that was attended to on the given date.

Results and Discussion:

The prototype had less than desirable results, so many revisions and tests were done to improve the overall design and results. The final product demonstrates accuracy and precision with an aesthetically pleasing appearance. Also the finished product is safe and adjustable.

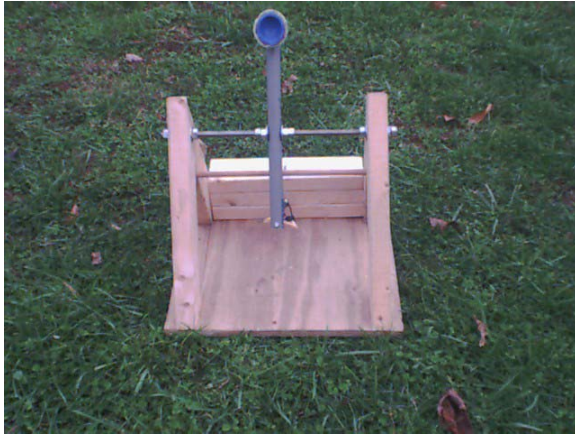


Figure 3

In Figure 3 the prototype is shown from a frontal view. The racquet ball cup is easily seen nested inside the tennis ball. The arm is grey electrical PVC pipe, the base is a plywood sheet, and the axis upon which the arm is attached is a threaded metal dowel rod.



Figure 4

In Figure 4 the side braces are easily seen. They are constructed from two-by-four boards cut at angles and dowel rods secure them together. Screws hold them to the base, forming an equilateral triangle.

Table 1: Results from Prototype Test

	Trial One
Shot One	0
Shot Two	50
Shot Three	50
Total	100

The prototype was ranked 6th place out of eight competitors. Table one shows the results from the prototype test in class. The first shot did not hit the target area at all; it was about three feet too high. The angle of the catapult was increased before the next shots were released. Shots two and three each earned fifty points. The total of the three shots was one-hundred points out of a possible three hundred.

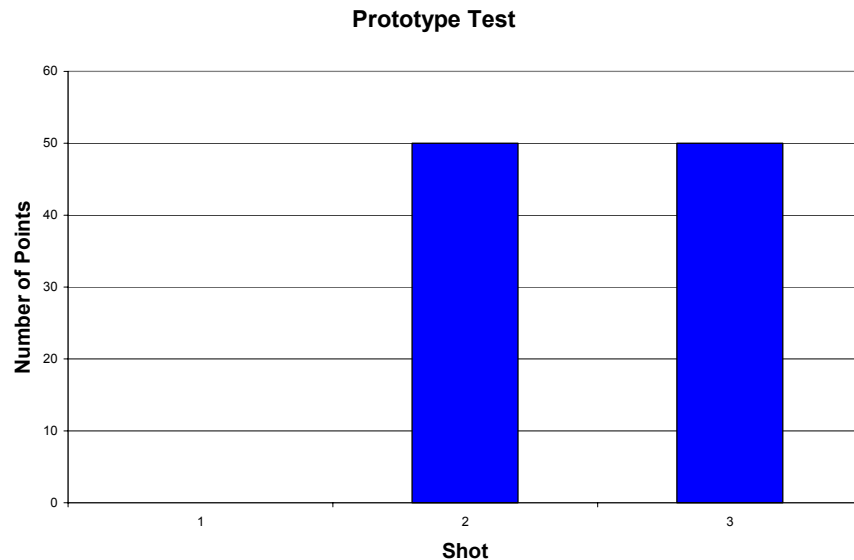


Figure 5: Prototype Test Data

Figure 5 is a graphic demonstration of the point values earned by each shot fired in the prototype test. The first shot missed the target area, therefore receiving zero points. The second shot earned fifty points and the third shot also earned fifty points.

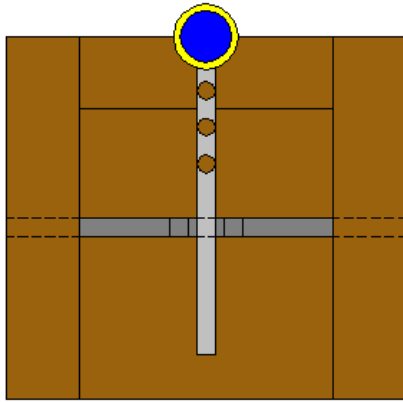


Figure 6: Top View

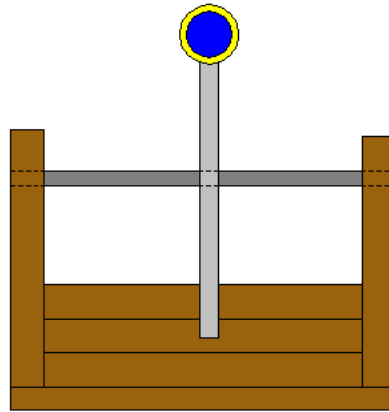


Figure 7: Front View

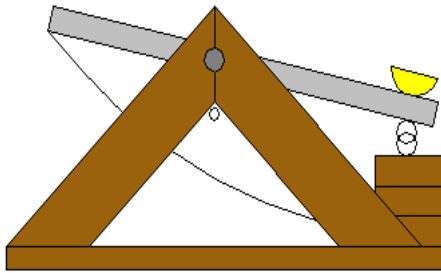


Figure 8: Side View

Figure 6 through 8 are AutoCAD drawings of the final catapult design. Figure 6 is an aerial view from the top of the catapult. The adjustment holes in the arm are easily seen. Figure 7 is the frontal view; this view demonstrates the three two-by-fours used to increase the height of the bungee attachment point. Figure 8 is a side view that demonstrates the equilateral triangles used to strengthen and frame the catapult. Also the bungee cord is seen attached to the arm and the two-by-four block. The eye-hooks used for the trigger mechanism are shown in Figure 8.

Table 2: Results from Final Catapult

	Trial One	Trial Two	Trial Three
Shot One	90	80	90
Shot Two	80	80	80
Shot Three	80	100	90
Total	250	260	260

Table 2 holds the test results from the trials of the finished product. Three trials were completed; each trial contained three shots at the target. Trials two and three both earned 260 points, which is 160 points above the prototype's score. The first trial totaled 250 points. The only bull's eye was recorded in the third shot of trial two.

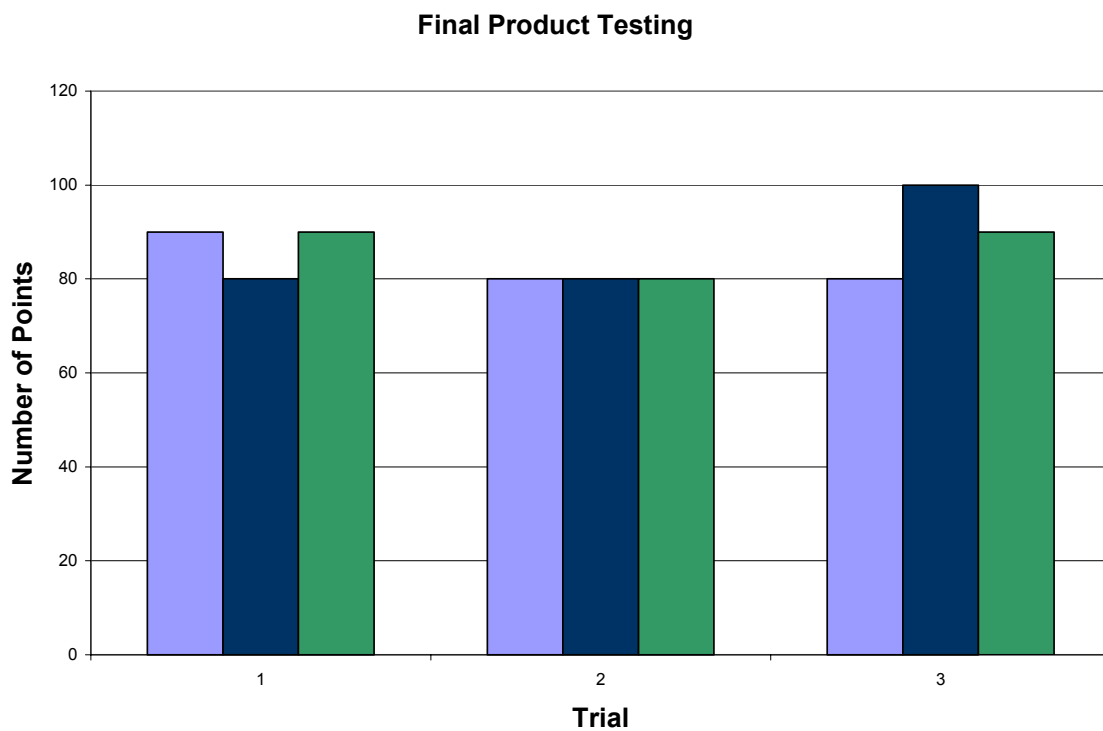


Figure 9: Results from Final Product Tests

Figure 9 graphically represents the data gathered from the testing of the final product. The graph contains information gathered from three trials. Each trial consists of three shots. The data for the first shot is represented by lavender, the data from the second shot is represented by dark blue, and the final shot is green on the graph

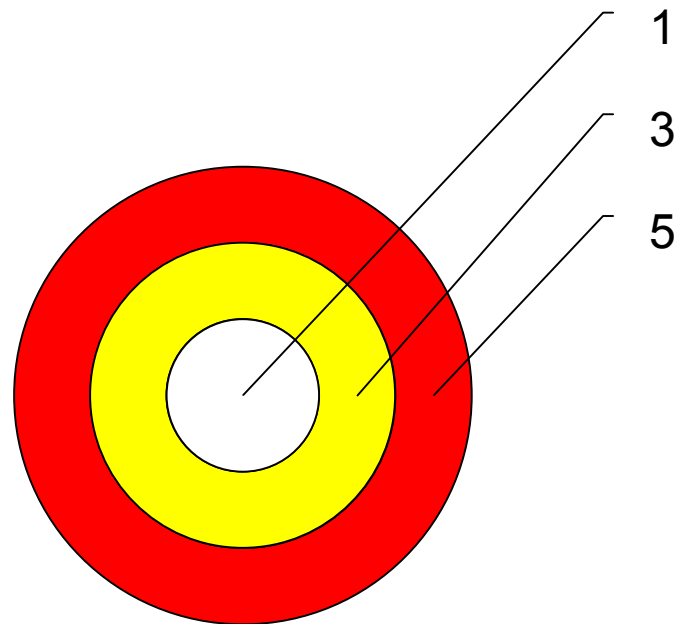


Figure 10: Distribution of Shots

Figure 10 shows the distribution of the shots fired during the three test trials of the final catapult. The white middle ring represents the bull's eye, which was struck once by the golf ball. The next ring is yellow and it was hit three times during the three trials. The point value for the yellow ring is ninety points. The outer most ring pictured in figure one is red, which has a point value of 80 points. The golf ball struck the red area five times.

The results from the final product were greatly increased from the results that were gathered with the prototype. The adjustments that were made to the prototype improved accuracy and adjustability of the catapult. The holes drilled into the arm allowed the cup to move down further correcting the problem of overshooting that occurred with the prototype. The new bungee cord also added the consistency that is evident in the final testing.

Conclusion:

This project intended to teach the design process. Engineering groups were to construct a catapult (no larger than 1.5'X1.5'X1.5') which would launch a 50 gram object towards a target 3 meters away. This target would be 20.5 inches off the ground and consist of a bull's eye that is 3 inches in diameter. The goal was to hit the target with as much accuracy and precision as possible.

Common knowledge, resources, and brainstorming were used in order to accomplish the design objective. As the process went forward, the poor and not feasible ideas were thrown out and the quality ideas were examined with depth.

Documentation was very important in designing the catapult, because it allowed illustrations from the beginning to end. Also a list of materials, tests, and redesigns were documented for a concrete layout of the process followed to the final design. The documentation especially made the flaws much easier to visualize, and also the changes that were administered to the catapult were easily seen in the new sketches.

As the progress is viewed from brainstorming, constructing, and documenting the catapult, it is evident that the design process is a valuable tool with which every engineer should be familiar and confident. Although this design was not too complex, it will be the foundation of the future designs engineers create.

The catapult build for this project succeeded in meeting all requirements and being accurate.