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ENG 10

Mouse trap Boat

Purpose: The goal of this project is to build a boat powered by the spring tension from a mousetrap to achieve the greatest amount of distance traveled while minimizing the cost of materials used. The project's success will be determined by comparing the ratio of the distance traveled by the boat to the amount of money spent on materials.

Concepts: Initial designs explored the idea of double and single propulsion systems. In addition, alternate designs inspired by the airboats used in Florida for traversing swamps were considered with the goal of avoiding water resistance as much as possible by gliding over the water's surface. Though this concept would provide little water resistance, the design was axed due to the requirement of maintaining a high enough speed to keep the nose of the boat angled upwards.

To determine the amount of energy we were given by the mousetrap, the speed at which the mousetrap closed was calculated using the following formula for circumference:

$$c = 2r\pi$$

Where c is the distance travelled by the outer part of the metal trap, and r is the length from the center of the trap's spring to the outer part of the metal trap.

$$\frac{1}{2}c = r\pi$$

$$c = r\pi$$

The measurement from the center of the spring to the end of the trap was found to be 1.75'', and thus the distance travelled by mousetrap is about 5.5''.

Additionally the action of the mousetrap was filmed at 240 frames per second and it was found that it takes 4 frames for the trap to snap shut. Using the formula:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

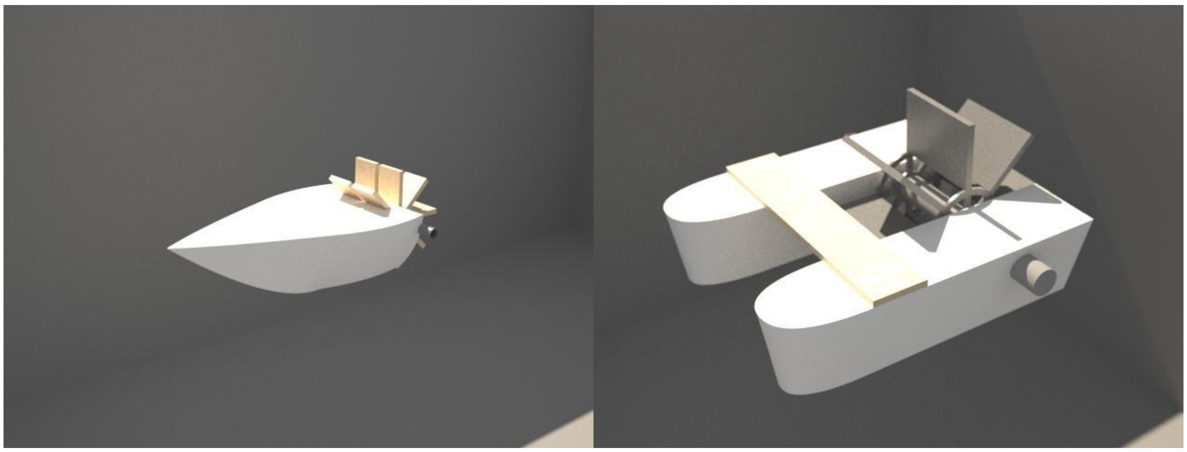
The speed of the trap was found to be

$$\text{speed} = \frac{5.5''}{4\text{frames}/240\text{frames}/\text{second}} \approx 330\ \text{inches}/\text{second}$$

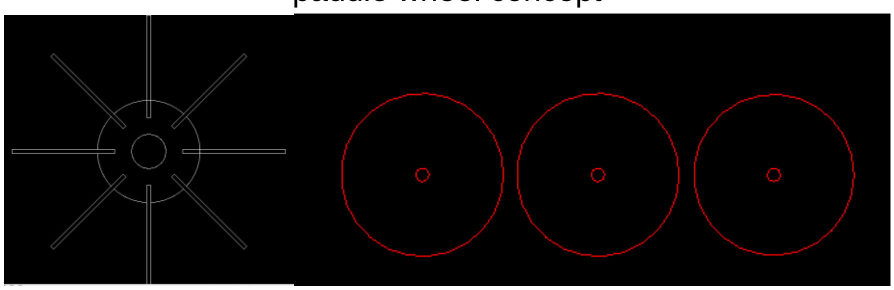
Due to the nature of the speed at which the trap closes, it was decided that the design should have a relatively large single-paddle wheel, with a long torque bar, held together by a two-part body, and guided by small fins under the boat.

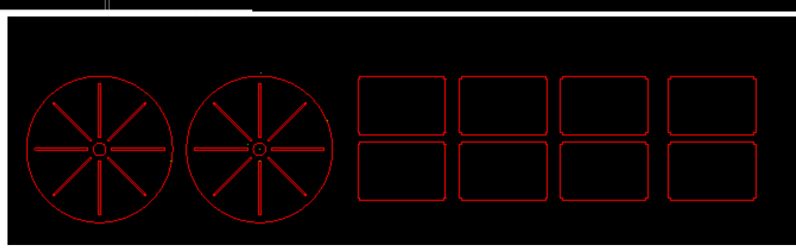
<u>Function</u>: A paddle wheel sits in the center of the boat assembly, partially submerged in the water. A string is wound around the axle of the paddle wheel while the other end of the string is tied to the end of the metal rod that is attached to a mousetrap. As the metal frame is retracted, potential energy is stored in the spring. Once the trap is released, the potential energy converts to kinetic energy, moving the metal rod forward whilst unravelling the wounded string from the axle ; thus, moving the paddle wheel and advancing the boat forward.

<u>Initial Design</u>

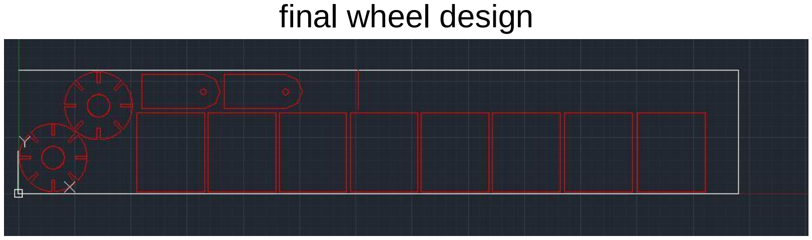


paddle wheel concept





final wheel design



Construction

Materials Used

- one 36’’long, 5/32’’ diameter metal rod (for propulsion)
- one 12 x 1.75 x 4 in. block of styrofoam (for body)
- one 8’’ x 2’’ x 1/8’’ piece of Balsa wood (for body support)
- eight pieces of 3’’ x 3.5’’ x 5/16’’ MDF wood (for paddle blades)
- two 3’’ diameter circles of Balsa wood (for paddle wheels)
- two 1/4’’ diameter 8’’ long wooden rods (for axle and body support)
- three 3.5’’ x 1.5’’ pieces of Balsa Wood (for axle mounts)
- 5 yards of craft string
- 1 ‘Dead End’ mousetrap
- 3” x 24” x 1/32” Walnut wood
- 8” x 2” x 1/8” Basswood
- 50’ of fishing line
- 0.6’’ wide rubber band
- heavy duty double sided tape

Tools used

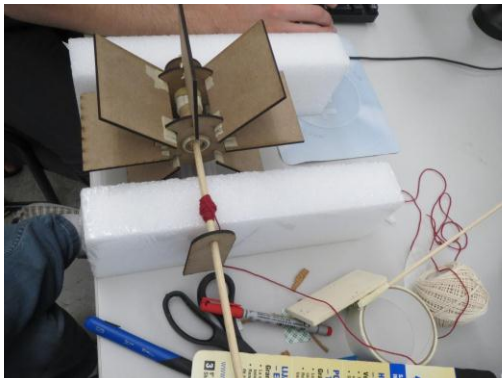
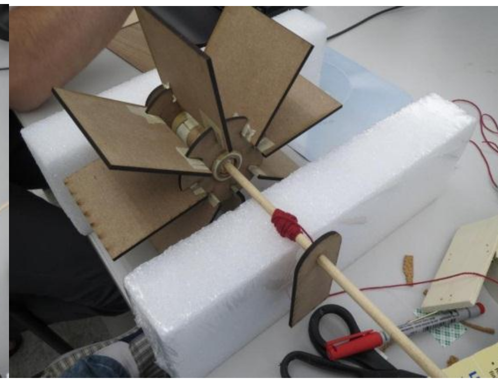
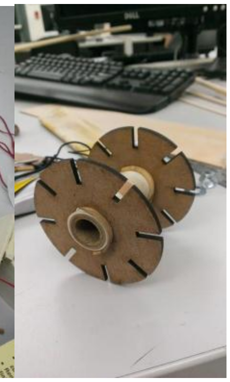
- Sandpaper
- Superglue
- Hot glue gun
- Crafting knife
- Ruler
- Scissors
- Laser cutter
- AutoCAD

Body: The body is the base of the boat that holds all components and contains the most buoyant properties. The body was chosen to be made of styrofoam, because it is a lightweight material that floats and can withstand a reasonable amount of weight on it.

The source material for the body was a 12’’ x 3’’ x 2’’ brick of styrofoam. The brick was cut in half height-wise to become two smaller blocks of 12’’ x 1.75’’ x 2’’ each. A front and top of the boat was designated from the two halves, and the bottom of each of the halves was shaved into a curved form using a saw to cut chunks off and a ruler to scrape off the remainder of the styrofoam until a level rounded edge was achieved. This was done in an effort to streamline the boat and reduce the amount of friction the water exerted on the body as it traveled through the water.

After printing the paddles, wheels, and axle holders, along with a 8’’ long, 1/4’’ diameter wooden rod was used to brace and space the two halves of the body. The piece was secured onto the styrofoam using hot glue 1 inch from the bottom on the back of the boat.

Paddle Wheel: The paddle wheel is the mechanism that drives the boat in a forward by displacing water. The paddle wheel is made of Medium-density fiberboard (MDF), because unlike wood, MDF does not have knots or a grainy structure. This helps in easy cutting and fitting of this material.

Slabs of MDF and Balsa wood were laser cut to create the pieces for the paddle wheel. The pieces of MDF were fitted into the pre-cut notches on the wooden disks, ensuring the wooden disks lined perfectly along the edge of the rectangular pieces. In order to ensure the pieces did not fall out of the sockets, hot glue was applied at each adjoining edge from the inside using a glue gun.

The 1/4’’ diameter wooden rod was fitted through the center of the paddle wheel, leaving 1/2’’protruding from one end. This serves as an axle that rotates the paddle wheel in the water. Hot glue was also applied along the wooden rod where the paddle wheel disks contact it, creating a stronger bond for rotating the paddle wheel without slipping.

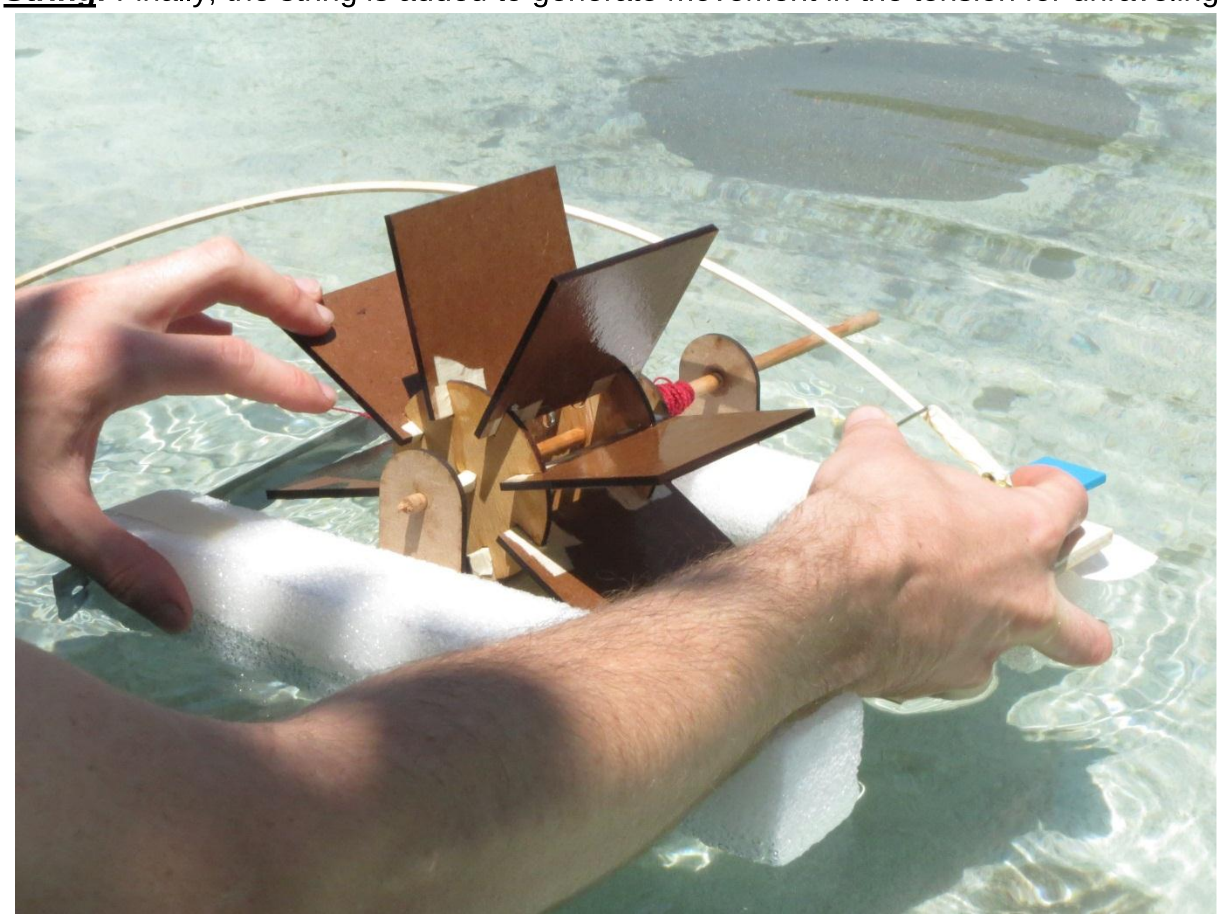
About an inch from the long part of the axle, the rubber band is wrapped around the wooden rod once and then cut. The piece is then adhered to the rod in the same location using superglue. This serves as a gripping mechanism for the string so it doesn't slide or unravel as it is pulled by the torque applied by the rod attached to the mousetrap. It also makes it easier to wind the string without tying it, giving more room for the string to unwind freely and keep the boat in motion through momentum even after the mousetrap has closed.

Mousetrap: The mousetrap's function is to act as the "power supply" for the boat by making use of potential energy to kinetic energy from the spring action. One end of the 24’’ square stick was secured along the edge of the metal mousetrap frame with tape, while the end of a 4’ craft string was tied to the other end of the rod.

<u>Additional Components</u>: Once the major assemblies have been constructed, they can be attached together to complete the product. The paddle wheel with the attached axle is secured into place through the use of axle holders. The holders, measuring 3.5'' x 1.5'', were constructed out of MDF and are positioned asymmetrically with two on the inside of the boat's body and with a third on the right side of the outer part of the body.

The paddle wheel assembly is then placed between the body assemblies, allowing the end of one of the blades to be no closer than 0.5 inches from the back. The axle holders are adhered with superglue to the styrofoam parts of the body assembly. After, the paddle wheel is spun to ensure it's movement is not impeded by other parts of the boat. The mousetrap assembly is then glued onto the right front corner of the body assembly using hot glue. With enough pressure, the mousetrap will have a sturdy base to exercise the spring.

<u>String</u>: Finally, the string is added to generate movement in the tension for unraveling.

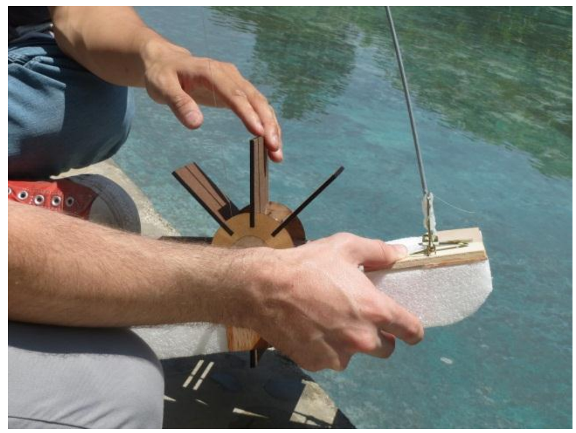


--Completed prototype--

Results of the First Test

During the testing of the prototype, motion was not successful. After the spring was loaded and the boat was placed into the water, it did not move at all. The paddle wheel could not rotate, leaving the mousetrap unsprung.

Upon inspection of the paddle wheel movement it was evident the wood and MDF expanded as a result of water contact, creating unwanted friction along the interior of the sockets on the axle holders. Not only was the paddle wheel movement bad enough, but unwinding became nearly nullified as the string became wet. The texture of the craft string was slightly rough which resulted in greater amounts of friction during unwinding. In an effort to counter the resistance from these forces, the wooden rod was bowed back by increasing the tension on the string with the axle. This resulted in a broken torque rod and zero movement.

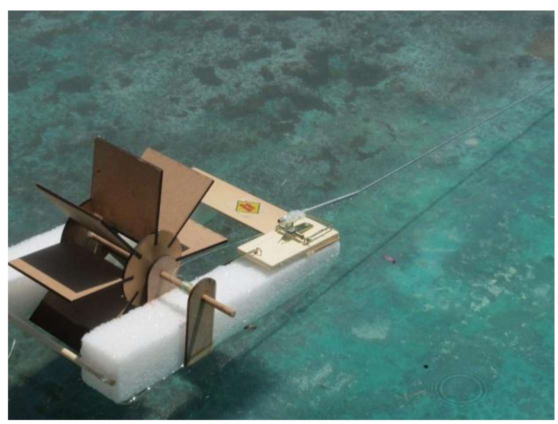


Changes from previous model

- The craft string was replaced with fishing line to also reduce friction during the unwinding process.

Results of the Second Test

After removing one of the axle holders, the paddle wheel was able to spin more easily. When the modified boat design was tested, the boat began to move since the fishing line did not encounter as much friction as the previous test nor did it absorb any water. However, as the metal rod began to approach the front of the boat, the weight of the metal forced the bow downward, immediately stopping the boat without the chance to continue with forward momentum.



Third Test

Changes from previous model

- The metal rod was trimmed to 27 inches long to reduce the weight and address balance issues.
- One of the axle holders from outside of boat body was removed in order to reduce the amount of friction on axle against sockets.

Results of the Third Test

The boat travelled 8 feet, a feat compared to to the previous test, but was still not sufficient. The metal rod seems to have a large effect on the distance due to it's weight. It was decided that a lighter material be used for the torque rod in future tests to lighten the weight in order to increase the probability for higher travelling speeds.

Fourth Test

Changes from previous model

- An extra wheel was added onto the axle to widen the string spool diameter to test if a wider diameter increases distance.
- The broken rod was replaced with a round 48-inch wooden rod


Results of the Fourth Test

Originally, having a wider spool diameter was thought to provide more force with increased torque. Prior to testing this design in the water the movement was tested in the lab to ensure it’s functionality. It was proven that the increased torque had unwanted results: the increased torque came at reduced rotations provided by the mousetrap. With only five revolutions in the air the boat would surely not advance far enough in the water as desired. This idea was immediately rejected.

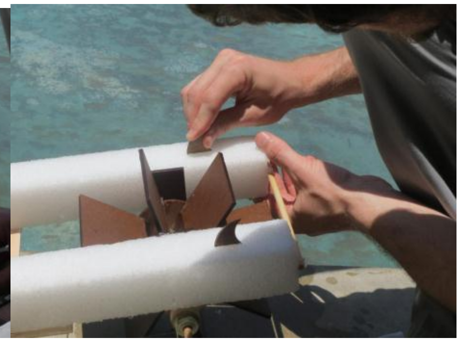
Fifth Test

Changes from previous model

- The spool diameter was restored to .25 inches due to the failure of the previous test.
- Two fins were added to bottom of boat body to guide water flow and straighten the boat’s path.

Procedure

Based on previous tests, the boat usually veered to the right, because of the slight difference in weight on both sides. This created an idea to create fins in order to keep the boat on course was put to action to test it’s effectiveness. The fins were laser cut out of a slab of wood and sanded down at the edges, making them pointy. This is to prevent the boat from veering off course as it floats by slicing water as is passes under the boat. The fins were attached to the bottom of the boat’s body using superglue.

Results of the Fifth Test

The long rod made the paddle wheel rotate slowly, giving more time for power distribution. Although there was a large amount of weight unevenness, the fins helped the boat sail in a straight line. Even with the wind blowing slightly the degree of change in direction was much lower than before when the boat did not have fins.

Sixth Test

Changes from previous model

- A modular mousetrap set up was fabricated on the deck of the boat by using zip ties are used to create a holder for interchangeable mousetraps.
- Instead of testing one rod, 4 different length rods are tested on separate mouse traps using the interchangeable setup.

Procedure

Four mousetraps were used to individually test four different lengths of wooden rods. The lengths of the rods tested were 48’’, 16.5’’, 12’’, and 24’’. The place where the mousetrap was previously set was modified to allow interchangeability of each mousetrap. Using zip ties allowed a small opening wide enough to secure the mousetrap, yet still able to slide it out when removal is necessary.

One mouse trap’s rod shape was altered into a triangular form, while another traps springs were wound an additional time in an effort to increase the amount of potential energy. The extra winding proved to be quite laborious and was aborted after it was observed that one spring had been bent and resulted in negative performance.

Results of the Sixth Test

Of the four mouse set ups, the 48'' rod performed the worst since the mousetrap did not have enough power to retract the rod forward. It only traveled 3 feet, excluding the fact that the weight forced the boat to veer in a circle, driving it back to it's starting place. The rod was trimmed down to 18'' which resulted in a 21' travel distance when mated with the triangular trap. (see data comparison chart for results on all traps tested)

The idea of MDF-water contact area was brought up. It was calculated that at any time, there could be 4 paddles in the water. Each paddle was submerged 1.5'' and was 3.5'' wide, resulting in a surface area of 5.25 sq. inches per paddles, with a total of 21 sq. inches of contact area.

Seventh Test

Changes from previous model

- The entire boat was disassembled and reconstructed to ensure all parts were securely glued.
- The elevation of paddle wheel was raised to have less contact submerged in the water.
- The MDF axle holder was replaced with acrylic axle holders for more flexibility.
- A quick-release mousetrap holder was created.

Procedure

The paddle wheel was disassembled from the original model and cleaned of residual hot glue. The pieces were re-fitted into their respective sockets and joined using the glue gun. The axle was sanded down to increase smoothness and movement space in acrylic holders. The acrylic holder assembly was modified to raise the paddle wheel 1/2'' higher. This results in an area of 1'' x 3.5'' in the water per paddle; thus reducing the amount of surface area in the water by 1/3%.

<u>Results of the Seventh Test</u>

With less surface area of the paddles submerged in the water, the boat had the ability to move faster since there was less resistance from the water to push the boat forward. Less power was required to apply force on the paddle wheel, resulting in more total revolutions.

Eighth Test

<u>Changes from previous model</u>

- Parts of the front bottom of the foam body were trimmed into a more slanted angle to reduce the amount of weight of the boat and to lessen the water resistance.
- Counterweights were added on the back left side of the boat to balance the it and to ensure it moves in a straight line.

<u>Results of the Eighth Test</u>

The boat was more stable as it moved across the water. The counterbalance made up the weight of the mousetrap and wooden rod. However the boat traveled only about 7’ during a trial because it was traveling against the wind.

Ninth Test

<u>Changes from previous model</u>

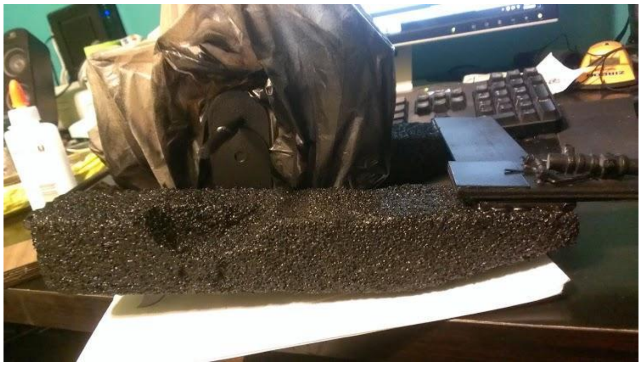
- More styrofoam was trimmed from the bottom to remove excess water surface contact.

<u>Results of the Ninth Test</u>

The boat managed to travel 17 ft. as it floated against the wind direction. Although some energy may have been wasted trying to overcome the wind’s force, it worked well enough to produce a further distance on a less windy day.

Finishing Touches

Now that the final design has been confirmed, moderate changes have been made to create a more appealing appearance. The color of the boat was painted black using a rubber coating spray to give it a sleek, shiny, yet menacing appearance.



Final Product

Conclusion: After thorough consideration of each particular design and extensive testing, an optimal boat design was finally made that both, considers a considerable amount of distance, and is composed of as much recycled material as possible. With a total cost of $5.90 and a max distance travelled of 17 feet in windy conditions, the boat has a minimum cost to distance-traveled ratio of 2.88 feet per dollar spent.

Gerardo James Young

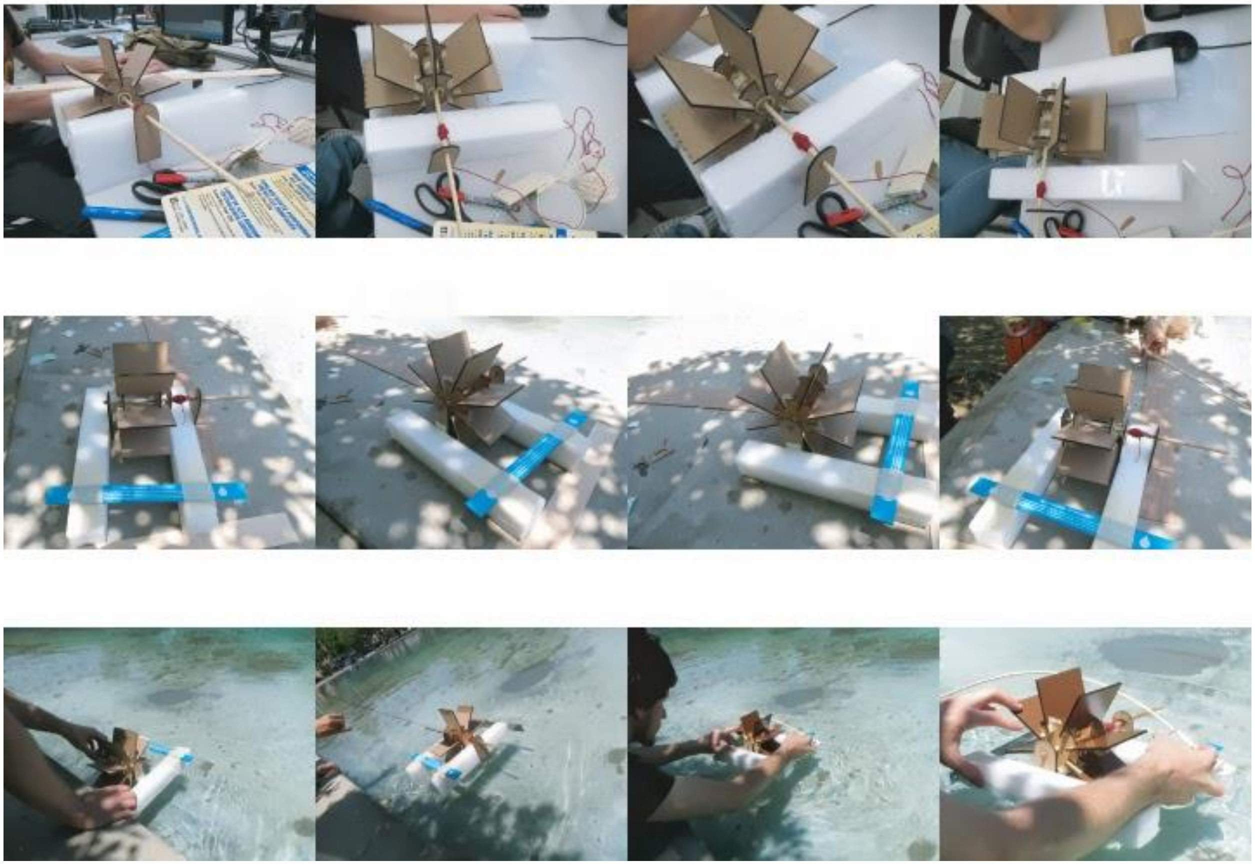
Bill of Materials

Material	Price	Material	Price
Foam Core	$ 3.50	**Walnut Wood**	10 ¢
Mouse Trap	10 ¢	**Balsa Wood**	10 ¢
MDF	10 ¢	**Basswood**	10 ¢
Fishing Line	10 ¢	**Super Glue**	10 ¢
Rubber Band	10 ¢	**Hot Glue**	10 ¢
Washer	10 ¢	**Double Side Tape**	10 ¢
Nut	10 ¢	**Rod (1/4'' diameter)**	10 ¢
Acrylic	10 ¢	**Hardwood Dowel (3/8'' diameter)**	$ 1.00
		TOTAL COST	$5.90

Data Comparison

Test Iteration	Mouse trap #	Rod Length (in)	Diameter (inches)	Distance Travelled (inches)	Shape	Material	notes
1		24	0.4	0	square	wood	stick broke
2		36	0.15	0	round	metal	too heavy
3		36	0.15	5	round	metal	
4		27	0.15	8	round	metal	
5		48	0.35	Not tested in water	round	wood	rejected idea
6		48	0.35	4	round	wood	stops unravelling
7	1	48	0.35	3	round	wood	
	1	18	0.35	21	round	wood	*trimmed from previous test
	2	16.5	0.25	16	round	wood	
	3	12	0.4	0	square	wood	
	4	24	0.4	16	square	wood	used two sticks together
8		18	0.35	7	round	wood	
9		18	0.35	17	round	wood	Perfect!

1st Day Progress



2nd Day Progress

3rd Day Progress 01

3rd Day Progress 02