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Abstract
To demonstrate the underlying physics behind hydraulics in a fun and hands-on approach, a hydraulic claw was constructed out of particle board and plastic syringes. Liquids are incompressible so any pressure exerted on a liquid will be felt by all surfaces in contact with it. By varying the area over which a pressure is exerted, the resulting force can be controlled. The hydraulic claw demonstrates how the incompressibility of liquids can be used advantageously and teaches kids about the fundamentals of hydraulics.

Background
Hydraulics are used all the time in objects ranging from simple squirt guns to large industrial machinery. All of this equipment relies on fundamental property that liquids are incompressible. When a pressure is exerted on a liquid, all surfaces in contact with the liquid are exposed to the same pressure. Pressure can also be thought of as the force exerted over an area. By varying the area over which a pressure is felt, the resulting force can be controlled. This concept can be seen graphically in Figure 1.

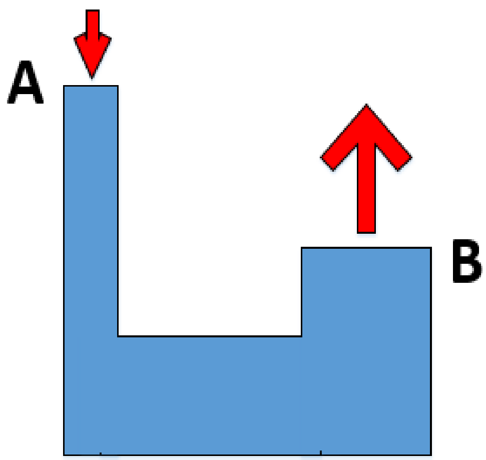

Figure 1. Hydraulics example. A small force can be applied to the left side of the tubing which has a smaller surface area. Since the pressure in the system is constant, and the area on the right side is larger, a larger upward force will result.

Liquid incompressibility allows for heavy machinery to operate. By applying a moderate force over a very small area, the resulting force experienced over a larger area can be several times larger than the original force. Tractors and cranes use this increase in force to their advantage when lifting heavy loads. This phenomenon is also used in reverse in applications such as squirt guns. By applying a force to the larger area side, a large amount of liquid is being displaced. The water has no were to go except out of the smaller nozzle. The resulting water stream is ejected with less force, but at a much higher velocity.

Materials and Methods
The body of the hydraulic claw was constructed out of a 2’ x 2’ x ¼” piece of particle board. Six 20 mL plastic syringes were used along with 4’ of rubber tubing for the hydraulic connections. Segments of a ¼” x 3’ wooden dowel were used connect rotating pieces. Glue was used secure all fixed connections. Ten 6” zip ties were used to connect the syringes to the wooden dowels. The hydraulic lines were filled with water and all air bubbles were removed. An old AA battery was used to secure the base of the claw.

The individual pieces of the claw body were cut from the 2’ x 2’ x ¼” particle board. A full list of pieces and dimensions is given in Figure 2.

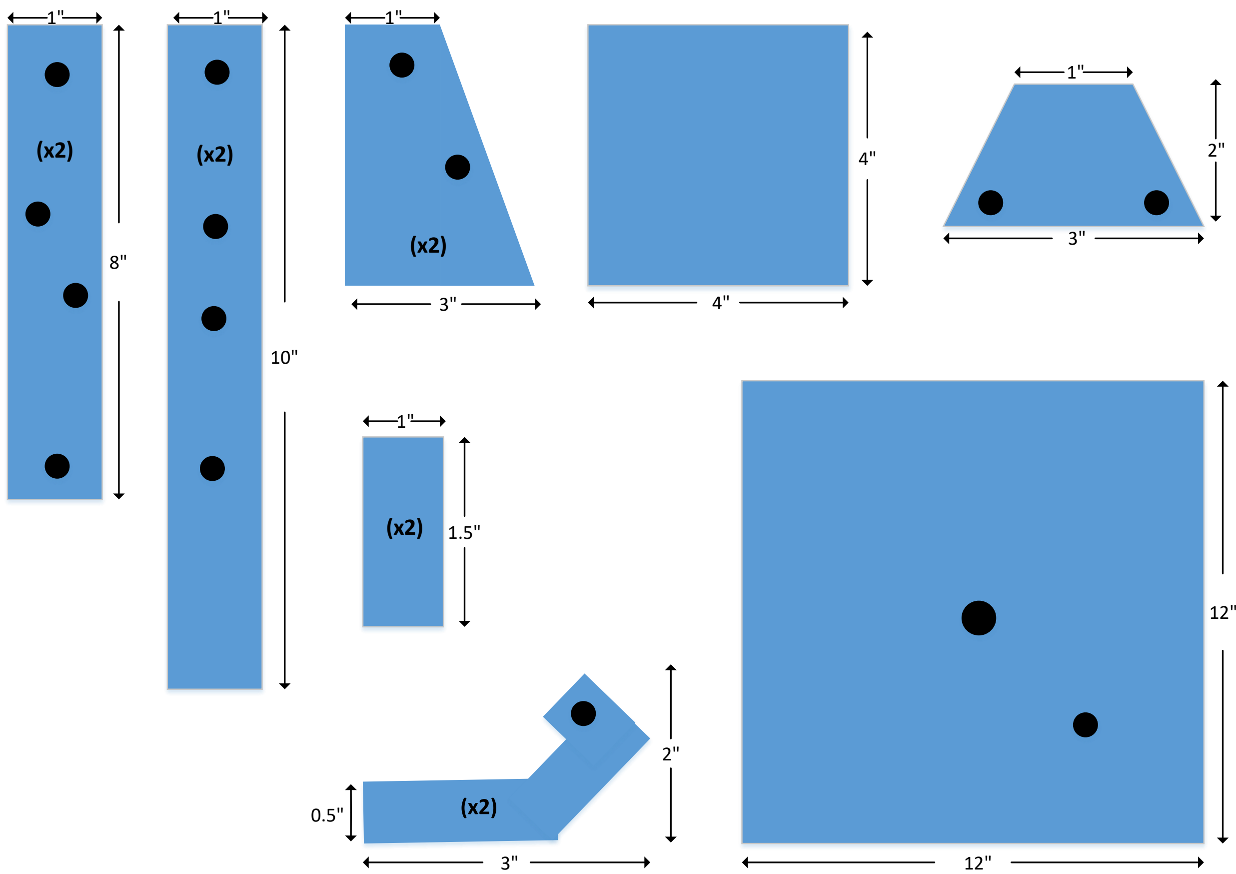

Figure 2. Hydraulic claw particle board pieces. Dimensions and the number of pieces are indicated on each piece. The black dots indicated holes where the wooden dowels were placed.

A top and side view of the finished hydraulic claw is given in Figure 3 and 4 below.

Figure 3. Side view of finished hydraulic claw.

Figure 4. Top view of finished hydraulic claw

A full list of materials and pricing can be found in Table 1. All materials can be found at local hardware stores. The syringe sizes can be varied to adjust the required force and extent of mobility. The exact positions of the wooden dowels can be varied to control the reach of the hydraulic claw.

Table 1. Material list with pricing.

Material	Quantity	Cost
2’ x 2’ x 0.25” particle board	1	$4.00
4’ plastic tubing	1	$2.00
¼” x 3’ wooden dowel	1	$0.50
20 mL syringes	6	$3.00
glue	1	$2.00
AA battery	1	$0.50
6” zip ties	10	$0.50
Total		**$12.50**

Results and Discussions

Pushing water in or out of one of the four control syringes results in the opposite effect in the syringes connected to the hydraulic claw. From the set of four control syringes, the hydraulic claw can be controlled and used to pick up and move various objects. When the water is pushed out of a control syringe, it is forced into the other syringe resulting in movement of the claw. This control is directly related to the incompressibility of the liquid within the syringes and tubing. By applying pressure to a control syringe, an equal pressure is felt within the entire hydraulic line. Once enough pressure is exerted, the syringe located on the hydraulic claw will fill with water and the claw will move.

Different syringe sizes can be used to better control the desired response. By using a small syringe, less force is required to move the same part. However, the range of movement is limited because the syringe contains less volume of liquid. Similar steps could be taken if more control over movement was desired, and additional force was not an issue, by using a larger syringe. One application of these observations was used for the control syringe used to move the claw pincers. The pincers were found to have a limited mobility. If all of the water was forced out of the control syringe, the pincers would extend too far and become unhinged. To limit the pincer movement and make it easier to grab objects, a smaller, 10 mL, syringe was used. When compared to the other syringes, this syringe is much easier to control, and required far less force to move.

The hydraulic claw should provide kids with the means to acquire a basic understanding of how hydraulics work. By providing them with a fun and hands on experiment, the kids will hopefully remember their claw experience and share it with others. Additionally, the hydraulic claw designed for this experiment can be made for around $10 at home. Motivated individuals could make their own hydraulic claw at home and improve upon the design.

Conclusion

The hydraulic claw provides a fun and easy way to teach kids about the incompressibility of liquids. This experiment should provide kids with enough knowledge to have a better understanding of how hydraulics work and some examples of where they can be found in everyday life. By providing a fun and hands on experience the hydraulic claw should leave a lasting memory with the kids that they can carry with them and share with others. Because the claw is made out of low cost materials, driven individuals could even build their own hydraulic claw at home and improve upon the design.

References

"How Hydraulics Works | Science of Hydraulics." *Explain That Stuff*. N.p. 27 Apr. 2017. Web. 05 June 2017.

The Q. "How to Make Hydraulic Powered Robotic Arm from Cardboard." YouTube. YouTube, 18 Mar. 2017. Web. 05 June 2017.