Defeat the Lambdanean Hydra

Grace Xie & Safaa Mouline | Fall 2024

Fields of Interest: Physics, Engineering

Brief Overview:
In this lesson, mentees will be learning about the science behind hydraulic machines and how liquids can be used to generate and transmit power. Mentees will engage in hands-on activities to build hydraulic sumo-robots to practice the engineering design process.

Agenda:
- Introduction (5 min)
- Module 1: Press to Impress (10-15 min)
- Module 2: It's Soda-Pressing (10-15 min)
- Module 3: Defeat the Lambdanean Hydra (20-25 min)
- Conclusion (5 min)

Main Teaching Goals/Key Terms:
- Force
- Area
- Pressure
- Hydraulic fluid
- Cylinder
- Pison
- Hydraulics
- Pneumatics
- Engineering Design Process
- Pascal's Principle

Background for Mentors

Module 1

- Force
- Area
- Pressure

Force is a vector quantity that describes an interaction capable of changing the motion of an object. This can be a push or pull on an object that can cause it to move, stop, or change direction. **Area** is the measure of the surface over which force is distributed. It is an essential factor in determining how force impacts objects.

Pressure is defined as the force applied per unit area, it is the effect of applying force to a given area. Understanding pressure involves recognizing that the same force can have different effects depending on the area over which it is applied. A smaller area will experience a higher pressure for a given force, while a larger area will experience lower pressure.

Figure 1: Area affects pressure

The relation between force, area and pressure can be described by **Pascal's Principle**:

$$P = \frac{F}{A}$$

A good example of this principle in action is comparing the results of putting a balloon on a single thumbtack versus a handful of thumbtacks. In the case of the single thumbtack, the balloon would pop, as a large amount of pressure was exerted on a small area of the sharp end of a single thumbtack. However, for the case of the handful of thumbtacks, because the same amount of force is spread on a larger area of multiple thumbtacks, the balloon experiences much less pressure and therefore would not pop.

Figure 2: Blaise Pascal

Module 2

- Hydraulic fluid
- Cylinder
- Pison
- Hydraulics
- Pneumatics

Hydraulics is the technology that uses fluids to generate, control, and transmit power. By applying Pascal's Principle, hydraulic systems amplify force by using the pressure of fluids. This principle allows for the design of powerful machines and tools, such as hydraulic lifts and presses, that can perform significant tasks with minimal effort.

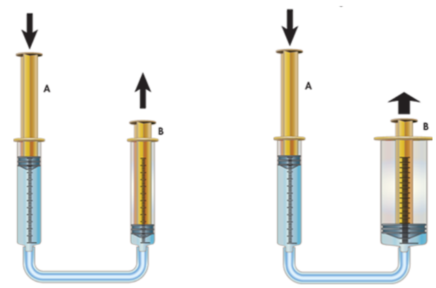


Figure 1: Force is multiplied based on area

Hydraulic fluid is a liquid used in hydraulic systems to transmit force. It acts as a medium through which pressure is applied and transferred. Commonly used hydraulic fluids include oil and water, which help in operating machinery and equipment by transmitting force efficiently. A **cylinder** in a hydraulic system is a component that holds the hydraulic fluid and provides a space for the piston to move. It is essential for converting hydraulic pressure into mechanical force. A **piston** is a movable component within a hydraulic cylinder that pushes against the hydraulic fluid. As pressure is applied to the fluid, the piston moves, creating mechanical force that can be used to perform work. The piston's movement is directly proportional to the pressure applied within the cylinder.

Pneumatics is similar to hydraulics but uses gasses instead of liquids to transmit power. It relies on the principles of pressure and flow of compressed air to operate machinery. Pneumatic systems are commonly used in applications where a more flexible or lighter system is needed, such as in tools and control systems.

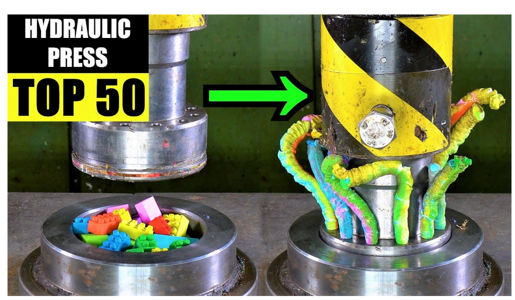


Figure 2: Top 50 hydraulic press moments

Module 3

- Engineering Design Process
- Pascal's Principle

The **Engineering Design Process** (EDP) is the series of steps that engineers follow to come up with a solution to a problem, usually including multiple stages of trial and error. The steps of the EDP include: Identifying the problem, Brainstorming solutions, Designing and building a prototype, Testing the solution, and Improving the solution.

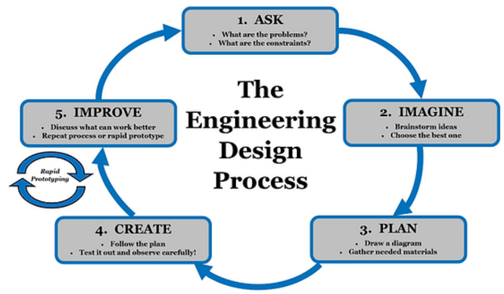


Figure 1: Engineering Design Process

The relation between force, area and pressure can be described by **Pascal's Principle**. This principle is key in hydraulic systems, such as hydraulic lifts or brakes, where a small force applied to a small area can create a much larger force by increasing the area of the output. For example, in a car lift, a small force applied to a small piston is transmitted through a fluid to a larger piston, creating enough force to lift a car. The pressure is the same on both pistons, but because the larger piston has a bigger surface area, the force it exerts is greater.

$$P = \frac{F}{A}$$

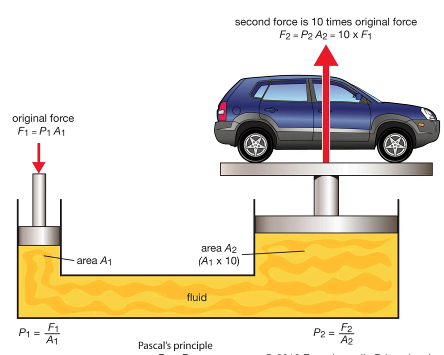


Figure 2: Pascal's Principle in action

Introduction

Understanding the principles of force, area, and pressure is essential for grasping many fundamental concepts in science and engineering. This lesson introduces students to the basic principles of hydraulics, which are pivotal in a wide range of technologies and everyday applications.

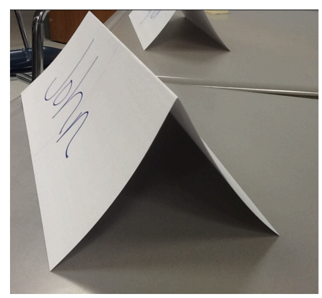
Concepts to Introduce	Questions to Pique Interest
• Prompt mentees to think about the different types of forces they've encountered in their day-to-day life. This can be from the force they use to pull a door shut to the force they use to push a swing high. • Ask mentees if they've heard of hydraulics or pneumatics before. Some mentees may have watched hydraulic presses crushing everything videos on YouTube, feel free to use that to introduce the vocabulary!	• How do you think a hydraulic press generates so much force to crush an apple, or a tin can so satisfyingly? Would you be able to achieve that same level of force with your hands?
Scientists, Current and Past Events	**Careers and Applications**
• Joseph Bramah invented the hydraulic press in 1975, which uses Pascal's Principle to amplify force through hydraulic fluids. This innovation revolutionized metalworking and manufacturing. • NASA uses hydraulic systems in spacecraft and space rovers for controlling landing gear and robotic arms. These systems are crucial for precision and reliability in space missions.	• Mechanical engineers and hydraulic engineers design and implement systems that use fluids to transmit force and perform work. They work on projects such as hydraulic machinery, water treatment systems, and flood control systems.

Module 0: Welcome to BEAM!

This is your mentees first time with mentors this semester, so this first module will serve as a chance to meet your mentees! Have fun with it and give them a good impression of BEAM, we want to get them excited about STEM from the beginning of the semester!

Teaching Goals	**Materials**
1. **Names:** Learn the names of your mentees	• Construction Paper • Markers

Different Methods for Teaching
Feel free to adapt to the name game to your site. (work on this)

Procedure	
1. Organize mentees into a circle in the classroom 2. Go around the room and have everyone introduce themselves (say their name) and something from some category (animals, food, colors, science topics, etc.) that starts with the first letter of their name. (For example you could say Safaa and Sardine if your site chose animals). 3. After this, have mentees return to their seats and pass out a piece of construction paper for each mentee, as well as some drawing materials for each table (if applicable). 4. Have mentees make themselves a name tag to keep on their desks throughout the semester! (they should put this somewhere safe to save it for the next site) – this way we can better remember everyone's names!	 **Figure 1:** *Name tag example (make it more festive!)*

Classroom Notes

For learning names, try to set up a rule on this first day of site that anytime someone raises their hand, they should say their name. Along the same lines also during activities and builds mentors can walk around and talk to mentees, try to get to know your mentees!

Module 1: Press to Impress

Mentees will explore the relation between force, area and pressure with a hands on activity with plastic wrap and various objects.

Teaching Goals

1. **Force**: a push or pull on an object that can cause it to move, stop, or change direction
2. **Area**: the size of the surface of an object
3. **Pressure**: amount of force applied per unit area on a surface
4. **P = F / A**

Materials

- Plastic Cup
- Pencil
- Blunt Stick
- Plastic Wrap

Different Methods for Teaching (Cassie & Ekansh)

- **Relating to Real Life Examples:** Emphasize how pressure is experienced in everyday life, such as the difference between wearing high heels and flat shoes on the soft ground
- **Force:** for younger mentees who may not have heard about forces before, feel free to act out pulling or pushing an object to make it clear that you can put forces on things. Then, for the activity they will be able to see that when we push an object on the plastic wrap, we are applying a force.
- **Visualizing P = F/A:** For older mentees, try exploring how changing the area affects the pressure when force remains the same, and how changing other variables affects pressure as well
- **Critical Thinking:** Ask mentees to predict what they think will happen before performing the experiment — promotes critical thinking!

Procedure

1. Mentees should be split into small groups of 4-5.
2. Cover the top of a cup tightly with plastic wrap, making sure it's smooth and secure.
3. Press the blunt stick onto the plastic wrap using a moderate, steady force. Observe how the plastic wrap bends but doesn't break, as the force is spread over a larger area.
4. Press the sharp pencil down onto the plastic wrap with the same force. Observe how the pencil easily punctures the plastic wrap due to its small surface area.
5. Explain to the mentees that since P = F/A, the

Figure 1: *Cup covered in plastic wrap*

pencil applied more pressure because its area is smaller, leading to the plastic tearing. 6. The blunt stick applied less pressure because the force was distributed over a larger area, so the plastic wrap only bent.	 **Figure 2:** *Poking through plastic wrap with sharp object*

Classroom Notes

Pencils can be sharp and dangerous, make sure the mentees are handling the pencils safely.

Module 2: It's Soda-Pressing

This module provides a hands-on approach to understanding hydraulic systems, encouraging students to explore and connect scientific principles with practical applications.

Teaching Goals

1. **Hydraulic Fluid**: Liquid used in a hydraulic system to transmit force.
2. **Cylinder**: Container holding the hydraulic fluid.
3. **Piston**: Plunger moving inside the cylinder to transfer force.
4. **Hydraulics**: The science of using fluids to generate, control, and transmit power.
5. **Pneumatics**: Similar to hydraulics but uses gasses instead of liquids.

Materials

- Two small syringes
- One large syringe
- A piece of soft plastic tubing

Different Methods for Teaching (Cassie & Ekansh)

- DON'T feel overwhelmed by the teaching goals. Teach what you think your site will be receptive to– there's never a requirement to go through them all!
- Mentees most likely have heard of cylinders before. Feel free to reference the syringe as an example.
- **Hydraulics:** If this fancy word is too much for your mentees, feel free to simply explain how the water in the tubes pushes on the object it connects to. Instead of me pushing an object, in hydraulics, we let liquids like water do the work.
- **Hand-On Approach:** Allow mentees to feel the difference between the force needed to move water in small syringes vs. large syringes.

Procedure

1. Mentees should be split into small groups of 4-5.
2. Attach a syringe filled with water to each side of a piece of soft plastic tubing. To make sure the plastic tubing slides on snug, you can wrap on a piece of tape before securing it. (see Figure 2.)
3. Attach tubing to syringe, pull syringe plunger up to suck water up into tubing and syringe, attach second syringe.
4. Have mentees push and pull the syringe to feel the force being transferred via water from one syringe to the other.

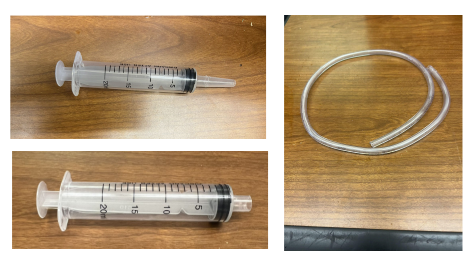


Figure 1: *Preparing materials (cut syringe)*

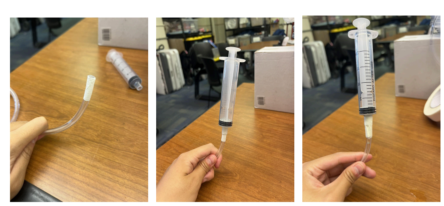
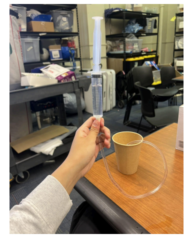


Figure 2: *Attaching syringe to tubing*

5. Connect different size syringes to the tubing and compare the effect of syringe size on force output. (A smaller syringe would need to move a longer distance to move a larger syringe plunger than to move a small syringe plunger for equal distance. The larger syringe plunger would however output more force as well.)	 **Figure 3:** *Filling syringe and tubing with water*  **Figure 4:** *Attaching other syringe*

Classroom Notes

The plastic tubing should twist on into the syringes easily, but in case it leaks, feel free to secure it with tape provided in the next module.

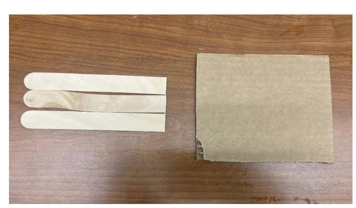
Module 3: Defeat the Lambdanean Hydra

In this module, students will apply their understanding of hydraulics by building a simple hydraulic robot using syringes and popsicle sticks. They will design and assemble a robot that uses hydraulic systems to perform tasks, demonstrating how fluid power can be harnessed in mechanical devices.

Teaching Goals	**Materials**
1. **Engineering Design Process**: A series of steps that engineers follow to come up with a solution to a problem, usually including multiple stages of trial and error. 2. **Pascal's Principle**: P = F/A. Conceptually for hydraulics: when pressure is applied to a confined fluid, that pressure is transmitted equally in all directions throughout the fluid. This means that any change in pressure at one point in a fluid is felt everywhere in the fluid without any loss.	• Syringe system from Module 2 • Tape • Popsicle sticks • Cardboard base • Scissors

Different Methods for Teaching (Cassie & Ekansh)

- **Pascal's Principle:** What happens when you squeeze the middle of toothpaste? The toothpaste doesn't just move in one spot—it spreads out and comes out of the top. This demonstrates Pascal's Principle because the liquid pushed everywhere not just where you pushed.
- **Check-in:** If you've gone through all the modules, now is a good time to check understanding. For example, for younger mentees this can be done through questions about what the water does (it is pushing the syringes!) and for older mentees this can be done with questions about how force, pressure, and area relate.
- **Engineering in the Real World:** Highlight how hydraulics are used in real robots as well as heavy machinery they see on the road (car brakes, bulldozers, garbage trucks, etc.)
- **Encouraging Teamwork:** Encourage discussion and teamwork amongst mentees to solve problems — using the Engineering Design Process can be frustrating for some mentees, so allowing them to work collaboratively could help alleviate some of this frustration

Procedure	
1. Mentees should be split into small groups of 4-5. 2. Take a piece of a cardboard base and secure popsicle sticks perpendicular to the base. This will serve as the back of our robot.	 **Figure 1:** *Popsicle sticks (cut) and cardboard base*

3. Tape together 3-4 popsicle sticks to form a long structure, which will serve as the back of our robot.
4. Tape the arm to the back with one consecutive piece of tape. The arm should be loosely attached with the space to pivot around the top of the popsicle sticks which are attached to the cardboard base.
5. Attach one side of the syringe system to the back of the robot. Tape the top of the syringe to the arm. Make sure the syringe attached to the arm is able to move the arm up and down when the other syringe is pushed up and down.
6. Tape part of the plastic tubing to the cardboard base to secure the syringe system to the robot.
7. Have the mentees try to topple each other's robots while operating the syringe power system!

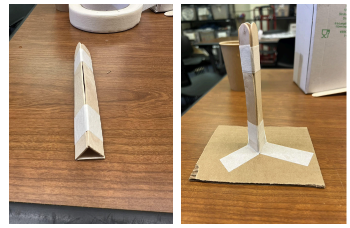


Figure 2: Body of robot

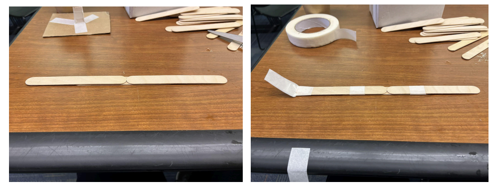


Figure 3: *Arm of robot*

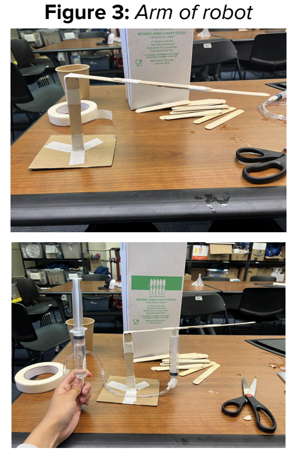


Figure 3: *Assembly*

Classroom Notes

If the popsicle sticks don't want to stand perpendicular to the cardboard base, try using scissors to cut away the rounded part of the popsicle stick so that it's able to stand flat on the cardboard.

Conclusion

In this lesson, we explored the fascinating world of hydraulics through hands-on activities and experiments. By learning how force, pressure, and fluid power work together, we built our own hydraulic systems and robots, gaining insight into how these principles drive real-world technology.

References

- Teaching Hydraulics and Pneumatics Unit to Children, Bogusia Gierus, Nucleus Learning https://www.nucleuslearning.com/teaching-hydraulics-and-pneumatics-unit-to-children/

Summary Materials Table

Material	Amount per Site	Expected $$	Vendor (or online link)
Construction paper	1 per student		MCL
Markers	1 per student		MCL
Syringes (two small, one big)	3 per group		Ace Hardware, Amazon
Plastic tubing	2 ft. per group		Ace Hardware
Cardboard base	1 per group		MCL
Popsicle sticks	15 per group		Amazon
Tape	1 per group		MCL
Scissors	1 per group		MCL