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The Physics of Hydraulics

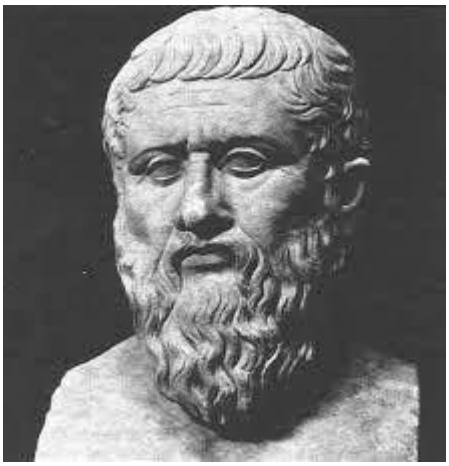
Respective blueprint	The Fire pump of Ctesibius
Description	In this pedagogical sequence students will learn the basics of hydraulics using the Fire pump of Ctesibius
Learning Objectives	Students will: - Learn how to recreate the Fire pump of Ctesibius - Understand the physics' theory behind the fire pump - Be able to use basic hydraulics theory for other purposes

Related curricular subject(s)	Physics, History
Prerequisites / preparatory actions for teachers	Teachers should gather the materials for the blueprint
Prerequisites / preparatory actions for students	Understand the basics of physics, know how to use a water pumping system
Age of students	14-17
Duration	2-3 hours
Level of difficulty	Advanced

Step by step description of the tasks

Step 1: Who is Ctesibius?

The teacher introduces Ctesibius, also written “Ktesibios” to the class.



Source: http://www.computer-timeline.com/timeline/ctesibius-of-alexandria/

Ctesibius or Ktesibios (Greek: Κτησίβιος; fl. 285–222 BC) was a Greek inventor, physicist and mathematician that lived in Alexandria, in Ptolemaic Egypt. Many discoveries and inventions have been attributed to him, although little is known about his life. He is the author of the first treatises on the science of compressed air and its uses in pumps (pneumatics). He also worked on the elasticity of air, which earned him the title of "father of pneumatics." His most famous invention is the “Hydraulis” (the earliest known mechanical pipe organ) and he is known for having improved the “Clepsydra” (water clock) which is believed to have been the most accurate clock ever created until the invention of the pendulum clock (1656).[1]

Most importantly for us, his work on compressed air overlapped with his work in hydraulics leading to the creation of a hand pump able to lift water from wells, which is what we will be exploring today.

Ctesibius described one of the first force pumps for producing a jet of water, or for lifting water from wells. Examples have been found at various Roman sites.[2]

Step 2: Introducing hydraulics

The teacher explains what the basic principles of hydraulics are: the study of liquids in motion, liquids' mechanics. [3]

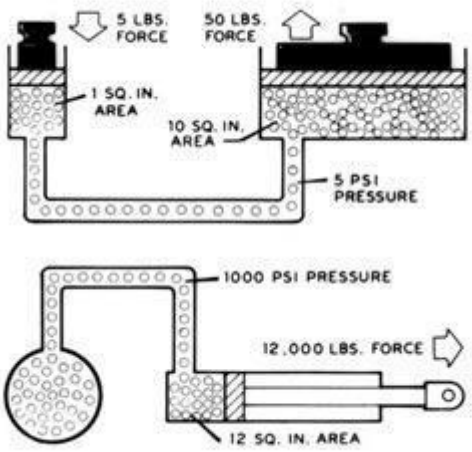
The basis for all hydraulic systems is expressed by Pascal's law which states that:

The pressure exerted anywhere upon an enclosed liquid is transmitted undiminished, in all directions, to the interior of the container. [4]

$$\Delta p = \rho g \cdot \Delta h$$

[1] *Ctesibius of Alexandria*. (n.d.). Encyclopedia Britannica. https://www.britannica.com/biography/Ctesibius-of-Alexandria
[2] Hannah Cheshire. (2021, September 10). *Fire extinguishers - A brief history (Part 1)*. FireArrest. https://firearrest.com/fire-extinguishers-a-brief-history-part-1/
[3] *Hydraulics*. (n.d.). Encyclopedia Britannica. https://www.britannica.com/science/hydraulics
[4] *Basic hydraulic theory | Cross Mfg*. (n.d.). Cross MFG. https://crossmfg.com/resources/technical-and-terminology/basic-hydraulic-theory

This principle allows to generate large forces with relatively little effort. Pneumatics' principles rest on the same law but using gas instead of a liquid.



[5]

The teacher can illustrate this with a set of syringes, linked to one another. One is filled with water and the other is not. They are both linked with an airtight tube. By pushing on the first one, the second one will expand. A weight can be attached to the second syringe in order to illustrate the power behind the system.

[5] *Basic hydraulic theory | Cross Mfg*. (n.d.). Cross MFG. https://crossmfg.com/resources/technical-and-terminology/basic-hydraulic-theory

Step 3: Make the students brainstorm ideas on how the fire pump may work and/or build it.

The teacher may either show the pump (previously created) to the pupils and ask them to brainstorm how they think it works or, the teacher may follow the blueprint to build the fire pump with the pupils and discuss each component and their use in the pump.

Step 4: Presenting the fire pump experiment and mechanism

The teacher should briefly explain the principles of liquids and pressure that are involved in the inner working of a water pumping system.

An important component to explain is the valve, as the whole system relies on them to work properly.

A valve is a mini one-way door-like system that allows the water to flow one way but prevent it from flowing back the other way, as we can naturally observe in the human heart. Using the pressure from the pistons, the water from outside the pump is being pulled inside one piston when we pull on it, opening the valve and then gets fed into another container (the one that will project the water) through another one-way valve when it is pushed down. The lever is in place so that when one piston goes up, the other goes down, keeping the water flow continuous inside the central container. As the area exerting pressure inside the pistons are pretty large, but the output tube in the central container is pretty thin, the water pressure when it comes out is quite high. This allows this system to project water far in a continuous way.

The teacher can also show videos:

Youtube video of the fire pump in action:

https://www.youtube.com/watch?v=d5jAyI3piSE

The water pump of Ctesibius used to pull up water

https://www.youtube.com/watch?v=q506nEzC1Vk

Step 5: Finding other occurrences of this same principle in everyday life

The teacher should ask the pupils if they can think of any other objects that could be benefitting from the same principle as a fire pump.

Some of those examples include:

- Car brakes
- Modern hydraulic Cranes
- Garbage truck system

Conclusion

In this lesson the students learn about Pascal's law and the basics of hydraulics. They learn how they were used in ancient Greece, and they can use them to do some of our everyday tasks.

Assessment activities

Activity 1. Find information about Ctesibius' works and present them to the class.

Activity 2. Search for information on how Ctesibius used hydraulics in other inventions.