Simple Hydraulic Lifter WIP

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Meta Description

Experiment with a simple hydraulic lifter to learn about pressure in liquids and the forces at work. Discover why hydraulics are so important in machines.

Learning Objectives

Understanding the relationship between pressure, area and force.

Observing that fluids transmit pressure.

Awareness of the importance of hydraulics to lift heavy loads.

Key Terms

Cross Sectional Area
The area of the shape produced when an object is cut in half and it’s internal shape viewed.

Force
A pull or a push which acts on an object.

Hydraulics
The science associated with the flow of liquids and their use to produce forces.

Hydraulic Lifter
A machine used to lift objects using liquids under pressure.

Pressure
The force per unit area.

Pressure in Liquids
Pressure is distributed equally throughout a trapped liquid.

Weight
The downward force on a mass due to the Earth's gravitational pull.

Method

Step 1
Pre-stretch the balloon by inflating and then deflating it.

Step 2
Insert the end of the tubing into the balloon and secure the joint with tape. Ensure that the joint is watertight by using the funnel to fill the balloon through the tube. Empty the balloon through the tube.

Step 3
Cut off the top of the bottle, so that it is slightly taller than the can.

Step 4
Use scissors and a pencil to make a hole in the side of the bottle, close to the bottom.

Step 5
Pass the free end of the tube through the hole in the bottle, from the inside of the bottle to the outside. Leave the balloon inside the bottle.

Step 6
Place the can on top of the balloon.

Step 7
Place the heavy book on top of the bottle.

Step 8
Fit the funnel at the free end of the tube and pour the water into the pipe. Holding the funnel high allows air bubbles to escape.

Step 9
As the balloon fills, what do you observe?

Step 10
Once the balloon is full, remove the book and can and use your hand to gently press down on the balloon – hold the tube facing upwards when doing this step. What do you notice?

Precautions

1. Ensure that the edges of the can are blunt and do not pose a cutting hazard.
2. Use scissors responsibly. Do not place your hand in the way of the blade and place on a table when not in use.
3. Protect any surfaces which could be damaged by the water.

Narrative

When you're swimming underwater, you can feel the pressure of the liquid on your skin. All liquids exert a pressure on their container and on objects submerged in them.

The water filling the balloon creates a pressure which causes the balloon to expand. This pressure acts on the can sitting on top of the balloon, pushing against it. This pushing effect is called a force. The can is moved upwards until it starts pushing against the book.

So the book has two forces acting on it. It's weight, which acts downwards, and the force from the balloon, which pushes upwards. The book only moves when the upward force is greater than it's own weight.

Questions

Why does the water not come out of the pipe?
Due to the pressure of the water in the pipe and the angle of the pipe.

Why can the balloon move the book?
Upward resultant force due to pressure in the water > weight of book.

Why does the balloon not burst?
If stretched beyond the capabilities of the rubber it would burst.

Is the pressure even across the surface of the balloon?
Yes.

Why do we have to hold the pipe in the air?
To release air bubbles and give the fluid more potential energy, to create greater pressure at the outlet.

Brief Explanation

Hydraulic machines use liquids under pressure. They rely on two important characteristics of fluids: firstly that liquids are incompressible (you can't squash them) and secondly that when pressure is applied to a trapped liquid, the pressure is transferred to all parts of the liquid.

In general, pressure can be expressed by a simple equation:

$$P = F/A \quad [1]$$

where P is the applied pressure (in Pa or N/m2), F is the resulting force (in N) and A is the cross sectional area (in m2).

The water flowing into the balloon increases the volume of water in the balloon and contributes to the pressure (Video) transmitted through the can to the book. The pressure in the fluid is transmitted to thebook via the can. The can has a fixed cross-sectional area. Thus, the pressure in the balloon exerts a pressure on the balloon via the can. When this force is large enough, it pushes the book upwards. This happens when the upward force due to the pressure in the balloon is greater than the weight of the book, which acts downwards.

Detailed Explanation

This problem is more complicated than than a simple hydraulic jack problem. In a simple hydraulic jack pressure is transmitted through a trapped liquid. In this example, some of the fluid is not trapped, but flows into a reservoir (the balloon).

From the law of conservation of energy, the energy of the water at any point in the pipe in constant. Bernoulli's equations were based on this concept (Video) and can be used to understand the energy of the water in the pipe:

Energy of water at the top of the pipe = Energy of the water exiting the pipe

Top pressure + Top kinetic energy density + Top potential energy = Outlet pressure + Outlet kinetic energy density + Outlet potential energy

$$?_{top} + ½v2top + ?g?top = ?out + ½?v2out + ?g?out$$

As the water flows down the pipe it's kinetic energy can be expected to increase slightly (because of acceleration due to gravity), while it's potential energy decreases appreciably (because of a decrease in height). Therefore, the pressure at the output of the pipe can be expected to be greater than the pressure at the top.

The water flowing into the balloon increases the volume of water in the balloon and creates a pressure within the balloon. Recall that pressure = Force/ Cross-sectional area. The pressure in the balloon acts on the book via the can, which has a fixed cross sectional area. Thus, the water pressure exerts a force on the book. When the force on the book exceeds the weight of the book, there is a resultant force upwards, which causes the book to be pushed higher. Since fluids are virtually incompressible, and the weight of the water in the pipe exerts enough pressure to prevent water being pushed back up the pipe, the balloon continues to grow as more water is added.

Applications and Research

Applications

Hydraulic lifts are used widely in industry to lift personnel and heavy loads, particularly in docks, construction sites, car repair, warehouses and factories. They can be used to raise heavy products, vehicles or machinery. In car repair mechanics use a hydraulic lift to raise vehicles. Many industries use huge lifters to load and unload goods from vehicles or ships.They can be used to lift personnel to, for example, service street lights. Hydraulic systems are also used in lifts within buildings. Hydraulic lifts can be controlled remotely or manually.

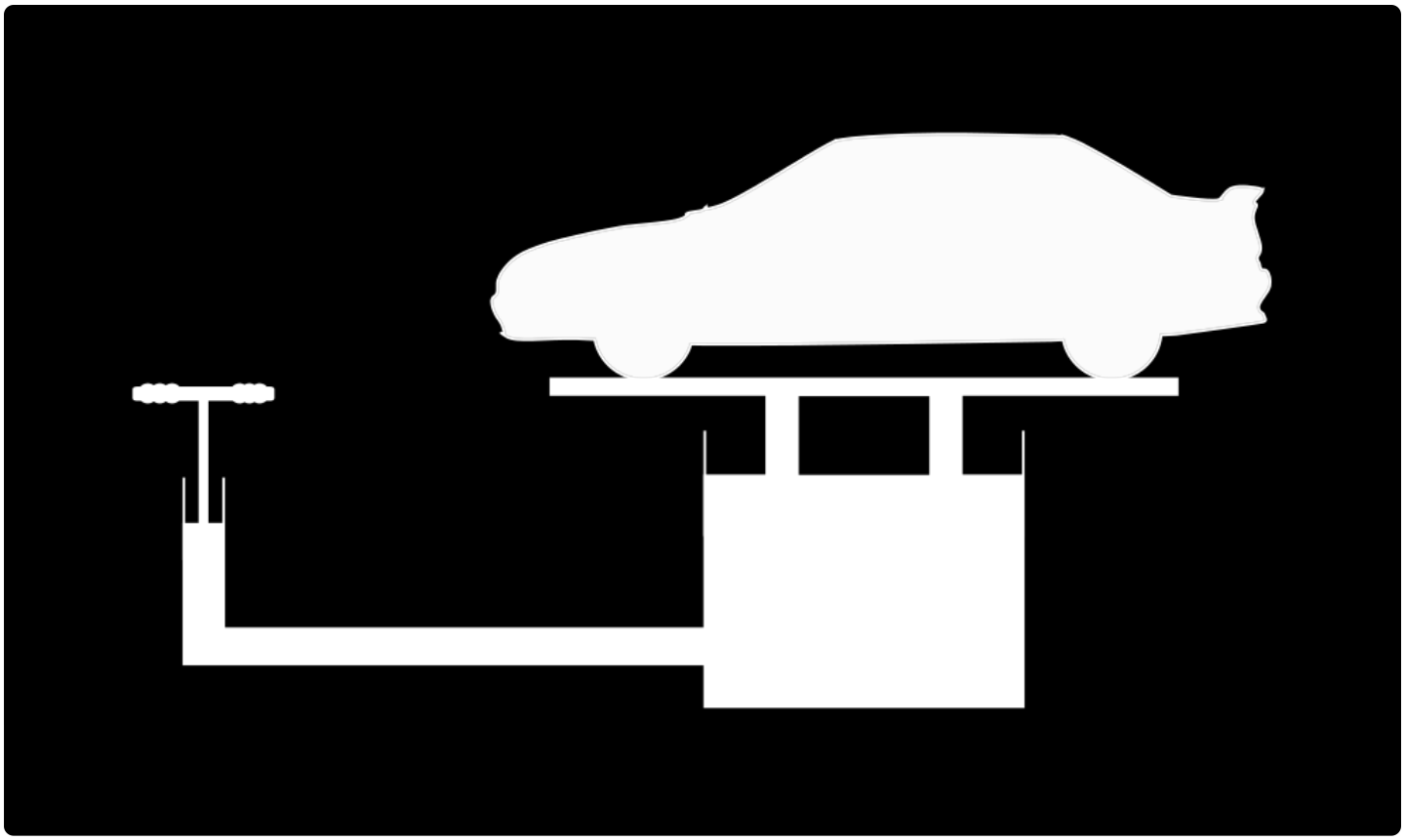
Hydraulic lifts are very powerful: safety checks must be carried out to make sure they are stable and operators must adhere to various precautions.

Research

Heavy hydraulic machines including lifters, diggers and bulldozers use oil-based hydraulic fluids. Over a machine's lifetime, about 85% of these fluids leak away, posing an immediate fire risk and causing long-term harm to wildlife and the environment. Disposal of the fluid is also costly. Recent research has been focused on developing hydraulic systems which use water instead of oil. This makes them environmentally friendly. However, water creates problems of rusting and friction in the power transmission, which must be overcome.

Investigation

- Add a smaller book on top of the first. This increases the downward force due to the weight of the books. How does this affect the system?
- Experiment with lifting the pipe to different heights and angles and observe how this affects the outcome.



Subjects

Engineering & Technology
Physics

Education

Primary
Secondary
Informal

Time Required

~45 minutes
Preparation: 15 minutes
Conducting: 15 minutes
Clean Up: 10 minutes

Cost

0 – 10 €

Recommended Age

6 – 9
10 – 12

Number of People

1 participant

Supervision

Required

Location

Indoors
Outdoors
Festivals
Laboratory

Materials

Balloon

Empty can

Funnel

Heavy book

Large empty plastic bottle

Pencil

Scissors

Short piece of tubing

Tape

Water

Contributors

Natasha Padfield
Author
Benji Fenech Salerno
Editor

Sources

Complete Physics, Stephen Pople, Pg 56-57; 60-61 (Book)

Force, Mass and Acceleration

Hands-On Hydraulics – Science Fun for Kids

More about Hydraulic Lifts

The Working of a Hydraulic Lift

Water-friendly Hydraulic Technology to make Heavy Machinery Greener

Additional Content

Applications of Hydraulics (Beginner)

Easy Hydraulic Machine (Beginner)

Rise of the Human Exoskeleton (Beginner)

Archimedes (c.287 – 212 BC) (Intermediate)

Easy Hydraulic Machines (Intermediate)

Leaking Hydraulic Fluid could Damage Aircraft Rudders. (Intermediate)

Fracking Can Contaminate Drinking Water (Advanced)

Korean Shipbuilder Testing Industrial Exoskeleton for Future Cybernetic Workforce (Advanced)

What's the Difference Between Pneumatic, Hydraulic, and Electrical Actuators? (Advanced)

Cite this Experiment

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