Demonstrating Pascal's Law with the Help of Hydraulic Lift Experimental Model

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ACKNOWLEDGEMENT

I am delighted to express my profound sense of satisfaction and immense pleasure upon the successful completion of my one-month summer internship. I would like to take this opportunity to extend my most humbleand sincerest gratitude to **Dr. Uday Shanker Dixit**, Head of Centre for Indian Knowledge Systems (CIKS). His invaluable guidance, unwavering support, and constant encouragement throughout the internship were instrumental in shaping my learning experience.

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July 2023 **Supratim Roy**

Intern, IIT Guwahati

CERTIFICATE

This is to certify that the work contained in this report entitled "**Demonstrating Pascal's Law with the Help of Hydraulic Lift Experimental Model**" by **Supratim Roy**, has been carried out in the Centre for Indian Knowledge Systems, Indian Institute of Technology Guwahati under my supervision and that it has not been submitted elsewhere for a certificate.

Prof. UDAY SHANKER DIXIT

Department of Mechanical Engineering

Indian Institute of Technology Guwahati

July 2023

DECLARATION

I hereby declare that the entire work embodied in this report entitled "**Demonstrating Pascal's Law with the Help of Hydraulic Lift Experimental Model**" has been carried out by me during my summer internship, which took place from June 3 to July 3, 2023. The internship was carried out under the able guidance and supervision of **Prof. Uday Shanker Dixit.** Throughout the duration of the internship, I have diligently worked on the assigned tasks and conducted the experiment in a professional and ethical manner.

I affirm that the contents of this report are a true reflection of my work and findings during the internship period. Any references, data, or information used from external sources have been duly acknowledged and cited in the appropriate sections of the report.

The experiment described in this report is conducted solely by me, with necessary guidance and support from my internship supervisor.

Date: 03/07/2023

Supratim Roy

Intern, IITG

ABSTRACT

This report explores Pascal’s Law using a hydraulic lift model as a demonstration tool. Pascal’s Law is crucial in fluid dynamics and has practical applications in hydraulic transmission, hydraulic press, and hydraulic lift. The objective is to provide a clear and intuitive demonstration of Pascal’s Law through the construction and analysis of a hydraulic lift model.

The report introduces the science behind lifting heavy cars, automobiles, or any heavy objects by the aid of hydraulic lift. It introduces how pascal’s law is used to calculate the minimum force required to lift a heavy weight.

By conducting controlled experiments, the report investigates the height of lift with respect to applied displacement, also the force applied to lift a weight.

In conclusion, this report provides a clear understanding of pascal’s law with the help of hydraulic lift model. It enhances understanding of this concept in fluid dynamics, serving as a valuable resource for educators, researchers, and enthusiasts interested in applying the pascal’s law in various fields.

Contents

Chapter 1

Introduction

1.1Pedagogy

Pedagogy is the study of teaching and how the content is presented to students. It is the development of an educational process that helps learners gain knowledge.

Importance of pedagogy are:

- Improves quality of education
- Harnesses team learning
- No monotonous learning
- Convenient for special students
- Improves student and teacher communication.

1.2Pascal's Law

According to Pascal's law, any force applied to a confined fluid is transmitted uniformly in all directions throughout the fluid regardless of the shape of the container. Uniform transmission of force is showed in Fig 1.1.

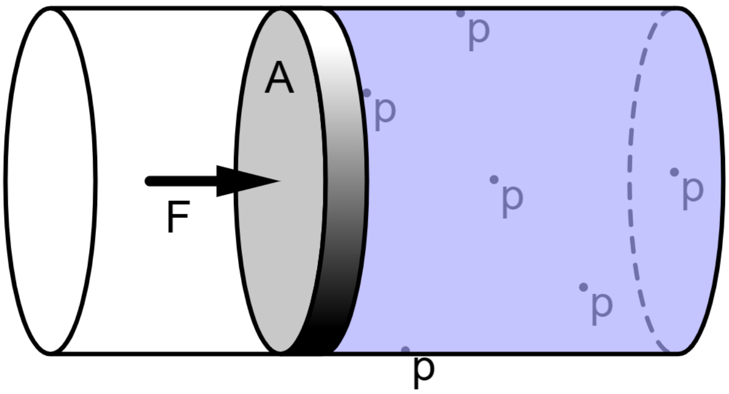

Fig 1.1 Pressurized Fluid

Source: https://commons.wikimedia.org/wiki/File:Pascals-law.svg (©creative commons license)

1.3Application of Pascal's Law

Applications of Pascal's Law are as follows:

- **Hydraulic Lift:** Hydraulic lift in a car maintenance shop is shown in Fig 1.2.

Fig 1.2 Hydraulic Lift

Source: https://www.indiamart.com/proddetail/two-post-lift-19991955730.html

(Under creative commons license)

- **Hydraulic Jack:** Hydraulic Jack is shown in Fig 1.3.

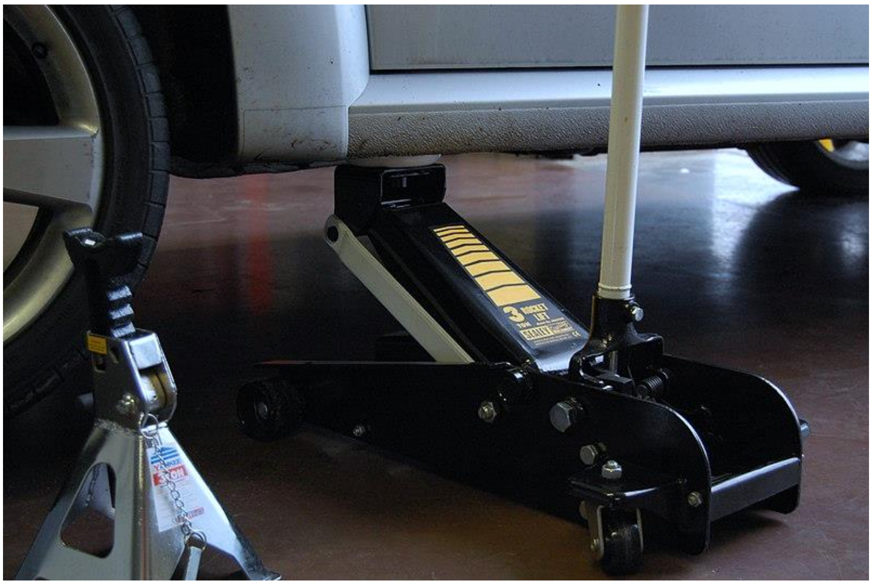

Fig 1.3 : Hydraulic Jack

Source:https://commons.wikimedia.org/wiki/File:Sealey_hydraulic_jack_and_jack_stand.jpg (Under creative commons license)

- **Hydraulic Press:** Hydraulic Press is shown in Fig 1.4.

Fig 1.4: Hydraulic Press

Source: https://commons.wikimedia.org/wiki/File:HD2-440_ton_Servo_Hydraulic_Press.jpg

(Under creative commons license)

1.4History of application of Pascal's Law

- The principles behind Pascal's law were likely applied in a practical sense in Mauryan fountain structures.
- Manually operated Rahat was used to lift water.
- Water lifting device such as dhenki was used in ancient India.

History of Shaduf:

- Shaduf was not exactly hydraulic lift, but water was lifted by the aid of mechanical advantage.
- Weight was attached at one end and water was lifted at other.
- Shaduf is represented in Fig 1.5.

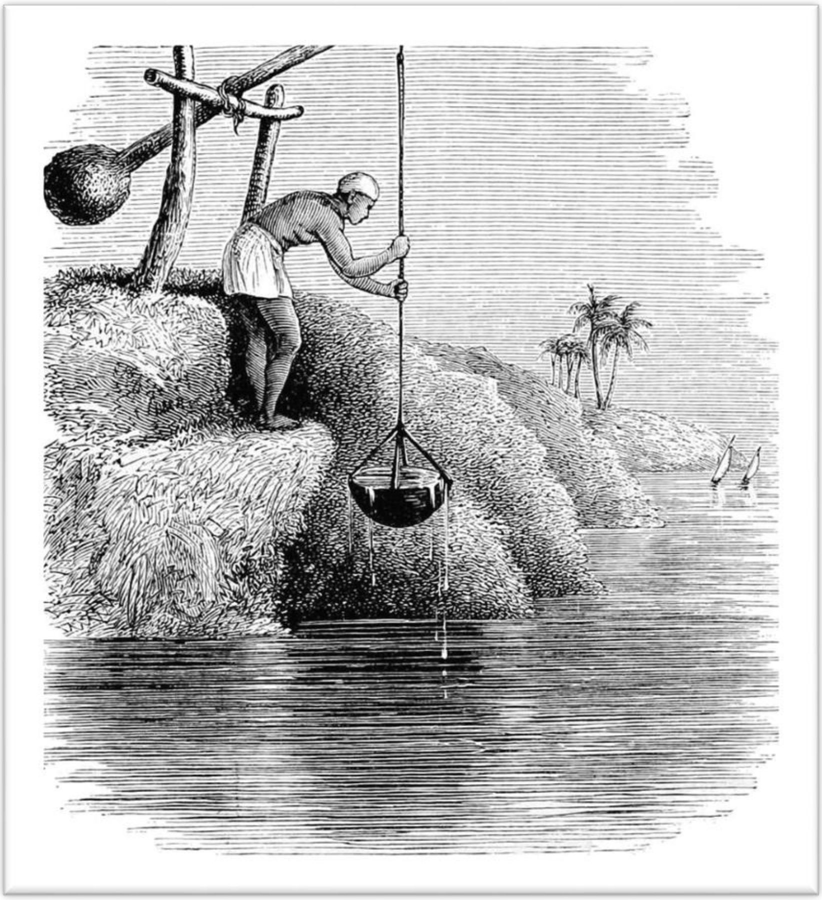

Fig. 1.5: Shaduf

Source: https://picryl.com/media/shaduf2-11e521 (Under creative commons license)

Mauryan fountain structures:

- One common mechanism used in ancient Indian fountains was the use of gravity.
- Water was channeled from a higher source, such as a well or reservoir, and allowed to flow down through pipes or channels to the fountain.
- The elevation difference between the water source and the fountain created the necessary pressure for water to rise and create a jet or spray.

Chapter 2

Hydraulic Lift

2.1 Definition

A hydraulic lift is a device for moving objects using force created by pressure on a liquid inside a cylinder that moves a piston upward. Incompressible oil is pumped into the cylinder, which forces the piston upward. The schematic diagram of hydraulic lift is shown in Fig 2.1.

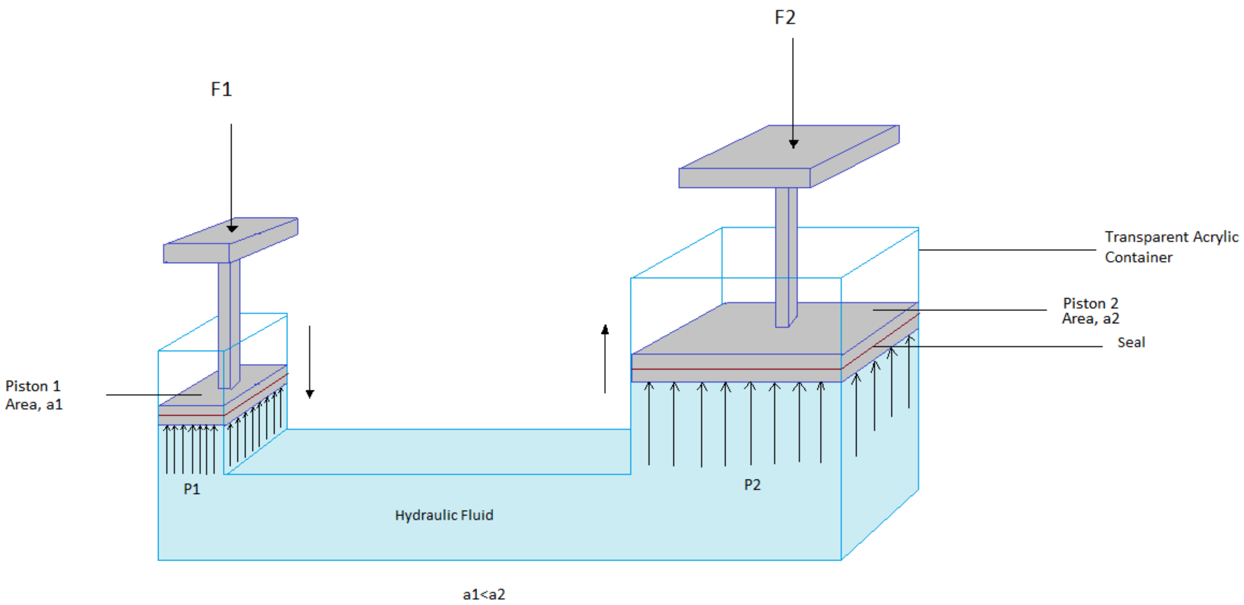

Fig 2.1: Hydraulic Lift Schematic Diagram

2.2 Uses of Hydraulic Lift

Hydraulic lifts are used in a variety of different applications. They can be found in automotive, shipping, construction, waste removal, mining, industrial lift trucks (shown in Fig 2.2) and retail industries as they're an effective means of raising and lowering people, goods, and equipment.

Fig 2.2: Industrial Lift truck

Source: https://pixabay.com/illustrations/forklift-transport-industry-machine-6229520/

2.3 Methodology behind Hydraulic Lift.

According to Pascal's Law,

$$P_1 = P_2$$

$$\Rightarrow \frac{F_1}{a} = \frac{F_2}{A} \tag{2.1}$$

$$\Rightarrow F_1 \times A = F_2 \times a$$

where F_1 is the applied force, F_2 is the weight to be lifted, "a" is the area at piston end, "A" is the area at the ram end.

- Since,

$$a < A$$

- Therefore,

$F_2 > F_1$

i.e., The small force applied at piston end will lift comparatively large force at ram end.

Height of Lift

The height of lift is calculated as follows.

Volume displaced at Piston end = Volume displaced at Ram end

$$\Rightarrow a \times l = A \times L$$

$$\Rightarrow \frac{a}{A} = \frac{L}{l}$$

where l is the length of displacement at piston end, L is the length of lift at ram end.

From Equation 2.1,

$$\frac{F_1}{F_2} = \frac{a}{A}$$

Therefore,

$$\frac{F_1}{F_2} = \frac{a}{A} = \frac{L}{l} \qquad (2.2)$$

Since, $a < A$

Therefore,

$L < l$

i.e., For a small displacement at ram end leads to a large displacement at piston end and vice versa.

2.4 Experimental trial of hydraulic lift.

An experiment with pipe and syringe was performed to demonstrate the mechanism of hydraulic lift. The small syringe was piston end and large diameter was considered as ram end.

The apparatus is shown in Fig 2.3(a).

A little force was applied at piston end to a distance of 3.75 cm. Fig 2.3(b) and Fig 2.3(c) shows the length of travel of piston and ram along with their respective diameter.

Fig 2.3(a): Experimental Apparatus

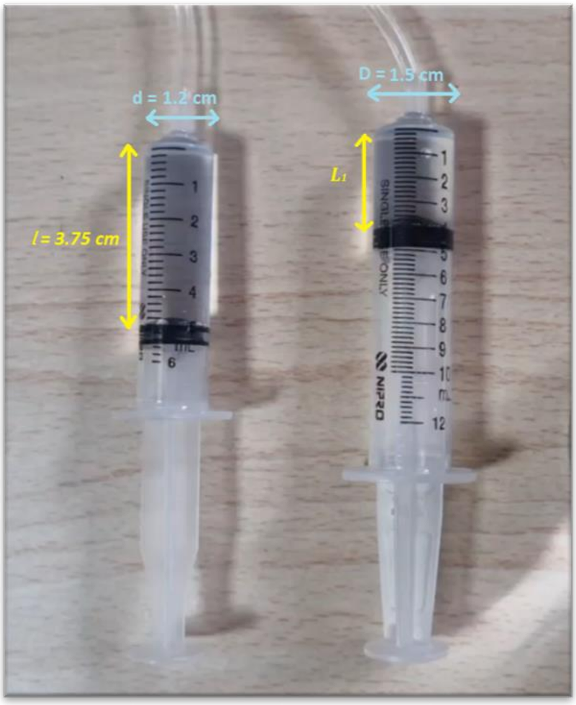

Fig 2.3(b): Initial Position

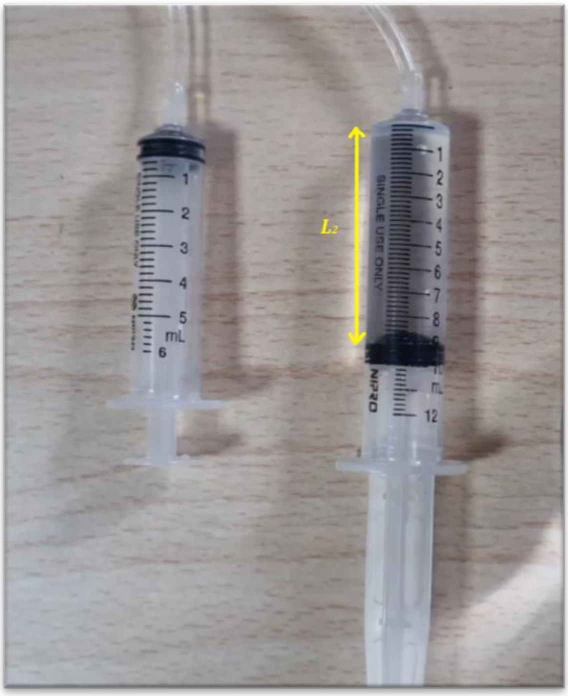

Fig 2.3(c): Initial Position

Small syringe

Diameter $(d) = \ 1.2\ cm$

Displacement $(l) = \ 3.75\ cm$

Large syringe

Diameter $(D) = \ 1.5\ cm$

Displacement $(L) = L_1 - L_2$

2.5 Calculation of lift

From equation 2.2,

$$\frac{a}{A} = \frac{L}{l}$$

$\Rightarrow \ \frac{d^2}{D^2} = \frac{L}{l}$, where d and D are internal diameter, l and L are length of small and large syringe, respectively.

$$\Rightarrow \ \frac{1.2^2 cm^2}{1.5^2\ cm^2} = \frac{L}{3.75cm}$$

$\Rightarrow \quad L = 2.4\ cm$

i.e., **for a displacement of 3.75cm at small syringe causes a lift of 2.4cm at large syringe.**

Also, in the other way if we apply small force at piston end, we could lift much larger weight at the ram end.

Chapter 3

Experimental model of Hydraulic Lift

3.1 Designing Hydraulic Lift.

The model was first designed in Siemens NX CAD and was assembled in Siemens NX Assembly Design. The Fig 3.1 shows the assembled CAD model.

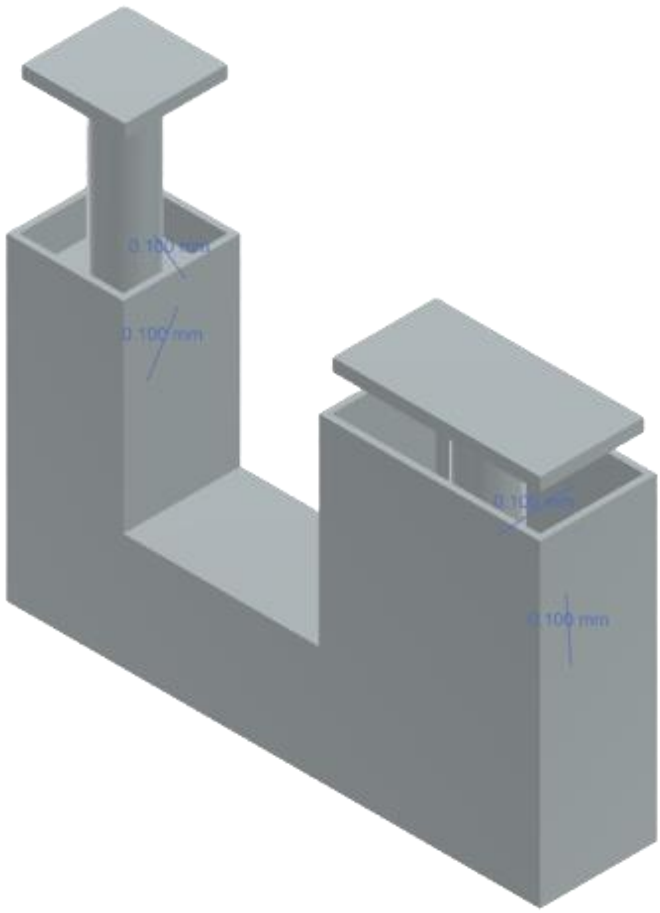

Fig 3.1: CAD Model of Hydraulic Lift

3.2 Part Drawing of the Model

Fig 3.2 shows the isometric, top, side, and front view of the model. It also shows the dimensions of the model.

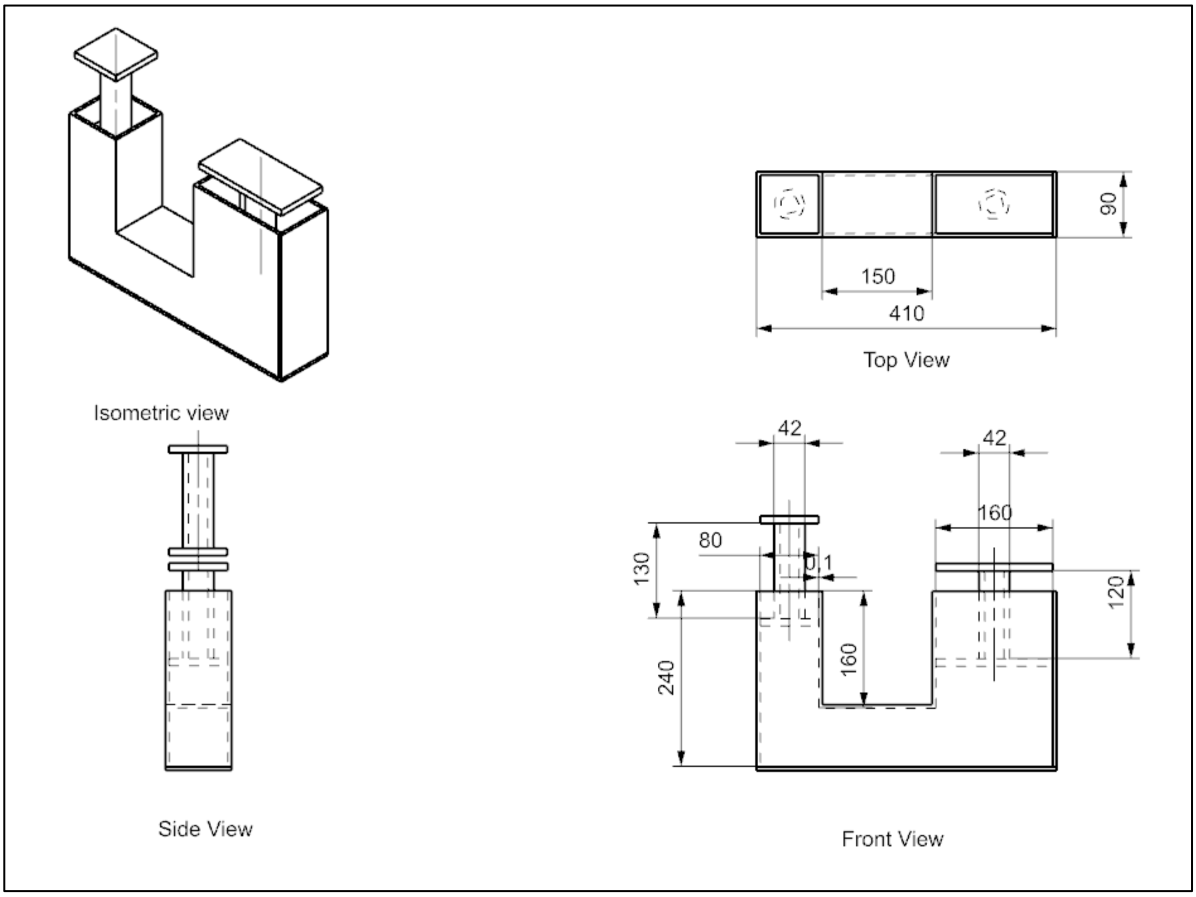

Fig 3.2: Part Drawing of the Model

3.3 Materials Required

- Acrylic Sheet: Area= $0.42m^2$
- Foam Pad for Sealing: $Two\ 8 \times 8\ cm^2\ and\ two\ 8 \times 16\ cm^2$
- Water bottle as piston
- Weight Box
- Colored Water
- Transparent Ruler
- Double sided tape
- Epoxy resin

3.3.a. Expense Sheet

Table 3.1 shows the cost of the materials required for the experimental model.

Sl. No	Materials	Specification	Quantity	Total Cost (in Rs.)
1	Acrylic Sheet	Area= $0.42m^2$	1	1150
2	Foam and rubber pad for sealing	$8 \times 8\ cm^2$	1	80
		$8 \times 16\ cm^2$	1	100
3	Water bottle	1 lite	1	178
4	Weight Box	10 N	1	-
5	Transparent Ruler	15 cm	2	10
6	Double sided tape	10 m	1	50
7	Watercolor	Set of 6	1	95
8	Epoxy Resin	90 gm	1	198
			Total	1861

Table 3.1: Expense Sheet

3.4 Machining

To cut the acrylic sheet we have used hack saw keeping an allowance of 2mm. The sheet bought was of breadth 457.2mm and length 914.4mm. The dimension of required pieces was shown in the Fig 3.3.

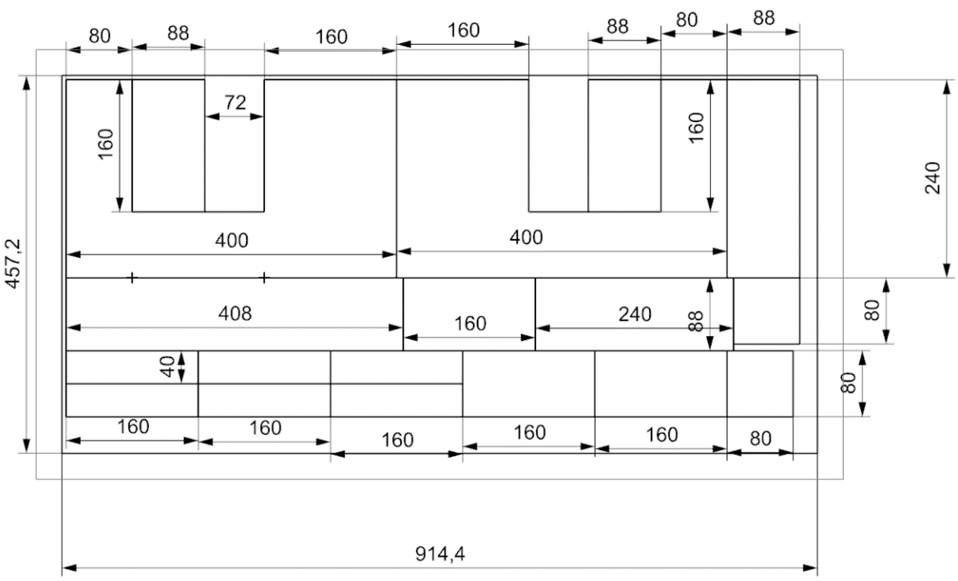

Fig: 3.3 Cutting Layout, *all dimensions are in mm.*

3.5 Assembly of the model

The model was made in 3 parts namely, casing, piston, and ram. The pictorial representation of the parts is described below.

Part I: Fig 3.4(a) shows the casing or body of hydraulic lift.

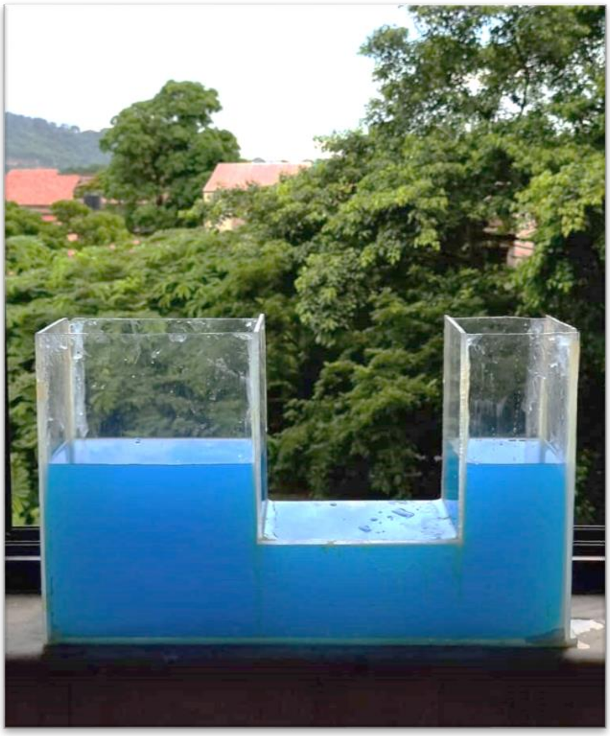

Fig 3.4(a): Casing

Part II: Fig 3.4(b) and 3.4(c) shows ram and piston respectively.

Fig 3.4(b): Ram

Fig 3.4(c): Piston

Final model: The final model after assembly is shown in Fig 3.5.

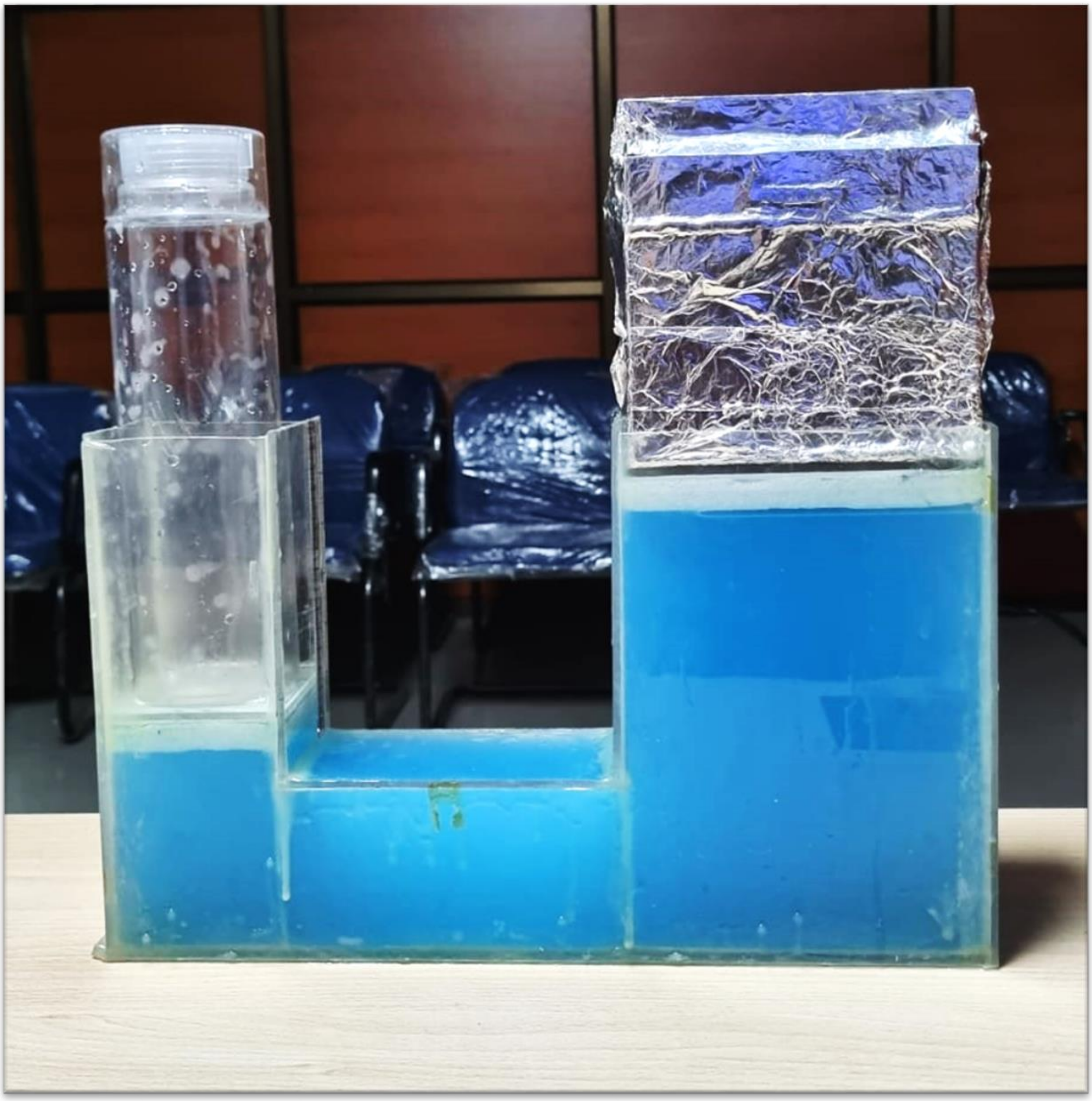

Fig 3.5: Final model

3.6 Calculation of Lift:

For calculation of lift, we apply a small force at piston end to a distance of 10cm. At the ram end the weigh box weighs 10N. Fig 3.6 shows the displacement of ram and piston. The calculation for the lift and force applied is discussed below.

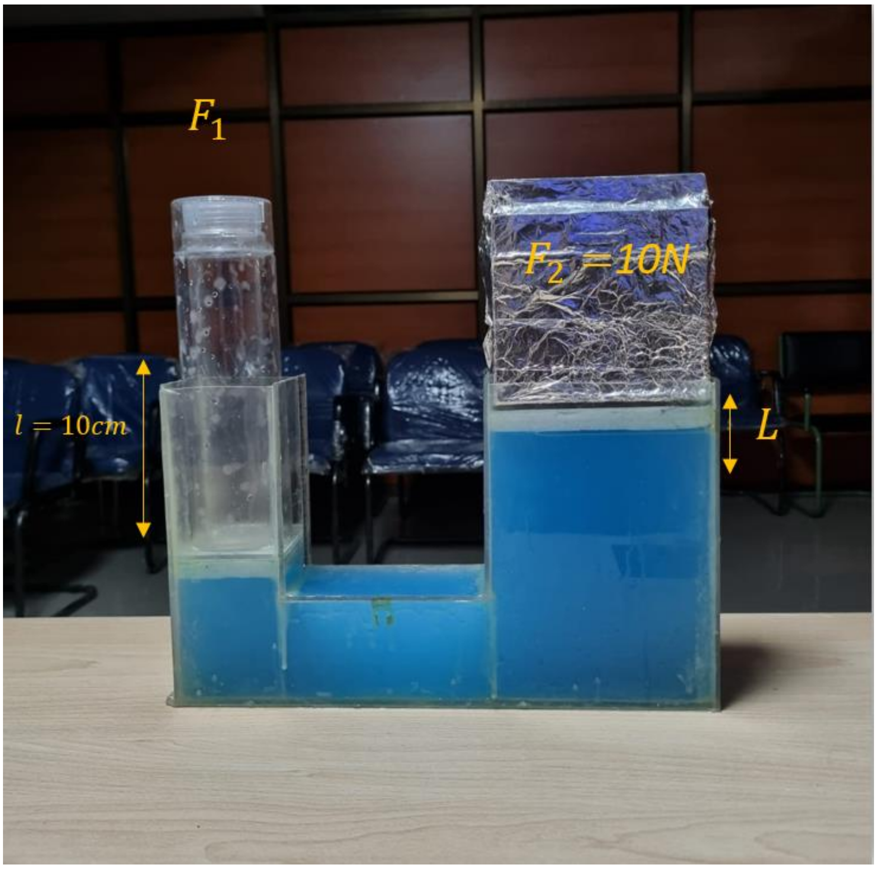

Fig 3.6: Calculation of Lift

Length of displacement at piston end, $l = \ 10\ cm$

Area of piston, a= $8 \times 8 = 64\ cm^2$

Area of Ram, $A = 16 \times 8 = 128 cm^2$

From equation 2.2,

$$\frac{a}{A} = \frac{L}{l}$$

Therefore, length of lift at ram end, $L = \frac{al}{A} = 64 \times \frac{10}{128} = 5cm$

i.e., the length of lift is 5cm.

From equation 2.2,

$\frac{F_1}{F_2} = \frac{a}{A}$ = 0.5, where F_1 is applied force, F_2 is weight of weight box(=10N).

Therefore, $F_1 = 10 \times 0.5 = 5N$

i.e., for lifting 10N weight we applied 5N force.

3.7 Result

- The Hydraulic Lift experimental setup demonstrates Pascal's Law.
- The height of lift of weight was 5cm for a displacement of 10cm at piston end.
- The weight of lift was 10N for an applied force of 5N.

Conclusion

An experiment was performed on Hydraulic Lift to demonstrate the Pascal's Law. The demonstration will help students to build interest in the subject. It will help student to relate theories with physical world. It is very important to clear the basics from the school itself. Pedagogical gadgets are to be implemented not only in science centres but at every school and colleges. It will lead to easy understanding of the concept and increasing the engagement with the subject.

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