DEMONSTRATION OF SIPHON USING A PYTHAGORAS CUP MODEL

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July 2023

CERTIFICATE

This is to certify that the work contained in this report entitled "**DEMONSTRATION OF SIPHON USING A PYTHAGORAS CUP MODEL**" by **Abhinab Sharma**, 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.

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STUDENT DECLARATION

I hereby declare that the entire work embodied in this report entitled "**DEMONSTRATION OF SIPHON USING A PYTHAGORAS CUP MODEL**" has been carried out by me. No part of it has been submitted for any certificate of any institution previously.

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Date: 03/07/2023

Abhinab Sharma

Intern, IITG

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ABSTRACT

This report explores the siphon principle using a Pythagoras cup model as a demonstration tool. The siphon principle is crucial in fluid dynamics and has practical applications in plumbing, water management, and industry. The objective is to provide a clear and intuitive demonstration of the siphon principle through the construction and analysis of a Pythagoras cup model.

The report introduces the siphon principle and its importance in fluid behavior, specifically in transferring liquid from a higher to a lower level without external pumping. The experimental section focuses on building the Pythagoras cup model, which showcases the siphon effect by automatically draining its contents when filled above a certain level.

By conducting controlled experiments, the report investigates factors affecting the siphon effect in the model, such as liquid volume, cup dimensions, and fluid properties. It discusses the practical applications of the siphon principle in plumbing, water management, and industry.

In conclusion, this report provides a comprehensive examination of the siphon principle using a Pythagoras cup model. It enhances understanding of this concept in fluid dynamics, serving as a valuable resource for educators, researchers, and enthusiasts interested in applying the siphon principle in various fields.

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Chapter 1

Introduction

1.1. Pedagogy

Pedagogy means theory, practice and teaching and learning. It includes the ideas, strategies and techniques teachers use to support students' learning and development. Pedagogy involves careful planning and use of instruction, assessment strategies, and classroom discussions to create effective learning.

Effective teaching includes creating a supportive and learning environment, using appropriate teaching methods, providing timely feedback, and encouraging student participation and collaboration. It also considers the integration of technology, cultural practices and personal systems to meet the educational needs of many people.

1.2. Aim of Pedagogy

The aim of pedagogy is to facilitate effective teaching and learning processes that lead to meaningful and transformative educational experiences. It encompasses several specific goals and objectives, including:

- **Promoting Learning**: Pedagogy aims to create an environment that fosters active engagement, critical thinking, and knowledge acquisition among learners. It seeks to support the development of cognitive, social, emotional, and practical skills necessary for lifelong learning.
- **Nurturing Understanding**: Pedagogy strives to help learners develop a deep and meaningful understanding of the subject matter. It goes beyond memorization and encourages higher-order thinking, problem-solving, and the application of knowledge in real-life contexts.
- **Enhancing Student Engagement:** Pedagogy aims to create learning experiences that actively involve and engage students. It seeks to spark curiosity, motivation, and a sense of ownership in the learning process. By incorporating interactive and participatory methods, pedagogy encourages students to become active learners.
- **Supporting Individual Needs:** Pedagogy recognizes and responds to the diverse needs, interests, and abilities of learners. It seeks to provide differentiated instruction,

personalized learning approaches, and inclusive practices that accommodate various learning styles, backgrounds, and abilities.

- **Cultivating Critical Thinking and Creativity:** Pedagogy aims to develop learners' critical thinking skills, problem-solving abilities, and creativity. It encourages them to analyze, evaluate, and question information, as well as to generate innovative ideas and solutions.
- **Fostering Collaboration and Communication:** Pedagogy emphasizes collaborative learning and effective communication skills. It promotes teamwork, cooperation, and the ability to express ideas, listen actively, and engage in constructive dialogue with peers and educators.
- **Cultivating Ethical and Responsible Citizenship:** Pedagogy aims to foster ethical awareness, social responsibility, and empathy among learners. It promotes values such as respect, fairness, inclusivity, and environmental consciousness, preparing students to be active and responsible citizens in society.

Overall, the aim of pedagogy is to create a supportive and stimulating learning environment where learners can develop the knowledge, skills, attitudes, and values they need to succeed academically and thrive in their personal and professional lives.

1.3. Siphon

A siphon as seen in Figure 1.1 is a tube or pipe that allows liquid to flow from a higher level to a lower level, without the need for pumping or external power. It operates based on the principles of atmospheric pressure and gravity. A siphon consists of two ends, with one end placed in a container or source of liquid at a higher elevation and the other end positioned below the liquid level or at a lower elevation.

To start the siphoning process, the initial end of the tube is filled with liquid and then sealed to prevent air from entering. Gravity takes over, causing the liquid to flow down the tube. As the liquid descends, it creates a vacuum or partial vacuum behind it. This vacuum pulls the liquid from the higher level, up and over any obstacles, and down to the lower level.

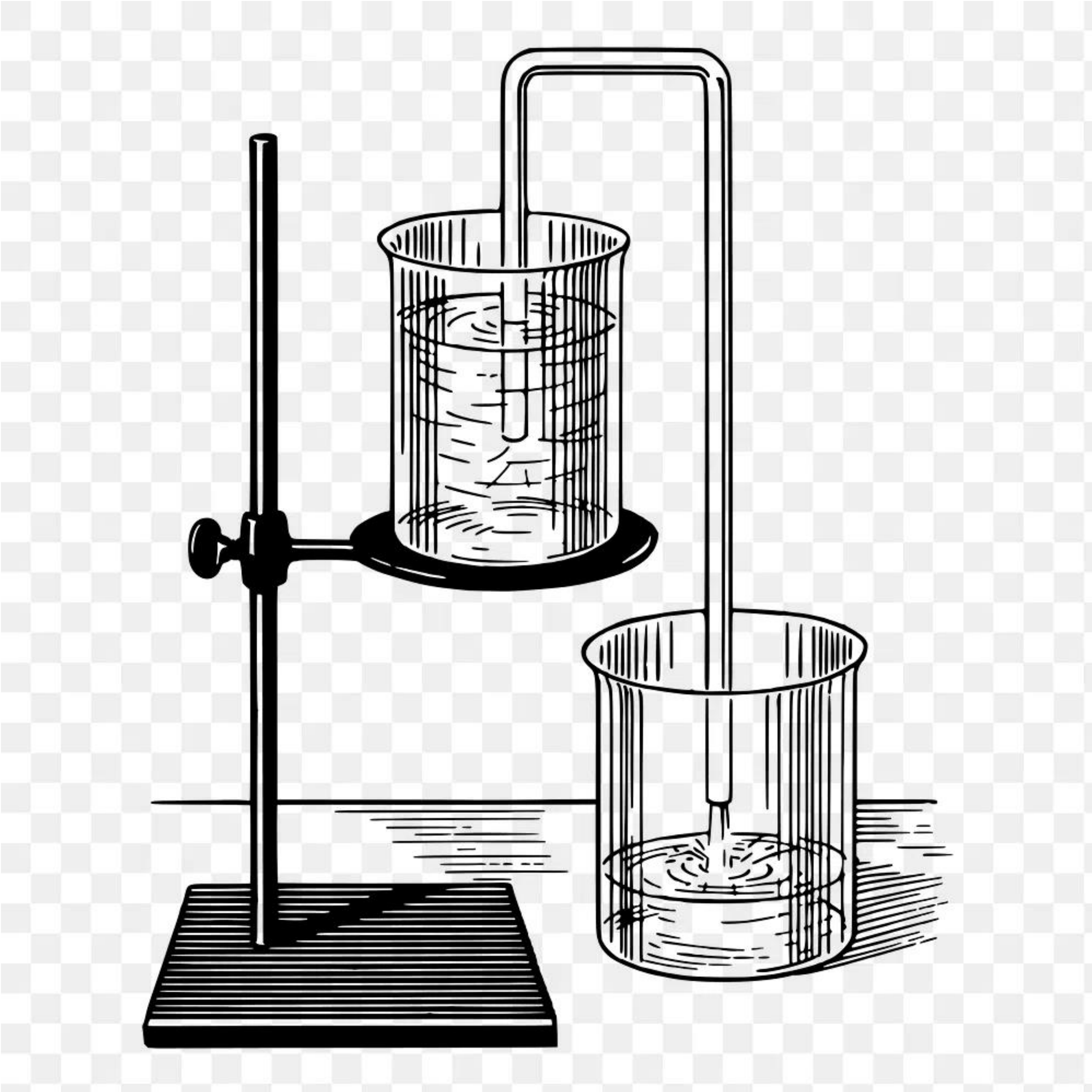


Figure 1.1. A Siphon

Source: https://www.rawpixel.com/image/6333424/png-sticker-public-domain (Under the Creative Commons License)

Siphons are commonly used in various applications, such as transferring fluids between containers, draining water from one location to another, or even in certain irrigation systems. They are simple yet effective devices that rely on natural forces to facilitate the flow of liquid.

1.4. Application areas of Siphons

Siphons have various application areas where their unique properties of liquid flow without the need for external power or pumping are beneficial. Some common application areas of siphons include:

Liquid Transfers: Siphons are frequently used to transfer liquids from one container to another. This can be useful in situations where it is challenging to directly pour or lift the liquid, such as when emptying large tanks, aquariums, or fuel containers.

Aquaria and Fish Tanks: Siphons are widely employed in maintaining aquariums and fish tanks. They help in removing debris, waste, and excess water during cleaning processes without disturbing the aquatic life.

Fuel and Fluid Transfers: Siphons are commonly used to transfer fuels, such as gasoline, diesel, or kerosene, from one container to another. They are also used for transferring fluids like water, oil, or chemicals in various industrial applications.

Home Brewing and Winemaking: Siphons are utilized in the brewing and winemaking processes to transfer liquids between different vessels, such as fermenters, carboys, and bottles, while minimizing oxygen exposure and maintaining the desired flavors and quality.

Irrigation Systems: Siphons are employed in certain types of irrigation systems, particularly gravity-based systems. They allow water to flow from higher elevation sources, such as reservoirs or tanks, to lower-lying areas without the need for pumps, providing a cost-effective and energy-efficient irrigation solution.

Laboratory Applications: Siphons find application in laboratories for various tasks, including transferring liquids between containers, separating liquids of different densities, or controlling liquid levels in experiments or equipment.

Household Chores: Siphons can be handy for household tasks, such as unclogging sinks or draining water from washing machines, bathtubs, or waterbeds.

Emergency Preparedness:

In emergency situations or outdoor activities, a siphon can be useful for obtaining water from hard-to-reach sources or for transferring fuel in case of emergencies or power outages.

These are just a few examples of the application areas where siphons are utilized. The simplicity and versatility of siphons make them a practical solution for liquid transfer in various contexts.

1.5. Advantages of using a siphon

The use of a siphon offers several advantages in various contexts. Here are some of the key benefits:

- **Fluid Transfer:** A siphon is a simple and effective way to transfer liquids from one container to another without any external power or complex machinery. It allows for the movement of fluids by utilizing the force of gravity, making it a practical solution for situations where a power source is unavailable or impractical.
- **Versatility:** Siphons can be used with various liquids, including water, fuels, chemicals, and more. They can be employed in multiple settings such as homes, laboratories, industries, and agricultural applications.
- **Cost-Effectiveness:** Siphons are relatively low-cost tools that require minimal equipment. They typically consist of a tube or hose and utilize the force of gravity, eliminating the need for additional pumps or power sources. Hence it becomes a cost-effective option for fluid transfer compared to more complex systems.
- **Simplicity and Ease of Use:** Siphons are straightforward to set up and operate. The basic principle involves creating a vacuum or suction by filling the siphon tube with liquid and initiating the flow by positioning the outlet lower than the source. Once the siphon establishes, it operates automatically, requiring minimal effort to maintain the flow.
- **No Contamination or Cross-Contamination:** Siphons provide a hygienic method of transferring liquids. With the force of gravity, the flow is unidirectional, preventing any backflow or mixing of fluids, and is particularly important in applications such as food and beverage handling or laboratory experiments, where maintaining purity and preventing cross-contamination is crucial.

Safety: Siphons can be used in areas where it may be unsafe or impractical to use electrical or mechanical pumps. They eliminate the risks associated with electrical malfunctions, sparks, or the need for power sources in potentially hazardous environments. Additionally, siphons can be utilized during emergencies or in areas with limited access to power, providing reliable fluid transfer.

It's important to note that while siphons offer numerous advantages, they also have limitations. They are primarily effective for transferring fluids over relatively short distances and require careful consideration of factors such as the height differential and the compatibility of the liquids. Proper handling, maintenance, and adherence to safety guidelines are essential to ensure optimal performance and prevent accidents or spillages.

1.6. Historical Evidence of the Use of the Siphoning Principle

Historical evidence of the use of the siphoning principle dates back thousands of years, demonstrating its widespread and long-standing application in various civilizations. Here are a few examples:

- **Ancient Egypt:** The use of siphons can be traced back to ancient Egypt, where they were employed in irrigation systems and hydraulic engineering. The ancient Egyptians utilized siphons in canals, aqueducts, and water transportation networks to efficiently move water between different levels and areas.
- **Ancient Greece and Rome:** Both ancient Greek and Roman civilizations employed siphons in their water supply systems. The Romans, in particular, were known for their advanced aqueduct systems, which often utilized siphons to transport water over hills and valleys, overcoming topographical obstacles.
- **Chinese Water Clocks:** Ancient Chinese water clocks, such as the clepsydra, employed siphons as part of their mechanism to regulate the flow of water. By using the siphoning principle, these clocks could accurately measure the passage of time through the controlled flow of water.
- **Medieval Islamic Civilization:** During the medieval period, Islamic scientists and engineers made significant contributions to the understanding and application of the siphoning principle. Scholars such as Al-Jazari described the use of siphons in various hydraulic devices and water-raising machines.

Renaissance and Industrial Era: The understanding and application of siphons continued to evolve during the Renaissance and the subsequent Industrial Era. The advancements in physics, engineering, and scientific knowledge during this period led to further refinement and utilization of the siphoning principle in various fields, including fluid mechanics, manufacturing processes, and scientific experiments.

1.7. Indian History associated with Siphon

India has a rich history of water management and hydraulic engineering, and it is likely that siphonic principles were employed in various water-related systems. Here are a few examples of Indian history associated with water management:

Stepwells: Stepwells, also known as baoris or vavs, are architectural structures found in various parts of India. These elaborate wells were not only used for accessing groundwater but also incorporated intricate water distribution systems. While there might not be explicit documentation of siphonic principles being used in stepwells, the presence of underground tunnels, galleries, and channels within these structures suggests the potential utilization of siphonic action to move water between different levels.

Irrigation Systems: India has a long history of sophisticated irrigation systems, such as canals and water channels, designed to distribute water for agricultural purposes. While the specific mechanisms and technologies used in these systems vary, it is possible that siphonic principles were employed in certain aspects of water flow management and distribution.

Water Clocks: Ancient India had a tradition of water clocks, also known as ghatika or jalakumbha. These timekeeping devices utilized the flow of water to measure the passage of time. While the detailed mechanisms of these clocks are not extensively documented, it is likely that siphonic principles played a role in regulating the water flow and maintaining accuracy in timekeeping.

Aqueducts: Ancient India had aqueducts like the Bukka Aqueduct in Hampi, which used siphoning to transport water over long distances.

Indus Valley Civilization: The advanced water management systems of Mohenjo-daro and Harappa likely used siphoning to channel water for various purposes.

Rani ki Vav

This Stepwell is almost 1000 Years Old and Ancient Stepwell in Patan, Gujarat.

Designed as an inverted temple as shown in Figure 1.2, it is divided into seven levels of stairs.

The fourth level is the deepest and leads into a rectangular tank (9.5m×9.4m), at a depth of 23m.

It is in the westernmost end of the property and consists of a shaft 10m in diameter and 30m deep.

Figure 1.2: Rani ki Vav

Source: https://www.unescowhs.com/ancient-queens-well/ (Under the Creative Commons License)

The Kallanai Dam

The Kallanai Dam as shown in Figure 1.3 was built during the second century AD by Karikalan, a king of southern India's old Chola Dynasty and is also one of the oldest irrigation systems in the world that is still in use" (Agoramoorthy and Hsu, 2008).

It was built to divert floods from the kaveri branch of the river into the kollidam branch via a short connecting stream when the water level rose above its crest.

Figure 1.3: The Kallanai Dam

Source: https://www.thecivilengineer.org/education/online-historical-database-of-civil-infrastructure/kallanai-dam-grand-anicut, https://commons.wikimedia.org/wiki/File:Kallanai_dam.jpg (Under the Creative Commons License

Chapter 2

The Pythagoras Cup

2.1. Definition

A Pythagorean cup, also known as a Tantalus cup or greedy cup is a type of self-emptying or self-regulating cup with an ingenious mechanism. It is named after the ancient Greek mathematician and philosopher Pythagoras.

2.2. Construction and working

The Pythagorean cup consists of a drinking vessel with a hidden tube or channel in its stem. When the cup is filled with liquid to a certain level, it functions like a regular cup. However, if the liquid surpasses this threshold, the cup's mechanism is triggered.

The hidden tube acts as a siphon, and when the liquid exceeds the predetermined level, it starts to drain out of the cup through the tube. This causes the cup to empty itself completely, frustrating the user's attempts to consume more than the intended amount of liquid.

2.3. Purpose of the creation

The purpose of the Pythagorean cup is often regarded as a symbolic lesson in moderation and self-control. It serves as a reminder that excessive indulgence or greed can lead to undesirable consequences. By showcasing the consequences of overindulgence, the Pythagorean cup encourages individuals to practice restraint and moderation in their actions and desires.

Today, the Pythagorean cup is primarily seen as a novelty item or a curiosity, and it is often found in museums or private collections. It continues to captivate people with its clever mechanism and serves as a tangible reminder of the wisdom imparted by Pythagorean teachings.

2.4. History

The history of the Pythagorean cup, also known as the Tantalus cup or greedy cup as shown in Figure 2.1, is intertwined with ancient Greek philosophy and its teachings on self-control and moderation.

It is commonly associated with Pythagoras, the renowned Greek mathematician and philosopher who lived around the 6th century BCE.

Pythagoras was known for his teachings on ethical and moral principles, which emphasized moderation and self-discipline. The story behind the Pythagorean cup reflects these principles. According to the legend, Pythagoras invented the cup as a lesson to his students and associates, illustrating the consequences of greed and excessive indulgence.

(a)

(b)

Figure 2.1: The Pythagoras cup (a): Full View (b): Cross-sectional view

Source: https://commons.wikimedia.org/wiki/File:Pythagorean_cup_cross_section.jpg, https://commons.wikimedia.org/wiki/File:Pythagorean_cup_from_Samos.jpg (Under the Creative Commons License)

The Pythagorean cup has become a symbol of the philosophical concept of moderation. The cup's clever mechanism serves as a reminder to avoid excessive desires and to practice self-control.

CHAPTER 3

Pedagogical Models of the Pythagoras Cup

3.1 The Simple Design

The Simple Design is a name given to the Pythagoras Cup model which required nothing but just a bottle and a tube.

The Simple Model is shown in Figure 3.1.

Figure 3.1: The Simple Design of the Pythagoras Cup

3.1.1. Material Used while creating this design:

1. A bottle
2. A 6mm internal dia. silicon tube

3.1.2. Construction and Working

This model worked in a way like that of the original Pythagoras cup.

A hole was made in the bottle of the size of the outer diameter of the Silicon tube, and in which the silicon tube was inserted, such that its one end touched the bottom of the bottle from inside and the other end remained suspended vertically downwards.

At the hole, the bending of the tube took place, thereby creating a limit of the bottle. This means that the water in the bottle can be filled only until this height. As soon as the water level in the bottle exceeds this height, all the water from the bottle drains out from the other end of the tube thereby demonstrating a self-starting Siphon.

The Simple Model was created only to understand the Pythagoras Cup and ultimately the Siphon mechanism, its working principle, and its mechanism.

The Simple model worked fine, thereby explaining to us the working mechanism of a Pythagoras cup and hence a Siphon.

3.2. The Model Cup

The Model Cup as shown in Figure 3.2 is a Pythagoras cup model created by me that can be used as a pedagogical gadget to understand the siphon mechanism.

Figure 3.2: The Pythagoras Cup Model

3.2.1. Materials Used:

- A plastic cup,
- A tube,
- Adhesives,
- A knife,
- Some coloured papers.

3.2.2. Construction and working:

The design of this cup is simple yet very effective. A hole is created at the centre of the bottom of the cup. The hole dimension is kept equal to the outer dimension of the tube. The tube is then inserted inside the hole from outside. It is inserted until a very small portion of the tube end is seen at the bottom of the Cup. The tube is then bent such that its other end touches the bottom of the Cup from inside. This U-shaped tube inside the Cup depicts the Central column of the Pythagoras Cup. I call it the magical central column because all the magic of the cup happens here. A better understanding of the Central column is seen in section 3.3 with the aid of another pedagogical model. This model Cup when filled with liquid upto the height of the tube inside the cup, works as a normal drinking Cup. But as soon as you pour more liquid thereby exceeding the limit height, all the liquid from the cup drains out from the outer end of the tube and thus from the bottom hole of the cup.

3.3. The Magical Central Column

The central column model also called as cross-sectional model of the Pythagoras cup as shown in Figure 3.3 shows and explains the central column of the cup in an elegant manner.

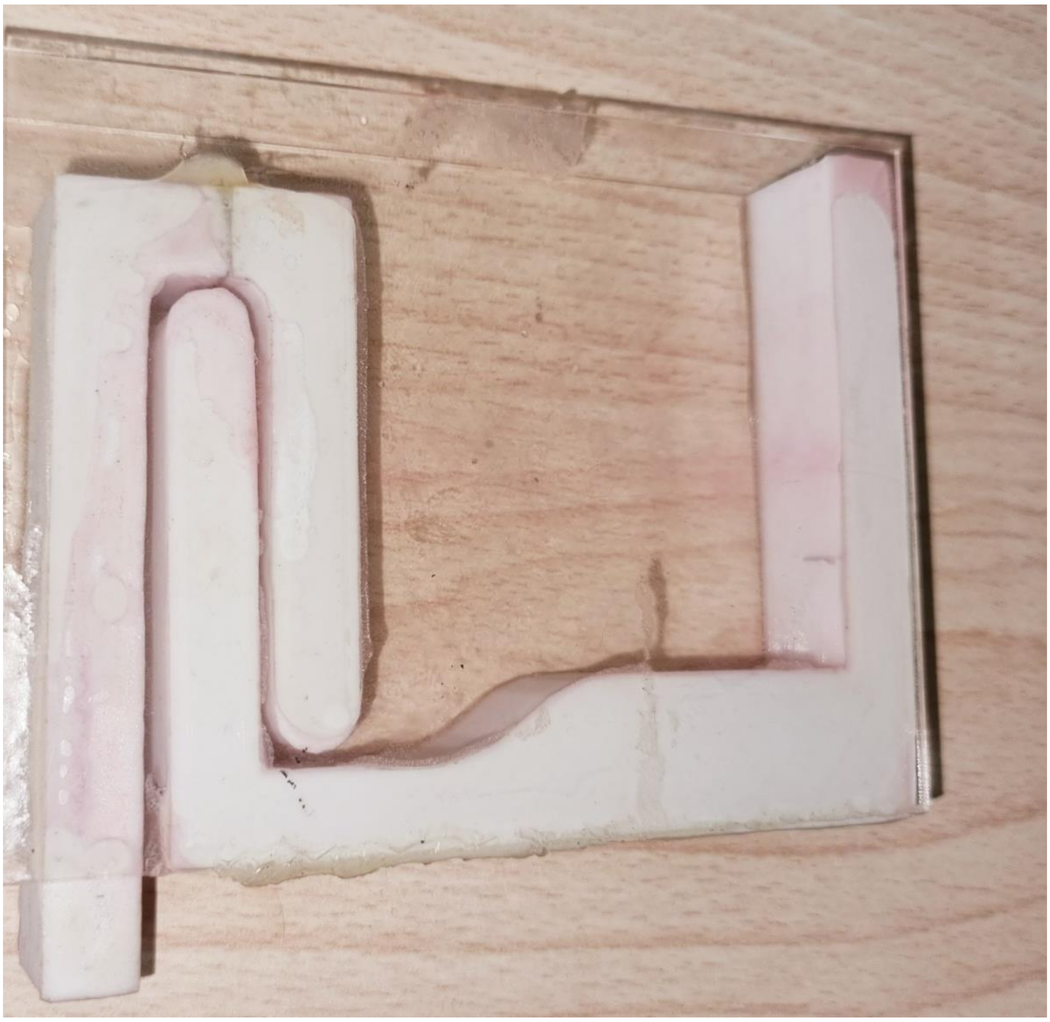


Figure 3.3: The Cross-Sectional Model

The central column of the Pythagoras cup is a unique feature that adds an interesting twist to a regular drinking cup. The tube or channel in the column acts as a siphon. As the liquid rises above the level set by the column, it flows through the channel and down into the base of the cup. This creates a siphoning effect that drains the cup from the bottom, causing the liquid to spill out. The central column of the Pythagoras cup adds an element of surprise and humor to an otherwise ordinary drinking vessel. It serves as a clever mechanism to discourage people from taking more than their fair share and promotes the virtue of moderation.

3.3.1. CAD Design

To fabricate the required parts, the design of the required parts was created in CATIA V5 as shown in Figure 3.4.

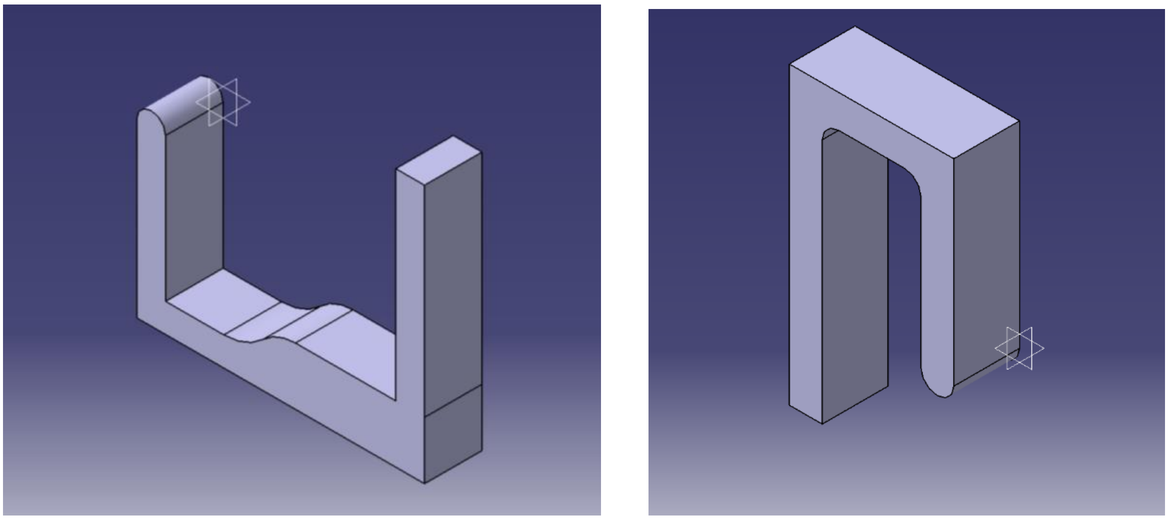
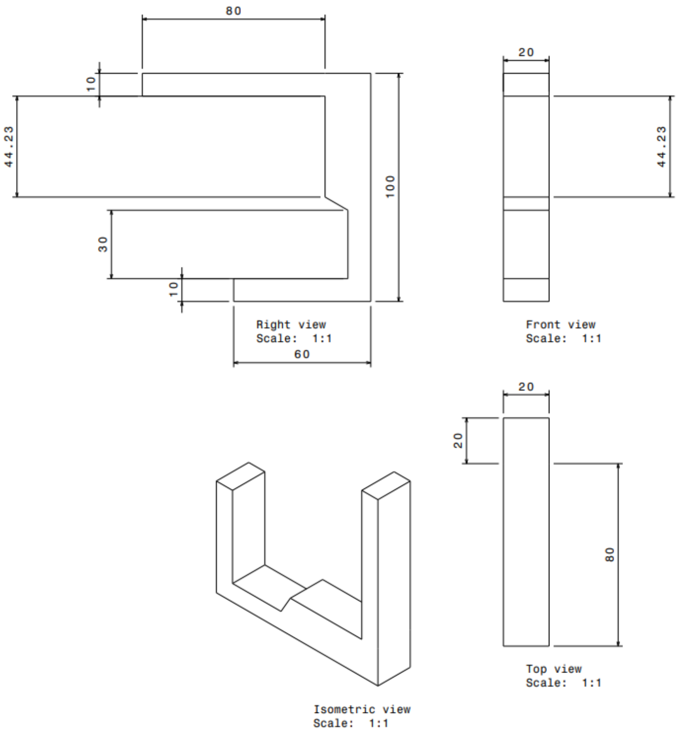


Figure 3.4: CAD models of the fabricated parts

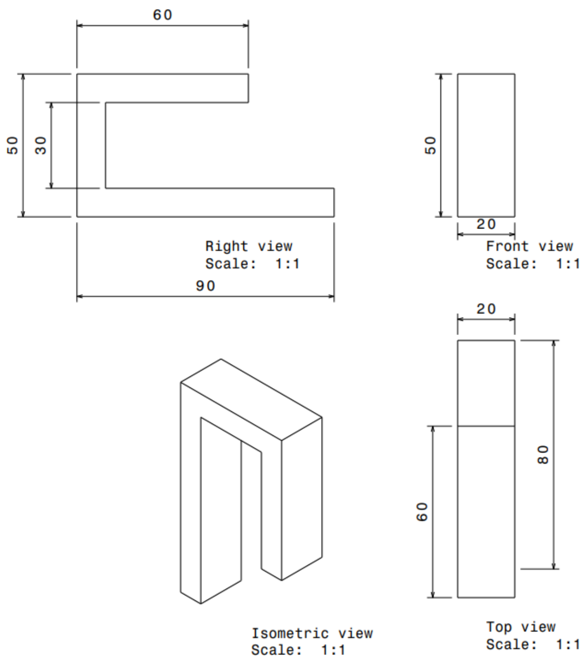
The CAD models created were kept in precise dimensions to ensure the proper functioning of the cross-sectional model.

The dimensions of the parts as shown in Figure 3.5 are provided with necessary calculations required for smooth functioning of the cup model.

The part designs were then assembled to check whether the parts would fit properly to create the required assembled design.



(a)



(b)

Figure 3.5: Dimensions of the CATparts

The Central Column considers the entire mechanism of the cup along with the underlying principles and equations. A brief description of these principles and equations is seen in section 3.3.2.

3.3.2. Underlying Principles and Equations

- **Hydrostatic Pressure Equation:**

The hydrostatic pressure at a given depth in a fluid is given by,

$$\boldsymbol{P = \rho g h} \tag{3.1}$$

where P is the pressure, ρ is the density of the fluid, g is the acceleration due to gravity, and h is the depth.

- **Bernoulli's Equation:**

Bernoulli's equation relates the pressure, velocity, and height of a fluid along a streamline. In the context of a siphon, it can be used to understand the fluid flow:

$$\boldsymbol{P_1 + \frac{1}{2}\rho v_1{}^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2{}^2 + \rho g h_2} \tag{3.2}$$

where P_1 and P_2 are the pressures at two different points along the siphon, v_1 and v_2 are the velocities at those points, and h_1 and h_2 are the heights.

- **Continuity Equation:**

The continuity equation states that the mass flow rate of an incompressible fluid is constant along a streamline:

$$\boldsymbol{A_1 v_1 = A_2 v_2} \tag{3.3}$$

where A_1 and A_2 are the cross-sectional areas at two different points along the siphon, and v_1 and v_2 are the velocities at those points.

- **Torricelli's Law:**

Torricelli's law relates the velocity of a fluid exiting an opening to the height of the fluid above the opening:

$$v = \sqrt{2gh} \tag{3.4}$$

where v is the velocity of the fluid, g is the acceleration due to gravity, and h is the height of the fluid column.

3.3.3. 3D Printing

The stl files were utilized in Ultimaker Cura for Slicing and getting the file ready for 3D printing.

Following are the details of 3d printing:

- **Machine Used**: FDM 3D Printing Machine
- **Model**: Creality Ender 5 Plus
- **Printing Material**: PLA+
- **Weight**: 60 grams
- **Layer Thickness**: 0.2 mm
- **Print Time**: 6 hours and 51 minutes

The 3D printed Parts as shown in Figure 3.6 are then assembled. This assembly was then supported by acrylic sheets from both sides which led to the creation of the final Cross-sectional model.

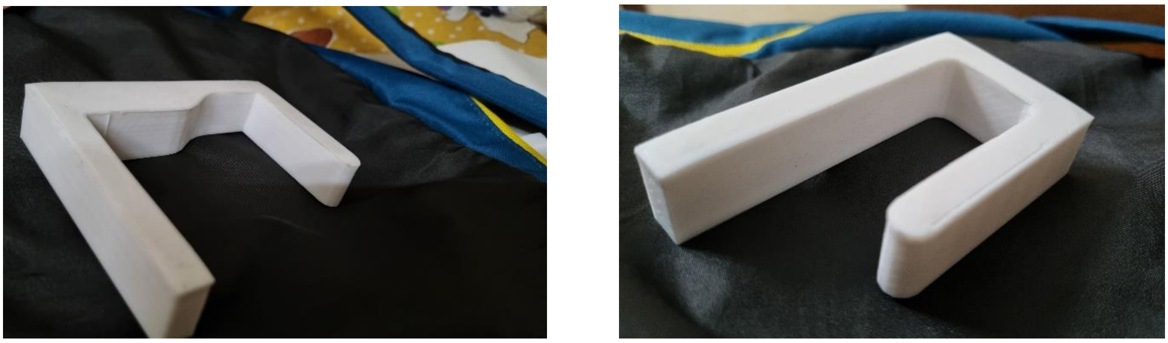


Figure 3.6: 3D printed Parts

APPENDIX

Table A: <u>Project Cost Report</u>

Material	**Cost (Rs.)**	**Quantity**	**Total Cost (Rs.)**
Acrylic Sheet (120*90)	125	2	250
Acrylic Sheet (90*90)	50	2	100
Epoxy resin	198	1	198
FeviQuick	10	3	30
Poster Colour	95	1	95
Total			**673**

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