

# **DEMONSTRATING BERNOULLI'S PRINCIPLE WITH THE HELP OF A HYDRODYNAMIC LEVITATION MODEL**

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**July 2023**



## CERTIFICATE

This is to certify that the work contained d in this report entitled “**Demonstrating Bernoulli’s principle with the help of Hydrodynamic Levitation Model**” by **Shubham Gayan** 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.

July 2023

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Date: 03/07/2023

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**Shubham Gayan  
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## ABSTRACT

Hydrodynamic levitation, also known as fluid levitation, is an intriguing phenomenon that defies gravity and offers exciting possibilities across various scientific and industrial applications. This abstract provides a concise overview of hydrodynamic levitation, its underlying principles, and its practical implementations.

Hydrodynamic levitation involves the levitation and stabilization of objects using fluid pressure and flow dynamics, without the need for solid mechanical supports. It relies on the delicate balance between fluid forces, such as buoyancy, pressure gradients, and viscous effects, to counteract the gravitational pull and maintain objects suspended in mid-air or liquid mediums.

In conclusion, hydrodynamic levitation is a captivating scientific phenomenon that has the potential to revolutionize various industries. Its ability to suspend objects in a fluid medium without physical contact opens new possibilities for research, manufacturing, and technological innovation. By understanding the underlying principles and exploring the challenges and opportunities, researchers can harness the power of hydrodynamic levitation for a wide range of fascinating applications.



## TABLE OF CONTENTS

	<b>Page No.</b>
CERTIFICATE	2
CANDIDATES DECLARATION	4
ACKNOWLEDGEMENT	6
ABSTRACT	8
TABLE OF CONTENTS	10
LIST OF FIGURES	12
LIST OF TABLES	14
<b>Chapter 1 – Introduction</b>	
1.1 Pedagogy	16
1.2 Aim of pedagogy	17
1.3 Bernoulli's Principle	17
1.4 Application of Bernoulli's Principle	19
<b>Chapter 2 – Hydrodynamic Levitation</b>	
2.1 Brief Introduction	21
2.2 Principles of Hydrodynamic Levitation	22
2.3 Historical applications of Hydrodynamic Levitation	23
2.4 Historical References	24
2.5 Indian Historical references to Hydrodynamic Levitation	26
2.6 Application of Hydrodynamic Levitation	27
2.7 Nozzle	28
2.8 Why do the ball levitate	29
2.9 Equations Involved	30
<b>Chapter 3 – Model of Hydrodynamic Levitation</b>	
3.1 Demonstration	32
3.2 Materials Required	32
3.3 Result	33
3.4 Conclusion	33
<b>Appendix</b>	34
<b>References</b>	35



## LIST OF FIGURES

	<b>Page No.</b>
Figure 1.1. Bernoulli's principle demonstration	18
Figure 1.2: Atomizer	20
Figure 1.3: Venturi meter	20
Figure 2.1: Hydrodynamic Levitation of a ball	21
Figure 2.2: Granite wheel fountain	25
Figure 2.3: Nozzle	29
Figure 3.1: Materials used in experiment	32
Figure 3.2: Complete set up	33



## LIST OF TABLES

	<b>Page No.</b>
Table 1: Project Cost Report	34





# CHAPTER 1

## INTRODUCTION

### 1.1 PEDAGOGY

Pedagogy refers to the methods, techniques and strategies used in teaching and learning to facilitate learning and support student development. It includes the theories, principles and practices that guide teachers in designing and delivering effective teaching. Pedagogy involves understanding how students learn, identifying their individual needs and abilities, and choosing appropriate instruction to meet those needs. It covers many topics such as curriculum design, lesson planning, teaching methods, assessment methods and classroom management. Effective education takes into account factors such as students' content, age and development, experience and experience, leadership, and learning goals.

It is designed to create a collaborative and interactive learning experience that fosters critical thinking, problem solving, collaboration, creativity, and a lifelong love of learning. There are different teaching methods, each with its own theoretical basis and teaching methods.

Some teaching methods include:

- **Lecture-based:** In this traditional method, the teacher presents knowledge through lectures and demonstrations as well as interaction between teacher and students.
- **Inquiry-Based:** This approach emphasizes active learning and student inquiry. It encourages students to ask questions, explore problems, and improve their knowledge through inquiry and activities.
- **Collaborative Learning:** This approach emphasizes teamwork and collaboration among students. It encourages collaboration, communication and sharing of ideas and thoughts.
- **Problem-Based Learning:** In this way, students are confronted with real-world problems or situations that require thinking and problem solving. They analyze and solve problems in small groups, using their knowledge and skills in practical situations.
- **The Flipped Classroom:** This approach requires students to engage with the content outside of the classroom, often through pre-recorded videos or reading.

Class time is used for discussion, activities, and application of knowledge.

Pedagogy continues to evolve as educators adapt to new research, technological advances and changing educational needs. Choosing the right teaching method, educational background, educational goals, etc.

## 1.2 AIM OF PEDAGOGY

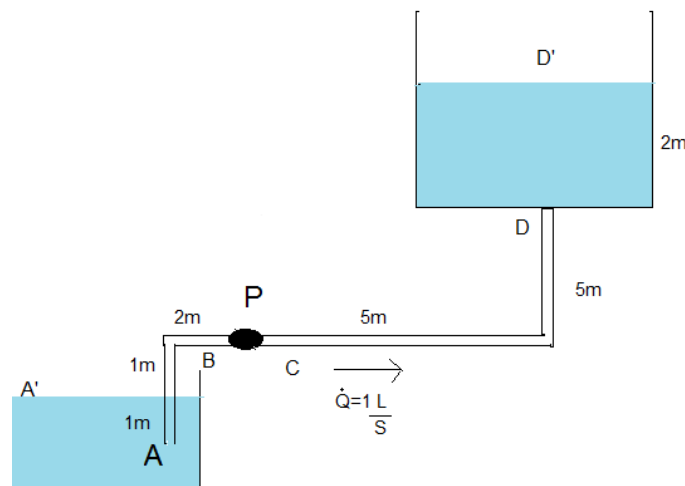
- The purpose of pedagogy is to facilitate effective teaching and learning. It consists of theories, methods and practices that teachers use to guide and motivate students to acquire knowledge, skills, attitudes, and values. The purpose of pedagogy is to facilitate meaningful learning that enables students to reach their full potential and become active, engaged, lifelong learners.
- Pedagogy includes understanding how students learn, developing and implementing appropriate instructional strategies, evaluating learning outcomes, and adapting instruction to individual and collective needs. It emphasizes creating a positive and inclusive learning environment that encourages positive thinking, creativity, collaboration, and problem solving.
- Pedagogy aims to be a framework with many principles, ideas, and practices, all of which contribute to the effectiveness of teaching and learning. With a deep understanding of how students learn, pedagogy aims to create the best learning environment in which students gain knowledge, develop skills, behave and benefit.
- Pedagogy focuses on creating an environment that fosters critical thinking, creativity, collaboration and problem-solving skills. It encourages students to explore, question and form their own understanding of the world rather than simply using accessible information.
- Pedagogy involves the integration of technology and other disciplines to improve teaching and learning. It recognizes the transformative power of digital tools, multimedia resources and interactive communication to expand access to information, encourage collaboration and improve learning outcomes. Teaching methods include responsible and efficient use of technology, teaching objectives, and keeping up with the changing digital environment as students learn.

## 1.2 BERNOULLI'S PRINCIPLE

Bernoulli's principle, named after the Swiss mathematician and physicist Daniel Bernoulli, states that the pressure of a liquid (liquid or gas) decreases when its velocity increases, and vice versa, its pressure rises when the velocity of the liquid decreases. In other words, there is an interaction between the velocity and pressure of the fluid. Bernoulli's principle is based on the conservation of energy principle applied to fluid dynamics.

According to this principle, the total energy of the fluid remains constant with respect to the system, which is the reflection of the lines through which the water flows. The total energy has two components: the kinetic energy associated with the motion of the fluid and the potential energy associated with its height relative to the reference point.

As shown in Figure 1.1, when fluid flows through a narrow or curved portion of the pipe, the velocity of the fluid increases due to the conservation of mass. Therefore, according to Bernoulli's principle, the pressure of the fluid decreases in the high velocity field. This can be explained by considering the exchange of kinetic energy and pressure energy in the fluid. For example, consider the airflow over the wing of an airplane. The curved shape of the airfoil causes air to move faster at the surface than at the base. According to Bernoulli's principle, the pressure of the fast-moving air at the top of the wing is lower than the pressure of the slow-moving air below. This pressure difference creates a lift that keeps the aircraft in the air.



**Fig. 1.1 Bernoulli's Principle Demonstration**

Source: [https://commons.wikimedia.org/wiki/File:Diagram\\_of\\_Bernoulli%27s\\_principle.png](https://commons.wikimedia.org/wiki/File:Diagram_of_Bernoulli%27s_principle.png)

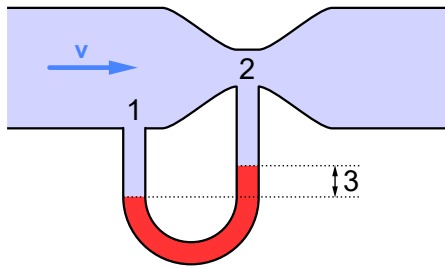
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## 1.4 APPLICATION OF BERNOULLI'S PRINCIPLE

Bernoulli's principle has many practical applications in many fields. Here are some important applications:

- 1. Aviation and Aerodynamics:** Bernoulli's principle is important for understanding the lift of an airplane wing. The faster the airflow over the curved surface, the lower it is, which creates lift and allows the airplane to fly. It also describes the operation of air profiles such as helicopter rotor blades and wind turbine blades.
- 2. Venturi effect:** The Venturi effect is based on Bernoulli's law and is used in applications such as carburetors and injectors of internal combustion engines (as shown in Fig. 1.3). By restricting flow, it increases speed and reduces pressure, promoting atomization and mixing of fuel and air.
- 3. Flow measurement:** Bernoulli's law is used in devices such as Pitot tubes and Venturi meters to measure flow. Pitot tubes use this principle to measure the velocity of a fluid, while Venturi meters measure flow by comparing the pressures in different sections of a constricted tube.
- 4. Blood flow:** Understanding Bernoulli's principle helps to understand blood flow. Vasoconstriction helps blood flow by increasing blood pressure and lowering blood pressure. This principle applies to medical applications such as understanding changes in blood pressure and measuring heart disease.
- 5. Water and Air Purification:** In water filters, the design uses Bernoulli's principle of creating a low-pressure space that facilitates the suction of liquid or air from the nature of the filter, thereby simplifying the purification process.
- 6. Sprayers and Nozzles:** Devices such as nozzles and atomizers use Bernoulli's method (as shown in Fig. 1.2) to convert liquids into fine sprays or mist. The falling pressure causes the liquid to break up into smaller droplets, restricting the flow of water and increasing the velocity of the water.

These are just a few examples of the effective use of Bernoulli's law. Its principles are widely used in engineering, fluid dynamics, aerospace, medicine, and many industries where understanding the behavior of water is important.

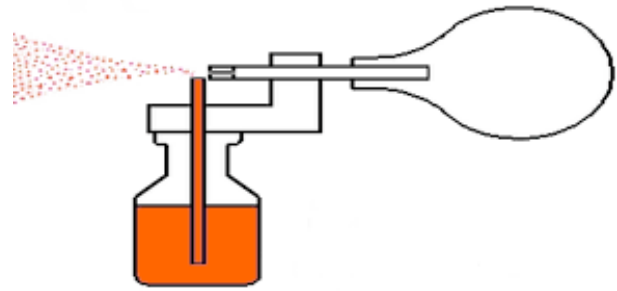


**Fig. 1.2** Atomizer

Source:

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**Fig. 1.3** Venturi meter

Source:

<https://commons.wikimedia.org/wiki/File:Venturi-tube.svg>

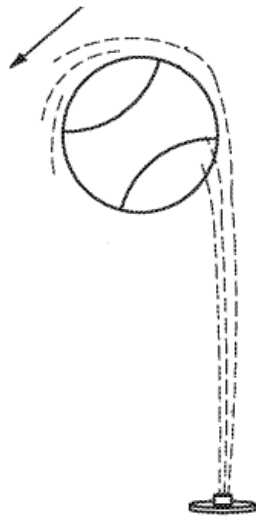
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## CHAPTER 2

### INTRODUCTION TO HYDRODYNAMIC LEVITATION

#### 2.1 HYDODYNAMIC LEVITATION

Hydrodynamic levitation is a fascinating phenomenon that involves the suspension or levitation of objects (as shown in Fig. 2.1) in a fluid medium by utilizing fluid pressure forces. It finds applications in various fields, including material processing, transportation, and contactless manipulation. This project aims to explore the principles and mechanisms behind hydrodynamic levitation, investigate its potential applications, and contribute to the understanding of this phenomenon. Hydrodynamic levitation relies on the principles of fluid dynamics and Bernoulli's principle. According to Bernoulli's principle, as the speed of a fluid increases, its pressure decreases. By carefully manipulating fluid flow patterns and pressure gradients, it becomes possible to create an upward force that counteracts the downward gravitational force on an object, resulting in levitation. The understanding and control of hydrodynamic levitation have opened possibilities for innovative applications.



**Fig. 2.1** Hydrodynamic Levitation of a ball

In industries such as metallurgy, hydrodynamic levitation can be used for precision heating, cooling, and shaping of materials. In semiconductor manufacturing, it offers a contactless and contamination-free method for handling delicate components. In biomedical engineering, hydrodynamic levitation enables non-invasive manipulation of cells or microorganisms. To investigate hydrodynamic levitation, experimental methods are employed. Through the careful design of experimental setups and measurement techniques, researchers can observe and analyze the levitation phenomena.

The results obtained from such experiments provide insights into the behavior of levitating objects, the effects of different fluid properties, and the optimization of levitation conditions. By understanding the principles and applications of hydrodynamic levitation, researchers can contribute to advancements in various industries. This project aims to contribute to the existing body of knowledge by conducting experiments, analyzing the results, and discussing the implications and potential future directions for hydrodynamic levitation. Hydrodynamic levitation is based on the concept of utilizing fluid pressure forces to counteract the gravitational force acting on an object. By carefully controlling fluid flow patterns and pressure distributions, it is possible to achieve stable levitation of objects without any physical contact or support.

The phenomenon of hydrodynamic levitation is governed by several factors, including the speed and viscosity of the fluid, the shape and size of the levitating object, and the geometry of the flow path. By manipulating these parameters, researchers can control the levitation height, stability, and orientation of the object. One common approach to achieve hydrodynamic levitation is using pressurized gases or liquids. For example, in gas levitation, a high-speed stream of pressurized gas is directed towards the object, creating a cushion of air that supports and suspends it. Similarly, in liquid levitation, a high-velocity liquid jet is used to generate a pressure gradient that lifts the object. Hydrodynamic levitation has found applications in various fields. In material processing, it can be used for precision heating or cooling of objects, as well as for shaping or forming materials without direct contact. This is particularly beneficial for delicate or sensitive materials that may be damaged by conventional mechanical methods.

## 2.2 PRINCIPLES OF HYDRODYNAMIC LEVITATION

The principles underlying hydrodynamic levitation are based on Fluid dynamics and Bernoulli's principle. Here are the key principles involved:

- **Fluid Dynamics:** Fluid dynamics is the study of how fluids (liquids and gases) behave and interact with their surroundings. It involves the analysis of fluid flow, pressure, velocity, and forces acting within the fluid.
- **Bernoulli's Principle:** Bernoulli's principle states that as the speed of a fluid increases, its pressure decreases, and vice versa, if no energy is added or lost from the system. This principle is based on the conservation of energy in a fluid flow.

- **Pressure Gradients:** A pressure gradient is a change in pressure over a distance within a fluid. In hydrodynamic levitation, pressure gradients are crucial in generating the forces necessary to support and levitate an object. By creating a pressure gradient, the fluid exerts upward forces on the object, counteracting the downward gravitational force.
- **Control of Fluid Flow:** The control and manipulation of fluid flow are fundamental to achieving hydrodynamic levitation. By directing the fluid flow around and under the object in specific ways, it is possible to create pressure distributions that lead to levitation. This involves designing the shape of the fluid flow path, optimizing the fluid velocity, and managing flow separation and attachment.
- **Object and Fluid Interaction:** The size, shape, and properties of the levitating object, as well as the properties of the surrounding fluid, play a significant role in hydrodynamic levitation. The object's geometry and orientation affect the pressure distribution and fluid flow patterns around it. The fluid properties, such as viscosity and density, influence the forces and interactions between the fluid and the object.

By understanding and controlling these principles, researchers and engineers can design and optimize hydrodynamic levitation systems. The manipulation of fluid flow, pressure gradients, and object-fluid interactions allows for stable and controlled levitation of objects without physical contact.

## 2.3 HISTORICAL APPLICATIONS OF HYDRODYNAMIC LEVITATION

Hydrodynamic levitation, also known as aerodynamic levitation in the case of gas flow, has been utilized in various historical applications, particularly in the fields of material science, metallurgy, and crystal growth. Here are a few notable historical applications of hydrodynamic levitation:

1. **Levitation Melting:** In the early 1960s, levitation melting was developed as a technique for melting and solidifying materials without any physical contact with a container or crucible. The levitation of the sample within a controlled gas flow or electromagnetic field prevented contamination and allowed to produce highly pure materials. This method played a crucial role in the production of specialty alloys, including superalloys used in aerospace and turbine applications.



2. **Levitated Droplet Combustion:** Levitated droplet combustion experiments have been conducted to study the fundamental combustion behavior of liquid fuels. By suspending fuel droplets in a gas flow, researchers were able to investigate combustion processes without interference from container walls or contact with solid surfaces.
3. **Crystal Growth:** Hydrodynamic levitation has been employed in crystal growth experiments to produce high-quality single crystals. By levitating the molten material in a controlled gas flow or magnetic field, the crystals can grow under highly controlled conditions, free from any contact with container walls. This technique has been particularly useful in growing semiconductor crystals and oxide crystals with desired properties for various applications, including electronics and optics.
4. **Levitated Microgravity Experiments:** Hydrodynamic levitation has also been utilized in microgravity environments, such as during space missions or parabolic flights. By suspending samples in a levitated state, researchers can study the behavior of materials and fluids in the absence of gravity. These experiments provide valuable insights into fluid dynamics, material properties, and phase transitions in a microgravity environment.

## 2.4 HISTORICAL REFERENCE

Granite sphere or “kugel” fountains (Fig. 2.2) are a familiar sight in town squares and science museums, and smaller ones—often with a marble sphere—decorate many private homes and gardens. These fountains consist of a perfectly polished ball floating in a socket that fits precisely around it. The fluid that wells up around the rim of the socket is pumped into the fountain via a hole at the base. Despite its considerable weight, the sphere is easily brought into a spinning motion, which is an attractive sight especially when the surface of the sphere is engraved with the Earth’s map, a soccer ball, the night sky, or something of the kind. The fluid layer between the socket and sphere is very thin (thinner than a credit card<sup>1</sup>), which is important for any kugel on display in a public place, since it means there is no risk of children’s fingers being caught under the spinning sphere. Despite its popularity, the granite sphere fountain is poorly understood by most people.

When we asked visitors of the House of Science in Patras, Greece, which physical mechanism they thought was responsible for the floating of the sphere in front of the main entrance (a granite ball with a diameter of 1 m), the most common answer was “Archimedes’ law of buoyancy,” as if the sphere were an iceberg or a ship. Perhaps the visitors who gave this answer were under the impression that the sphere was hollow. However, the sphere is solid, and the buoyant force is by no means capable of keeping the sphere afloat since granite has a density 2.75 times that of water.

The second most common answer was “the incompressibility of water.” This is not too convincing either, because it fails to explain why the sphere does not squeeze the water out of the space between itself and the socket and simply sits on top of the inlet nozzle like a giant granite plug. This comes much closer to the truth, as we will see, even though the water in the fountain is neither fully enclosed (it is open at the rim of the socket) nor at rest. A search on the internet did not yield much in the way of a conclusive answer.



**Fig. 2.2** “Granite wheel” fountain, in which the levitated object is a cylinder instead of a sphere.

Source: <file:///D:/IIT%20G/Photos/PhysicsOftheGraniteSphereFountainAm.J.Phys.82Nov2014.pdf>

## 2.5 INDIAN HISTORICAL REFERENCES TO HYDRODYNAMIC LEVITATION

Hydrodynamic levitation, as a specific concept, is not explicitly referenced in ancient Indian history. The term "hydrodynamic levitation" itself is a modern scientific term used to describe the phenomenon of levitation within a fluid medium, and its application in various fields. However, it is worth noting that ancient Indian scientific and technological advancements were significant in many areas, including mathematics, astronomy, metallurgy, and medicine. The ancient Indians had a deep understanding of fluid mechanics and hydraulics, as evidenced by the remarkable engineering feats, such as the construction of elaborate irrigation systems and water management techniques like stepwells.

1. **Water Management Systems:** Ancient India was known for its sophisticated water management systems.
2. **The Indus Valley Civilization,** which existed around **2600-1900 BCE**, had well-planned cities with advanced drainage systems and water supply networks.
3. **Stepwells:** Stepwells, also known as **baoris or vavs**, are elaborate structures found in various parts of India. These architectural marvels served as water reservoirs and places for people to access water.
4. **Ayurveda:** Ayurveda, the traditional Indian system of medicine, also considered the principles of fluid dynamics. Ayurvedic texts mention concepts such as doshas (humors) and the movement of fluids in the body, relating them to health and well-being.

While there may not be direct references to hydrodynamic levitation in ancient Indian texts or historical accounts, ancient Indian scientific knowledge and expertise in fluid dynamics certainly laid the foundation for later developments in this field. The intricate understanding of fluid behavior and the practical applications of hydraulics by ancient Indian scholars would have contributed to the broader understanding of fluid mechanics, which encompasses the principles underlying hydrodynamic levitation.

Overall, while hydrodynamic levitation may not have been explicitly discussed or practiced in ancient Indian history, the scientific and engineering prowess of ancient Indian civilization in areas related to fluid dynamics and hydraulics is worthy of recognition and appreciation.

## 2.6 APPLICATIONS OF HYDRODYNAMIC LEVITATION

Hydrodynamic levitation finds various applications in modern technology and scientific research. Some notable applications of hydrodynamic levitation include:

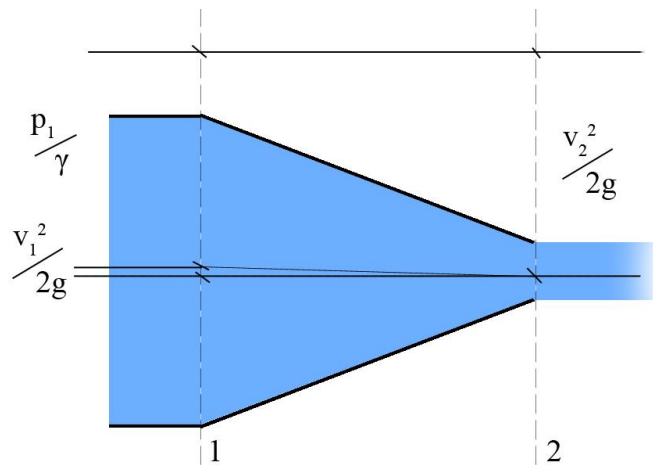
1. **Metallurgy and Materials Science:** Hydrodynamic levitation is used in the production of high-purity metals and alloys. By levitating the molten metal within a controlled gas or electromagnetic field, contamination from container materials can be avoided, resulting in purer materials. This technique is particularly useful for producing specialty alloys used in aerospace, electronics, and other industries.
2. **Crystal Growth:** Hydrodynamic levitation is employed in the growth of high-quality single crystals. By suspending the molten material in a gas or liquid stream, crystals can grow under controlled conditions, free from contact with container walls. This method allows to produce large, defect-free crystals used in various applications, including semiconductors, lasers, and optical devices.
3. **Combustion Studies:** Hydrodynamic levitation is used in combustion experiments to study the behavior of liquid fuels and combustion processes. By suspending fuel droplets within a gas flow, researchers can analyze the vaporization, ignition, and burning characteristics of the fuel without interference from container walls.
4. **Microgravity Research:** Hydrodynamic levitation is employed in microgravity environments, such as space missions or parabolic flights, to simulate the absence of gravity. By levitating samples in a controlled fluid stream, scientists can study material properties, fluid behavior, and chemical reactions in a microgravity environment, providing insights into phenomena that are difficult to observe under normal gravity conditions.
5. **Contactless Handling and Manipulation:** Hydrodynamic levitation enables contactless handling and manipulation of delicate or sensitive objects. By suspending objects within a fluid flow, the need for physical contact or mechanical fixtures is eliminated, reducing the risk of damage or contamination. This is particularly advantageous in industries such as electronics, biotechnology, and precision manufacturing.

Overall, hydrodynamic levitation offers a range of applications in various scientific, industrial, and research fields. Its ability to provide contactless handling, control environments, and eliminate contamination makes it a valuable technique in the production of high-purity materials, crystal growth, combustion studies, microgravity research, and non-contact manipulation of objects.

## 2.7 NOZZLE

A nozzle is a device used to control the flow and direction of a fluid (as shown in Fig. 2.3), typically a gas or a liquid. It consists of a tapered or constricted passage through which the fluid passes, resulting in an acceleration and redirection of the flow. Nozzles have various applications in different industries and fields. Here are some common applications of nozzles:

- **Rocket Propulsion:** Nozzles play a critical role in rocket engines. They are designed to efficiently accelerate and direct the high-velocity exhaust gases produced by the combustion of propellants. The shape and design of the nozzle are optimized to maximize thrust and improve the overall efficiency of the propulsion system.
- **Gas and Liquid Jetting:** Nozzles are used to create high-velocity jets of gas or liquid for various purposes. They find applications in fuel injection systems, where nozzles precisely spray fuel into combustion chambers of engines. Nozzles are also used in industrial cleaning applications, such as high-pressure water jets for surface cleaning or hydro blasting.
- **Spray Systems:** Nozzles are integral components of spray systems used in industries like agriculture, manufacturing, and firefighting. They are used to generate fine sprays or mists of liquid for applications such as crop spraying, cooling, humidification, coating, and fire suppression.
- **Industrial Processes:** Nozzles find applications in various industrial processes, including coating, drying, atomization, and powder dispersion. They are used to deliver precise amounts of fluids or powders in manufacturing processes, such as painting, food processing, pharmaceutical production, and powder coating.



**Fig. 2.3 Nozzle**

Source: [https://commons.wikimedia.org/wiki/File:Ugello\\_con\\_2\\_sezioni\\_-\\_Nozzle\\_-\\_Bernoulli.jpg](https://commons.wikimedia.org/wiki/File:Ugello_con_2_sezioni_-_Nozzle_-_Bernoulli.jpg)  
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## 2.8 WHY DO THE BALL LEVITATE

Hydrodynamic levitation is a fascinating phenomenon that occurs when a ball or an object is suspended and appears to float within a stream of fluid, usually a gas or a liquid. The levitation effect is achieved due to several interrelated factors, including fluid dynamics, pressure gradients, and the velocity of the fluid.

- When a ball is introduced into a flowing fluid, such as a gas or a liquid, it experiences a phenomenon known as the Coanda effect. The Coanda effect is characterized by a tendency of fluid streams to adhere to curved surfaces rather than follow a straight path. As the fluid flows around the surface of the ball, it clings to the curved contours, creating a thin layer of fluid that envelops the ball.
- Simultaneously, as the fluid encounters the curved surface of the ball, its velocity increases due to the principle of Bernoulli's equation, which states that an increase in fluid velocity corresponds to a decrease in pressure. As the fluid's velocity accelerates near the surface of the ball, the pressure in that region decreases. This pressure reduction generates an upward force on the ball, counteracting the force of gravity.
- The balance between the upward force caused by the pressure reduction and the downward force of gravity enables the ball to float or levitate within the fluid stream.

- It's important to note that for hydrodynamic levitation to occur, the fluid flow must be sufficiently controlled, maintaining a stable and directed stream.
- Additionally, the size, shape, and surface properties of the ball play a role in achieving stable levitation. The curvature and smoothness of the ball's surface influence the adherence of the fluid stream and the establishment of a stable boundary layer around the ball. These factors contribute to the overall stability and sustainability of the levitation effect.
- Hydrodynamic levitation finds applications in various fields, including material handling, advanced manufacturing processes, and scientific research. It offers advantages such as contactless manipulation, precise control, and reduced mechanical wear compared to traditional contact-based methods.

In conclusion, hydrodynamic levitation occurs when a ball is suspended within a fluid stream due to the Coanda effect, pressure differentials caused by Bernoulli's principle, and the interaction between the fluid and the ball's surface properties. This mesmerizing phenomenon showcases the intricate interplay between fluid dynamics and the manipulation of forces, resulting in the seemingly magical levitation of an object.

## 2.9 EQUATIONS INVOLVED IN THIS PROJECT

The following are the equations which are being used in the project:

1. **Buoyant Force:** The buoyant force is the upward force exerted on an object submerged in a fluid. It can be calculated using **Archimedes' principle**:

$$F_b = \rho_{fluid} V_{submerged} g \quad (3.1)$$

where  $F_b$  is the buoyant force,  $\rho_{fluid}$  is the density of the fluid,  $V_{submerged}$  is the volume of the object submerged in the fluid, and  $g$  is the acceleration due to gravity.

2. **Drag Force:** When an object moves through a fluid, it experiences a drag force due to the resistance of the fluid. The drag force can be calculated using various drag models, such as **Stokes' drag** for laminar flow or the drag equation for turbulent flow.

3. **Gravitational Force:** The force of gravity pulls the object downward. It can be calculated using:

$$F_g = m g \quad (3.2)$$

where  $F_g$  is the gravitational force,  $m$  is the mass of the object, and  $g$  is the acceleration due to gravity.

4. **Reynolds Number:** The Reynolds number is a dimensionless quantity used to determine the flow regime around an object. It is defined as the ratio of inertial forces to viscous forces and can be calculated using the equation:

$$R_e = \frac{\rho_{fluid} \times v \times L}{\mu_{fluid}}$$

where  $R_e$  is the Reynolds number,  $\rho_{fluid}$  is the density of the fluid,  $v$  is the velocity of the fluid relative to the object,  $L$  is a characteristic length scale of the object, and  $\mu_{fluid}$  is the dynamic viscosity of the fluid.



## CHAPTER 3

### 3.1 DEMONSTRATION OF THE MODEL

- Firstly, a silicon pipe of 6 millimeters was taken.
- Then, the pipe was connected to a hollow Pen cover with a nozzle (Pen tip) on top of it.
- The water was allowed to flow from this pen and tube setup, thereby creating a water jet.
- Next, a Plastic ball was taken and placed above the water jet, which eventually allowed the ball.
- In this way, the phenomenon of hydrodynamic levitation was demonstrated with the aid of this simple setup.

### 3.2 MATERIALS USED: -

- Two plastic bottles (water container, Pump sealing) (As shown in Fig 3.1)
- A Plastic Casing
- A 12 V, 2A Adapter
- A plastic Ball
- Nozzle
- A 12 V Pump (Flow Rate: 45 ml/s)



**Fig. 3.1** Materials used in the experiment.

### 3.3 RESULT

- With the aid of this compact yet effective physical model (as shown in Fig. 3.2), we have successfully demonstrated and gained a better understanding of the concept of hydrodynamic levitation.
- By observing the behavior and performance of the model, we have obtained valuable insights into the principles and benefits of this technology.
- In this physical model, a tube is connected from a pump to a nozzle made with a pen cover. The ball is levitated by the high-speed jet of water, exerting a force greater than its weight.



**Fig. 3.2** Complete Set up

### 3.4 CONCLUSION

In conclusion, the hydrodynamic levitation technique represents a remarkable achievement in the field of fluid dynamics and levitation technologies. Through our presentation, we have explored the fundamental principles and practical applications of hydrodynamic levitation, shedding light on its potential for various industries and scientific advancements.

**APPENDIX****Table 1: A Project Cost Table**

<b>Material</b>	<b>Cost</b>	<b>Quantity</b>	<b>Sub Total</b>
A 12-volt pump	220	1	220
A plastic container	200	1	200
A 9-volt battery	50	4	200
A 12-volt o/p Adapter	150	1	150
<b>Total Cost</b>			<b>770</b>

## REFERENCES

1. Author: OpenAI || Model: GPT-3.5 || Date: June 6th, 2023, || Title: Introduction to Hydrodynamic Levitation, Applications, History, || Chatbot: ChatGPT.
2. Title: Wikimedia Commons Website: <https://commons.wikimedia.org> Accessed: [Photos]