# Mechanical Circuits

## Design lab


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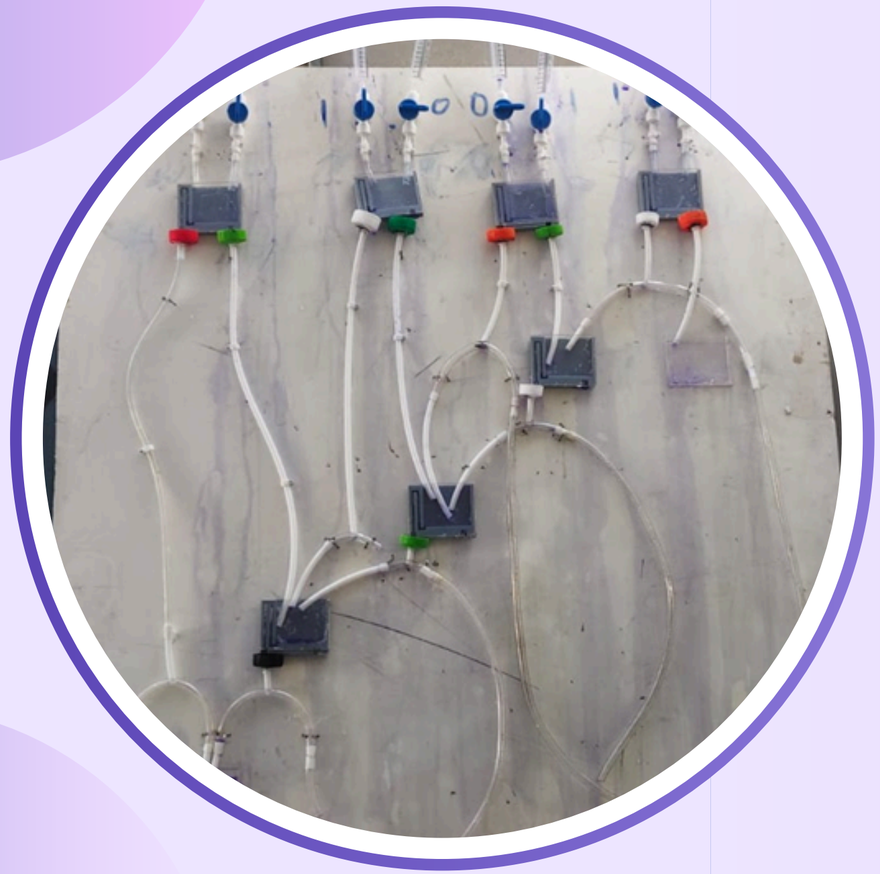
# PBOBLEM STATEMENT

We were assigned Mechanical Circuits as our ME-205 Design Lab-I project. In this, we had to design an analogous circuit to electrical circuits, where electrical components were replaced by mechanical components.

# Water based computing



For the analogous electrical circuit, we designed a water based computer

- **Water based computing**

  To design and implement basic logic gates and a 1-bit full adder using water-based fluidic systems, thereby simulating binary computation without electronic components.

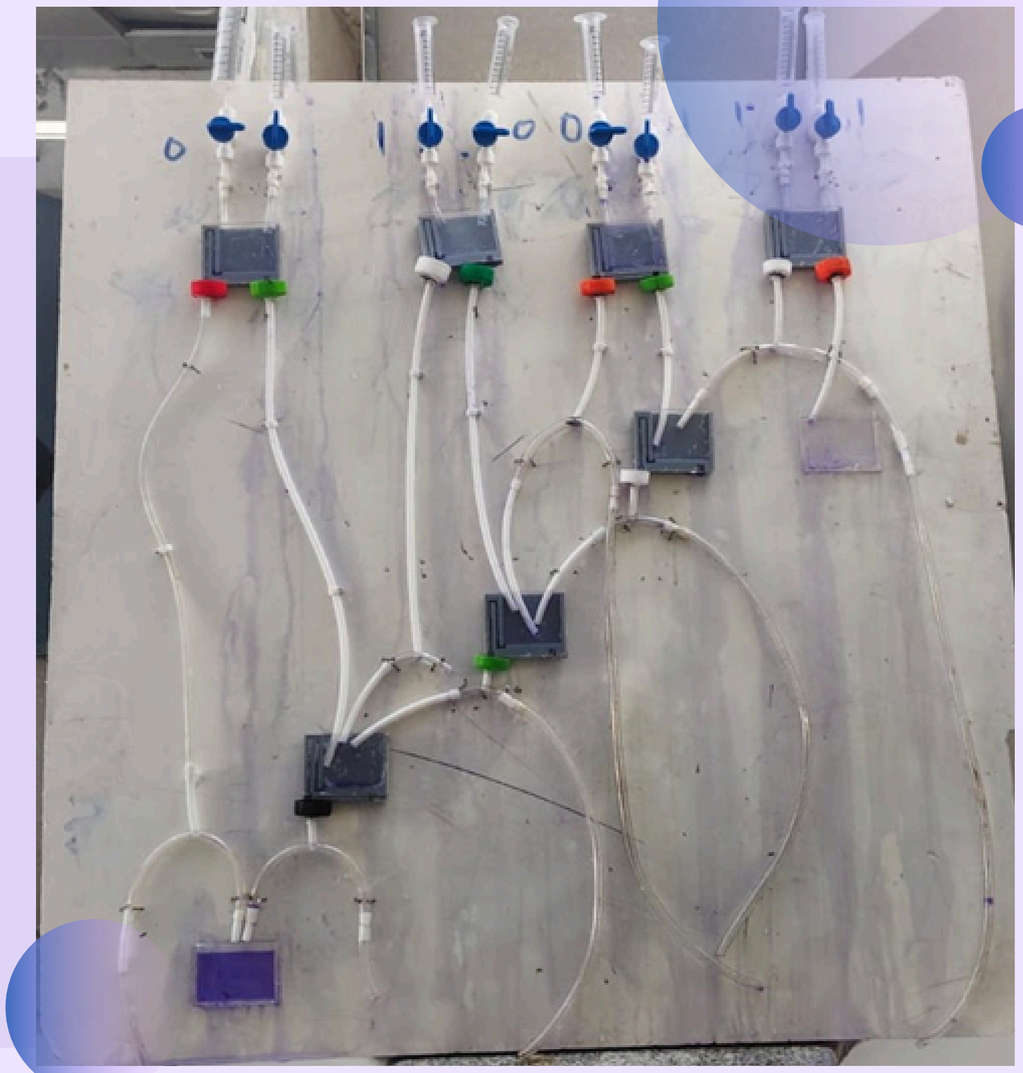
- **Fluidic LC Oscillator**

  To demonstrate an AC circuit equivalent we build a circuit to demonstrate LC Oscillations. The hydraulic analog of the inductor was a paddle wheel that we designed on SolidWorks.

# INTRODUCTION

## Water computer

The Water-Based Computer project investigates the use of fluidic logic to perform basic computational operations through the controlled flow of water. By replacing traditional electronic components with mechanical and fluid-based systems, this project highlights an alternative approach to computation. Such methods can be particularly valuable in scenarios where electronic solutions are either infeasible or undesirable, offering new perspectives on the design and implementation of computing systems.



# AC Circuit

## LC- Oscillator

To demonstrate an AC circuit equivalent we build a circuit to demonstrate LC Oscillations. The hydraulic analog of the inductor was a paddle wheel that we designed on SolidWorks. For the capacitor we took a soda bottle and cut it in two, attached a stretched balloon on one part and then joined the two parts. We had a T junction where the inlet would be connected to(The voltage source) As we fill the circuit with water, that is equivalent to charging the capacitor, once enough water is added to the circuit such that the balloon is distended to one side, the inlet is removed and covered(removing the voltage source) The balloon pushes the water in the other direction due to the energy stored in it causing the paddlewheel to spin in one direction, then the balloon distends in the opposite direction and the process repeats. This was the direction of water keeps flipping

# Theoretical Background of Water computer

## 3.1 Fluidic Logic

Fluidic logic uses the movement of water to represent and work with binary values. In this setup:

- Binary '1' (or True) means water is flowing or the chamber is filled.
- Binary '0' (or False) means there's no water flow or the chamber is empty.

By carefully designing channels and chambers, we can guide the water in a way that mimics how electronic logic gates function, allowing us to perform logical operations using just fluids.

## 3.2 Logic Gates Implementation

### AND Gate

An AND gate gives an output of '1' only when all its inputs are '1'. In the fluid-based version, this is done by creating a chamber where water reaches the output only if all input syringes are filled and released at the same time. This combined flow provides enough volume and pressure to activate the siphon, allowing the water to pass through—just like how an electronic AND gate works.

### XOR Gate

The XOR gate produces a '1' when exactly one of the inputs is '1'. If both inputs are the same (both 0 or both 1), the output is '0'. In fluidic terms, this is achieved by configuring the inputs and output such that only one input triggers water flow, resulting in an output if and only if the inputs are different.

### Full Adder

A full adder computes the sum of three binary inputs (A, B, and Carry-in) and produces a Sum and Carry-out. By combining the fluidic implementations of AND and XOR gates, a full adder circuit can be constructed. The precise arrangement ensures that the water flow patterns correspond to the logical operations required for addition.

# BASIC ANALOGIES

## Hydraulic and electric quantities and units

| | Hydraulic | Electric |
|---|---|---|
| **Amount** | Volume, *liters* | Charge, *coulombs* |
| **Flow rate** | Flow rate, *LPS (liters/sec)* | Current, *amps (coulombs/sec)* |
| **Potential** | Pressure, *kPa* or *PSI* | Voltage, *volts* |
| **Energy** | Energy, *joules (kPa-liters)* | Energy, *joules (volt-coulombs)* |
| **Power** | Power, *watts (joules/sec)* | Power, *watts (joules/sec)* |

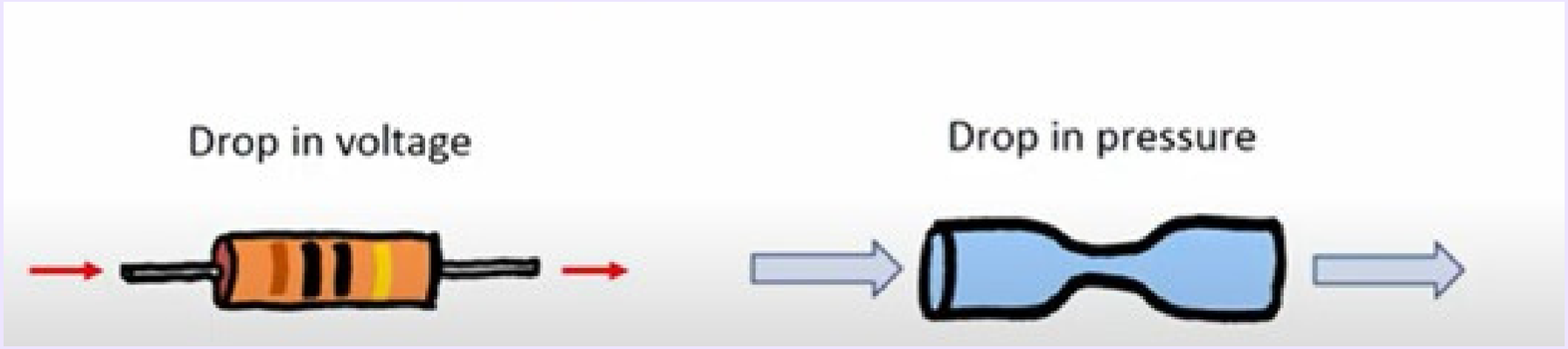
# Resistance

A decrease in the diameter of the pipe is analogous
to an electric resistor.
Electric- V=IR Hydraulic- Pressure Difference= Flow Rate * Resistance (Resistance=8$\mu L/ \pi r$^4)

# Voltage Source

A pump operates with Power = Pressure * Flow rate, and
from the analogies seen previously it is equivalent
to P=V*I, i.e. analogous to the power supplied by a battery.

A resistor partially blocks Flow
When there is a flow through resistor ,there is a voltage (pressure) drop in direction of flow.



# CAPACITOR :

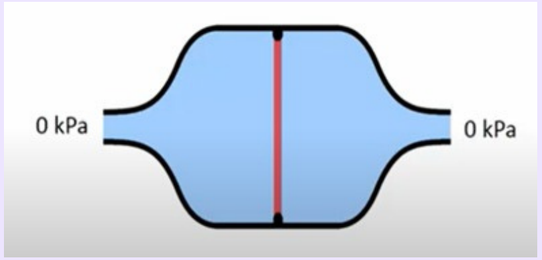
A pipe with a rubber sheet (Diaphragm) would serve as the capacitor

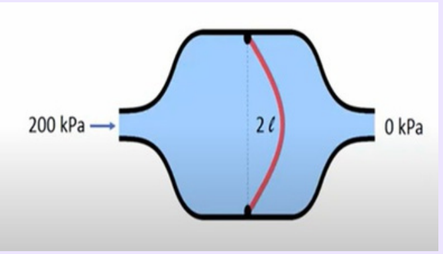
HYDRAULICS

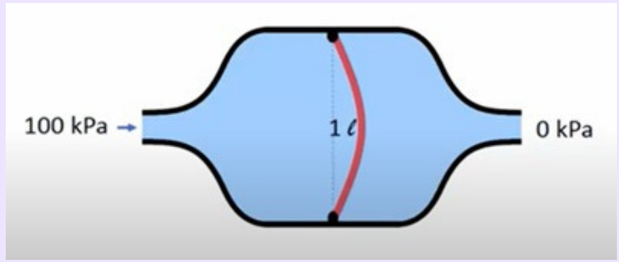
Volume = Capacitance x Pressure Consider the change over time: (change in Volume over time) = Capacitance x (change in Pressure over time) Flow Rate = Capacitance x (dP/dt)

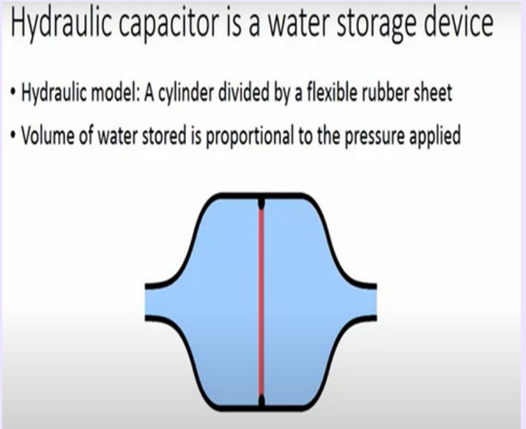
ELECTRICAL

Charge = Capacitance x Voltage Consider the change over time: (change in Charge over time) = Capacitance x (change in Voltage over time) Current = Capacitance x (dv/dt



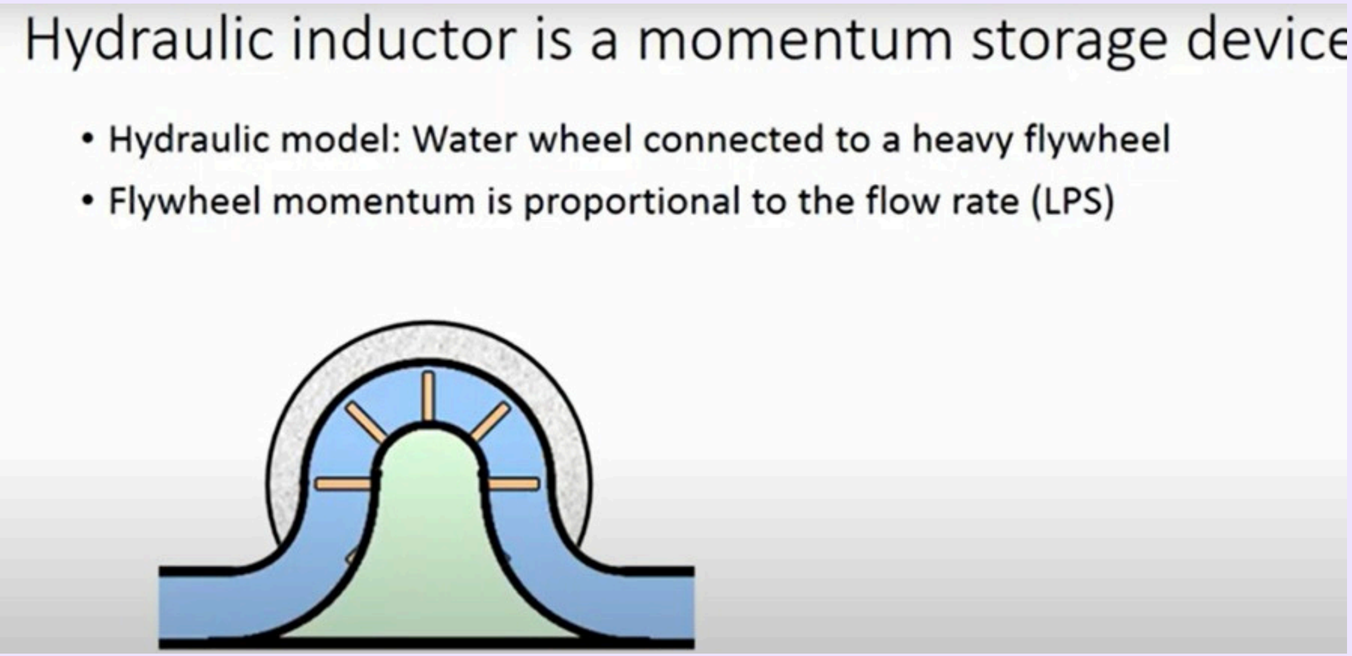



# INDUCTOR :

The hydraulic analogy to an inductor would be a heavy paddlewheel



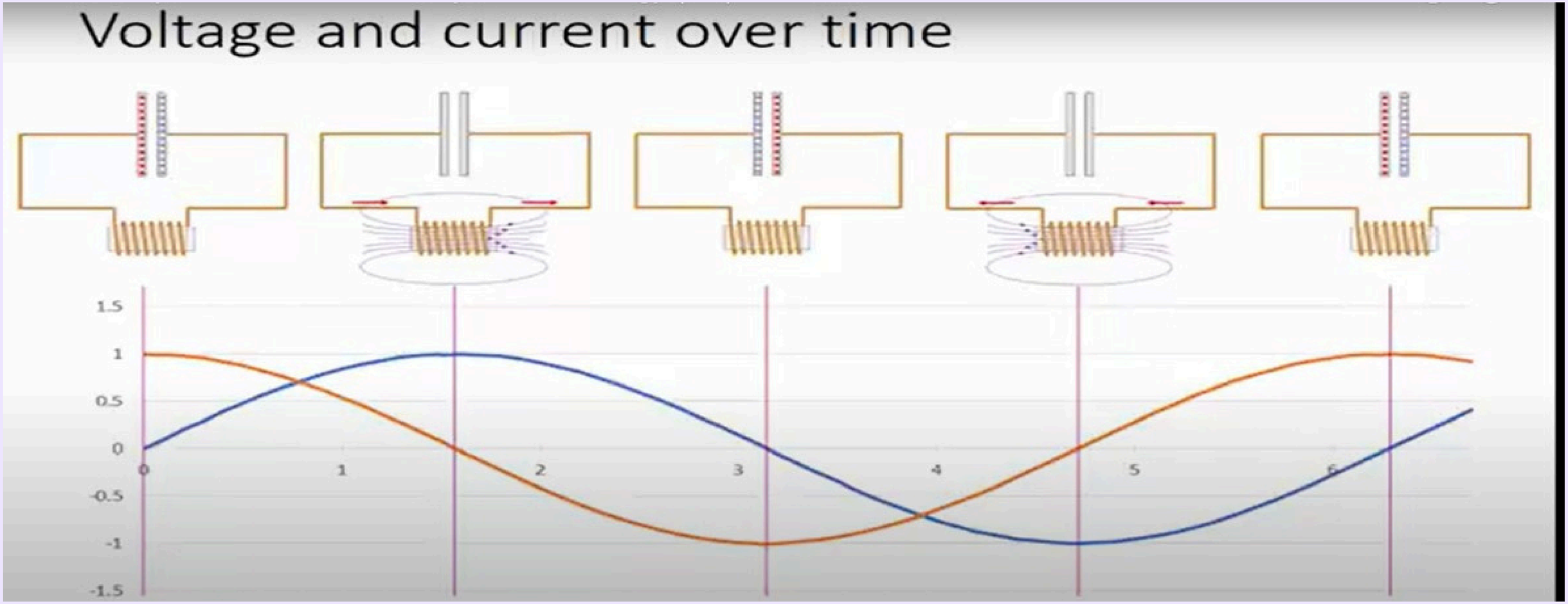

HYDRAULICS

Momentum = Inductance x Flow Rate Consider change over time: (change in Momentum over time) = Inductance x (change in Flow Rate over time) Pressure = Inductance x (dQ/dt)

ELECTRICAL

Flux = Inductance x Current Consider change over time: (change in Flux over time) = Inductance x (change in Current over time) Voltage = Inductance x (di/dt)

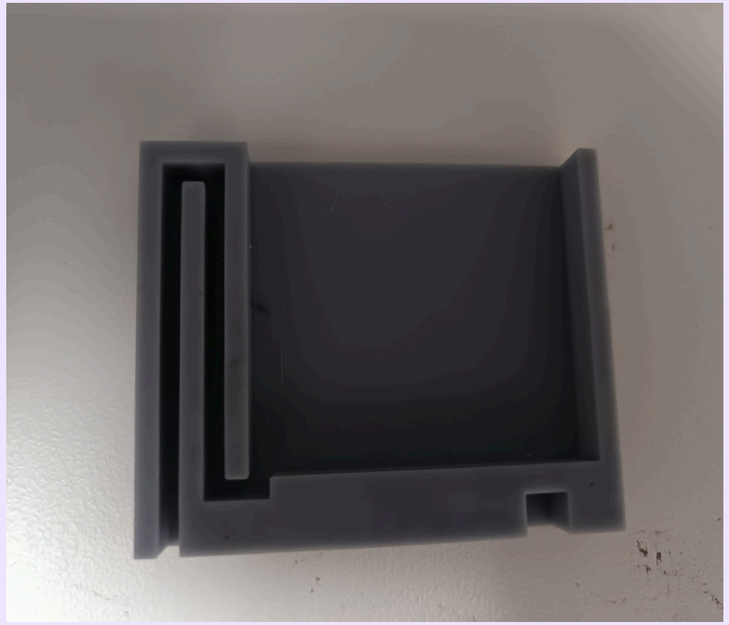
# GRAPH



# What We Made

Inductor

Capaciotor



Siphon tube

# Materials

**Water Computer**

- 10 mL syringes (for binary inputs)
- Valves
- Plastic tubing
- Siphon chambers (3D printed)
- Measuring chambers (for output collection)
- Supporting framework (wooden backplate)

**LC- Oscillator**

1. Wooden backplate
2. BOTTLE AS CAPACITOR
3. wheel as inductor

# Working Principle of Water Computer

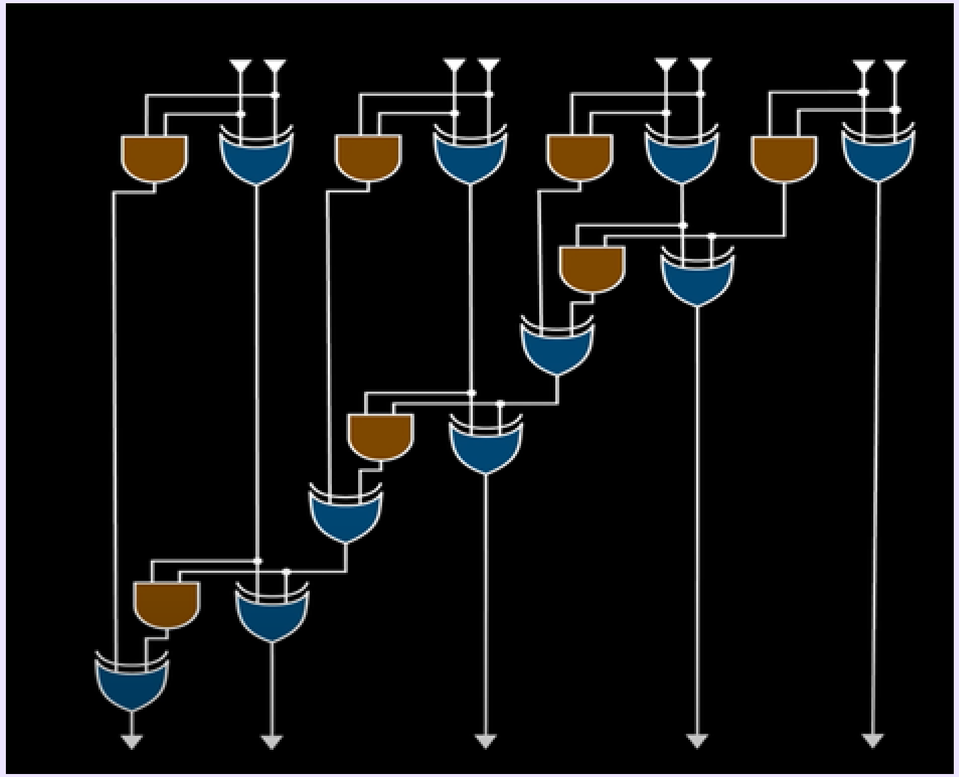
Each logic gate is constructed using syringes to represent binary inputs, with water flow controlled through siphon mechanisms and tubing arrangements. The gates are interconnected to form complex circuits, such as the full adder. The operation relies on gravitational potential and fluid dynamics to direct water flow, simulating logical operations.

## ---Bit Full Adder Using Fluidic Logic

The core component implemented in this project is a 1-bit full adder, which adds three binary inputs: A, B, and Cin (Carry-in), and produces two outputs: Sum and Cout (Carry-out).

In digital electronics, the Boolean expressions for a 1-bit full adder are:

- $Sum = A \oplus B \oplus Cin$
- $Cout = (A \cdot B) \oplus (Cin \cdot (A \oplus B))$

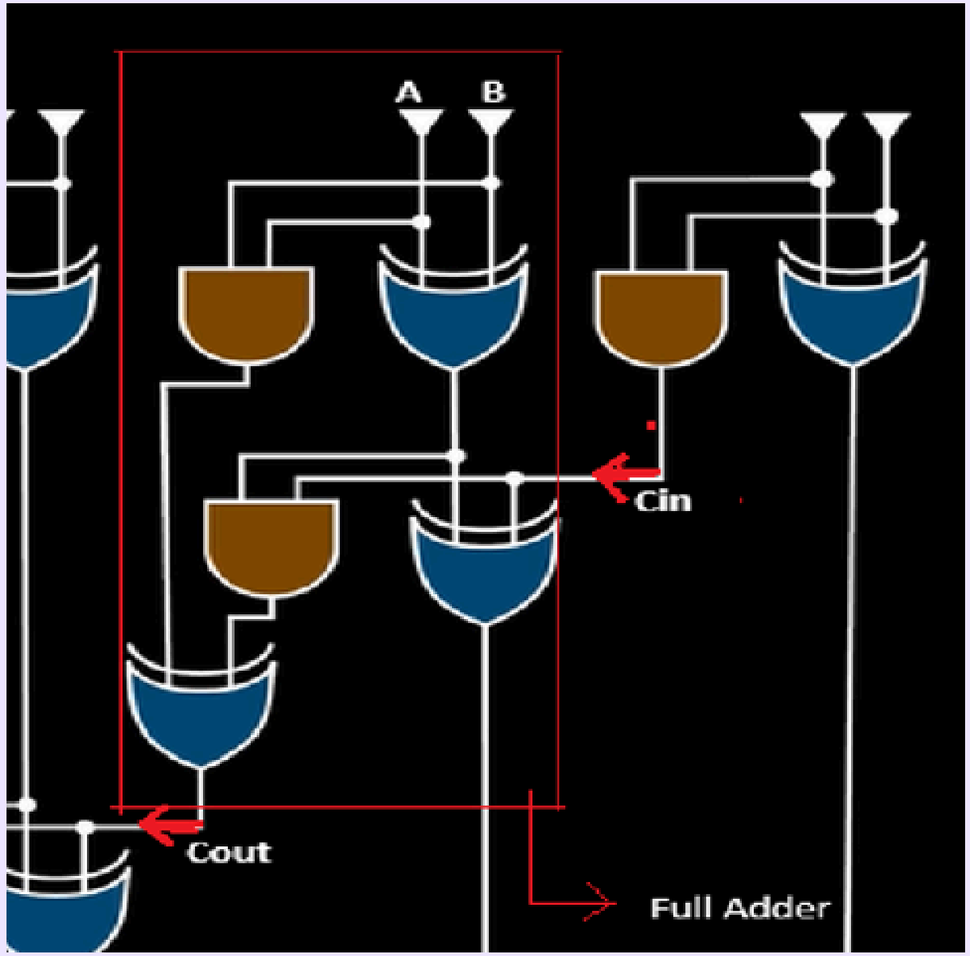


# In our fluidic implementation:

- XOR gates are simulated using two overlapping Y-splitters that allow water to pass to the output only when exactly one input is active.
- AND gates are simulated by combining flows such that water only reaches the output if both inputs are active, requiring pressure from both to pass through the channel.

Each input (A, B, Cin) is represented using 10 ml of water in syringes. The presence of water indicates binary 1, and absence represents 0.

Water outputs are collected in chambers to determine the Sum and Cout, where the presence of water denotes a logical high (1).

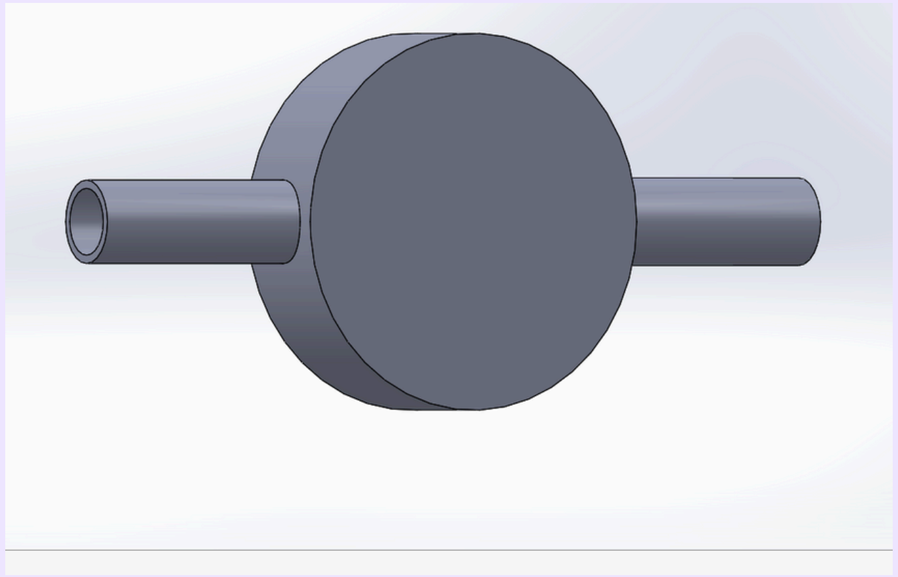


# The truth table for previous slide setup is as follows:

| A | B | Cin | A⊕B | Cin·(A⊕B) | A·B | Cout = A·B ⊕ Cin·(A⊕B) | Sum = A⊕B⊕Cin |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |

# Difficulties Faced- AC Circuit

The paddle wheel was not sealed properly at first causing water to leak out. We tried to use hot glue to seal it but it did not work that well. Then we used fevitite to seal it and it worked. The capacitor also had to same problem, and we had to attach the two parts of the bottle with fevitite. When pumping the water in the water did not go equally on both sides (while filling). This caused the balloon to be at risk of popping (which it did once). There was also air trapped inside and we had to pause in between to allow the air to rise up.



# Difficulties Faced - Water Computer

- **Leakage Issues**: One of the main challenges we faced was leakage at several junctions, which compromised the performance of the fluidic logic gates. These leaks were mainly caused by imperfections in the sealing process and the overall fluidic setup, which affected the accuracy and consistency of the outputs.

**Y-Splitter Fabrication**: Another significant challenge was the fabrication of the Y-splitters, which are essential for the XOR gates. Due to time constraints and limited resources, we weren't able to manufacture these splitters with the necessary precision, leading to instability in the XOR gate’s behavior and additional leakage issues

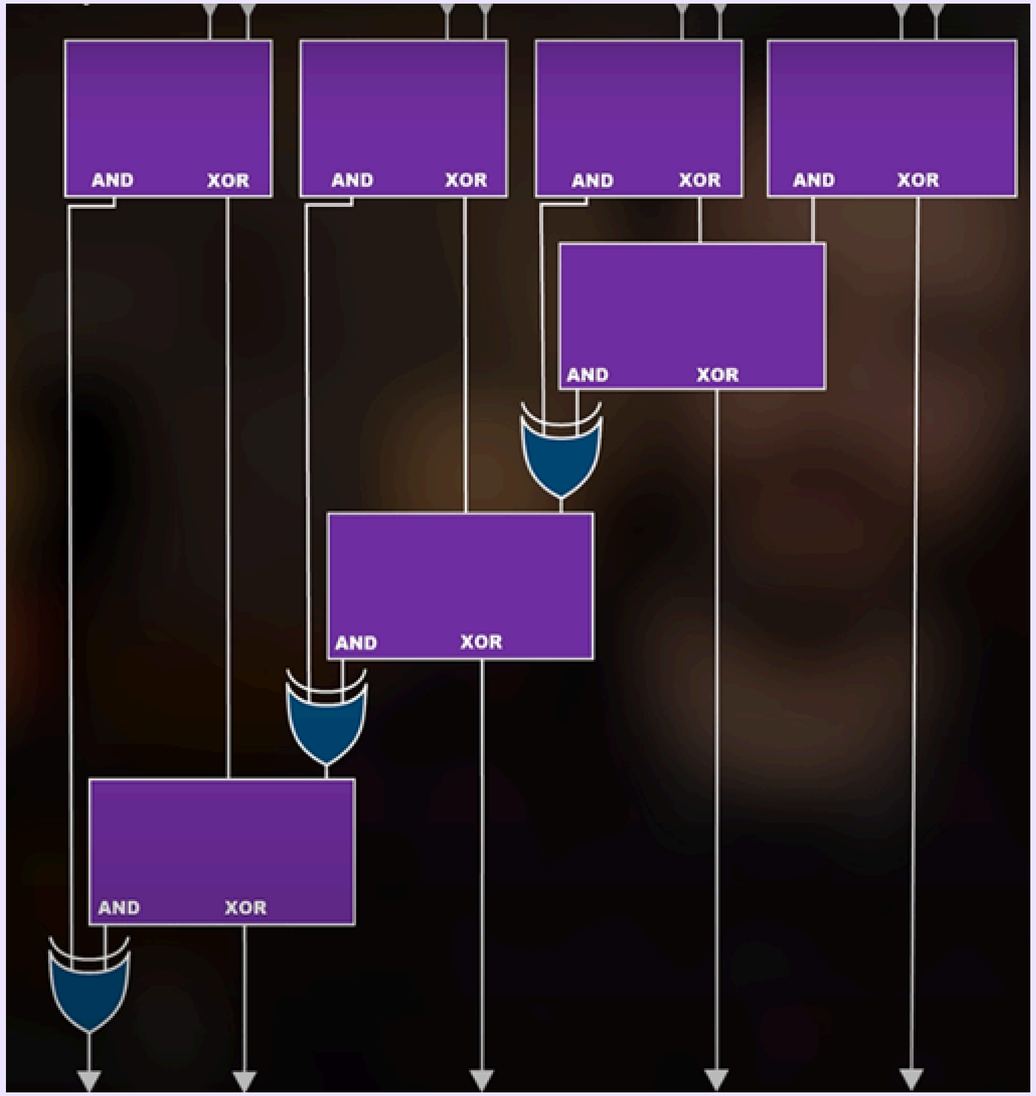
# Observation And Result Of Water Computer

While we successfully built and tested the water-based logic gates and the 1-bit full adder circuit, the ongoing forced many group members to return home. This significantly reduced the time and resources we had to complete the project. As a result:

1·The **Y-splitter,** a key component for controlling the water flow, wasn’t implemented as effectively as planned. This, along with the time constraints, caused some leakage in parts of the system.

2·Because of these issues, we couldn't demonstrate the fluidic logic gates fully, as the leakage affected the system’s performance.

3.Despite these setbacks, we were still able to see that the water flow in the gates responded to different input combinations, and the gates were able to perform their basic logic operations, although not perfectly.



# Individual Contribution

• **Ujjal**:

Ujjal was responsible for designing the siphon chambers, a crucial aspect of the water computer, and overseeing the 3D printing of all the necessary parts. He coordinated with the lab facilities to ensure the parts were printed accurately and efficiently, playing an essential role in the construction of the water computer.

• **Pooja**:

Pooja played a key role in designing the paddle wheel system, a vital component for the water computer's operation. Additionally, she contributed to the final report, ensuring that all necessary details were included and presented cohesively.

• **Nikhil Meel**:

Nikhil Meel was primarily responsible for developing the underlying logic and theory behind the water computer. He designed and implemented the siphon chambers for the fluidic system, ensuring their proper functioning within the adder circuit. In addition, Nikhil contributed significantly to the report work for weekly assessments and the overall construction of the water computer

• **JUVVANAPUDI NIKHIL**:

Juvvanapudi Nikhil focused on the development of the LC oscillator by researching its logic and theoretical application in the project. He was responsible for building and assembling the LC oscillator, ensuring it met the required specifications and functioned as intended within the water-based system.

• **Rajeev**:

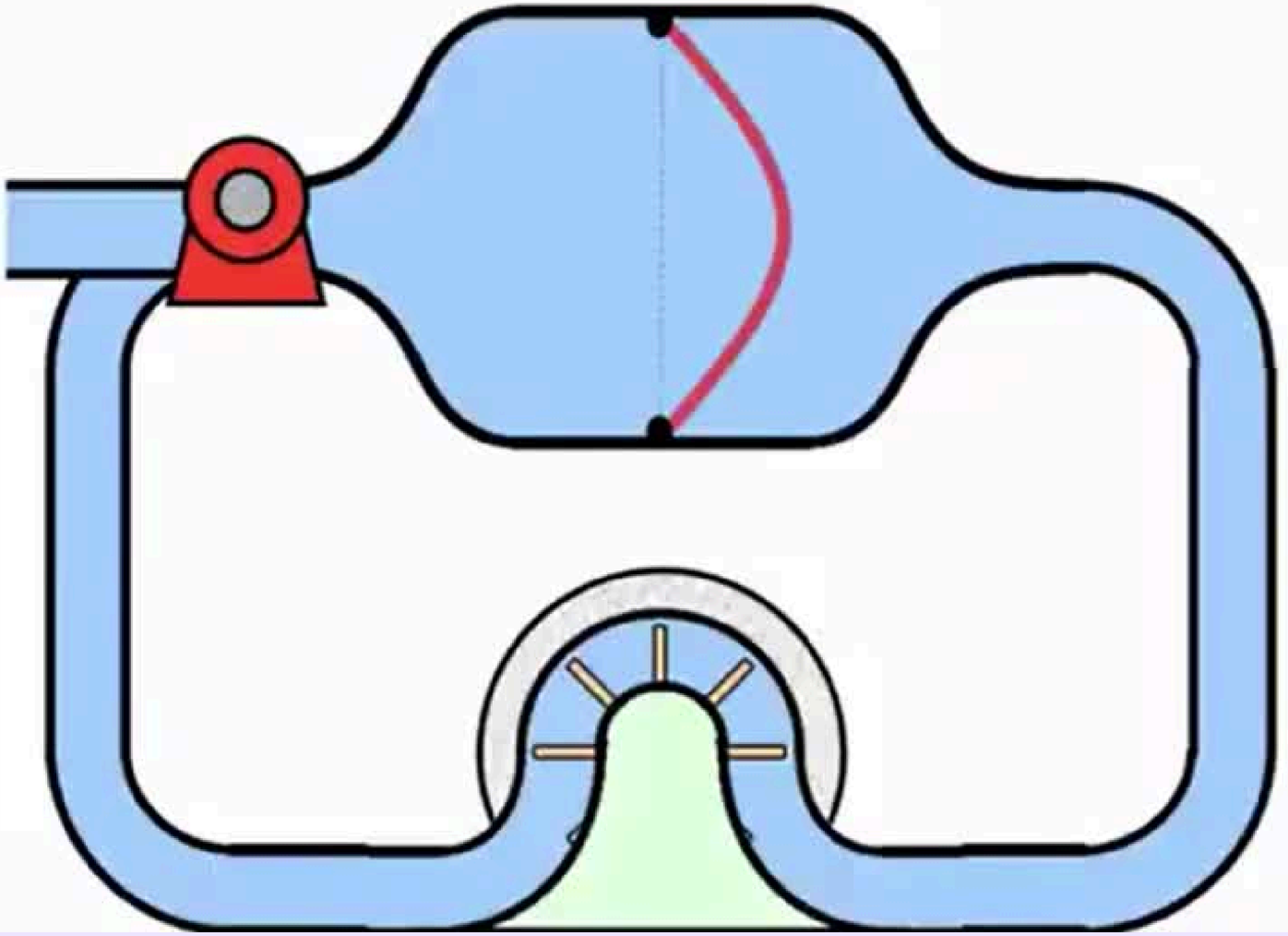
Rajeev was instrumental in the design and construction of both the paddle wheel and the water computer, integrating them with the rest of the project. He also worked on the LC oscillator, contributing to the assembly and fine-tuning of the system components.

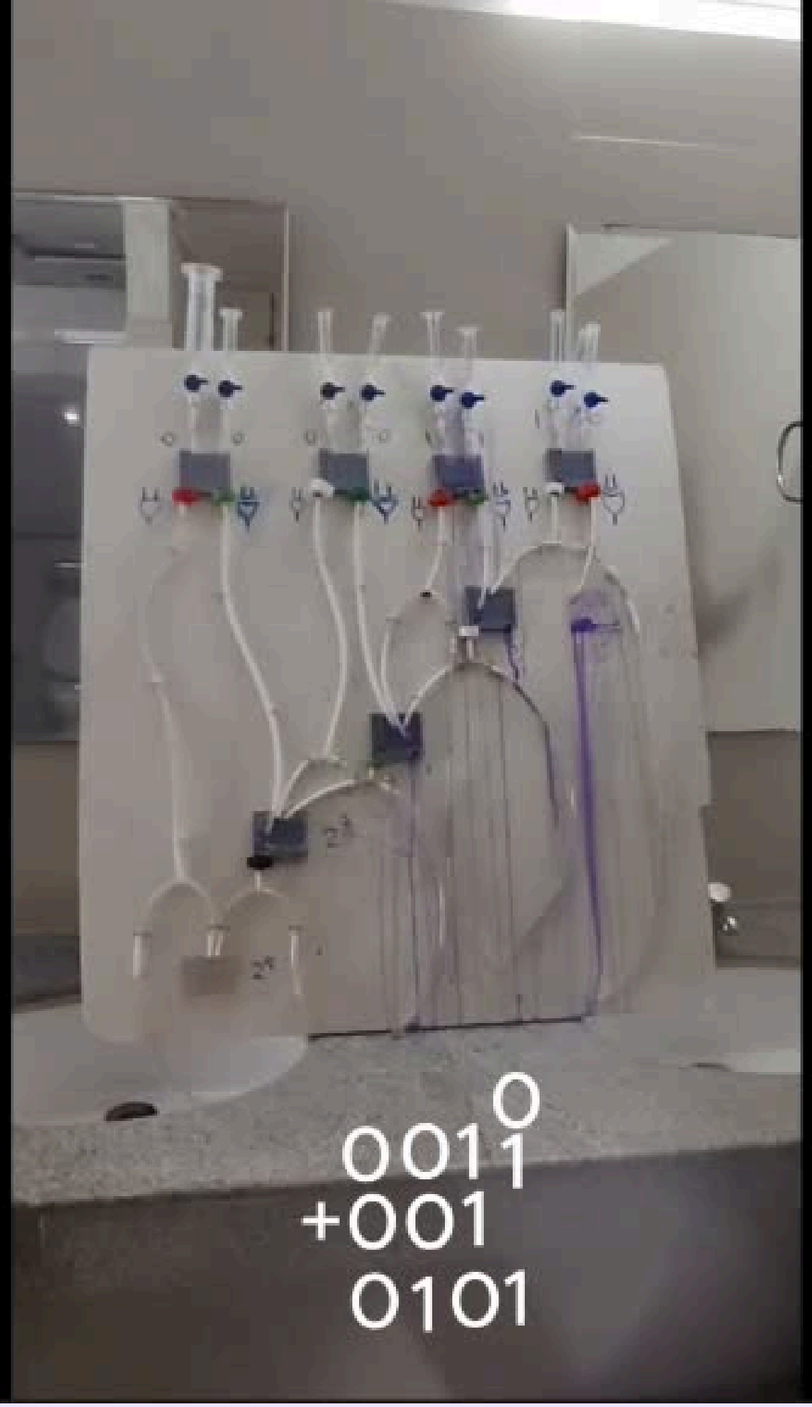
# References

https://www.youtube.com/watch?v=RIFRY2IXhj0

https://youtu.be/IxXaizgIscw?si=V300DqHvVyXvHmgA

# Capacitor & inductor connected in a circuit

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