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RESEARCHTHON- 2025

INNOVHERS (TECH FOR HUMANITY)

TRIBOELECTRIC NANOGENERATOR FOR HYGROELECTRIC ENERGY HARVESTING

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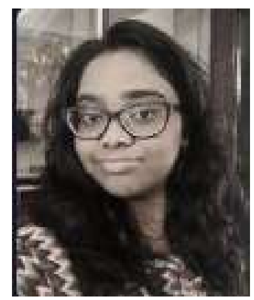

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Introduction

Our project is based on a concept called **Triboelectric Nanogenerator (TENG)**, which is a device that generates **electricity using friction** between two different materials.

Hygroelectricity: A phenomenon where moisture or water droplets move across certain surfaces like Aluminium and Teflon and cause charge transfer due to friction, producing a small but usable voltage.

In our project, we are building and testing a prototype that uses hygroelectric effect to generate electricity when water flows over or pressure is applied to these surfaces.

This prototype offers a clean, low-cost way to harness energy in humid or rainy environments.

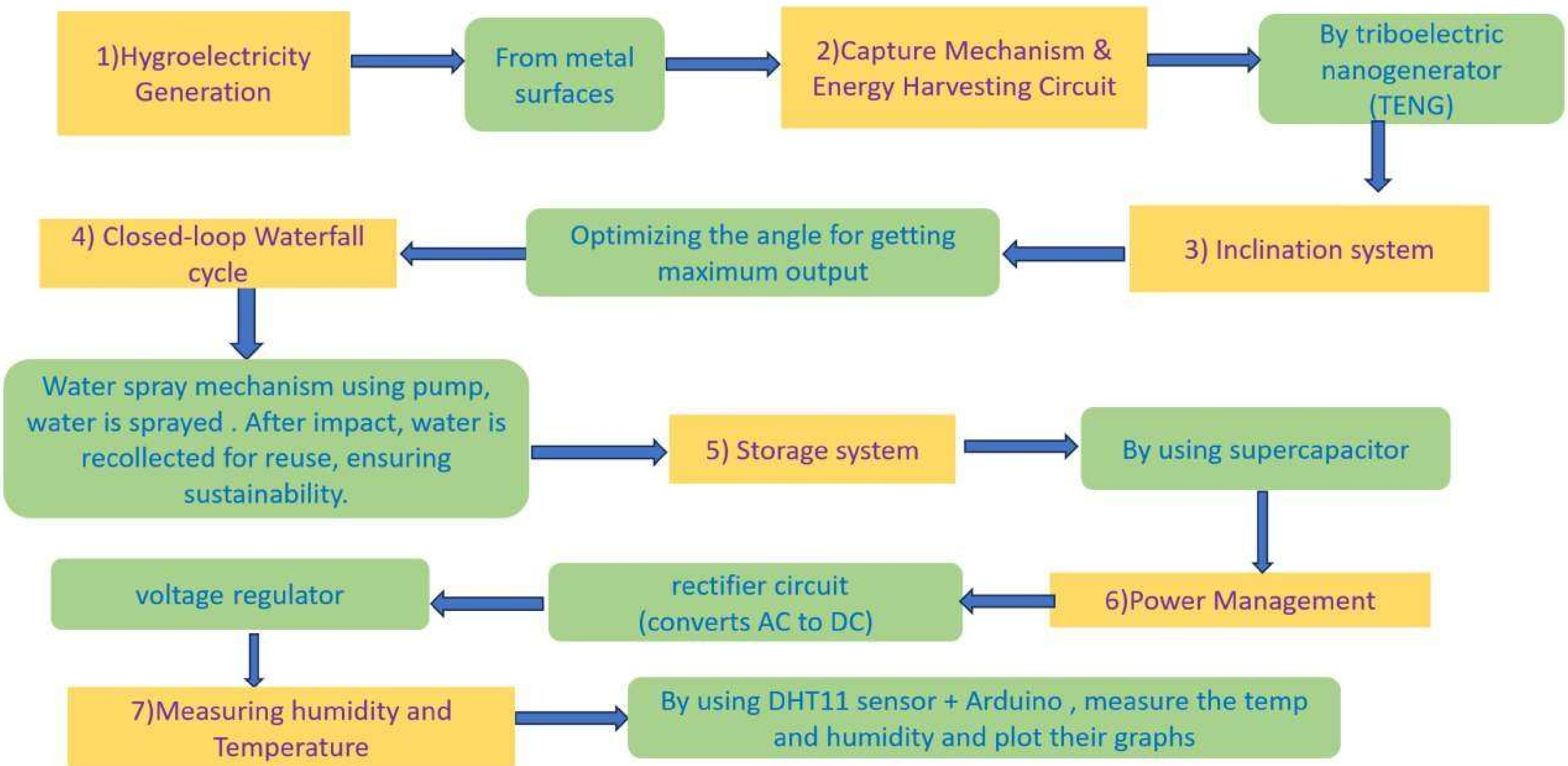
Problem Statement

Modern IoT devices and environmental sensors demand compact, self-powered systems that eliminate reliance on conventional batteries. Current energy solutions often lack sustainability, longevity, and integration flexibility.

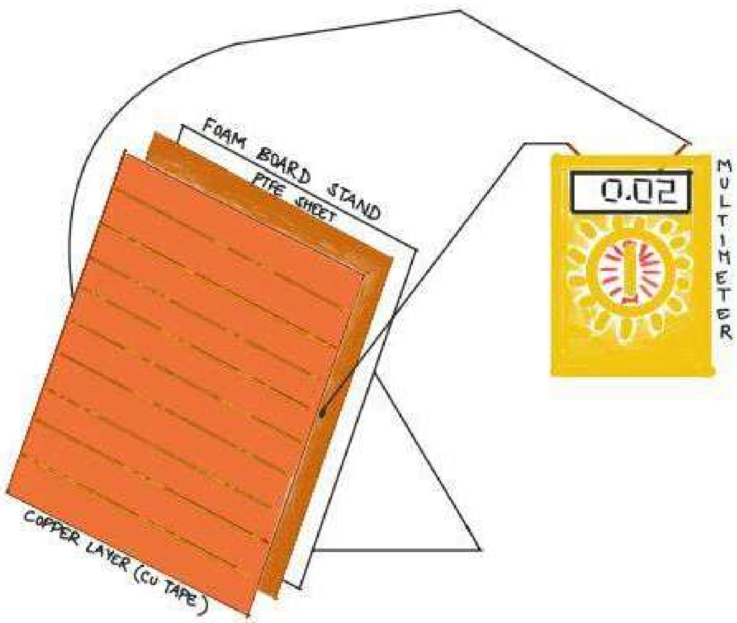
Triboelectric nanogenerators (TENGs) offer a promising alternative by converting mechanical energy—like falling water droplets—into usable electricity. However, real-world testing, material optimization, and current output remain key challenges.

This project develops and compares copper- and aluminum-based TENG prototypes layered with PTFE, tested using a CPVC-mounted water spray system driven by a quarter HP pump. The goal is to validate their potential as scalable, eco-friendly micro-energy sources.

Methodology



Design and Implementation



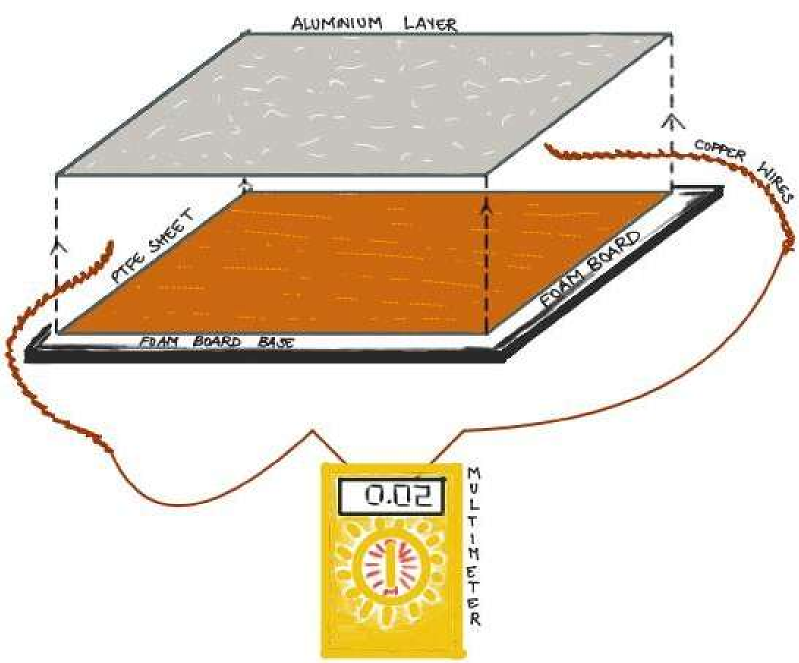
Design and Material Optimization & Energy Harvesting Setup Design

Material Selection & Structure(Prototype 1)

- Triboelectric materials with large charge affinity difference
- Layer 1: Metal surfaces - Cu
- Layer 2: Electron-accepting -PTFE(polytetrafluoroethylene)
- Layer 3: Plastic board support
- Metal electrode Cu

Design and Implementation

Aluminium prototype:



Design and Material Optimization & Energy Harvesting Setup Design

Material Selection & Structure (Prototype 2)

- Triboelectric materials with large charge affinity difference
- Layer 1: Metal surfaces -Al
- Layer 2: Electron-accepting PTFE (polytetrafluoroethylene)
- Layer 3: Form board support
- Cu wire used as current carrier

Design and Implementation

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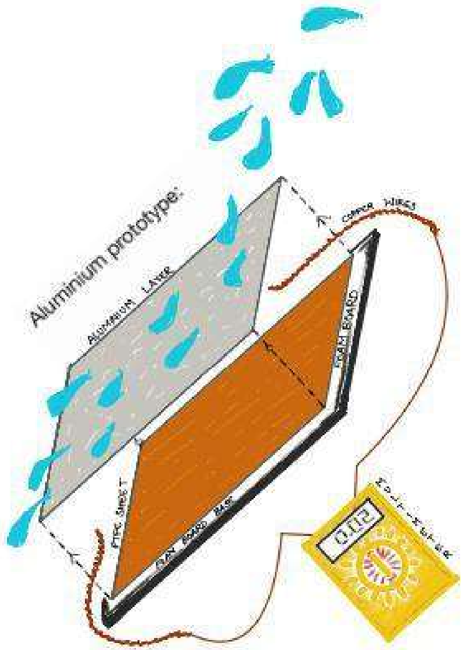
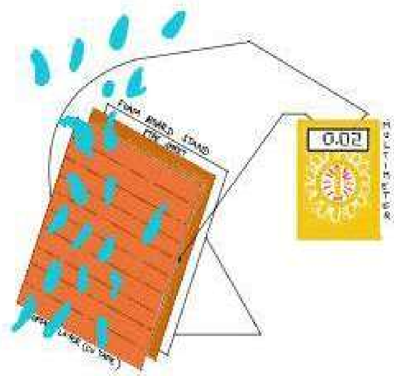


Copper-PTFE prototype:



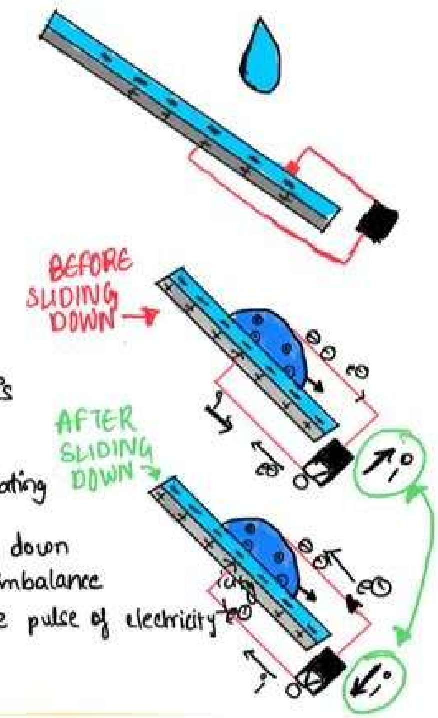
STEP - ①

- water droplets are polarised when water drop touches electrode, it transfers positive charges to the electrode and negative charges are induced at the back side.

STEP - ②

- An electrical potential difference is created due to material difference & water. electrons flow in the external circuit to balance this difference creating current:

STEP - ③: water droplet here slides down taking some charges away creating imbalance electrons flow back giving reverse pulse of electricity



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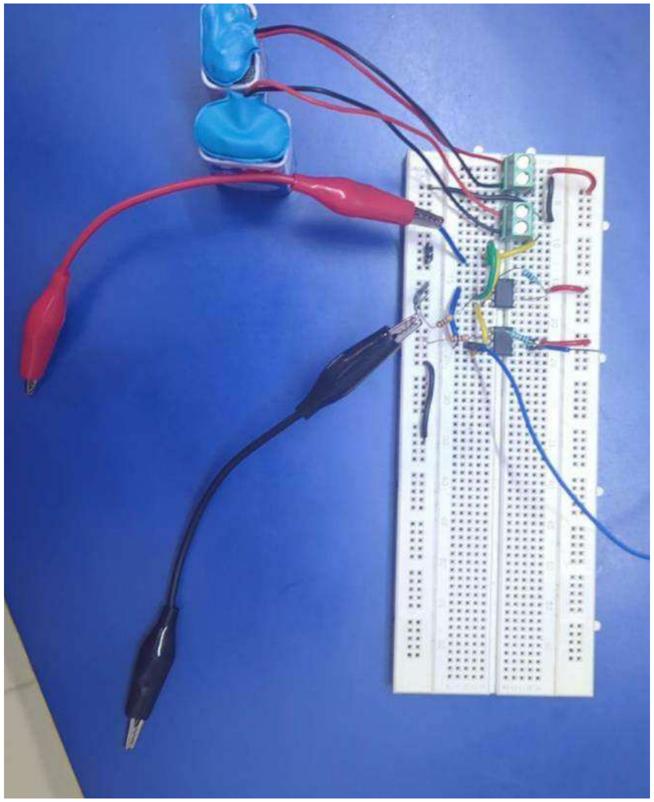
Design and Implementation

- **Dual Power Supply Setup:**
  Two 9V batteries provide +9V and -9V to the op-amp
  Proper polarity-one battery connected normally, other in reverse
- **Voltage Signal Input:**
  Voltage from the TENG setup is connected via crocodile clips to op-amp input.
- **Op-Amp Amplification (741):**
  Op-amp configured in non-inverting mode
  Resistors (10k & 1k) define gain
- **Output Voltage:**
  Amplified voltage appears at the op-amp output pin
- **Arduino Input:**
  Output connected to Arduino analogue pin via crocodile clip
- **Real-Time Monitoring:**
  Voltage is plotted on Serial Plotter in Arduino IDE
- **Integration with DHT11:**
  DHT11 sensor reads temperature and humidity
  Data plotted alongside voltage for analysis



Design and Implementation

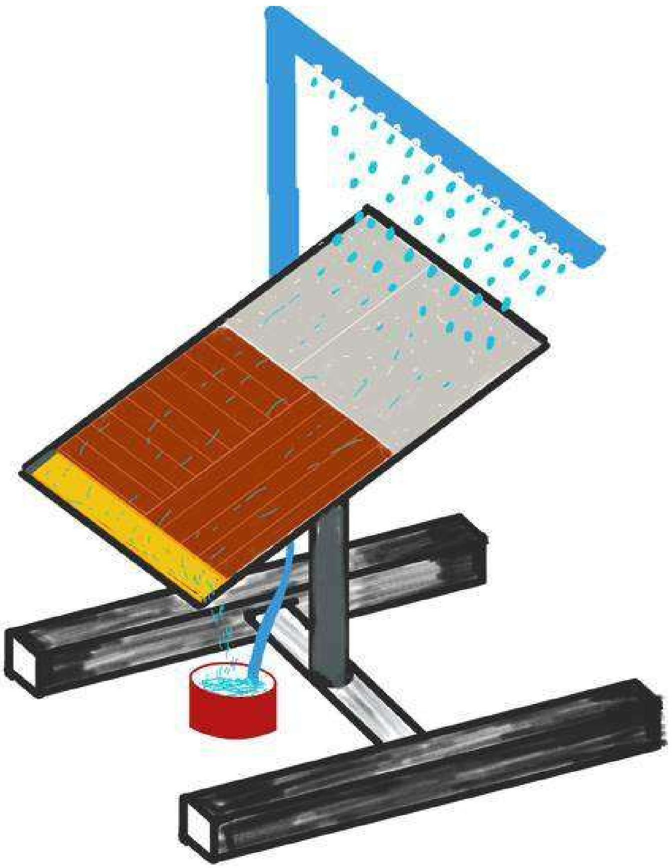
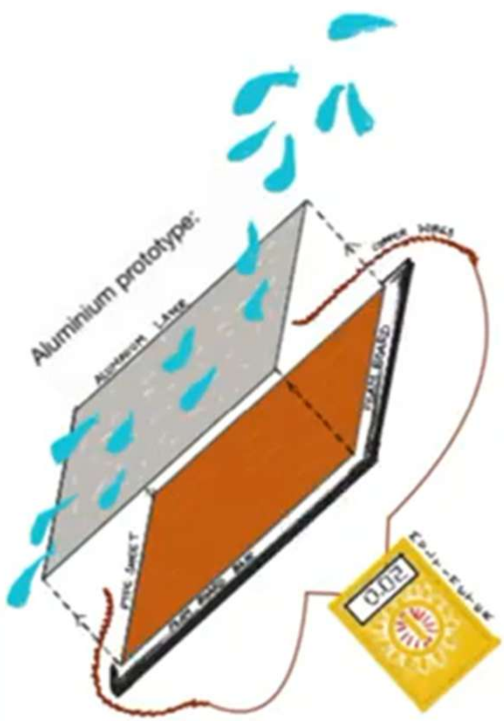
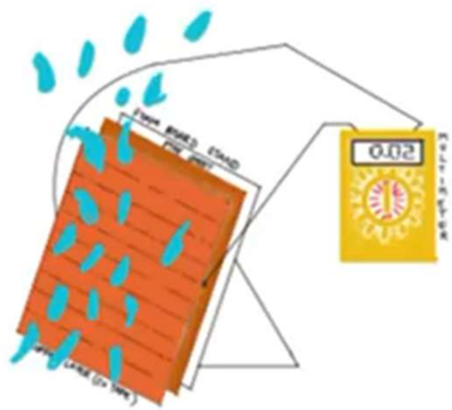


Figure 14:TENGs

Copper-PTFE prototype:





STEP - 1

- water droplets are polarized when water drop touches electrode, it transfers positive charges to the electrode and negative charges are induced at the back side.

STEP - 2

- An electrical potential difference is created due to material difference & water. electrons flow in the external circuit to balance this difference creating current.

STEP - 3: water droplet here slides dow taking some charges away creating imbal electrons flow back giving reverse pu

Final Outcome

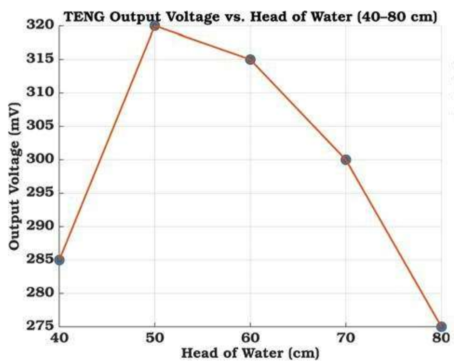
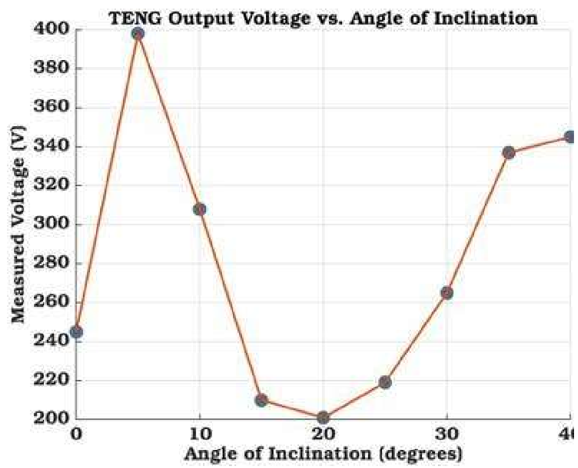


Figure 9: Scatter plot obtained from the earlier table values, plotted using MATLAB.



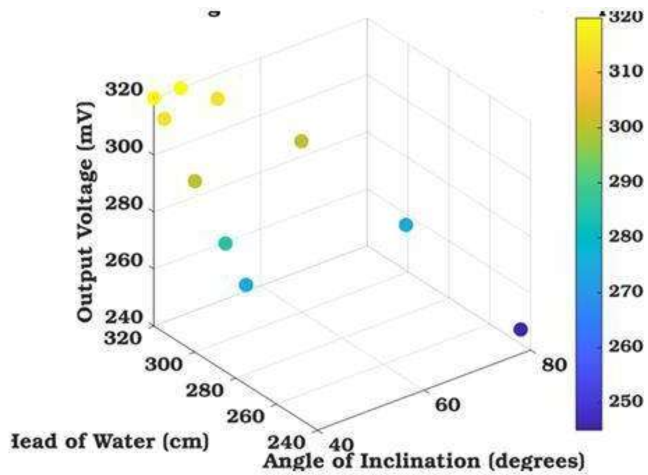


Figure 10: 3D scatter plot

Head of Water vs Output Voltage

Head of Water (cm)	Output Voltage (mV)
40	285
50	320
60	315
70	300

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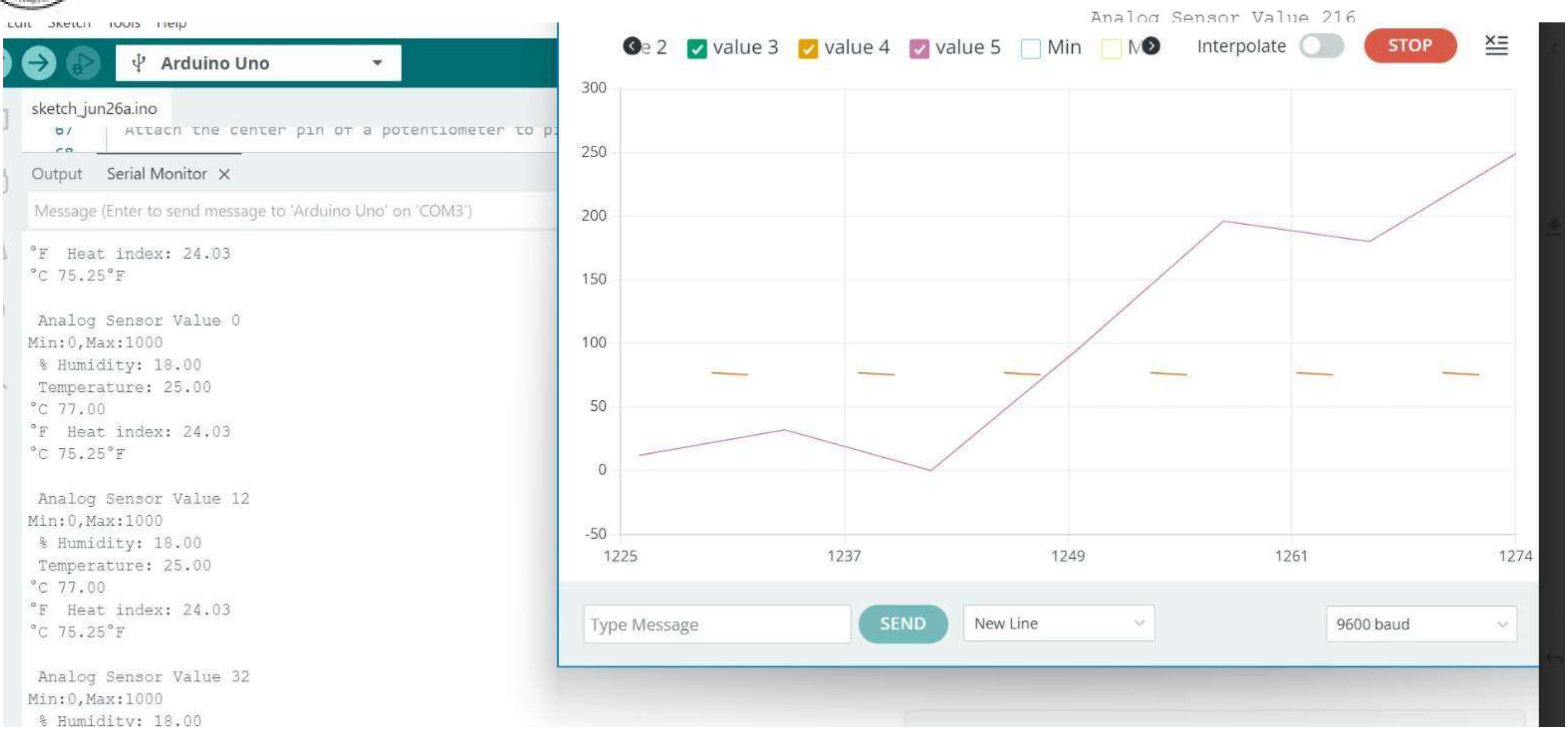
Final Outcome



Final Outcome

Prototype Performance:

- **Copper–PTFE Prototype**:
  Output voltage ~0.25 V; effective under slow, sliding droplet conditions.
- **Aluminium–PTFE Prototype**:
  Output ranged from **0.1 V to 0.7 V** depending on:
  - Inclination angle
  - Head of water
  - Droplet consistency
- **Combined System (Series Connection)**:
  Combining Al + Cu prototypes in series resulted in **hundreds of millivolts** output.

- **Graphical Analysis:**
- **Inclination vs Voltage**:
  Peak voltage (~0.4 V) recorded at **5°–10°** inclination. Too steep or flat angles reduced efficiency.
- **Head of Water vs Voltage**:
  Best output at **50 cm**. Beyond that, droplet dispersion reduced contact efficiency.
- **Humidity vs Voltage**:
  Higher humidity levels showed **clear increase in voltage output** (DHT11 + Arduino Plotter).
- **Data Visualization Platforms:**

Used **Arduino IDE (Serial Plotter)** for real-time analysis.

- **MATLAB** employed for plotting angle-based and 3D performance trends.

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WEB APP- predict and total energy generation

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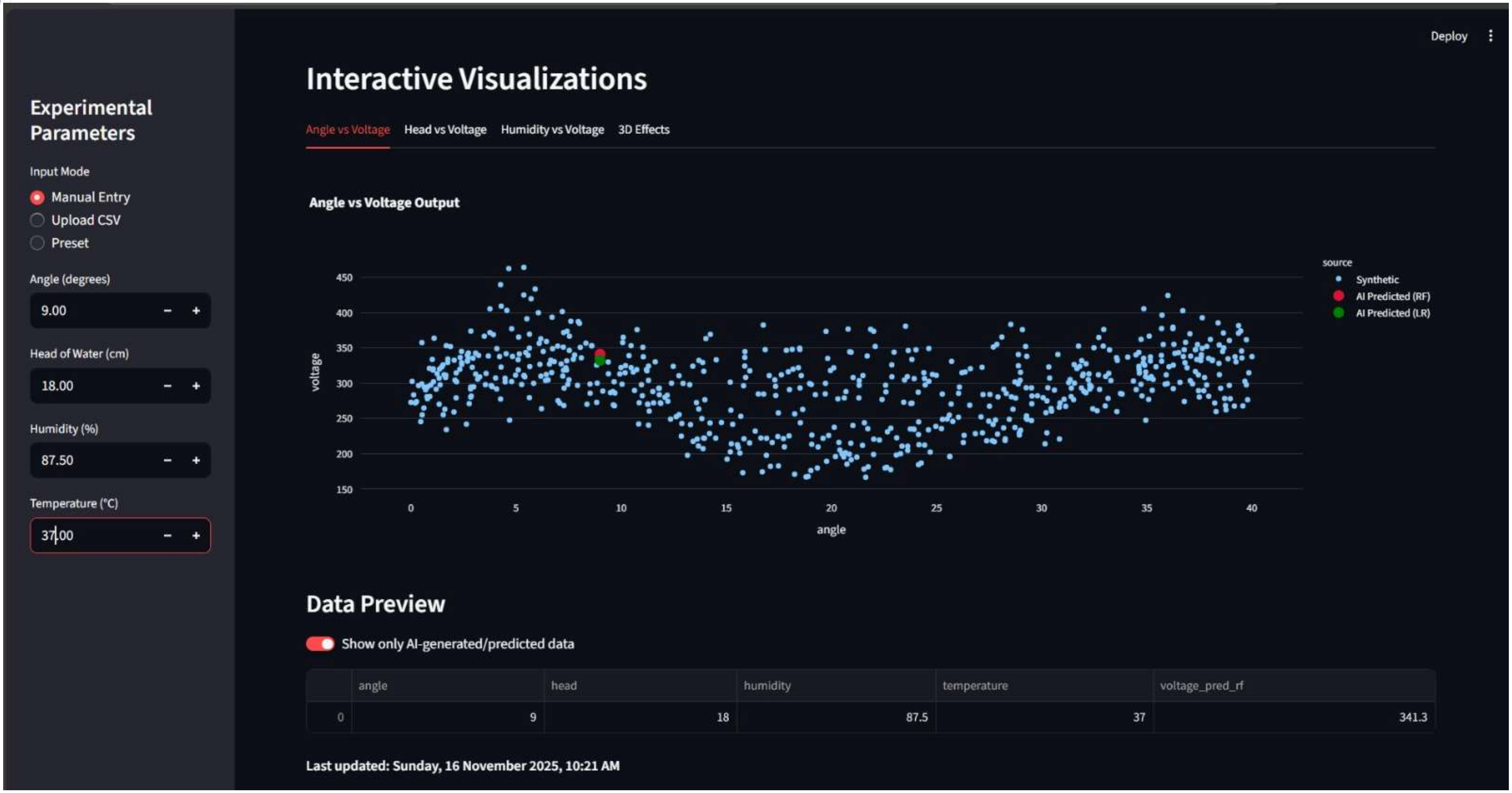

Category	**Observation**
Objective Achievement	Prototypes successfully demonstrated **hygroelectric + triboelectric energy generation**.
Material Performance	Aluminium gave better results than copper due to **higher electro positivity**.
	Non-adhesive PTFE sheets enabled better charge transfer compared to adhesive ones.
	Low-resistance copper wires improved signal conduction and voltage output.
Environmental Simulation	PVC pipe setup effectively **simulated rainfall** for consistent water droplet flow.
Optimization Findings	Optimal voltage observed at **5°–10° inclination**.
	Adhesive PTFE reduced output—highlighting importance of **material surface quality**.

Future Scope

The developed TENG prototype offers promising potential for further improvements and practical deployments:

- **Material Enhancement**: Using nanostructured or textured PTFE surfaces can significantly increase output efficiency.
- **Energy Storage Integration**: Coupling with capacitors or supercapacitors for storing generated energy can enable real-time use.
- **Flexible and Wearable Designs**: Developing flexible TENGs for integration into clothing, umbrellas, or backpacks.
- **Wireless Transmission**: Incorporating wireless modules to send signals for remote sensing or IoT applications.
- **Large-Scale Deployment**: Expanding surface area and combining multiple units for powering distributed sensor networks.
- **Real Rain Testing**: Testing performance under actual rainfall conditions to study long-term durability and output stability.

These advancements can make TENGs more viable for sustainable, off-grid power solutions and smart environmental systems.

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Conclusion

This project focused on the development of a triboelectric nanogenerator (TENG) that can harvest electrical energy through the interaction of water droplets with specially chosen materials. The central aim was to address the growing demand for clean, affordable, and decentralized energy sources, particularly in areas where access to traditional power infrastructure is limited.

To demonstrate this, we designed and fabricated a prototype using Teflon (PTFE) and aluminum foil, which act as the electron acceptor and donor respectively, based on their relative positions in the triboelectric series. The device works on the principles of both **triboelectricity** (charge transfer via contact and separation) and **hygroelectricity** (electricity generation from water droplet interaction).

A major enhancement to the setup was the construction of a **recirculating water fountain system**, powered by a small pump. This created a **closed-loop water cycle** to allow continuous and automated droplet flow over the TENG surface. Additionally, to evaluate how surface orientation affects power output, we designed a **three-inclination system** with adjustable angles. This allowed us to experimentally determine the most efficient tilt (between 5°–10°) for maximizing voltage generation.

Overall, the project successfully demonstrated the feasibility of using basic, low-cost materials to harness mechanical energy from water and convert it into usable electrical signals, forming the foundation for further exploration into scalable and environmentally friendly energy harvesting systems.

Acknowledgments

We express our gratitude to RV College of Engineering, for presenting an opportunity to work on this project.

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