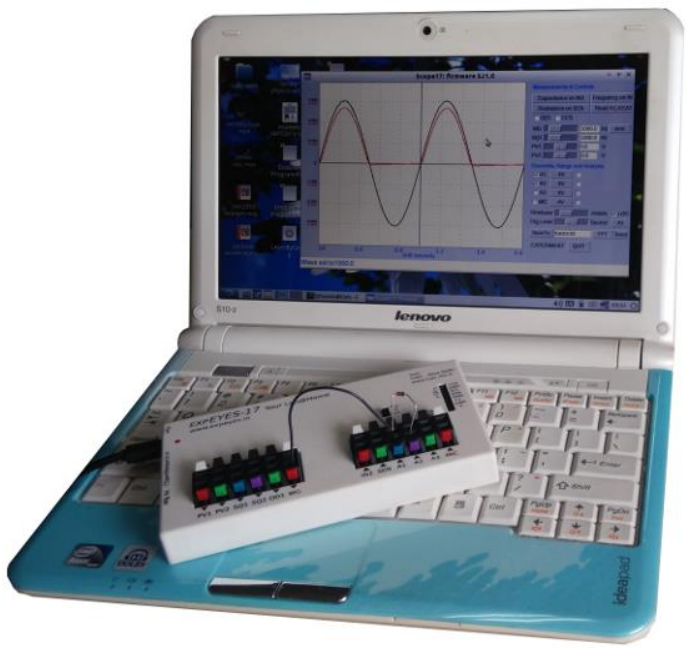
**Report on the Training Program on**

# Computer Interfaced Science Experiments Using ExpEYES

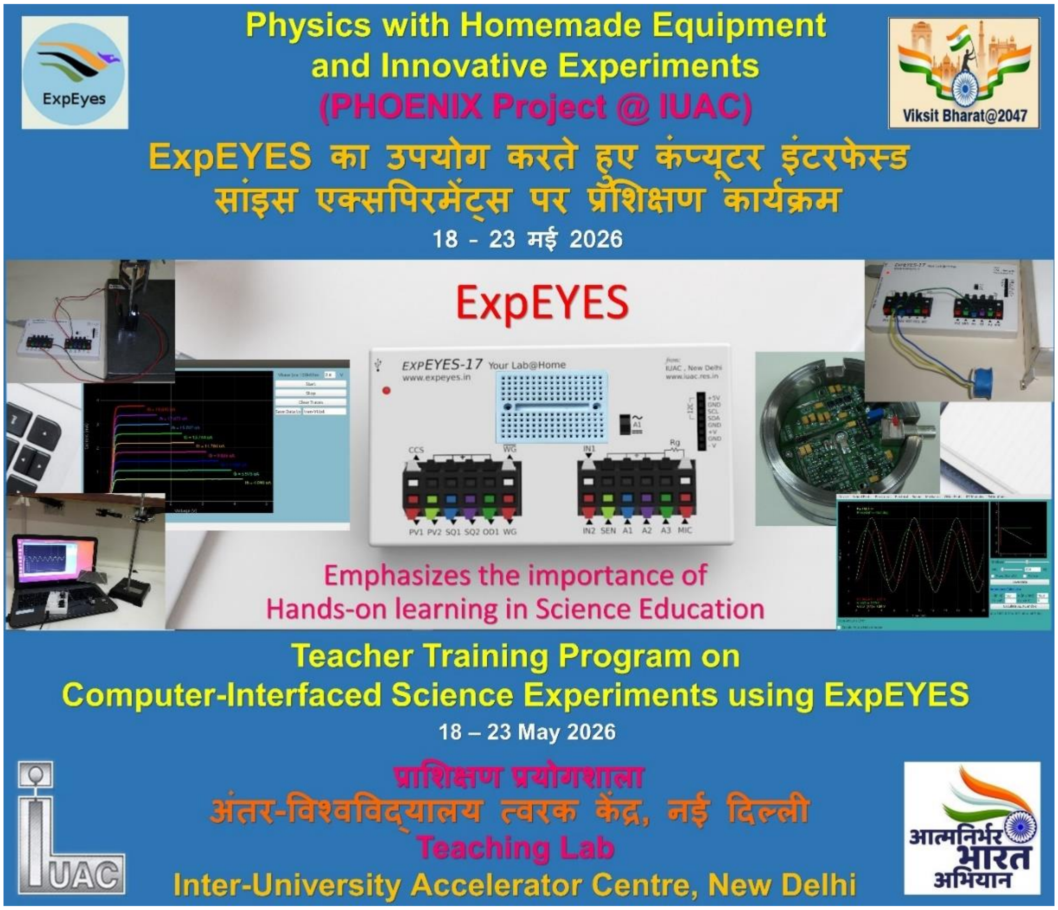
(18 – 23 May 2026)




**Inter-University Accelerator Centre**

**Aruna Asaf Ali Marg,**
**New Delhi-110067**

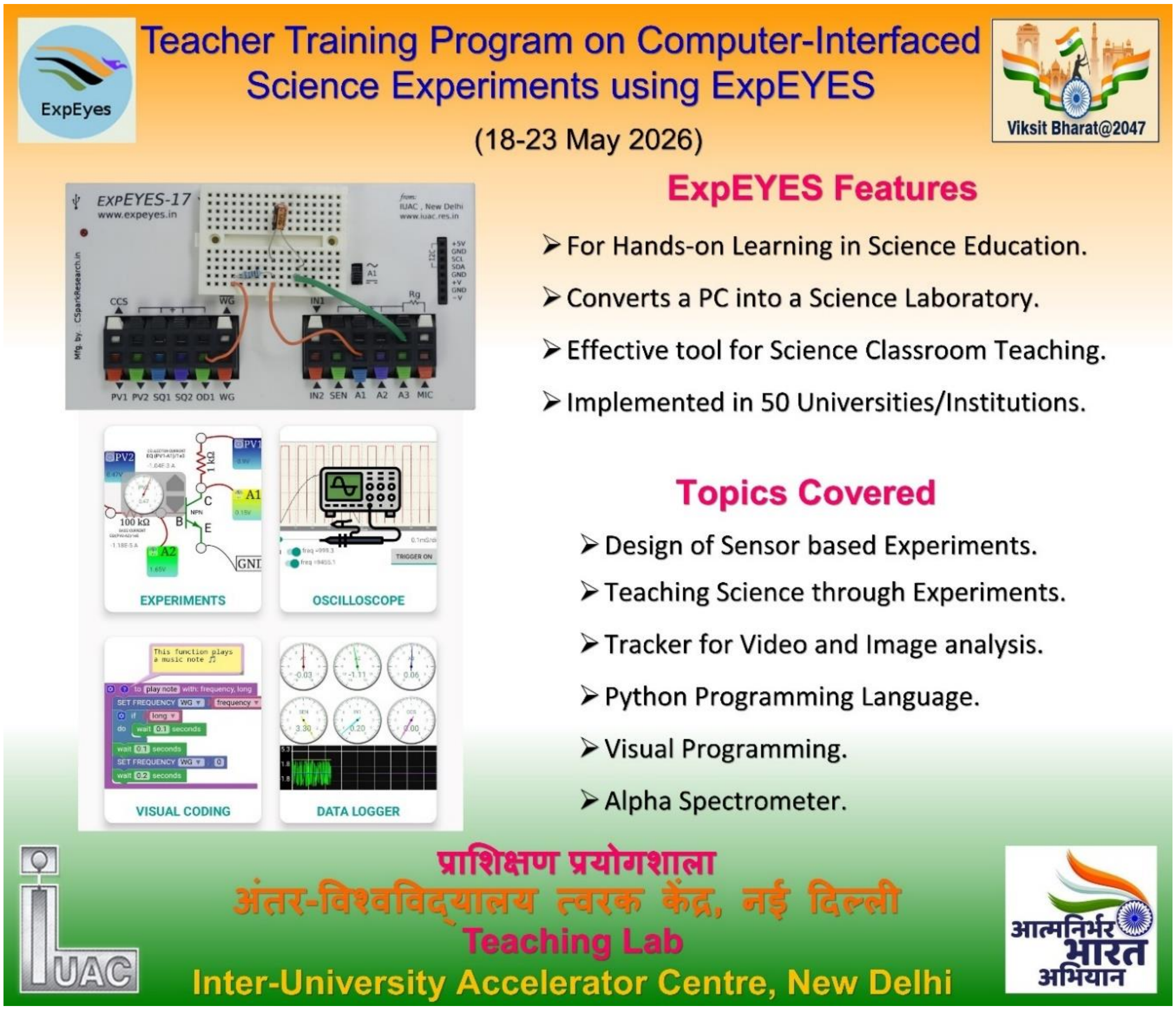
# Teacher Training Program on Computer-Interfaced Science Experiments using ExpEYES




**Venue: Ph. D. Classroom**

अंतर विश्वविद्यालय त्वरक केंद्र
**Inter-University Accelerator Centre - (IUAC)**

**Aruna Asaf Ali Marg, Near Vasant Kunj,**
**New Delhi, 110067, INDIA**


ExpEyes
Teacher Training Program on Computer-Interfaced Science Experiments using ExpEYES
(18-23 May 2026)
Viksit Bharat@2047
EXPEYES-17
www.expeyes.in
from: IUAC, New Delhi www.iuac.res.in
ExpEYES Features
➢ For Hands-on Learning in Science Education.
➢ Converts a PC into a Science Laboratory.
➢ Effective tool for Science Classroom Teaching.
➢ Implemented in 50 Universities/Institutions.
EXPERIMENTS
OSCILLOSCOPE
VISUAL CODING
DATA LOGGER
Topics Covered
➢ Design of Sensor based Experiments.
➢ Teaching Science through Experiments.
➢ Tracker for Video and Image analysis.
➢ Python Programming Language.
➢ Visual Programming.
➢ Alpha Spectrometer.
प्राशिक्षण प्रयोगशाला
अंतर-विश्वविद्यालय त्वरक केंद्र, नई दिल्ली
Teaching Lab
Inter-University Accelerator Centre, New Delhi
IUAC
आत्मनिर्भर भारत अभियान

# Program Schedule

## Day 1: Monday 18th May 2026

| | | |
|---|---|---|
| 9:30 – 10:00 | **Registration** | |
| 10:00-10:30 | **Inaugural Program**<br>**Welcome Address by**<br>**Prof. Avinash Chandra Pandey, Director, IUAC** | |
| | **Session-1** | |
| 10:30-11:15 | **Teaching Science through Experimentation and Exploration** | **Shri. V.V.V.Satyanarayana**<br>IUAC, New Delhi |
| 11:15-11:30 | **Tea Break** | |
| | **Session-2** | |
| 11:30-12:15 | **Introduction to ExpEYES** | **Shri. V.V.V.Satyanarayana,**<br>IUAC, New Delhi |
| 12:15-13:00 | **Design of Experiments** | **Prof O.S.K.S.Sastri,**<br>CUHP, Dharamshala**.** |
| 13:00-14:00 | **Lunch Break** | |
| | **Session-3** | |
| 14:00-15:30 | **Hands-on Experiments using ExpEYES**<br>(Demonstration & Hands-on) | **Shri. V.V.V.Satyanarayana**<br>IUAC, New Delhi |
| 15:30-16:00 | **Tea Break** | |
| | **Session - 4** | |
| 16:00-16:45 | **Hands-On Experiments** | |
| 16:45-17:30 | **Introduction to Tracker for Video and Image Analysis** | **Prof O. S. K. S. Sastri**<br>CUHP, Dharamshala |

## Day 2: Tuesday 19h May 2026

| | | |
|---|---|---|
| | **Session-5** | |
| 09:30-11:00 | **Classical Mechanics Experiments Demonstration & Hands-On** | **Prof O.S.K.S.Sastri**<br>**Shri. V.V.V.Satyanarayana** |
| 11:00-11:30 | **Tea Break** | |
| | **Session-6** | |
| 11:30-12:15 | **ExpEYESing the Peaks and Valleys of EM Induction**<br>(Online) | **Prof. Manoj Kumar G**<br>University of Hyderabad |
| 12:15-13:00 | **Hands-On Experiments** | |
| 13:00-14:00 | **Lunch Break** | |
| | **Session-7** | |
| 14:00-15:30 | **Hands-On Experiments** | |
| 15:30-16:00 | **Tea** | |
| | **Session-8** | |
| 16:00-16:45 | **Agentic AI: The App Developer** | **Prof O. S. K. S. Sastri**<br>CUHP, Dharamshala |
| 16:45-17:30 | **Hands-On Experiments** | |

## Day 3: Wednesday 20th May 2026

| | | |
|---|---|---|
| **Session-9** | | |
| 09:30–11:00 | **Introduction to Python Programming Language** | **Shri. V.V.V.Satyanarayana and Shri. Yatesh** IUAC, New Delhi |
| 11:00-11:30 | **Tea Break** | |
| **Session-10** | | |
| 11:30-12:15 | **Discussions and Hands-On Python Basics** | |
| 12:15-13:15 | **Introduction to Interfacing ExpEYES with Python** | **Shri. V.V.V.Satyanarayana** IUAC, New Delhi |
| 13:00-14:00 | **Lunch Break** | |
| **Session-11** | | |
| 14:00-15:30 | **Hands-On Experiments** | |
| 15:30-16:00 | **Tea Break** | |
| **Session-12** | | |
| 16:00-16:45 | **ExpEYES with Android Mobile and Visual Programming** (Online) | **Dr Ajith Kumar B. P.** Ex IUAC, New Delhi |
| 16:45-17:30 | **Hands-On Experiments** | |
| 17:30-18:30 | **Evening Snacks Break** | |
| **Evening Talk** | | |
| 18:30-19:30 | **Interfacing ExpEYES with Python** | **Prof Vandna Luthra** Gargi College, New Delhi |

## Day 4: Thursday 21st May 2026

| | | |
|---|---|---|
| **Session-13** | | |
| 09:30-10:15 | **High Performance Computer facility at IUAC** | **Dr. Joby Antony** IUAC, New Delhi |
| 10:15-11:00 | **Hands-On Experiments** | |
| 11:00-11:30 | **Tea Break** | |
| **Session-14** | | |
| 11:30-12:15 | **Hands on Pedagogy: Tailored LCR Resonance Experiment using ExpEYES** | **Dr. Rajesh B M** R V College of Engineering, Bengaluru |
| 12:15-13:00 | **Hands-On Experiments** | |
| | **Lunch** | |
| **Session-15** | | |
| 14:00-15:00 | **Hands-On Experiments** | |
| 15:00-15:30 | **Alpha Spectrometer Developed at IUAC** | **Shri. V.V.V.Satyanarayana** IUAC, New Delhi |
| 15:30-16:00 | **Tea Break** | |
| **Session-16** | | |
| 16:00-16:45 | **Hands-On Experiments** | |
| 16:45-17:30 | **Project Preparations** | |

## Day 5: Friday 22nd May 2026

| | | |
|---|---|---|
| **Session-17** | | |
| 09:30-10:15 | **Accelerators at IUAC** | **Shri. Sunil Ojha**<br>IUAC, New Delhi |
| 10:15-11:00 | **IUAC Facility Visit** | **Shri. V.V.V.Satyanarayana**<br>IUAC, New Delhi |
| 11:00-11:30 | **Tea Break** | |
| **Session-18** | | |
| 11:30-13:00 | **Project Preparations** | |
| 13:00-14:00 | **Lunch Break** | |
| 14:00-15:30 | **Project Presentations by Participants** | |
| 15:30-16:00 | **Tea Break** | |
| 16:00-17:30 | **Project Presentations by Participants** | |
| **Evening Snacks Break** | | |
| **Evening Talk** | | |
| 18:30-19:30 | **Quantum Computing** | **Prof Vandna Luthra**<br>Gargi College, New Delhi |

## Day 6: Saturday 23rd May 2026

| | |
|---|---|
| 09:30-11:00 | **Project Presentations by Participants** |
| 11:00-11:30 | **Tea Break** |
| 11:30-12:30 | **Distribution of Participation Certificates** |
| 12:30-13:00 | **Concluding Session** |
| 13:00-14:00 | **Lunch Break and End of the Programme** |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Inter-University
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A total of twenty-six participants from various parts of the country attended the training program, including two resource persons: Prof. O. S. K. S. Sastri from the Central University of Himachal Pradesh, and Prof. Vandna Luthra from Gargi College, Delhi University. The primary criterion used to shortlist candidates was ensuring broad regional representation across the country, with additional factors used to establish region-specific waiting lists. To prevent last-minute cancellations and allow waitlisted candidates sufficient notice to join, all selected participants were required to confirm their attendance by providing proof of booked travel arrangements.

Prior to the start of the program, participants were requested to bring laptops with the ExpEYES software pre-installed; those without laptops were paired with attendees who had them. The ExpEYES-17 user manual, a tentative list of experiments, and the official program schedule were distributed in advance via dedicated email and WhatsApp groups. To foster collaboration and teamwork, participants were organized into pairs at the beginning of the program, with one ExpEYES kit allocated to each group.

## List of the invited talks in online and offline modes

1. **Teaching Science through Experimentation and Exploration**
   Shri. V.V.V.Satyanarayana, IUAC, New Delhi.
2. **Introduction to Tracker for Video and Image Analysis**
   Prof. O.S.K.S.Sastri, CUHP, Dharamshala.
3. **ExpEYESing the Peaks and Valleys of EM Induction (Online)**
   Prof. Manoj Kumar, University of Hyderabad, Hyderabad.
4. **Agentic AI: The App Developer**
   Prof. O.S.K.S.Sastri, CUHP, Dharamshala.
5. **Introduction to Python Programming Language**
   Shri. V.V.V.Satyanarayana and Shri. Yatesh Dabas, IUAC, New Delhi.
6. **Android mobile version of ExpEYES and Visual Programming (Online)**
   Dr. Ajith Kumar B.P., Ex IUAC, New Delhi.
7. **High performance Computer Facility at IUAC.**
   Dr. Joby Antony, IUAC, New Delhi.
8. **Tailored LCR Response Experiments using ExpEYES.**
   Dr. Rajesh B.M., R.V.College of Engineering, Bengaluru.
9. **Alpha Spectrometer Development at IUAC.**
   Shri. V.V.V.Satyanarayana, IUAC, New Delhi.
10. **Accelerators at IUAC**
    Shri. Sunil Ojha, IUAC, New Delhi.
11. **Quantum Computing**
    Prof. Vandna Luthra, Gargi College, New Delhi.

## Day 1: Monday 18th May 2026

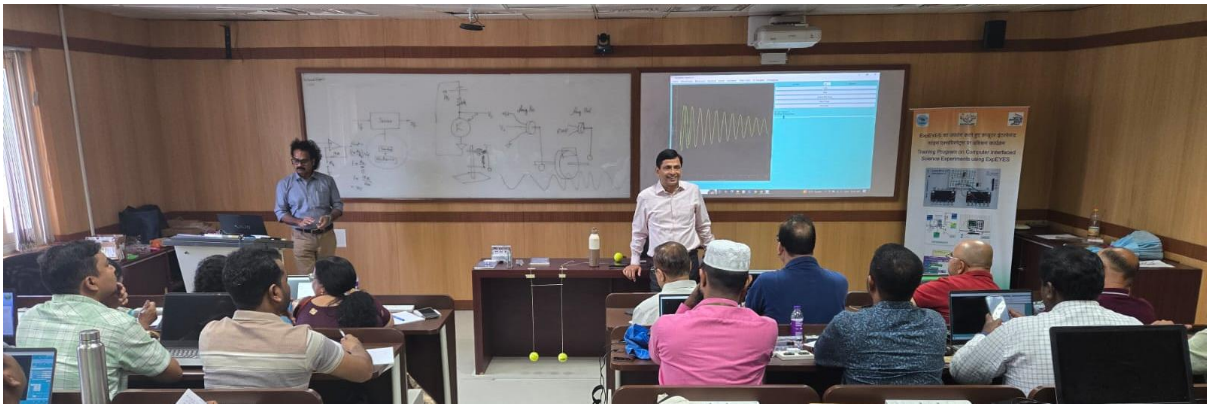
Shri V. V. V. Satyanarayana, Convener of the program, welcomed the participants, and the inaugural session officially commenced with the traditional lighting of the lamp by the dignitaries. Prof. Avinash Chandra Pandey, Director of IUAC, delivered the welcome address, highlighting the core objectives of the program. He emphasized that the participants carry a responsibility to perpetuate the spirit of scientific learning by organizing similar programs, mentoring students, and developing innovative experimental methodologies at their respective institutions. Prof. O. S. K. S. Sastri from the Central University of Himachal Pradesh, Dharamshala, who has been associated with this initiative for more than a decade, expressed his appreciation to IUAC for consistently conducting such meaningful training programs for the national teaching community.


The first technical session commenced with an introductory talk titled “Teaching Science through Experimentation and Exploration,” delivered by Shri V. V. V. Satyanarayana. During this session, he introduced the ExpEYES platform to the participants, demonstrating its utility as an effective classroom tool for experiential science education. He highlighted how a single ExpEYES kit can seamlessly function as a multi-purpose laboratory instrument—serving as a digital multimeter (capable of measuring resistance, capacitance, and voltage), a programmable power supply, a waveform generator, and a four-channel oscilloscope. Additionally, Shri Satyanarayana demonstrated the experiment for plotting the current-voltage (I–V) characteristics of a diode, providing a comparative illustration of how the experiment is executed using ExpEYES versus a conventional laboratory test bench.

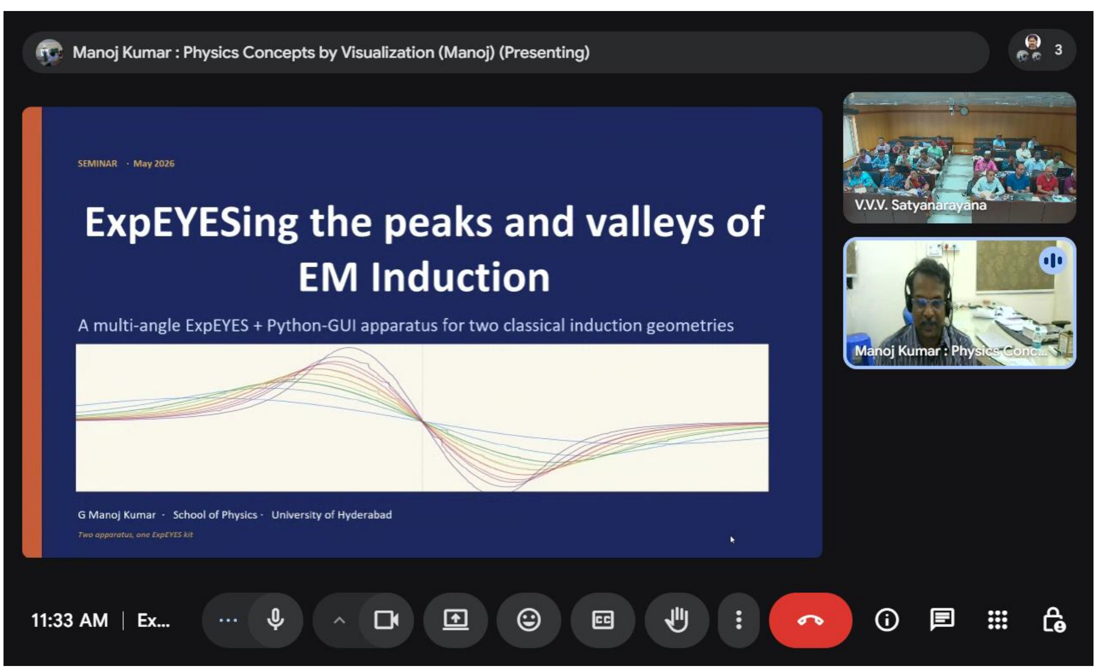
During the post-lunch session, participants engaged in practical, hands-on electronics experiments selected from the ExpEYES software menu. By the conclusion of the day, all attendees had established familiarity with the interface, and the majority of the experiments were successfully executed by the two-member teams. The inaugural day of the training program concluded with an insightful lecture on "Introduction to Tracker for Video and Image Analysis," delivered by Prof. Sastri.

## Day 2: Tuesday 19th May 2026

During the first session, Prof. Sastri and Shri V. V. V. Satyanarayana demonstrated a variety of classical mechanics experiments utilizing different sensors interfaced with ExpEYES. These included an ultrasonic echo module for distance measurements, a photogate sensor for timing measurements, and a DC motor repurposed as an angular position sensor. Following the demonstrations, participants actively practiced these classical mechanics experiments during the dedicated hands-on sessions.



During the post-tea session, a virtual demonstration titled "ExpEYESing the Peaks and Valleys of EM Induction" was conducted online by Prof. G. Manojkumar from the University of Hyderabad. Having previously participated in the September 2024 ExpEYES Training Program at IUAC, Prof. G. Manojkumar has since been actively involved in customizing classical mechanics experiments using the ExpEYES interface. Furthermore, he regularly integrates the platform into demonstrations and practical laboratory sessions during Teacher Training Programs hosted at the Malaviya Mission Teacher Training Centre, University of Hyderabad.

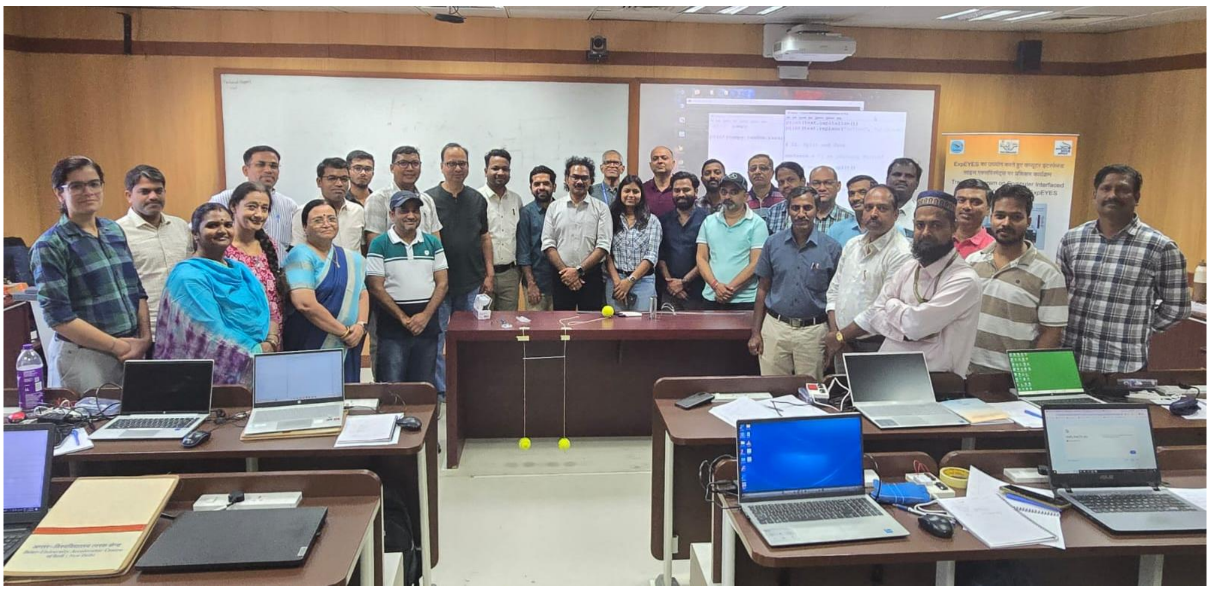


The apparatus consists of a small mass (magnet) attached to a rigid rod, which is connected to a motor-driven base. The motor can oscillate the rod at different frequencies, which are displayed in Hertz on the ExpEYES interface. A coil is placed just below the magnet. As the magnet oscillates, it induces an electromotive force (EMF) in the coil due to the changing magnetic flux. This induced EMF is recorded using ExpEYES to analyze the amplitude and frequency of oscillations. The system can be studied under both free and damped conditions in air.


Later, the participants practiced the experiments provided in the GUI menus under the Mechanics, Electronics, and Electrical sections. Divided into two-member groups, all participants actively explored the experiments. In the post-lunch session, Prof. Sastri delivered a talk titled “Agentic AI: The App Developer,” which was followed by a hands-on session. By the end of the two-day program, the participants were well-acquainted with ExpEYES, and almost all of the listed experiments had been successfully performed by everyone.

## Day 3: Wednesday 20th May 2026

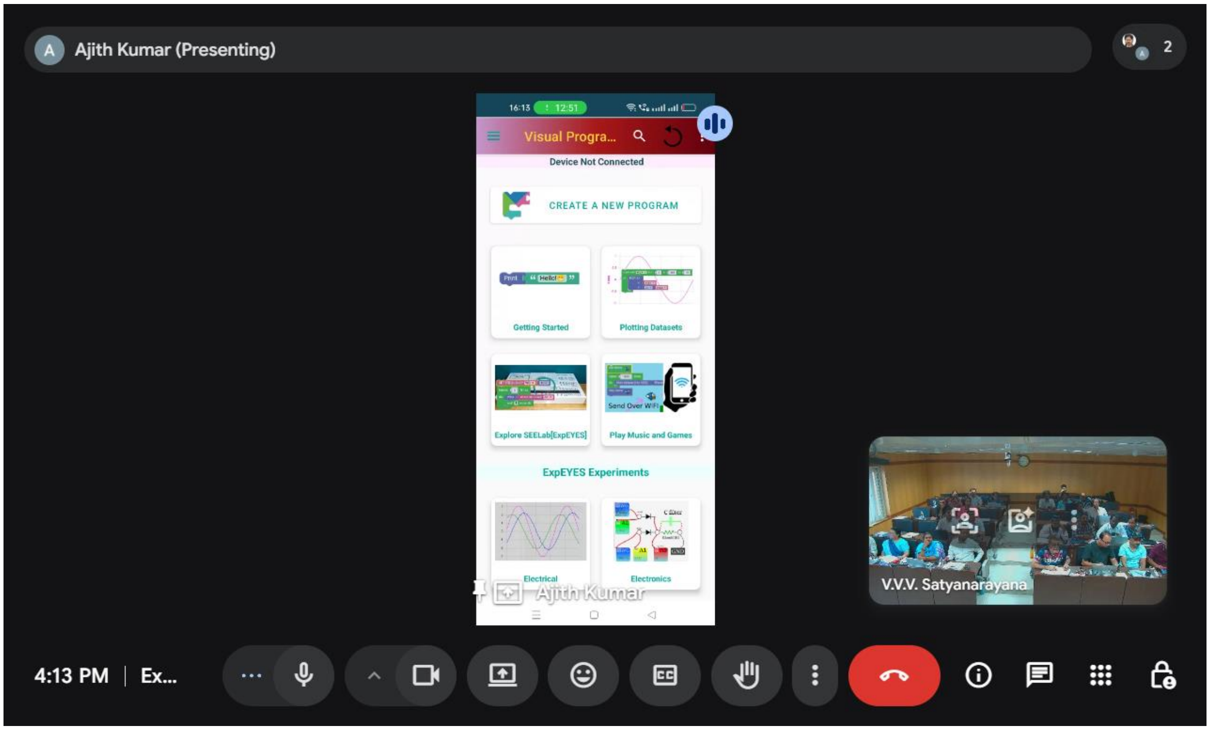
The morning session began with a talk titled "Introduction to the Basics of Python Programming Language," delivered by Shri. Yatesh Dabas and Shri. V.V.V. Satyanarayana. They introduced fundamental Python concepts, including variables, data types, and loops, along with basic coding practices. At the conclusion of the talk, participants were asked to write a small Python program for a designated task. In the subsequent hands-on session, participants practiced these basics, with those possessing prior coding experience assisting their peers. Additionally, members of the IUAC computer group kindly supported the participants by helping them install the required software and troubleshoot their code.



The post-tea session began with a revision of Python programming basics and the practice of a few examples. Communication with ExpEYES through Python was established, and programs from the user manual—such as setting voltages, reading inputs, setting a sinewave, and plotting it—were practiced. The software (PyCharm, *eyes17lib* (using pip), SciPy, and Matplotlib) required to communicate with ExpEYES through Python was installed, and PyCharm was used to write, compile, and execute the programs.

Post-lunch session featured an online talk and demonstration titled "Android Mobile Version of ExpEYES and Visual Programming" by Dr. Ajith Kumar B.P., former IUAC scientist and co-founder of the PHOENIX project. He demonstrated how to use ExpEYES with mobile devices and explained its applications in classroom teaching. The concept of visual programming was also introduced, illustrating how small code blocks can be combined to build a complete program for performing experiments.

After Dr. Ajith Kumar's talk, the participants practiced the experiments again using Android mobile phones. A few participants were particularly eager to explore visual coding and individually experimented with the basic code blocks. Through this exercise, they realized how easy it is to use ExpEYES in classroom teaching, even when explaining theoretical concepts.

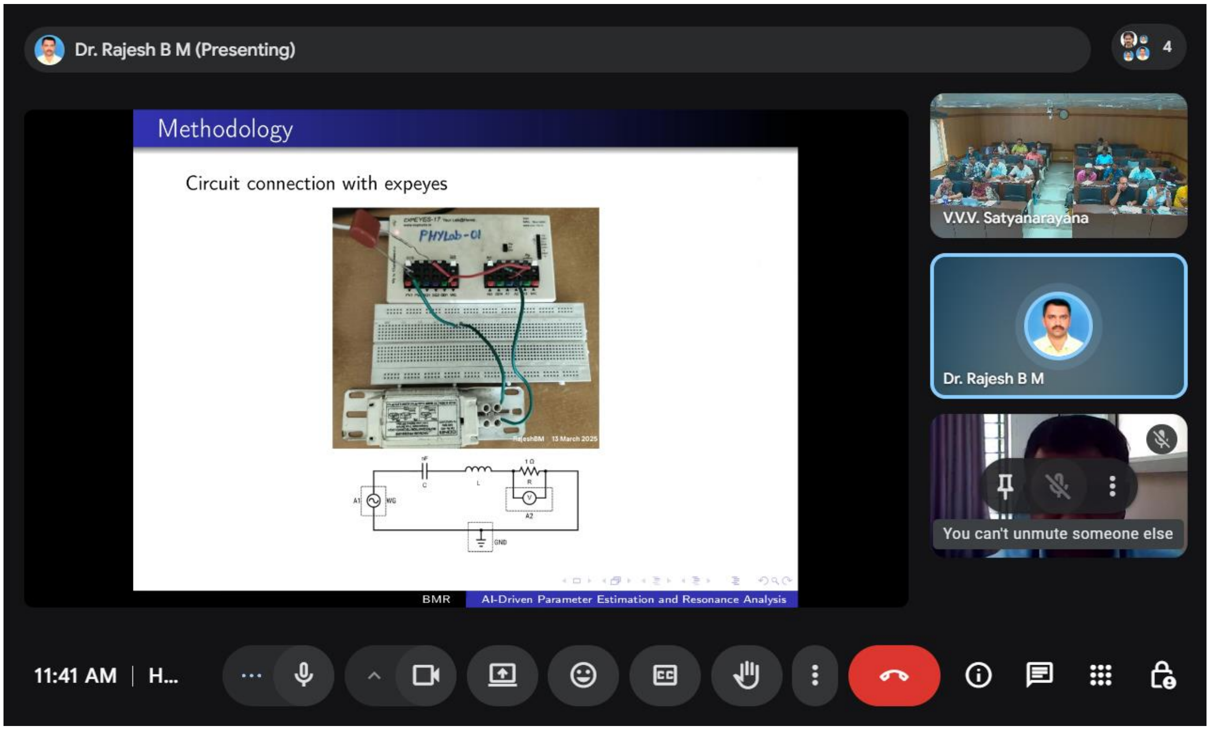



An evening talk and demonstration on performing experiments with ExpEYES through Python programming was given by Prof. Vandna Luthra. She explained the Diode I-V characteristics experiment step by step, which all participants then practiced. Afterward, the participants discussed the projects they would take up. A total of ten groups were formed, and eleven projects were finalized and assigned.

## Day 4: Thursday 21st May 2026

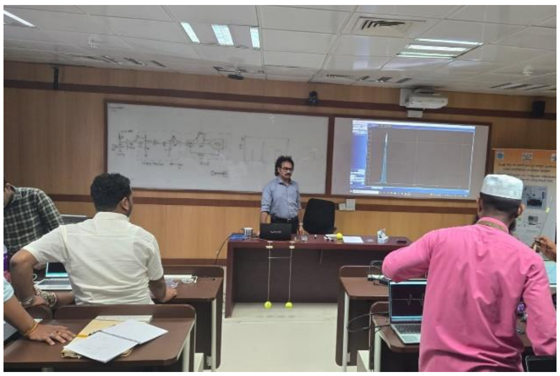
In the morning session, Dr. Joby Antony from IUAC gave a talk titled "High Performance Computer Facility at IUAC." The purpose of including this presentation in the training program was to introduce participants to the center's research facilities. Ultimately, this will help the participants and their associated students utilize the resources available at IUAC.

In the later session, the participants practiced hands-on experiments and simultaneously began working on their projects. The materials required to carry out these projects were arranged with the help of Shri. Om Mishra and Shri. Ajay, who provided technical support throughout the training program. The post-tea session began with an online talk and demonstration titled *"Tailored LCR Response Experiment using ExpEYES"* by Dr. Rajesh B.M. from R.V. College of Engineering, Bengaluru.




Dr. Rajesh shared his journey with ExpEYES and described how he implemented the platform to conduct conventional experiments using innovative methods at R.V. College of Engineering, Bengaluru. A dedicated experiments menu was designed and integrated into the main menu list of the ExpEYES GUI program. He also noted that most of the development work was carried out by his students, with several of them utilizing ExpEYES to complete their institutional project work. In the later session, the participants practiced hands-on experiments and simultaneously began working on their projects.

After two hands-on sessions, a talk and demonstration were given by Shri. V. V. V. Satyanarayana on the **Alpha Spectrometer developed at IUAC.** The reason to initiate this development at IUAC and the history of various prototypes developed in this regard were discussed. The various types of experiments designed with this equipment were discussed and demonstrated. Using nonenriched sources to perform alpha particle detection experiments was discussed. Measuring the foil thickness, the study of alpha particle energy with distance in air, etc. were discussed. The signal processing of the detector's signals before acquiring the data was explained. The basics and necessity of each and every block of signal processing like pre-amplifiers, shaping amplifiers, peak-sensing ADCs, and data acquisition systems were explained in detail. The alpha spectrometer was demonstrated with $^{241}$Am alpha source with and without vacuum. Later, a talk titled *"Quantum Computing"* was delivered by Prof. Vandna Luthra, after which the participants were engaged in preparing their projects.



The project presentations began during the post-tea session and continued the following day as well. A total of ten projects were prepared by the participants, and most of them showcased new ideas implemented using ExpEYES.

The Tea-time discussions

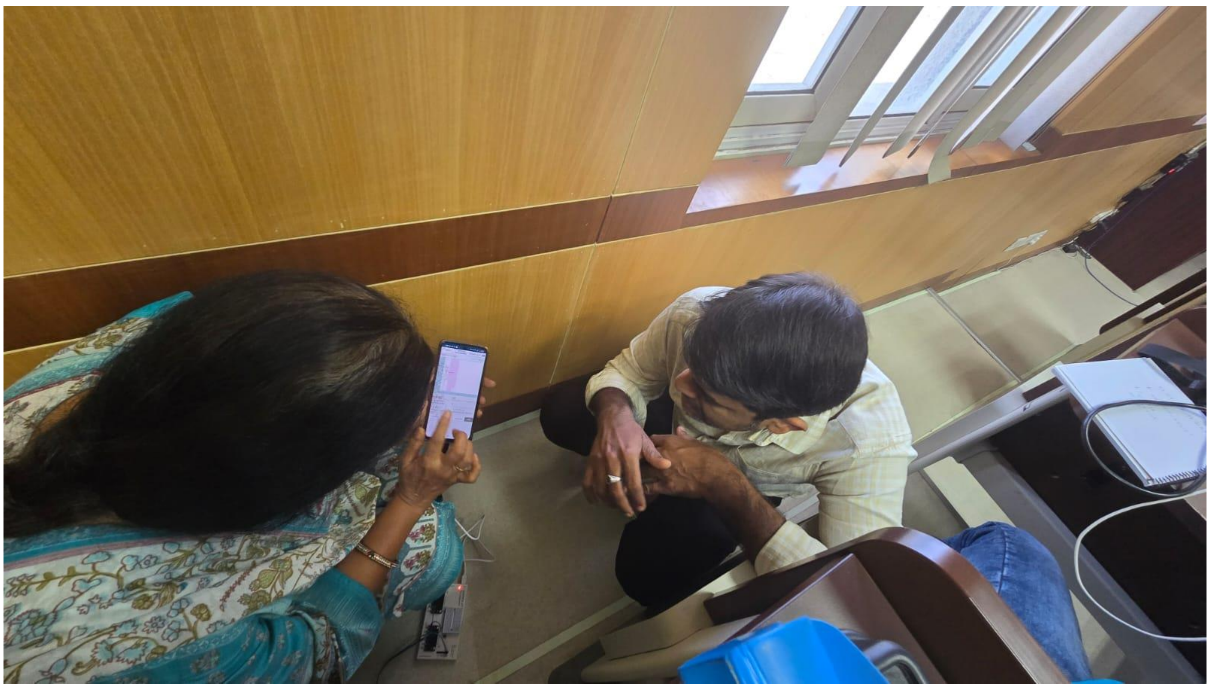
### Day 5: Friday 22nd May 2026

In the morning session, a talk on *"Accelerators at IUAC"* was delivered by Shri. Sunil Ojha, Scientist-G, IUAC. The purpose of including this talk in the training program was to acquaint the participants with the research facilities available at IUAC. This session aimed to help the participants, and their associated students, explore the possibility of utilizing these facilities for their research work. The talk covered the various accelerator facilities available at IUAC, along with the corresponding energy levels of each accelerator.

## IUAC Facility Visit

The purpose of the IUAC facility visit is to showcase the opportunities and resources available at IUAC to the Indian academic community so that they or their students can make use of them. The main control room and data room were among the accelerators, beam halls, and groups that participants visited during the visit.

## Projects Preparations by the Participants



The project presentations began during the post-lunch session and continued the following day as well. A total of eleven projects were presented by the participants, and most of them showcased new ideas implemented using ExpEYES.

# List of the Projects taken up by the Participants

1. ExpEYES-Smart Bot in Industry (E-SBI).
2. Determination of Electrical conductivity and pH value of liquids using ExpEYES.
3. Real-Time Waveform Transformation using Op-Amp and ExpEYES.
4. Insights of Impedance Spectroscopy for Gang Capacitors with ExpEYES.
5. Determination of Spring Constant using LIDAR Sensor with ExpEYES.
6. Wien Bridge Oscillator using LM358 Op-Amp & Testing using ExpEYES.
7. Testing of Cyclic Voltammetry using ExpEYES.
8. Testing of Astable Multivibrator using ExpEYES.
9. Development of Optical Setup for Water quality check using ExpEYES.
10. Memristive Emulator Circuit using ExpEYES
11. Revisiting Galileo's Ball and Bell experiment using Electromagnetic Induction and ExpEYES.

# Projects Presentations by the participants

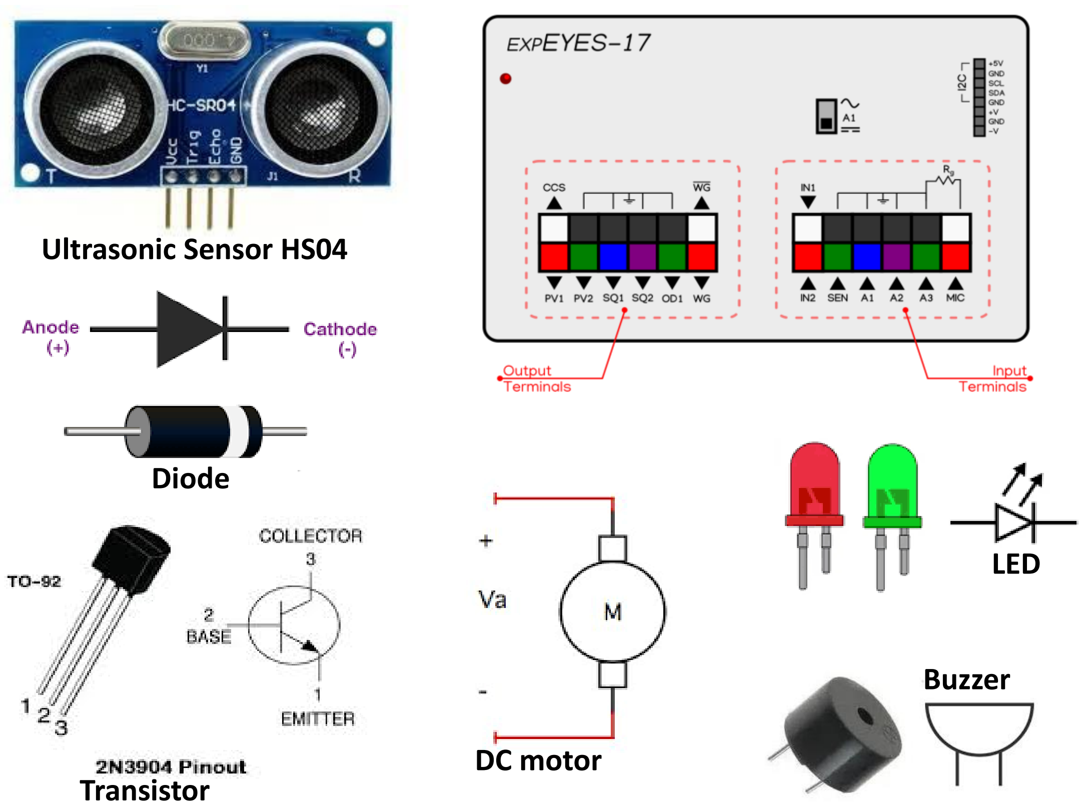
## ExpEYES-Smart Bot in Industry (E-SBI)

Dr. G. Karthik Kumar Reddy and Dr. Ganesh Ram Banjare

**Aim:**
The main aim of the E-SBI (ExpEYES Safety Bot in Industry) project is to develop a smart industrial safety system In modern industries and robotic automation systems, machines such as conveyor belts, robotic arms, drilling systems, and motor-driven equipment operate continuously at high speed, which may create dangerous situations for workers if proper safety monitoring systems are not used This model can be further expanded for use in smart factories, automated production units, warehouse robots, industrial safety robots, and Industry 4.0 applications. It also creates awareness about the role of technology in reducing industrial accidents, minimizing machine damage, improving operational efficiency, and ensuring safer interaction between humans and machines.


| Component | Purpose |
|---|---|
| ExpEYES Kit | Main controller and interface |
| Ultrasonic Sensor (HC-SR04 / HSO4) | Human/object detection |
| DC Motor | Industrial machine simulation |
| NPN Transistor (2N3904) | Motor switching/control |
| Diode | Protection against back EMF from motor |
| Red LED | Danger indication |
| Green LED | Safe indication |
| Buzzer | Alarm sound |
| Resistors | Current limiting |
| Connecting wires | Circuit connections |
| Power supply | Circuit operation |

## Components and Hardware




**Pin Connections:**

| ExpEYES Pin | Connected Device | Function |
|---|---|---|
| SQ2 & IN2 | Ultrasonic sensor output | Human detection input |
| SQ1 | Buzzer | Alarm output |
| OD1 | Transistor base → DC Motor | Motor ON/OFF control |
| PV1 | Red LED | Danger indication |
| PV2 | Green LED | Safe indication |

## Flow Chart

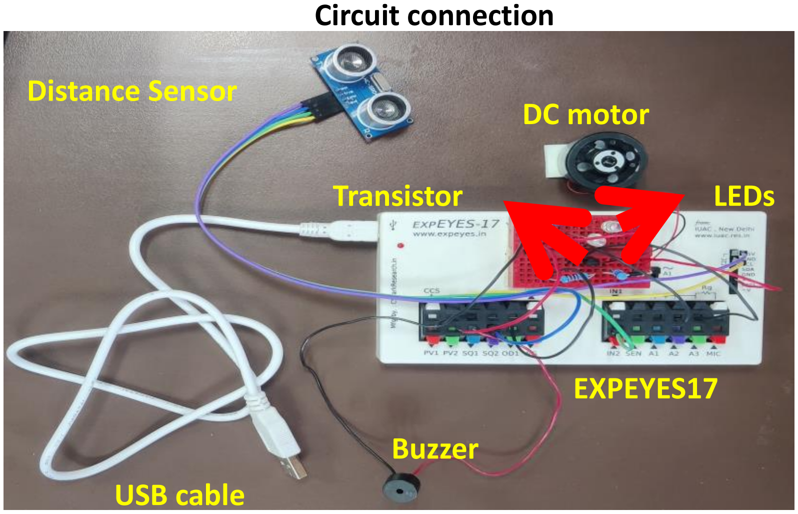
Start System
↓
Read Ultrasonic Sensor
↓
Human Detected?

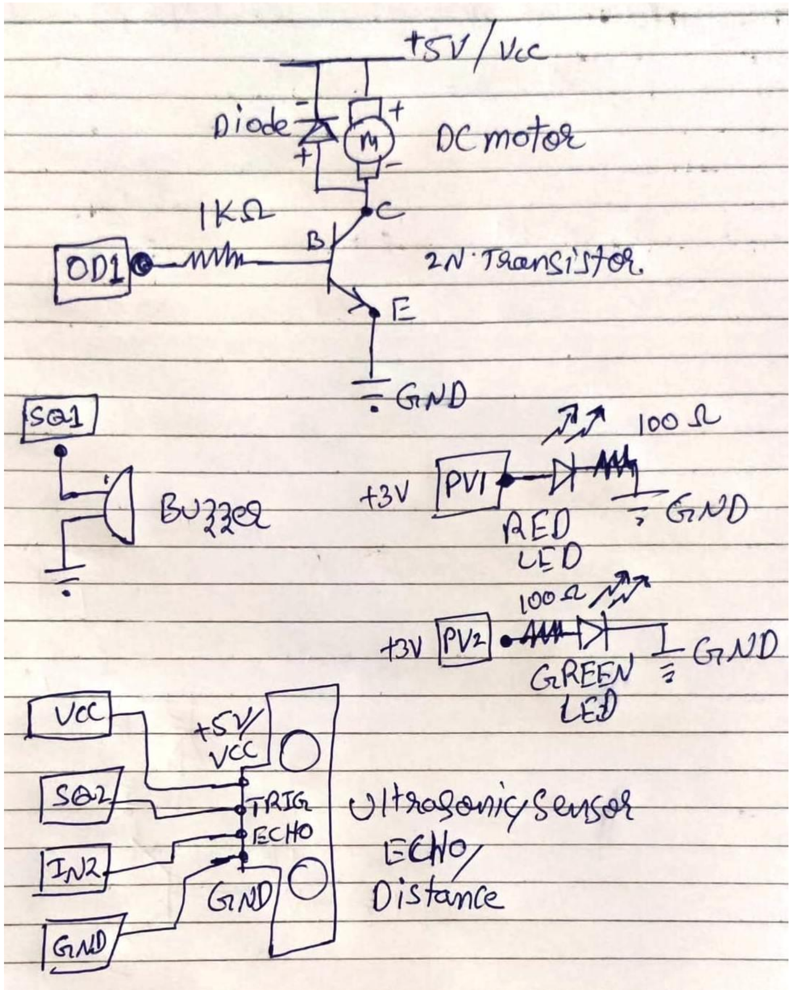
↓ Stop Motor ← YES
Turn ON Red LED
Turn OFF Green LED
Activate Buzzer

↓ NO → Start Motor
Turn ON Green LED
Turn OFF Red LED
Stop Buzzer

↓
Repeat Continuously

**Circuit connection**






**Conclusion:**

The **E-SBI ExpEYES Safety Bot** successfully demonstrates an industrial safety monitoring system using the ExpEYES kit and ultrasonic sensing. The project automatically detects human presence and performs safety actions such as: Stopping the motor, activating an alarm, providing visual indications using LEDs. When the area becomes safe again, the system resumes normal operation automatically. This project shows the practical use of embedded systems, sensors, and automation in industrial safety and robotics. It is a simple, low-cost, and effective solution for improving worker safety in modern industries.

# Determination of Electrical Conductivity and pH Value of Liquids using ExpEYES

Dr. Vishal Sharma, Dr. Devesh Kumar Tyagi and Dr. Narinder Kumar

**Abstract**

This project investigates the electrical conductivity and approximate pH value of different liquid samples using the ExpEYES-17 platform. Conductivity measurements provide insight into dissolved ionic content, water quality, and purity. Various samples including tap water, salt water, and lemon water were analyzed.

**Introduction**

Water quality assessment is important in environmental monitoring, agriculture, health sciences, and industry. Electrical conductivity is a rapid and inexpensive method for estimating the concentration of dissolved ions in water. Since pH and conductivity are related to ionic composition, conductivity measurements can also be used to estimate pH under controlled conditions.

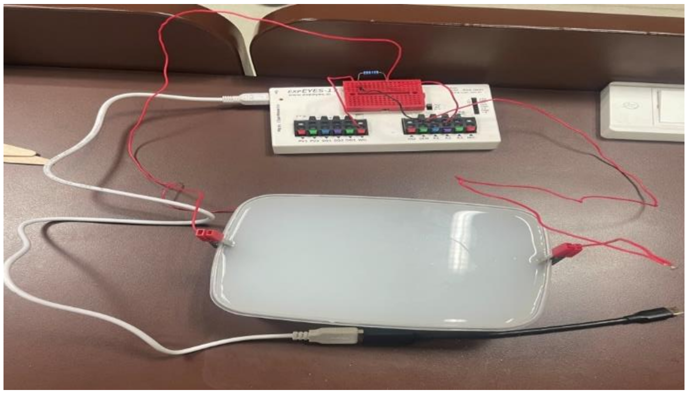
**Objectives**

- Measure resistance of liquid samples.
- Calculate conductivity and resistivity.
- Estimate pH values.
- Compare ionic concentration among samples.
- Demonstrate the use of ExpEYES-17 in experimental physics and electronics.

**Literature Review**

Conductivity-based measurements are widely used in environmental science and electrochemistry. Pure water has low conductivity, while dissolved salts increase conductivity significantly.

Conductivity sensors are commonly employed for water quality monitoring, wastewater analysis, and industrial process control.



**Experimental Setup**
Equipment used:
- ExpEYES-17
- Two ₹2 coins as electrodes
- Connecting wires
- Beakers containing liquid samples

Electrode distance = 15.4 cm
Electrode area = 5.31 $cm^2$

**Theory**
Conductivity is calculated using:
$\sigma = L/(RA)$
where σ is conductivity, L is electrode spacing, R is measured resistance, and A is electrode area.

Resistivity (ρ) = 1/σ

Approximate pH estimation:
$pH \approx 7 - \frac{1}{2} \log10(\sigma/\sigma_0)$
where $\sigma_0 = 5.5$ µS/cm.

**Methodology**
1. Prepare liquid samples.
2. Immerse electrodes in each sample.
3. Measure voltage and current using ExpEYES-17.
4. Calculate resistance using Ohm's law.
5. Determine conductivity and resistivity.
6. Estimate pH values.
7. Compare results.

**Observation Data (Tap Water)**

| Frequency (Hz) | Voltage (mV) | Current (μA) | Resistance (kΩ) |
|---|---|---|---|
| 1000 | 83 | 215.8 | 386 |
| 2000 | 86 | 217.8 | 394.8 |
| 3000 | 90 | 222.9 | 403.7 |
| 4000 | 92 | 227.5 | 404.3 |
| 5000 | 92 | 228 | 404 |

**Final Results**

| Sample | Resistivity (Ω·m) | Conductivity (S/m) | pH |
|---|---|---|---|
| Tap Water | 1333 | 0.00075 | 8.06 |
| Salt Water (One Spoon) | 154 | 0.00647 | 7.1 |
| Salt Water (Two Spoons) | 154 | 0.00647 | 7.1 |
| Tap Water with Lemon | 176 | 0.00566 | 6.4 |

**Results and Discussion**

The addition of salt substantially increased conductivity due to increased ionic concentration. Lemon water showed acidic characteristics with a lower pH. Tap water exhibited conductivity below the typical range of municipal water, suggesting lower mineral content.

**Applications**

• Water quality monitoring
• Environmental studies
• Industrial process control
• Educational laboratory experiments
• Estimation of dissolved salts and impurities

**Future Scope**

Future work may include calibration with standard conductivity solutions, direct pH meter comparison, temperature compensation, IoT integration, and machine-learning-based water quality classification.

**Conclusion**

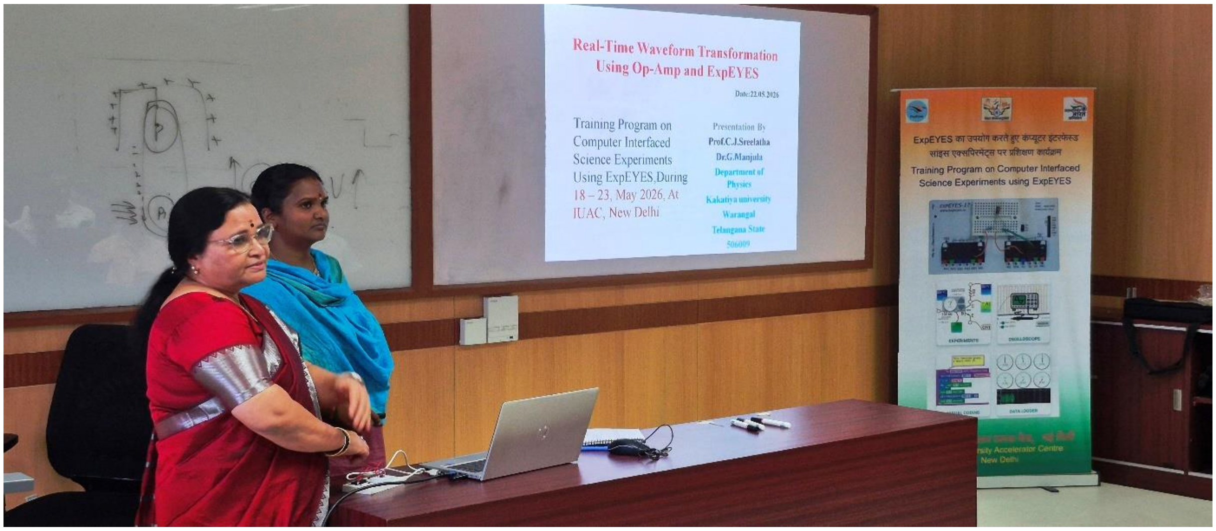
The experiment successfully demonstrated the use of ExpEYES-17 for determining conductivity and estimating pH. Conductivity measurements effectively distinguished between different liquid samples and provided useful information about ionic concentration and water purity.

**References**

1. ExpEYES User Manual.
2. Standard Electrochemistry Textbooks.
3. Water Quality Assessment Literature.
4. Conductivity and pH Measurement Standards.

# Real-Time Waveform Transformation using Op-Amp and ExpEYES

Prof. C.J.Sreelatha and Dr. G.Manjula





## Abstract

Operational Amplifiers (Op-Amps) are widely used in analog electronic systems for mathematical operations such as integration and differentiation. This project demonstrates real-time waveform transformation using Op-Amp-based integrator and differentiator circuits interfaced with the ExpEYES platform. The experiment involves generating input waveforms through ExpEYES, constructing integrator and differentiator circuits on a breadboard, and observing the transformed waveforms in real time. The system enables accurate visualization, waveform analysis, and signal processing using computer-interfaced experimentation. Ultimately, the project highlights the educational significance of ExpEYES in electronics laboratories by providing a low-cost, efficient, and interactive framework for experimentation.


## Introduction

Waveform transformation is a foundational concept in analog electronics and signal processing. Operational amplifiers (op-amps) are versatile devices capable of performing mathematical operations such as addition, subtraction, integration, and differentiation. This project focuses on implementing integrator and differentiator circuits using op-amps and the ExpEYES platform—an open-source hardware and software framework developed for science experiments and electronics education. The experiment demonstrates how triangular and square waveforms can be transformed into distinct output waveforms using these circuits.

## Theory of Operational Amplifier

An Operational Amplifier (Op-Amp) is a high-gain differential amplifier with very high input impedance and low output impedance.

## Characteristics of an Ideal Op-Amp

- Infinite voltage gain
- Infinite input impedance

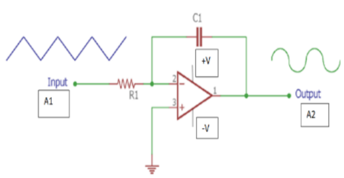
- Zero output impedance
- Infinite bandwidth
- Zero offset voltage

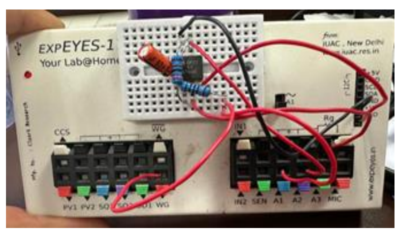
**Applications of Op-Amps**

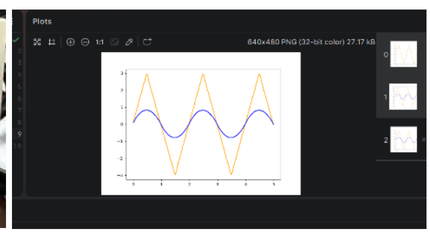
- Amplifiers
- Filters
- Oscillators
- Integrators
- Differentiators
- Signal conditioning circuits

**Integrator Circuit**

An Op-Amp integrator produces an output proportional to the integral of the input voltage.








**Circuit Description**

The circuit consists of:

- Input resistor R- 1kΩ and 10kΩ parallel to the capacitor for DC discharge path
- Feedback capacitor C-1µf
- Operational amplifier OP27

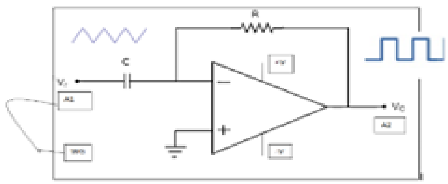
The capacitor in the feedback path accumulates charge over time, resulting in integration of the input signal.

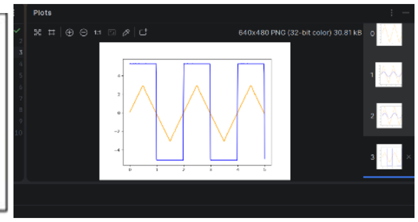
**Mathematical Expression**

$V_{out} = - 1/R_{in} C_f \int V_{in}(t)\, dt)$

**Differentiator Circuit**

An Op-Amp differentiator produces an output proportional to the rate of change of the input signal.





**Circuit Description**

The circuit contains:

- Input capacitor C-1µf
- Feedback resistor R-1kΩ
- Operational amplifier OP27

The circuit responds strongly to rapid changes in the input waveform.

**Mathematical Expression**

$V_{out} = - R_f C (dV_{in} /dt)$

**Experimental Procedure**

1. Connect the ExpEYES hardware to the computer.
2. Open the ExpEYES software.
3. Construct the Op-Amp integrator circuit on a breadboard.
4. Apply the input waveform from the ExpEYES output terminal.
5. Measure output signals using A1 and A2 terminals.
6. Observe waveform transformation.
7. Repeat the procedure for the differentiator circuit.
8. Record and analyze the obtained waveforms.

**Conclusion**

This project successfully demonstrates the implementation of op-amp-based integrator and differentiator circuits using the ExpEYES platform. The experiment validates the mathematical behavior of integration and differentiation in analog electronics, with ExpEYES providing an effective environment for real-time waveform observation, data acquisition, and educational experimentation. Ultimately, this project enhances the practical understanding of electronic signal processing and computer-interfaced laboratory techniques.

# Insights of Impedance Spectroscopy for Gang Capacitors with ExpEYES

Dr. Pardhu Yella

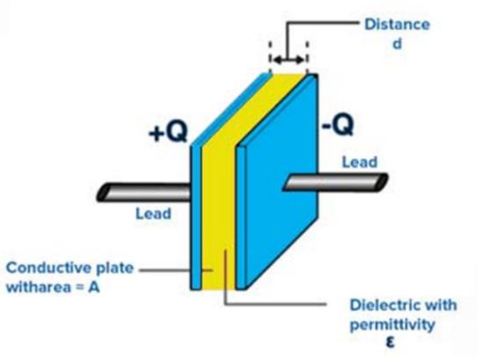
**Aim:** To observe the frequency response of different kinds of dielectric materials of a capacitor.

**Introduction:**

It is well known that when a dielectric material is placed between capacitor plates the capacitance increases.

$$C = \varepsilon_0 \varepsilon_r \frac{A}{d}$$

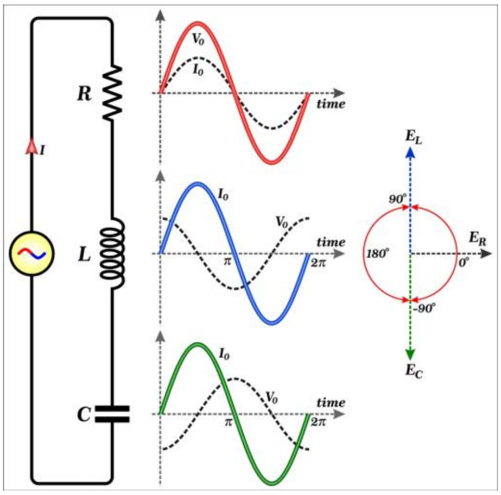
Where $\varepsilon_0$ is the permittivity of free space, $\varepsilon_r$ is the relative permeability, A is the area of the plates of capacitor and d is the distance between the plates.



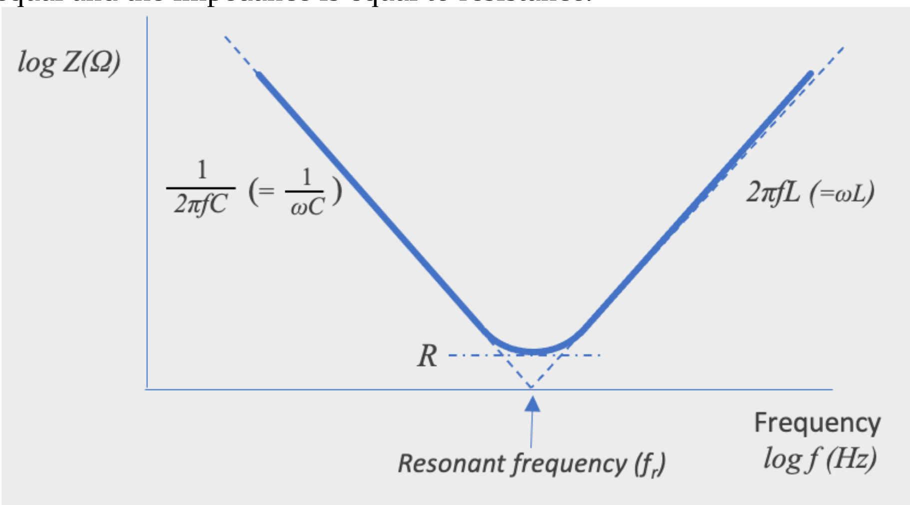

Although the capacitance is constant for a given capacitor and given dielectric material, however it varies with the frequency. $\varepsilon_r = \varepsilon_r(f)$. In other words, dc capacitance is fixed and ac capacitance varies with frequency.

For a capacitor:Z=R+jXc where R is the pure resistance and $X_c$ is the impedance offered by the capacitor. Although it is capacitor taken, it has not only the capacitiance element but it have the resistive and inductive elements.

When these elements subjected to a AC signal the response will be another AC signal however the phase changes.




The general response is as shown in the figure. When the frequency is higher the inductive element becomes higher. At self resonating frequency the capacitance and inductance elements are almost equal and the impedance is equal to resistance.




Where

Polarization Mechanisms:

- electronic,
- ionic,
- dipolar,
- interfacial

Materials respond differently at different frequencies.

Typical Relaxation time τ

Air ~$10^{-12}$–$10^{-9}$ s

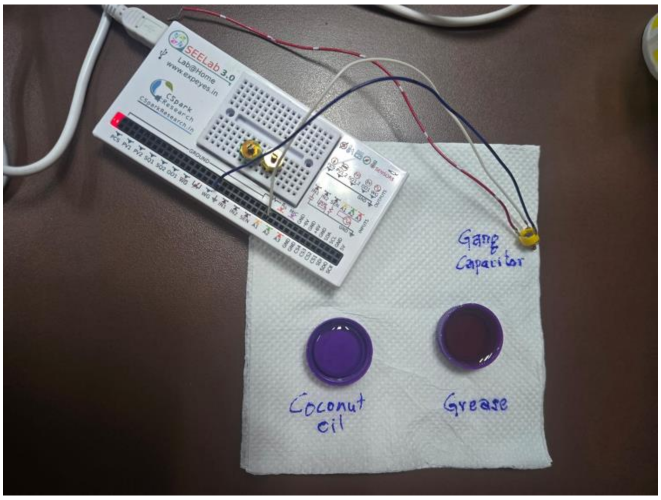
Oil~$10^{-6}$–$10^{-3}$ s

Grease~$10^{-4}$–$10^{-1}$ s

**Experiments and circuit connections:**

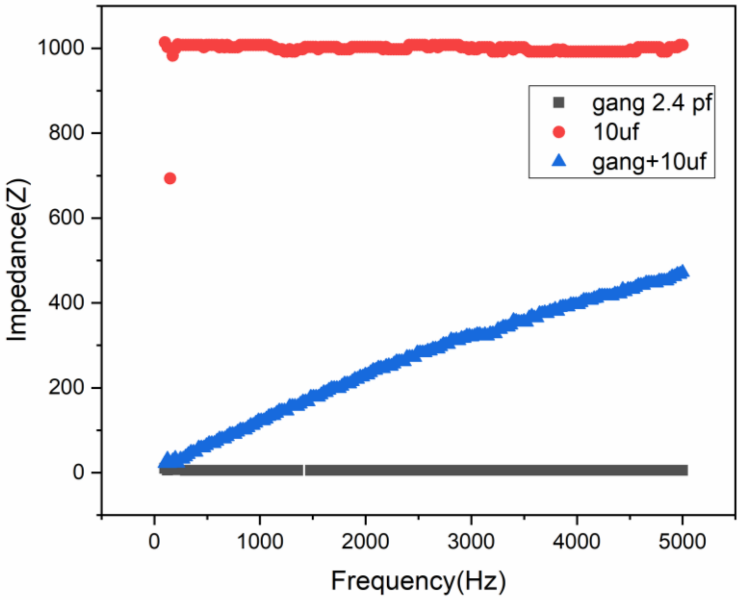
1. Using ExpEYEs kit we generated the sinusoidal waveforms and subjected to the capacitors and another end to the ground.
2. A series resistor of 10 KΩ is connected to the capacitor to observe the current and measured from the output A1 along with the phase by measuring the voltage.
3. Two different dieelctric media for gang capacitors are chosen 1. Coconut oil and 2.

Grease oil. to observe the effect of dielectric media with frequency.




## Results:

With the existing ExpEYES kit, we could able to give the frequency up to 5 kHz, the frequency response of the gang capacitor of 2.4 pf and paper based cylindrical capacitor of 10 μF were shown on the figure. Along with that the two capacitors were connected in series to obtain the impedance response is also shown here.

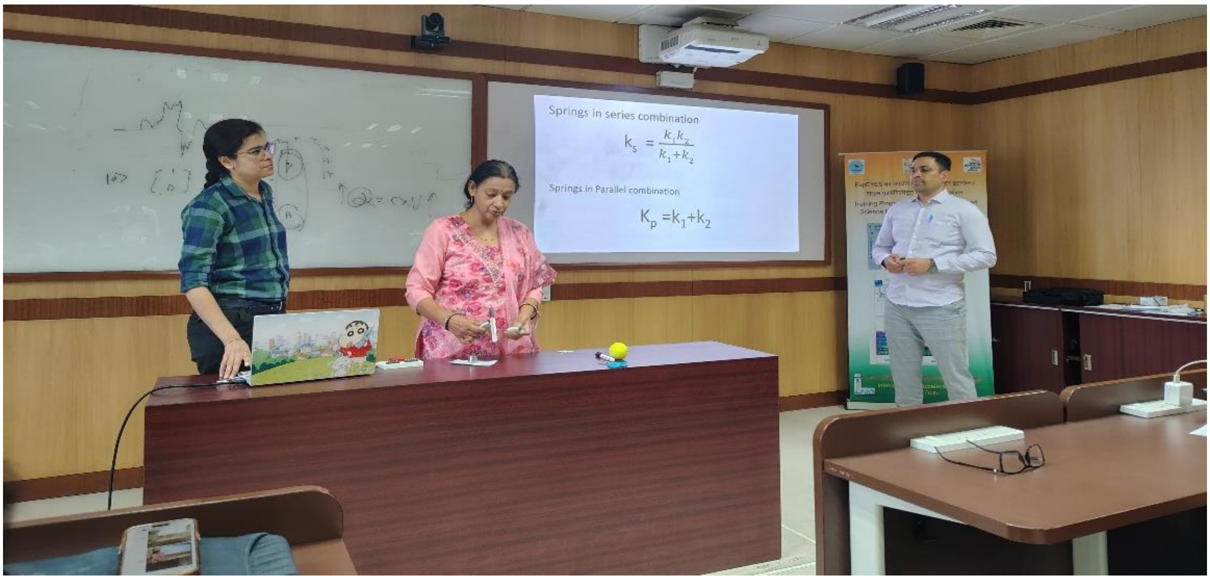



**Challenges and Conclusions:**

- The frequency response with the ExpEYES kit connected to two kinds of capacitors is measured with voltage and current response.
- Able to develop the code successfully and understood the response from various capacitors.
- Successfully observed the impedance response for various capacitors gang capacitors, paper-based capacitors.
- However, the frequency should be improved up to 0.5 MHz so that the response will be more practical. This will be implemented in future works.

# Determination of Spring Constant using LIDAR Sensor with ExpEYES

Dr. Pramila Gupta, Dr. Sangamesh Jakhati and Dr. Manisha Kumari




**Aim:**
Determination of Spring constant in series and Parallel combination using EXPEYES.

**Apparatus:**
Springs, weight hanger, slotted weights, Connecting wires and USB cable, LIDAR Sensor (UL53LDK), ExpEYES.

**Principal:** Spring constant (or force constant) of a spring is given by Hooke's Law

$$k = -F/x \text{ (N/m)}$$

Spring constant (k) is the restoring force per unit extension in the spring. Its value is determined by the elastic properties of the spring. When material is subjected to strain, stress is produced. The restoring force is always directed opposite to the displacement. When a mass m suspended by means of spring is displaced through a small distance and then released, it undergoes simple harmonic motion.
The time period T of oscillations of a spring is given by the relation,

$$T = 2\pi\sqrt{\frac{m}{k}} \qquad k = \frac{4\pi 2m}{T2}$$

Spring constant in series combination

$$k_s = \frac{k1k2}{k1+k2}$$

Spring constant in Parallel combination

$$K_p = k_1 + k_2$$

By finding the time period (T) spring constant k can be determined.

**Procedure:**

1. **Setup the Spring System**

- Fix the spring vertically on a stand.
- Attach a hook at the lower end for hanging weights.

2. **Mount the LIDAR Sensor**
    - Position the UL53LDK sensor so it faces the bottom of the hook or a reflective marker attached to it.
    - Ensure the sensor is aligned vertically and at a fixed distance from the spring's rest position.
3. **Connect to ExpEYES**
    - Connect the LIDAR sensor's output to the appropriate analog/digital input channel on expEYES-17 (depending on sensor interface type).
    - Power the sensor if required using the kit's regulated supply pins.
4. **Record Measurements**
    - Hang the first known weight on the spring.
    - Wait for oscillations to settle.
    - Repeat for multiple weights, increasing in equal steps.
5. **Data Logging**
    - Use the ExpEYES software to log readings automatically or manually note them in tables.

**Table 1: Spring constant $K_s$ for the given material**

(Mass of the hanger + Mass of the slotted weights) = $m_1$ _ gm.

| S. No. | Series Combination | Mass (gm) | Time for One Oscillation (sec) | $K_s$ (Spring Constant) Observed | $K_s$ (Spring Constant) Manually |
|---|---|---|---|---|---|
| 1 | | | | | |

**Table 2: Spring constant $K_p$ for the given material**

(Mass of the hanger + Mass of the slotted weights) = $m_1$ _ gm.

| S. No. | Parallel Combination | Mass (gm) | Time for One Oscillation (sec) | $K_p$ (Spring Constant) Observed | $K_p$ (Spring Constant) Manually |
|---|---|---|---|---|---|
| 1 | | | | | |

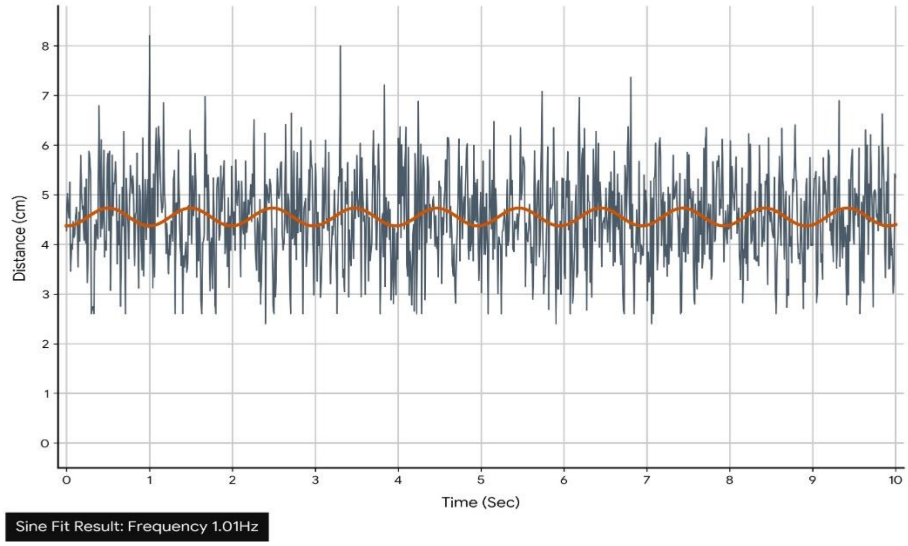
**Results and Discussion:**

If we consider of effective mass of spiral spring then the difference of theoretical and experimental spring constant in parallel and series may come closely.

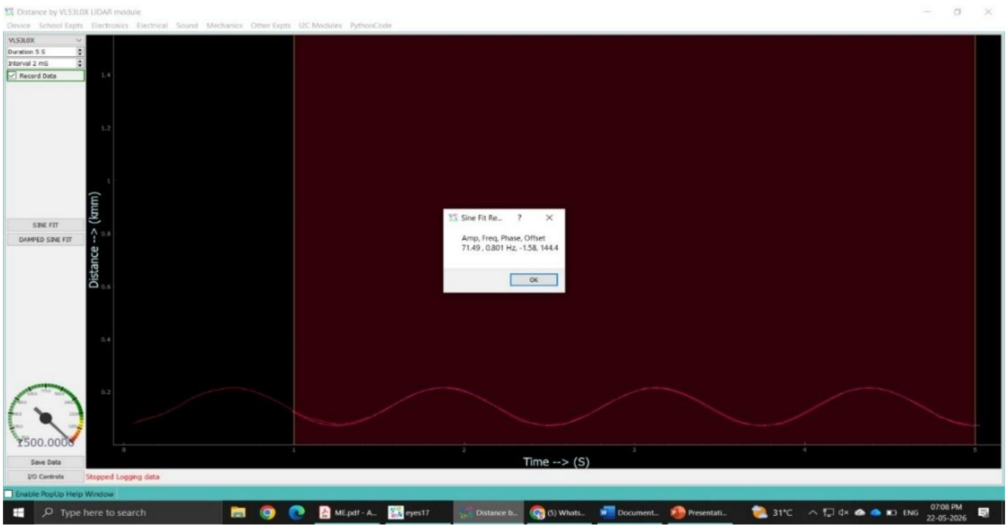
| | | |
|---|---|---|
| 1. | The spring constant for the given springs are | K1 = 7.84 (observed) K2 8.313 (manually) |
| 2. | The spring constants in series combination are | $K_s$ = 3.79 N/m (observed) $K_s$ = 4.034 N/m (manually) |

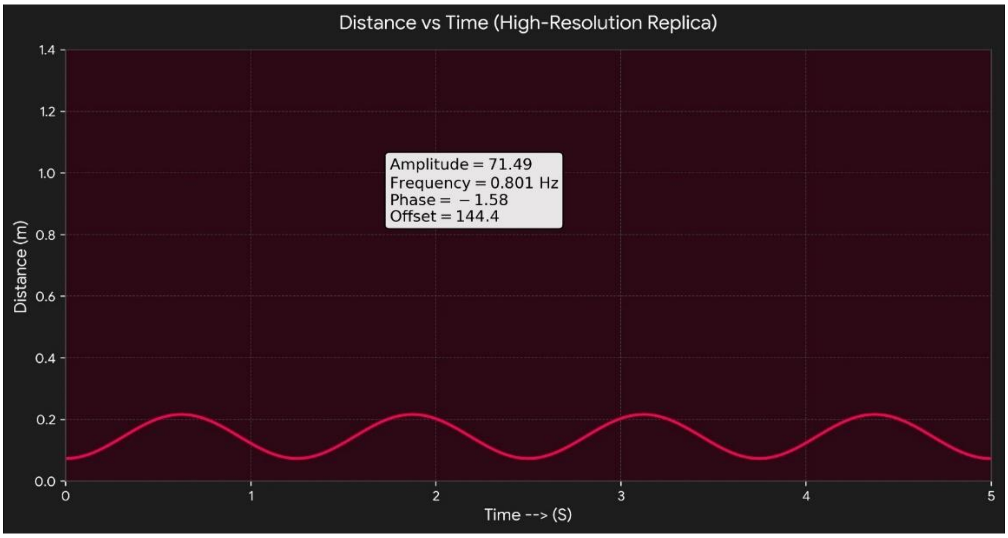
| | | |
|---|---|---|
| 3. | The spring constants in parallel combination are | Kp = 16.14 N/m (observed) Kp = 15.97 N/m (manually) |

**From ExpEyes-17 (tried initially from Eco-sensor):**




**Graph ExpEYES GUI (using LiDAR Sensor):**



**Future Aspects:**

**Material science:** Designing composites with tailored stiffness by combining micro-springs in series/parallel.

**Robotics:** Adaptive joints using spring combinations for flexibility and strength.

**Biomechanics:** Modeling muscles and tendons as spring systems to improve prosthetics.

**Nanotechnology:** Using nanoscale springs in MEMS/NEMS devices for precise control.

# Wien Bridge Oscillator using LM358 Op-Amp & Testing using ExpEYES

Varun D C


**Abstract**

The Wien Bridge Oscillator is a low-distortion sinusoidal signal generator widely used in audio-frequency applications. This project demonstrates the design, implementation, and testing of a Wien Bridge Oscillator using an LM358 operational amplifier and the ExpEYES platform. The generated waveform is observed and analyzed in real time, and the measured frequency is compared with theoretical calculations.

## Objective

• Study the principle and working of a Wien Bridge Oscillator.
• Design and construct the circuit using LM358.
• Generate a sinusoidal waveform using ExpEYES.
• Verify the frequency of oscillation.

## Introduction

An oscillator generates periodic electrical signals without an external input signal. The Wien Bridge Oscillator uses a frequency-selective RC network and positive feedback to produce stable, low-distortion sine waves, making it suitable for audio-frequency applications.

## Theory

The oscillator operates on the Barkhausen criterion. The total phase shift around the loop is 0° and the loop gain is unity. The Wien Bridge network provides frequency-selective feedback, while the amplifier gain is adjusted to approximately 3 to sustain oscillations.

## Components Required

1. LM358 Op-Amp
2. R1 = R2 = 10 kΩ
3. Rf ≈ 21 kΩ
4. Rg = 10 kΩ

5. C1 = C2 = 21 nF
6. Breadboard and connecting wires
7. ExpEYES Interface

**Frequency of Oscillations**

f = 1/(2πRC)

For R = 10 kΩ and C = 21 nF, the theoretical frequency is approximately 758 Hz.

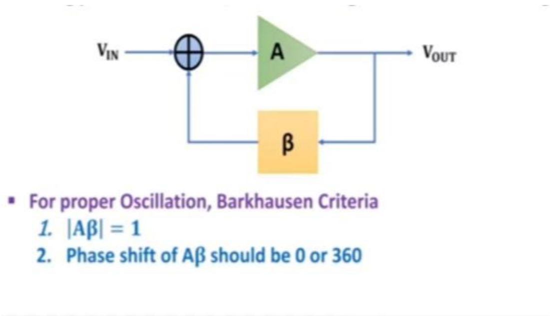
**Gain Setting**

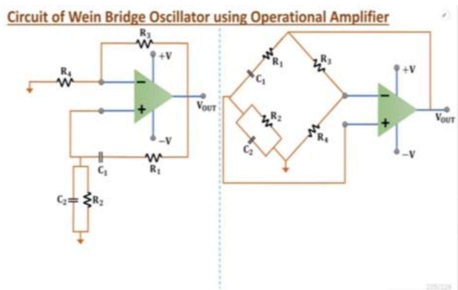
Gain = 1 + (Rf/Rg).

Using Rf ≈ 21 kΩ and Rg = 10 kΩ gives a gain of approximately 3.1, satisfying the Barkhausen criterion.

**Experimental Procedure**

1. Connect ExpEYES to the computer.
2. Assemble the Wien Bridge Oscillator circuit.
3. Apply ±6 V supply to LM358.
4. Connect the output to ExpEYES A1.
5. Observe and record the waveform.
6. Measure frequency and amplitude.
7. Compare with theoretical values.




**Applications**

Audio signal generators

Function generators

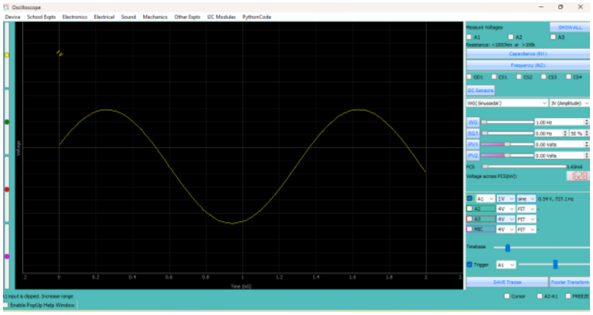
Test and measurement equipment

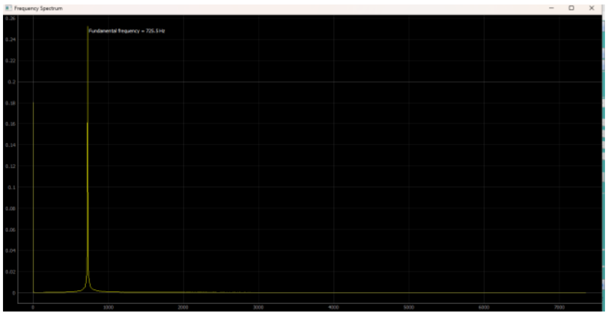
Tone generation circuits

Electronic instrumentation

**Observations & results**

A stable sinusoidal waveform was obtained. The observed frequency was close to the theoretical value of 758 Hz. Oscillations were sustained with low distortion.




## Conclusion

The Wien Bridge Oscillator using LM358 was successfully designed and tested using ExpEYES. The experiment verified the theoretical frequency and demonstrated the usefulness of computer-interfaced experimentation in electronics education.

# Testing of Cyclic Voltammetry using ExpEYES

Dr. Avijit Ghosh and Dr. R. Thangavel

**Abstract**

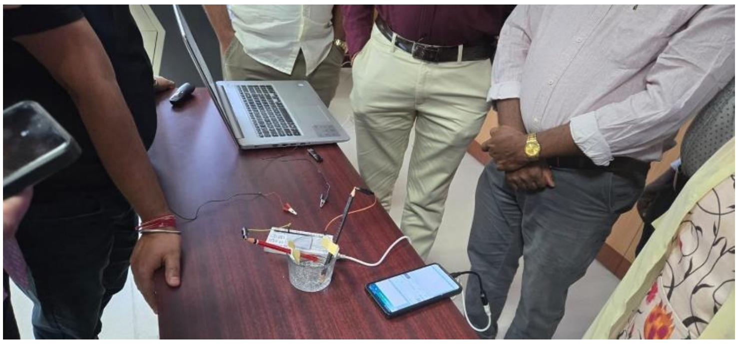
In this project, we investigated the cyclic voltammetry (CV) signature of graphite wires utilized as both the working and counter electrodes, without a reference electrode in a common salt solution across several scan rates. The charge-discharge behavior observed through the cyclic voltammetry responses consistently scales with the variations in the scan rate. Consequently, the ExpEYES kit demonstrates reliable performance within ±3V range at room temperature.


## Methodology

To study the redox behavior of the system through cyclic voltammetry, two graphite pencil leads were utilized as both the working and counter electrodes, without a reference electrode, in a common salt solution electrolyte. The electrochemical responses were analyzed across several scan rates. For the experimental setup, these two leads were connected directly to the PV1 and PV2 ports of the ExpEYES kit.

## Methodology

The CV measurements reveal no distinct oxidation or reduction peak currents with respect to peak potentials. Instead, the resulting voltammograms demonstrate the reversibility of the electrochemical system within ±3V window across various scan rates. Interestingly, as the sweep rate increases, the area enclosed by the voltammetry curve decreases; these curves are displayed in Figure 1. Note that this experiment cannot be reliably performed beyond ±3V threshold. Mechanistically, the current is generated by electron transfer between the redox species and the two electrodes as the potential of the working electrode is ramped linearly over time.

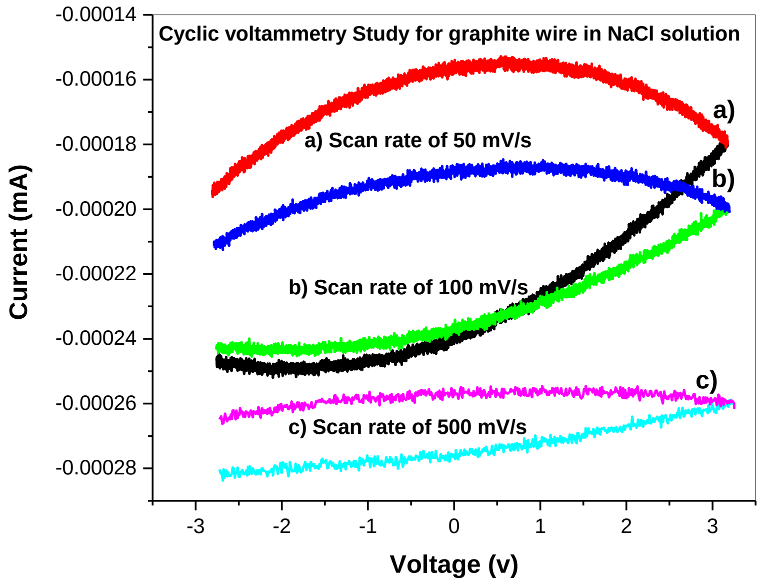


**Conclusion**

Understanding this demonstrative experiment on CV measurements using graphite wires provides a foundational framework for determining redox potentials, mapping reaction mechanisms, and detecting the oxidation and reduction responses of chemical species. Furthermore, it serves as a low-cost methodology for investigating electron-transfer kinetics in battery materials, supercapacitors, corrosion processes, and electrochemical sensors.

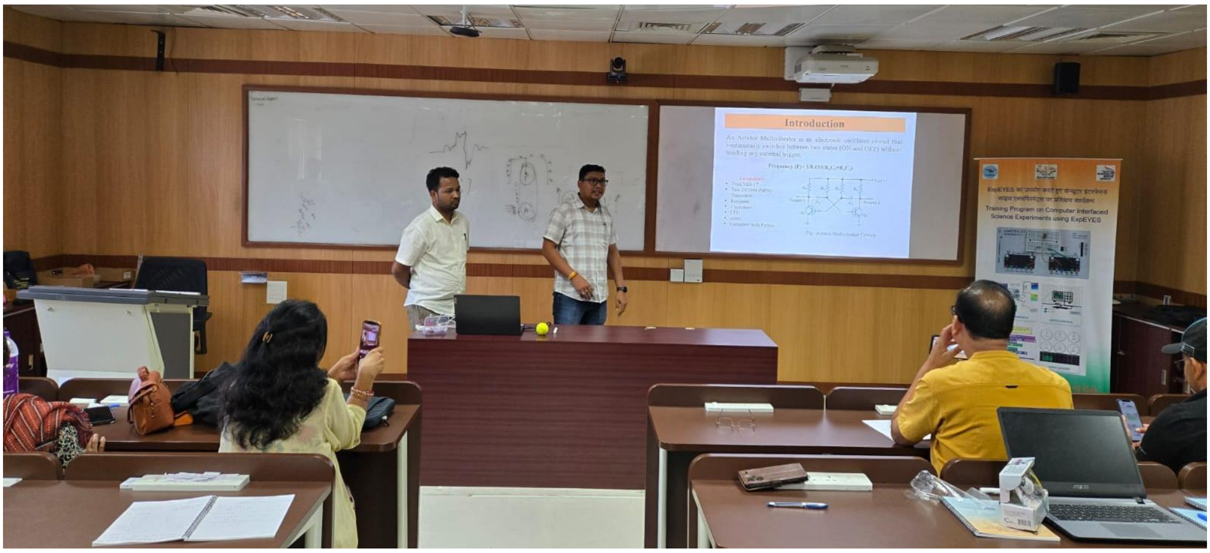
**References:**


1. ExpEYES User Manual
2. Standard Electrochemistry books

# Testing of Astable Multivibrator using ExpEYES

Dr. Chitrakant Belodhiya and Dr. Bhoopendra Kumar Dewangan




**Abstract**

The present work focuses on the study and analysis of an astable multivibrator circuit using the ExpEYES-17 interface and Python programming. An astable multivibrator is an electronic oscillator that continuously switches between two unstable states, generating square-wave signals without external triggering. In this experiment, the waveform generated by the circuit was observed using the ExpEYES-17 graphical user interface (GUI) while the time period and frequency of oscillation were measured experimentally. The blinking behavior of LEDs connected to the circuit was also analyzed. Additionally, Python programming was used to visualize the captured waveforms and verify the experimental data. This experiment demonstrates the utility of ExpEYES-17 as an effective educational tool for real-time visualization, signal measurement, and software-based data analysis.

**Introduction**

An astable multivibrator is a free-running oscillator circuit that continuously switches between two quasi-stable states, thereby producing a periodic square-wave output. It is widely used in electronic applications for pulse generation, timing, and LED flashing systems. The circuit typically consists of two transistors, resistors, and capacitors configured in a cross-coupled network.

In this experiment, the astable multivibrator was implemented using two NPN transistors (2N3904) alongside standard resistor-capacitor (RC) networks. The ExpEYES-17 platform—an open-source educational interface designed for science and engineering experiments—was utilized to observe and measure the generated waveforms. ExpEYES-17 enables real-time data acquisition, waveform visualization, and direct interfacing with Python programming.

The frequency of oscillation for this astable multivibrator configuration is given by the formula:

$$f = \frac{1}{0.693(R_2C_1 + R_3C_2)}$$

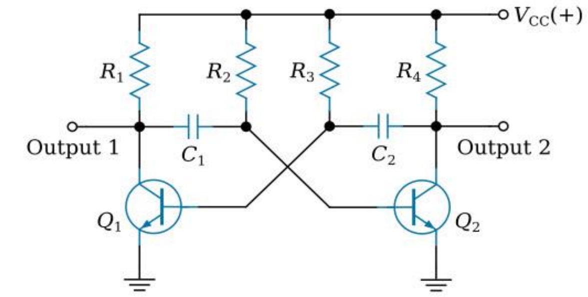
The experiment also demonstrates the seamless integration of hardware setups with Python-based analysis, fostering a deeper understanding and clearer visualization of electronic signals.

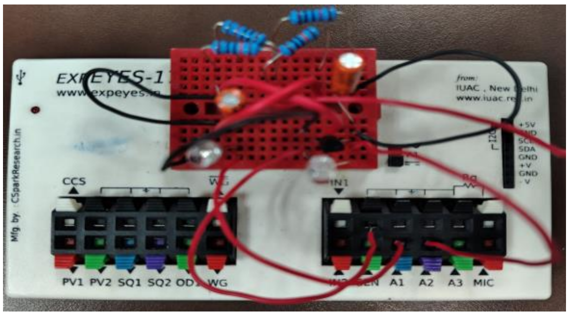
**Objective**
The major objectives of this experiment are:

- To study the operation of a two-transistor astable multivibrator using the ExpEYES-17 platform.
- To observe the generated square-wave signals using the ExpEYES-17 graphical user interface (GUI).
- To measure the time period and oscillation frequency of the circuit experimentally.
- To visualize and analyze the LED blinking behavior within the cross-coupled network.
- To verify the experimental results using Python programming and data analysis.

**Circuit Description**
The astable multivibrator circuit consists of two cross-coupled transistors connected in a feedback configuration via resistor-capacitor (RC) networks. When one transistor is in the saturation (ON) state, the other remains in cutoff (OFF). Driven by the continuous charging and discharging of the capacitors, these states alternate automatically, producing a continuous square-wave output.

For real-time observation, the output waveform was routed directly to the analog input of the ExpEYES-17 interface. The ExpEYES-17 GUI successfully displayed the waveform and calculated both the time period and frequency automatically. Furthermore, Python scripts were utilized to plot and analyze the captured waveform data for precise verification.



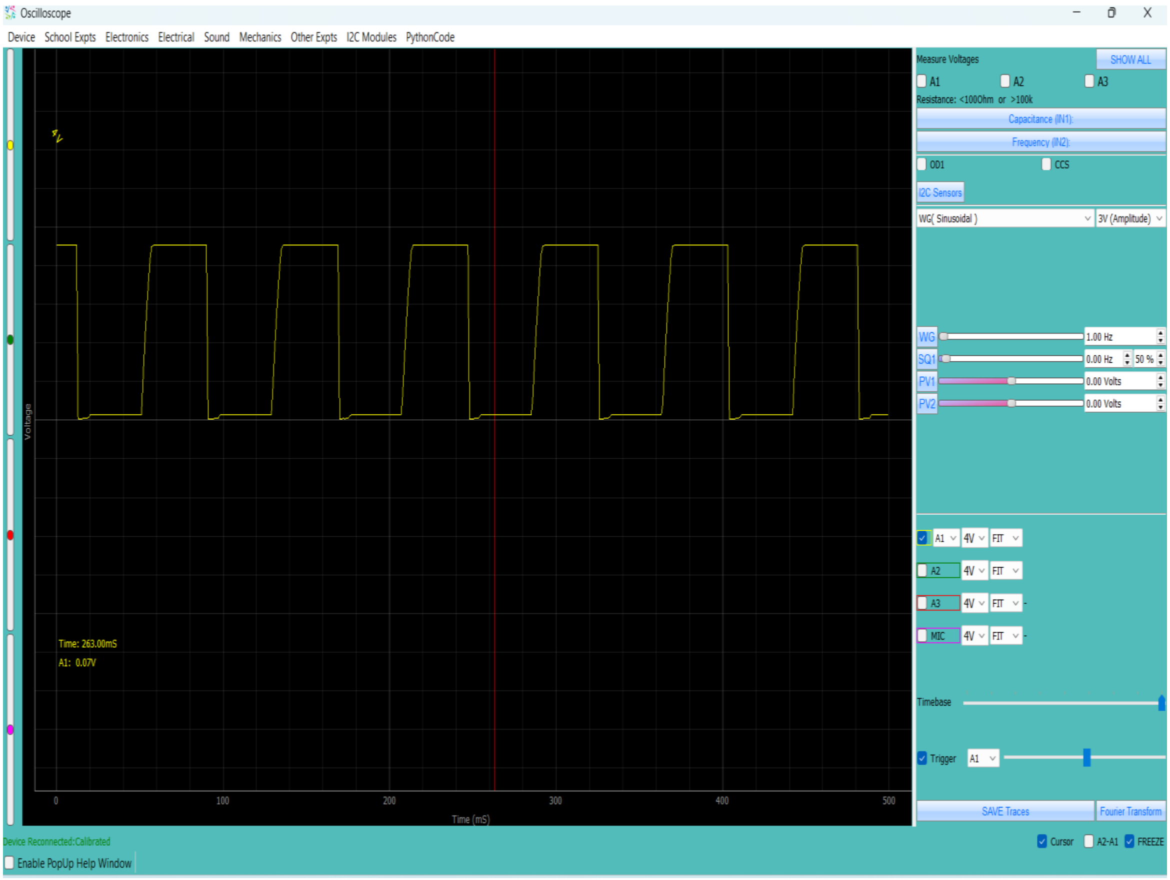




**Results and Discussion**

The experiment successfully generated stable square-wave signals using the astable multivibrator circuit, which were clearly captured and observed on the ExpEYES-17 GUI. Concurrently, the alternating blinking of the LEDs confirmed the periodic switching action of the cross-coupled transistors.

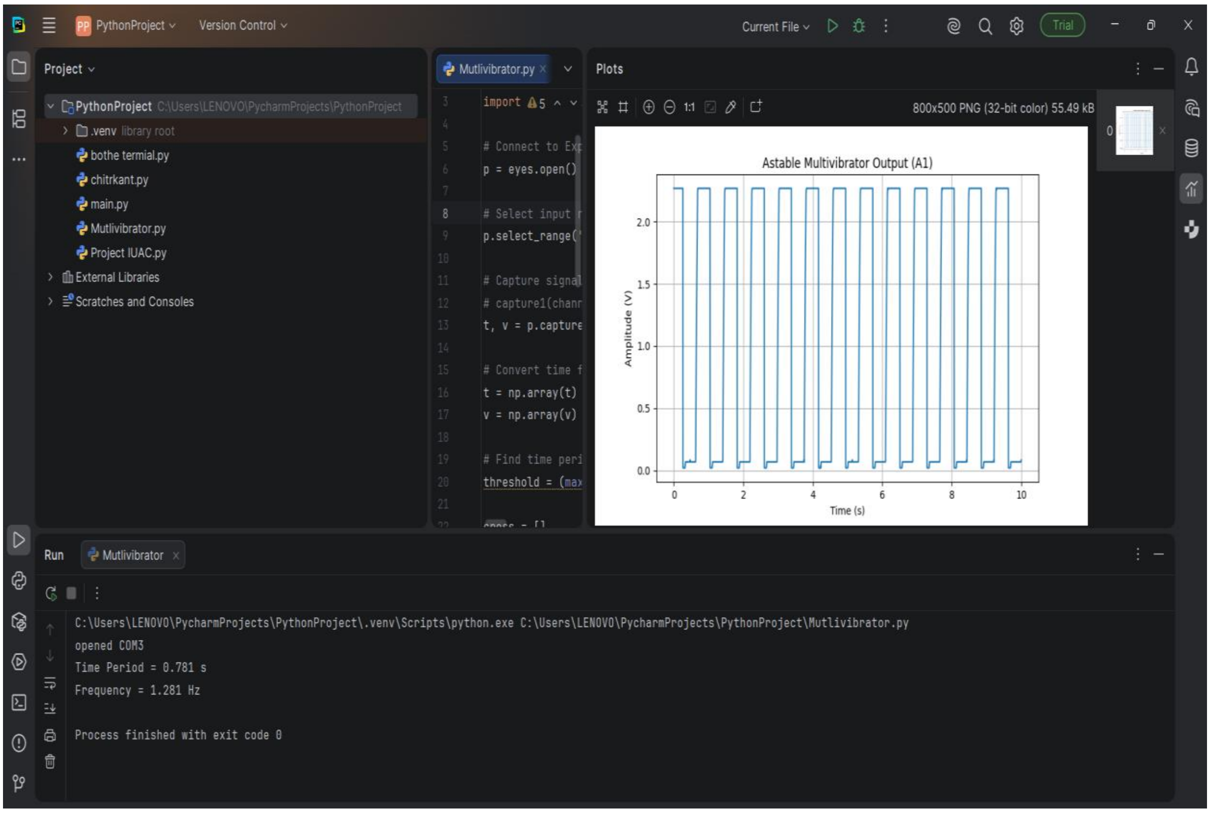
Different capacitor values were used while keeping resistor values constant. The measured time periods and frequencies are listed below.

| S. No. | $R_1/R_4$ (kΩ) | $R_2/R_3$ (kΩ) | $C_1/C_2$ (µF) | Time Period (s) | Frequency (Hz) |
|---|---|---|---|---|---|
| 1 | 10 | 100 | 1 | 0.078 | 12.778 |
| 2 | 10 | 100 | 2.2 | 0.184 | 5.425 |
| 3 | 10 | 100 | 10 | 0.781 | 1.281 |
| 4 | 10 | 100 | 22 | 1.954 | 0.512 |




From the observations, it is clear that increasing the capacitance increases the time period and decreases the frequency of oscillation. This agrees with the theoretical relation between frequency and RC time constant.

A small Python program was written to show the astable multivibrator output waveform and its output is given below.

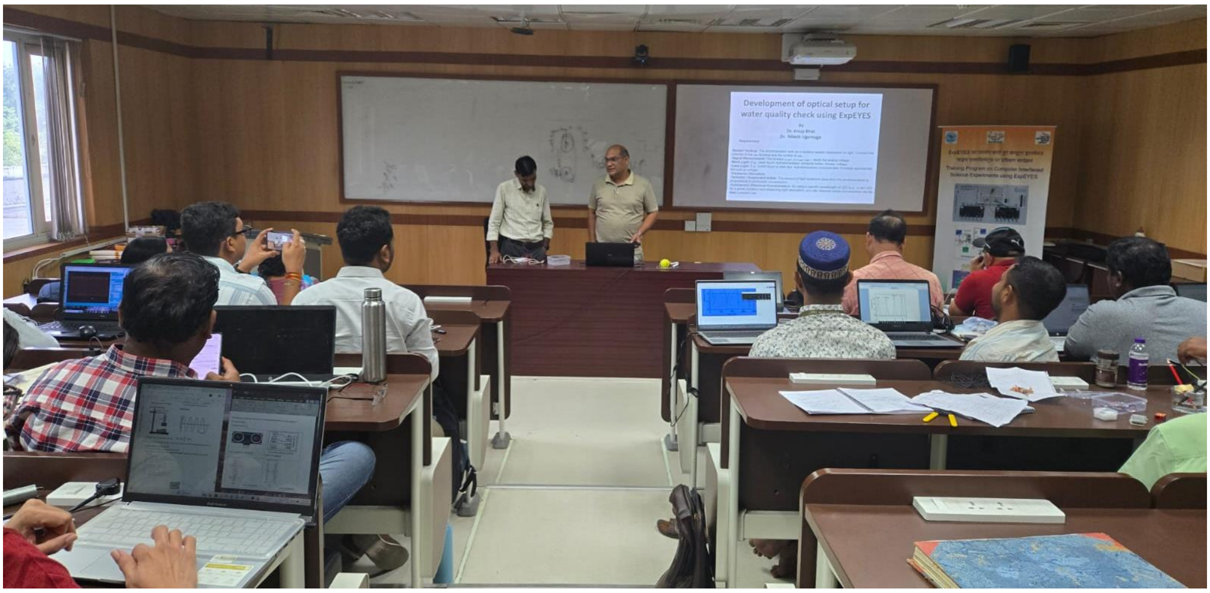



## Conclusion

The astable multivibrator experiment using ExpEYES-17 was successfully performed and analyzed. The generated square waveforms were observed in real time using the GUI, and the time period and frequency were measured accurately. Python programming provided an additional platform for waveform visualization and verification of experimental data. The experiment demonstrates that ExpEYES-17 is a powerful and effective educational tool for understanding electronic circuits, signal analysis, and programming-based experimentation.

# Development of Optical Setup for Water quality check using ExpEYES

Dr. Anup P Bhat and Dr. Nilesh S Ugemuge




## 1. Executive Summary

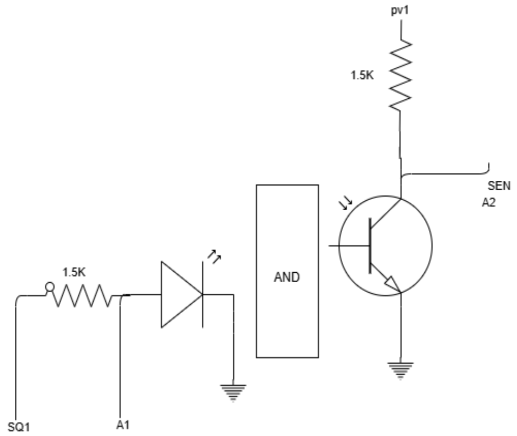
This report details the design, hardware configuration, mathematical framework, and software implementation of a low-cost, automated optical system engineered for water quality assessment. Utilizing the **ExpEYES (eyes17)** open-source hardware framework, the setup integrates anLASER Diodelight source and a phototransistor to establish high-precision sensing paths. The system is designed to perform concurrent analytical evaluations of liquid samples based on light scattering and absorption properties, providing real-time data acquisition for parameters including **Turbidity (NTU)**, **Absorbance (Abs)**, **Transmission (Trs)**, and **Turbidity percentage (Tur)**.

## 2. System Architecture & Hardware Interfacing

### 2.1 Component Configuration

The physical setup operates on a dual-channel measurement design to evaluate light attenuation through a liquid sample housed in a target test block:

- **Excitation Source (Emitter):** A LASER Diode is driven via the programmable square-wave output terminal **SQ1** through a 1.5kΩ current-limiting resistor to protect the diode components. The node between the resistor and the LASER Diode anode is monitored via Analog Input channel **A1** to act as a reference voltage tracker for source intensity.
- **Detector Circuit (Receiver):** A phototransistor acts as a variable resistor responsive to incident photon flux. The **Collector** is pulled up to the **pv1** supply terminal through a matching 1.5kΩ resistor, while the **Emitter** is anchored directly to the system Ground (**GND**).
- **Signal Output:** The analog output signal from the collector junction is fed directly into the **SEN** terminal, mapped concurrently to Analog Input channel **A2** for signal acquisition.




**2.2 Operational Dynamics**

The electrical response of the receiver circuit changes linearly based on the optical density of the fluid sample:

- **Clear Liquid Media:** Enhanced photon transmission leads to high phototransistor conduction. This lowers internal channel resistance, causing the analog signal at the collector node (**SEN / A2**) to drop toward 0V.
- **Turbid / Dyed Media:** Dissolved particles scatter or absorb incident rays, diminishing photon arrival at the detector base. The phototransistor restricts current flow, forcing the collector node voltage to rise toward the **pv1** pull-up threshold.

**3. Mathematical Modeling & Parameter Derivation**

The software processes the analog raw inputs (VA1 and VA2) collected from the hardware channels into standard water quality parameters.

**3.1 Intensity Tracking via Current Derivations**

The circuit currents corresponding to the source output and receiver response are calculated based on Ohm's law across the identical 1.5kΩ pull-up/limiting resistors (R):

$$\text{Source Current Tracking} \quad I_0 = \frac{V_{A1}}{R}$$

$$\text{Received Light Current} \quad I_0 = \frac{V_{A1}}{R}$$

**3.2 Core Analytical Formulae**

- **Turbidity (Standard NTU Calibration):** Calculated via a linear mapping function derived from empirical slopes where VA1 represents the primary transmission signal path:

$$NTU = V_{A1}x27.28$$

- **Optical Absorbance (Abs):** Calculated based on the log-ratio of the signals using the Beer-Lambert Law to gauge chemical solute concentrations:

$$Abs = 0.3010xlog_{10}(\frac{I}{I_0}) \approx 0.3010(\frac{V_{A1}}{V_{A2}})$$

- **Transmission Differential (Trs):** Quantifies the clean mathematical delta between the processed receiver channels:

$$Trs = VA2 - VA1$$

- **Turbidity Percentage Factor (Tur):** Represents the normalized scaling of the localized attenuation footprint across a percentage scale:

$$Tur = (VA2 - VA1)\ x\ 100$$

**4. Software Implementation**

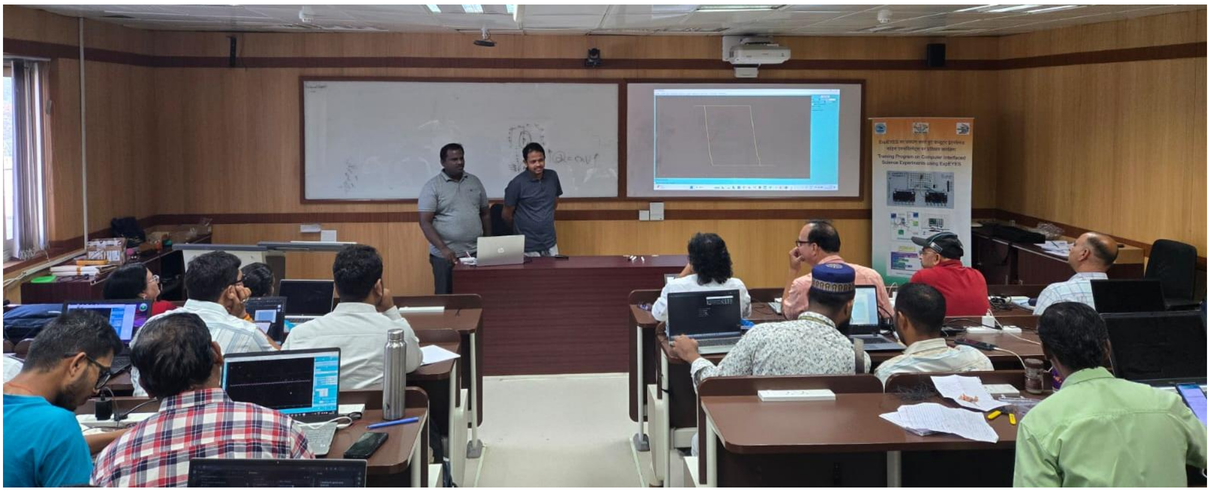
The tracking program is written in Python 3 utilizing the eyes17.eyes hardware library alongside matplotlib for graphical plotting. The corrected, logical script framework executes 10 sequential sampling sweeps over a 20-second timeline (2-second sleep steps):

**5. Applications & Analytical Capabilities**

1. **Turbidity & Suspended Solids Detection:** Measures light scattering away from the phototransistor axis, providing accurate readings for particulate or colloidal suspension concentrations.
2. **Colorimetry & Concentration Studies:** By replacing the standard emitter with specific monochromatic wavelengths (e.g., matching a red LASER Diode source to interact with a green chemical solution matrix), the system functions as a digital colorimeter capable of tracking solute shifts using the integrated absorbance calculation engine.

# Memristive Emulator Circuit using ExpEYES

Dr. Shuvendu Ghosh and Dr. Sahaya Dennish Babu



**Abstract**

This project demonstrates a low-cost memristive emulator circuit built around an LM358 operational amplifier and realized using the ExpEYES-17 kit. Rather than relying on exotic nanoscale devices, the circuit reproduces the two hallmark signatures of a memristor—a pinched current–voltage hysteresis loop and a charge-dependent "memory" of its previous state—using only common discrete components. The ExpEYES-17 kit, which combines a signal generator, oscilloscope, and data-acquisition system into a single low-cost, open-source platform, is utilized both to drive the circuit and to capture and plot its response in real time. The observed hysteresis behavior and voltage-dependent switching confirm that a simple op-amp-and-capacitor network can successfully emulate memristive dynamics, serving as an inexpensive, accessible teaching platform for neuromorphic computing and artificial synapse concepts.

## Experiment Objectives

### Primary Objectives

- **Demonstrate the Memory Effect:** To validate the memory-retaining capabilities of an LM358-based emulator circuit interfaced with the ExpEYES kit, demonstrating that its instantaneous electrical output depends intrinsically on the history of previously applied inputs.
- **Observe Hysteresis Behavior:** To characterize the circuit's current–voltage (I-V) relationships and verify the presence of a pinched hysteresis loop passing through the origin—the definitive signature of a memristive element.

### Secondary Objective

- **Bridge to Neuromorphic Applications:** To correlate this reproducible, low-cost tabletop emulator with real-world applications of memristive devices. Specifically, the experiment highlights how these elements mimic the synaptic plasticity of biological neural networks, offering a foundation for energy-efficient neuromorphic computing.

**Introduction**

The memristor (memory-resistor) was postulated by Leon Chua in 1971 as the fourth fundamental passive circuit element, establishing a functional relationship between electric charge (q) and magnetic flux linkage (phi), alongside the traditional resistor, capacitor, and inductor. The defining property of a memristor is that its instantaneous resistance, termed memristance M(q), varies dynamically according to the net charge that has historically flowed through it. Consequently, the device fundamentally retains a memory of its electrical conduction history.

While practical solid-state memristors are typically realized as nanoscale metal-oxide thin films, their fabrication demands specialized cleanroom facilities, making them cost-prohibitive and inaccessible for standard educational laboratories. To circumvent these limitations, the experiment detailed herein utilizes conventional operational amplifier (op-amp) and resistor-capacitor (RC) networks to emulate the precise input–output electrical signature of a memristor. This approach provides a robust, low-cost platform to explore memristive behavior on a standard electronics bench using the ExpEYES data acquisition system.

**Circuit Implementation and Experimental Setup**

The memristive emulator was constructed using a single LM358 dual operational amplifier (op-amp) integrated circuit (IC) configured with a resistor-capacitor (RC) feedback network. Within this architecture, the capacitor functions as the charge-storage (memory) element, while the op-amp dynamics shape the overall input–output transfer characteristic. The emulation mechanism operates as follows:

- **Dynamic Charge Accumulation:** The capacitor dynamically stores and releases electrical charge as the periodic input signal modulates the surrounding resistor network.
- **State-Dependent Output:** The instantaneous output voltage is inherently state-dependent, governed not only by the immediate input voltage but also by the residual charge state determined by prior electrical stimuli.
- **Hysteresis Progression:** Subjecting the circuit to a periodic voltage sweep continuously updates this internal state, forcing the current–voltage characteristic to trace a pinched hysteresis loop rather than a single-valued curve—the defining signature of memristive behavior.

Data acquisition was performed using the ExpEYES interface platform connected via its programmable voltage output (PV1) and analog input channels (CH1 and CH2). Channel PV1 was configured to supply the periodic drive signal (sinusoidal or triangular waveforms) to actuate the emulator. Concurrently, the analog inputs monitored the system: one channel captured the voltage drop across the emulator, while the other recorded the voltage drop across a series sensing resistor to determine the instantaneous current. This configuration enabled the accompanying software interface to plot the I-V hysteresis loop directly in real time. The physical breadboard realization utilized for this experiment is illustrated in Figure 1.

**Governing Equation:**

The voltage across an ideal memristor is related to the current through it by:

**V(t) = M(q)·I(t)**

where M(q) is the memristance, a function of the charge q that has flowed through the device, and I(t) is the instantaneous current. Because M(q) depends on the integral of the current up to time t, the device's effective resistance at any instant depends on its entire conduction history, which is precisely the behaviour reproduced by the charge stored on the RC feedback capacitor in this emulator circuit.

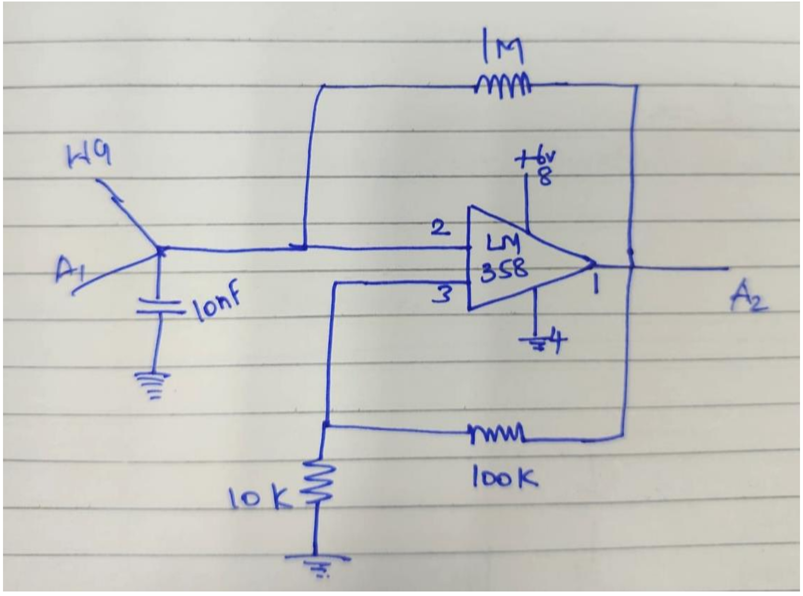



Figure 1: Breadboard realisation of the LM358-based memristive emulator circuit

**Results and Discussion**

Upon applying a periodic drive signal via channel PV1, the ExpEYES software captured the dynamic current–voltage (I-V) response of the emulator circuit. As illustrated in Figure 2, the recorded traces exhibit a well-defined pinched hysteresis loop that strictly closes at the origin, mirroring the diagnostic transport behavior of an ideal memristive element.

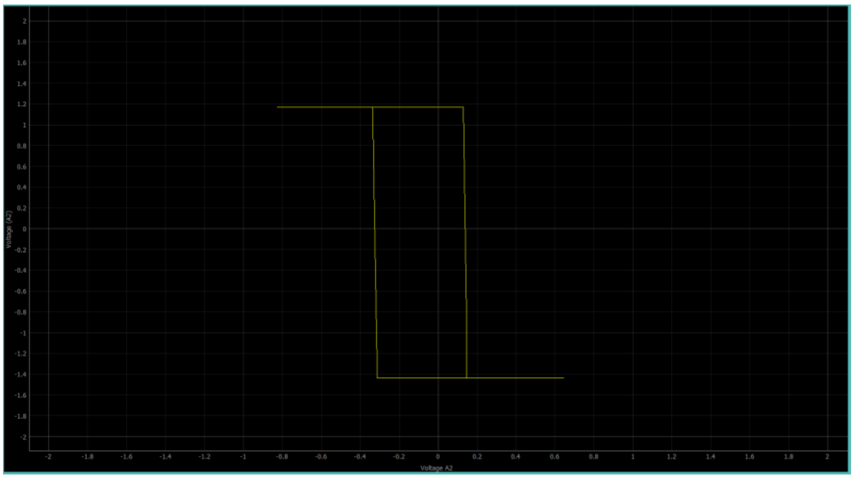


Figure 2(a): Output hysteresis loop captured on the ExpEYES oscilloscope/plotting interface

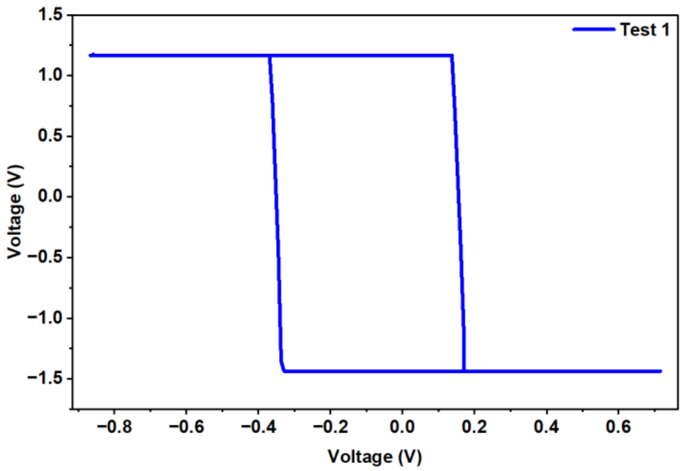


Figure 2(b): Zoomed I–V hysteresis trace showing state-dependent switching

The total area enclosed by the hysteresis loop—which serves as a direct metric for the strength of the system's memory effect—demonstrates a strong dependence on the operational frequency of the excitation signal. At lower frequencies, the loop area is maximized because the duration of each half-cycle provides sufficient time for the capacitor to undergo significant charging and discharging, driving substantial state variations in the feedback network. Conversely, as the drive frequency increases, the loop area progressively contracts. This degradation occurs because the rapid signal reversals restrict the net charge accumulation per cycle, leaving the capacitor insufficient time to alter its state away from its equilibrium or mean value. At the high-frequency limit, the hysteresis loop collapses entirely into a single-valued linear relationship, reproducing the classic frequency-dependent "pinched hysteresis" fingerprint characteristic of all physical memristive systems.

These results confirm that although the circuit does not contain a true nanoscale memristive element, the combined effect of the LM358 op-amp stage and its RC feedback network reproduces the two essential fingerprints of memristive behaviour — charge-dependent memory and pinched I–V hysteresis — using only inexpensive, readily available components and a low-cost open-source measurement platform.

**Applications**

Because this emulator circuit reproduces the essential input–output signature of a memristor at negligible cost, it is well suited as a demonstration and teaching platform for concepts that would otherwise require access to specialised nanofabrication facilities. Relevant application areas include:

- Neuromorphic computing — where memristive elements are used to build hardware that processes information in a brain-inspired, event-driven manner with very low power consumption.
- Artificial synapses — memristors are widely studied as analogues of biological synapses because their conductance can be incrementally and reversibly tuned by applied signals, mimicking synaptic plasticity (potentiation and depression).
- Resistive-switching memory (ReRAM) concepts, where a state-dependent, non-volatile resistance change is used to store information.

**<u>Conclusion:</u>**

The simple, low-cost LM358-based circuit interfaced with the ExpEYES-17 kit successfully demonstrates memristor-inspired behaviour, including hysteresis switching and a charge-dependent output response. While it is not a true nanoscale memristor, it effectively models artificial synaptic behaviour and resistive-switching dynamics, making it a valuable and accessible platform for introducing students to memristive devices and their emerging role in neuromorphic hardware, entirely using standard laboratory components and the open-source ExpEYES measurement system.

**Future Improvements:**

- Use larger capacitors to obtain smoother, more clearly defined hysteresis loops.
- Reduce the drive frequency further to obtain a more sharply pinched hysteresis characteristic.
- Extend the study to explore applications of this low-cost emulator platform in AI/neuromorphic hardware demonstrations.

**References:**


- ExpEYES-17 User Manual
- L. O. Chua, "Memristor — The Missing Circuit Element," IEEE Transactions on Circuit Theory, 1971.

# Revisiting Galileo's Ball and Bell Experiment using Electromagnetic Induction and ExpEYES

Dr. Md Gazzali P.M, and Dr. Arun Aravind

## Aim and Objective

The primary aim of this project is to modernize Galileo Galilei's historic ball and bell experiment by substituting traditional brass bells with electromagnetic coils. The objective is to employ the ExpEYES open-source hardware kit to precisely measure the rapid free fall of a magnet using electromagnetic induction, capturing transit times with microsecond accuracy to verify the laws of constant acceleration.

## Historical Background: The Legacy of Galileo

Historically, Galileo systematically questioned the established Aristotelian dogma, which claimed that heavier objects fall faster than lighter ones. Because precise clocks did not exist in his era, he slowed down the rapid motion of free fall by using inclined planes. He placed small bells at progressively larger, mathematically calculated intervals along the track (Fig. 1). As a ball rolled down, it struck the bells at perfectly equal time intervals, producing an elegant acoustic feedback system that demonstrated constant acceleration.

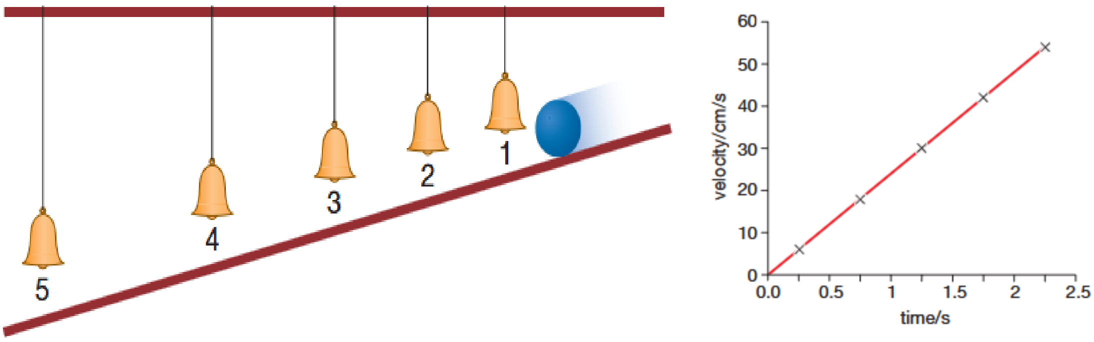



Fig-1 Galileo's Experiment using Ball and Bell
& showing the linear relationship of velocity-time graph

He shifted classical mechanics toward empirical observation by discovering the Law of free-falling bodies: the distance travelled by a uniformly accelerating falling body is strictly proportional to the square of the elapsed time ($s = ½ gt^2$, s- distance travelled, u- initial velocity= 0, g- acceleration due to gravity). Therefore, velocity is proportional to the time with the relation ($ds/dt = gt$)

## Modernization and Theoretical Framework

### Modernizing the Experiment

While the original experiment relied on acoustic feedback and human hearing, this modern approach utilizes digital technology to capture precise transit times. By replacing the rolling ball with a falling magnet and the bells with copper coils, the transit points are mapped directly onto a digital screen.

### Principle: Electromagnetic Induction

The setup is based on Faraday's Law of Induction, which states that whenever the magnetic flux linked with a closed coil changes, an electromotive force (emf) is induced, causing an electric current to flow through the circuit. In this experiment, a magnet falling freely through a copper wire coil generates a distinct, measurable electrical pulse. Crucially, the rate of change of the magnetic flux determines the magnitude of these induced voltage spikes, allowing the ExpEYES kit to register the exact moment the magnet passes the center of the coil.

### Instrumentation: ExpEYES-17

To capture these microsecond events, the experiment uses the ExpEYES-17 kit, a low-cost, portable science laboratory designed to make advanced physics experiments accessible to students. The hardware enables real-time visualization of high-speed electrical signals and microsecond voltage transients, and it features built-in programmable voltage sources.

### Apparatus and Setup

The physical setup consists of a long, transparent vertical tube used as the drop path for the magnet, with electromagnetic coils wrapped around its exterior at mathematically determined intervals. We adapted two distinct methods to verify Galileo’s experiment. In the first method, the coils were positioned at increasing intervals of 3 cm, 9 cm, 15 cm, and 21 cm—following the ratio 1:3:5:7—as shown in Fig-2.

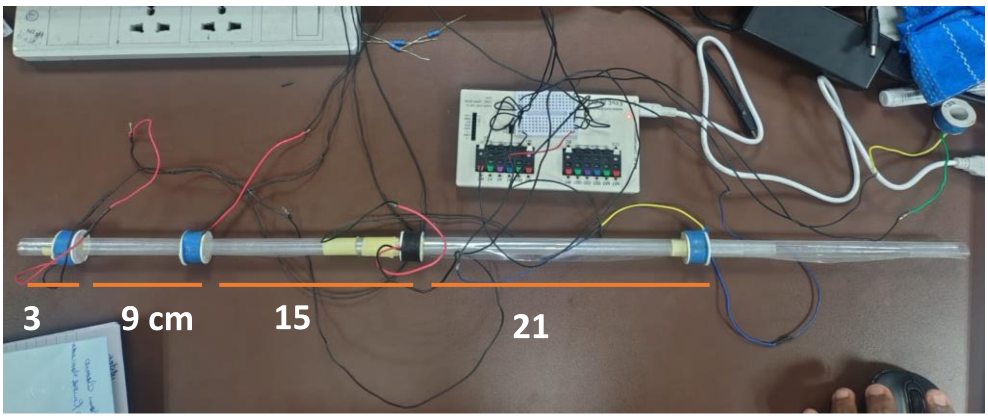



Fig. 2 Experiment set up wherein coils are positioned
at increasing distances of 3 cm, 9 cm, 15 cm, and 21 cm

In the second method, the electromagnetic coils are positioned at equal intervals of 10 cm apart.

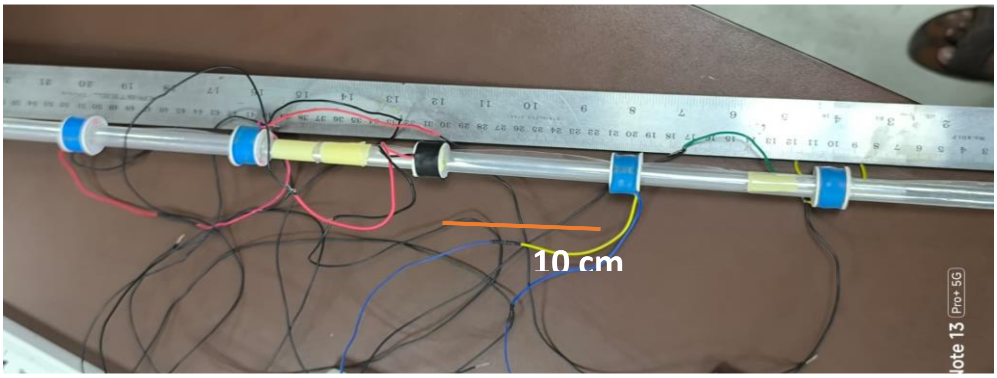



Fig. 3 Experiment set up wherein coils are positioned
with equal distance of 10 cm between them.

## Experimental Procedure

1. The coil system is connected directly to the ExpEYES-17 interface, with one terminal routed to the **A1 (**Analog Input**)** port and the opposite terminal connected to the GND (Ground) port.
2. A small neodymium magnet is released from rest and dropped cleanly down the center of the transparent vertical tube.
3. As the falling magnet transits each successive coil, the resulting induced EMF is registered by the ExpEYES-17 kit, mapping the voltage spikes in real time to capture precise timestamps for each passage.

## Data acquisition

A Python script automatically records the experimental results. The software initiates an acquisition sequence by employing the eyes17.eyes library to read the voltage from analog input A1 over a predetermined time array. It then stores the elapsed time data and generates a real-time plot of Induced EMF (V) versus Time (s).

## Results and Discussion

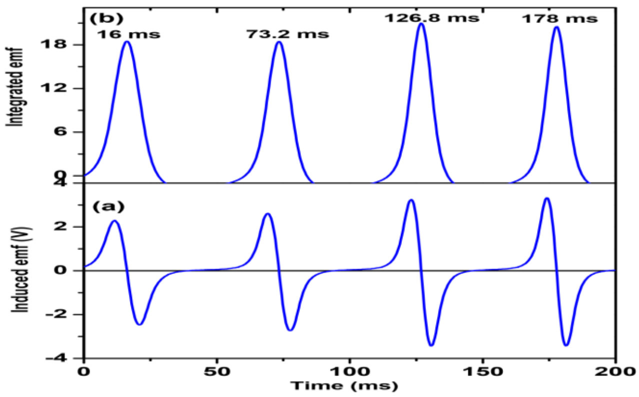



Fig. 4 (a) Induced EMF (V) versus graph for the method (2)
wherein coils are kept at equal distance apart and the integrated EMF plot (b)

The real-time data captured by the ExpEYES-17 oscilloscope yielded precise EMF versus time graphs (Fig. F(a)). These voltage plots reveal vital insights into the dynamics of accelerating bodies. The plotted waveform shows a distinct positive peak as the magnet enters the coil, followed immediately by a sharp negative peak as it exits. Notably, the exit peak is consistently narrower and taller than the entrance peak. Because the magnitude of the induced voltage depends directly on the rate of change of magnetic flux (d\phi/dt), this increased peak height demonstrates that the magnet is traveling faster as it leaves the coil than when it entered. This visual asymmetry elegantly validates that the falling body is continuously accelerating under the uniform influence of gravity.

By integrating the EMF and calculating the time differences between coil transits **(Fig. 4(b))** (e.g., recorded peaks at 16 ms, 73.2 ms, 126.8 ms, and 178 ms), the plotted speed (m/s) versus time (ms), the acceleration due to gravity for this setup (**method (2)**) is found to be **3.64 m/s²** across different data sets and variables (such as tube friction or magnetic drag).

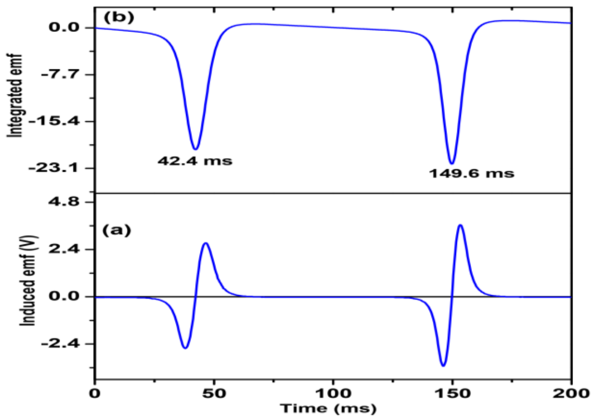



Fig. 5 (a) Induced EMF (V) versus Time (ms) graph for the method (1) wherein coils are kept at distance of 1:3:5:7 ratio apart and the integrated EMF plot (b).

Here, the number of peaks observed is not matching with that of the number of coils. The time taken to travel between the coils is expected to be same, but due to above constraint we are unable to deduce such relations and hence prove the acceleration due to gravity. By integrating the EMF and calculating the time differences between coil transits **(Fig. 5(b))** (e.g., recorded peaks at 42.4 ms and 149.6 ms), the plotted speed (m/s) versus time (ms), the acceleration due to gravity for this setup (**method (1)**) is found to be **5.87 m/s²** across different data sets and variables.

**Conclusion and Future Plan**

In this study, we utilized a series of electromagnetic coils paired with the ExpEYES-17 kit to revisit Galileo's historic ball and bell experiment and determine the local acceleration due to gravity (g). We employed two distinct experimental configurations: one with equidistant coil spacing, and another with coils positioned according to the ratio 1:3:5:7. Although the calculated results were slightly lower than the standard theoretical value of acceleration due to gravity (9.8 $m/s^2$)—likely due to experimental tolerances—the setup successfully demonstrates the power of active, hands-on experimentation. Ultimately, this modern adaptation bridges the gap between abstract mathematical formulas and physical reality. By integrating accessible hardware interfaces like ExpEYES into the classroom, educators can effectively connect historical scientific philosophy with modern engineering for students worldwide.

## Distribution of Participation Certificates

The participation certificates were distributed by Dr. Vandna Luthra, and Shri. V V V Satyanarayana.









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## Concluding Session

During the concluding session, Prof. Vandna has conveyed to the participants the efforts involved in this project by IUAC and congratulated Shri. V.V.V. Satyanarayana for continuing this program by involving the best teaching faculty across the country, like Prof. Sastri, Prof. Vandna, and others. It was conveyed to the participants to take forward the knowledge and aim of this program to their places in the form of classroom demonstrations, conducting small workshops by including the nearby institutions, involving the students in doing the conventional experiments using ExpEYES, etc. It was also conveyed to the participants to keep the WhatsApp group active by sharing information related to the training program and any new developments using the knowledge and experience gained with this program.

This time, participants presented six new experiments—a significant achievement for the training programme and a testament to the session's success.

### List of the Participants and Resource Persons

| # | Name of the Participant | Institute Details |
|---|---|---|
| 1 | Dr. Shuvendu Ghosh, Assistant Professor | Aditya University, Surampalem, Andhra Pradesh |
| 2 | Dr.G. Karthick Kumar Reddy, Assistant Professor | RGUKT-AP, RK Valley, Idupulapaya, Kadapa, Andhra Pradesh. |
| 3 | Dr. Ganesh Ram Banjare, Assistant Professor | Department of Physics, Govt. Engg. College, Raipur, Chhattisgarh |
| 4 | Dr. Bhoopendra K Dewangan, Assistant Professor | Government Madanlal Shukla PG College, Seepat, Bilaspur, Chhattisgarh |
| 5 | Dr. Chitrkant Belodhiya Assistant Professor | School of Physics and Astrophysics, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh |
| 6 | Dr. Manisha Kumari Assistant Professor | BRCM CET BAHAL, BHIWANI, Haryana |

| | | |
|---|---|---|
| 7 | Dr. C.J. Sreelatha<br>Professor | Department of physics, Kakatiya University, Warangal, Telangana. |
| 8 | Dr. Avijit Ghosh<br>Associate Professor | Central University of Jharkhand, Cheri Manatu, Kanke, Ranchi |
| 9 | Dr. Thangavel Rajalingam<br>Associate Professor | IIT ISM, Dhanbad, Jharkhand. |
| 10 | Dr Sangamesh Jakhati<br>Assistant Professor & HOD | Dept. Of Physics, Proudhadevaraya Institute of Technology, T.B.Dam, Hosapete. |
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| 12 | Dr. Devesh Kumar Tyagi Associate Professor | D A V P.G.College, Muzaffarnagar, Uttar Pradesh. |
| 13 | Dr. Narinder Kumar<br>Senior Scientist | Physics Department, University of Jammu, J & K. |
| 14 | Dr. Arun Aravind<br>Assistant Professor | Bishop Moore College, Mavelikara, Kerala. |
| 15 | Dr. Anup Purushottamrao Bhat<br>Assistant Professor | Dept of Electronics, Amolakchand Mahavidyalaya Yavatmal , Maharashtra. |
| 16 | Dr. Nilesh S Ugemuge<br>Assistant Professor | Anand Niketan College, Chandrapur, Maharashtra. |
| 17 | Dr. Rajesh Arora<br>Associate Professor | Dyal Singh College, Karnal, Haryana. |
| 18 | Dr. Vishal Sharma<br>Associate Professor | Govt. Degree College for Women, Udhampur, J & K |
| 19 | Dr. G. Sahaya Dennish Babu<br>Associate Professor of Physics | Department of ECE, Anna University, Chennai. |
| 20 | Dr. Cholleti Srinivasu<br>Assistant Professor | Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad. |
| 21 | Dr.G.Manjula<br>Assistant Professor | Department of physics, Kakatiya University, Warangal, Telangana. |
| 22 | Dr. Pardhu Yella<br>Assistant Professor | Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad. |
| 23 | Dr. Pramila Gupta<br>Assistant Professor | S.S.Khanna Girl's Degree College, Attarsuiya, Prayagaraj, Uttar Pradesh. |
| 24 | Mr.Varun D C<br>B.Sc Student | GFGC Malleswaram<br>Bengaluru City University |
| 25 | Prof O.S.K.S.Sastri<br>Resource Person | Central University of Himachal Pradesh, Dharamshala |
| 26 | Prof Vandna Luthra<br>Resource Person | Gargi College, New Delhi |
| 27 | Dr. Ajith Kumar B.P<br>Speaker (Online) | Retired Scientist-H,<br>IUAC, New Delhi |
| 28 | Dr. G.Manoj Kumar<br>Speaker (Online) | School of Physics,<br>University of Hyderabad |
| 29 | Shri. Sunil Ojha<br>Speaker | Inter-University Accelerator Centre,<br>New Delhi |
| 30 | Dr. Joby antony<br>Speaker | Inter-University Accelerator Centre,<br>New Delhi |
| 31 | Mr. Yatesh Dabas | Inter-University Accelerator Centre, |

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|---|---|---|
| | Engineer | New Delhi |
| 32 | Mr. Om Mishra<br>Technician | Inter-University Accelerator Centre,<br>New Delhi |
| 33 | Shri. V.V.V.Satyanarayana<br>Convener | Inter-University Accelerator Centre,<br>New Delhi |

Teacher Training Program on

# Computer-Interfaced Science Experiments using ExpEYES

ExpEyes

**May 18–23, 2026**

**Inter-University Accelerator Centre**

Aruna Asaf Ali Marg, New Delhi

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### Tentative Speakers

Dr. Ajith Kumar B.P., Ex IUAC
Prof. OSKS Sastri, CUHP, Dharamshala
Prof. Vandna Luthra, Gargi College, New Delhi
Dr. Ashwini Kumar, Dr RML Avadh University, Ayodhya
Dr. Manoj Kumar, University of Hyderabad
Shri. Sunil Ojha, IUAC, New Delhi
Dr. B.K.Sahu, IUAC, New Delhi
Shri. V V V Satyanarayana, IUAC, New Delhi

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### Registration Fee Rs. 3000.00

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### Contact Persons

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प्राशिक्षण प्रयोगशाला
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