



NCICP - 2024  
Category 2(A) - UG Student  
Sub Category: (a) Experiment using Arduino

A 3D wireframe illustration of an Arduino Uno microcontroller board. The board is populated with several diodes of various sizes and colors, connected to the pins. The word 'ARDUINO' is visible on the board's surface.

Planck's constant determination using diodes of different energy band gaps interfaced with Arduino microcontroller

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# Planck's Constant?

- ❖ Energy is expected to be continuous at every level according to Classical Physics, but Planck discovered that in case of atoms it's untrue and there energy is in form of packets called quantum.
- ❖ Major breakthrough in field of physics, which led to the development of QUANTUM PHYSICS.
- ❖ Relates energy with the frequency of light emitted ( $E = n \cdot h \cdot f$ )
- ❖ **Fun fact** : Energy emitted by one mole of photons is equivalent to 216 kJ which is about three apples which will keep three doctors away which helps us know how minute the order of planck's constant is.



# The Quest for Planck's Constant

- ❖ Planck's constant is fundamental in Modern Physics.
- ❖ Explored diverse methods to determine Planck's constant.
- ❖ LEDs: Essential component of modern technology.
- ❖ Traditional methods demand significant human intervention.
- ❖ Arduino provides precision and consistency.
- ❖ Derived Planck's constant with advanced techniques.



# Why Arduino?

- **Arduino** is a microcontroller which is user friendly as well as compact making it suitable for experiments.
- **Analog reading**
- **Real-Time data**
- **Automated consistent and repeatable Data Collection**
- **Consistency and Repeatability**
- **Efficient Workflow**
- **Minimal human intervention**



# Methodology

**Objective :** To estimate the value of Planck's constant using diodes of different energy band gaps interfaced with Arduino microcontroller.

## Materials and Equipment :

LEDs (red, green, blue, yellow, infrared, ultraviolet)

Arduino

Breadboard

Connecting wires

## Experimental Setup:

Diagram - same as fig 1.1

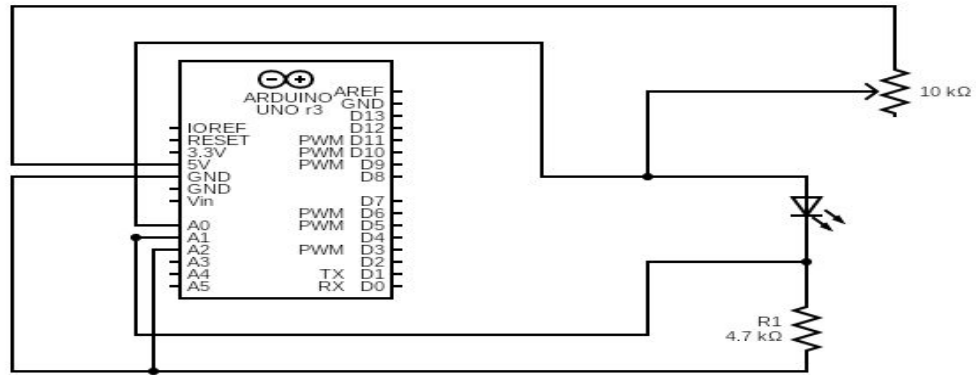
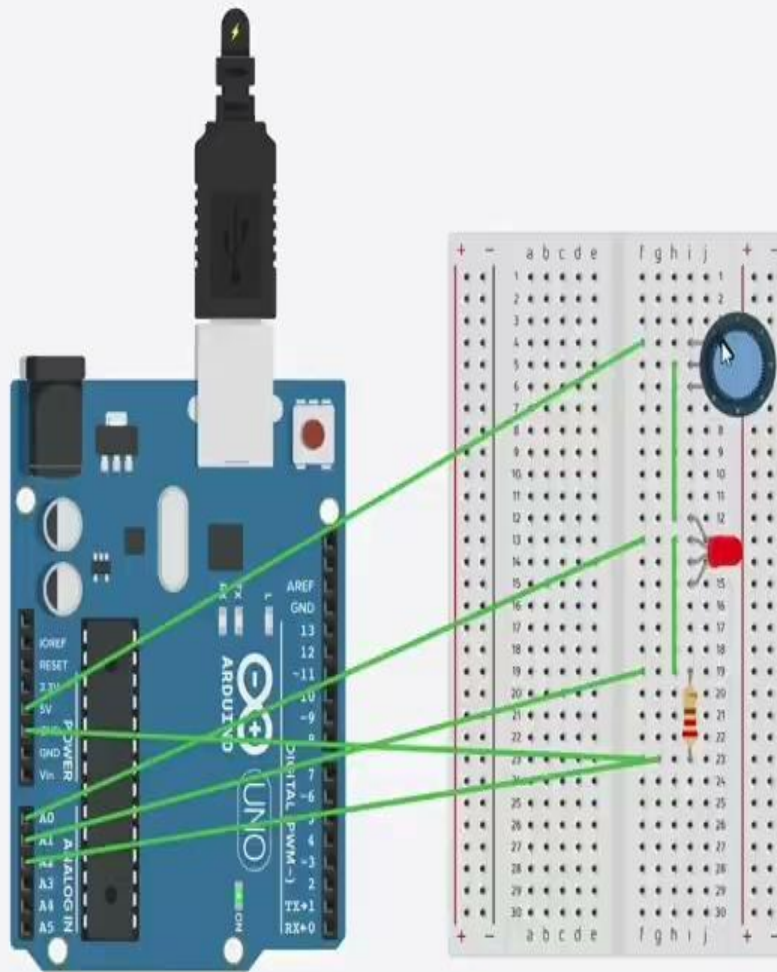


fig 1.1 Circuit setup for data collection



# Measurement Outlay

- ❖ **Forward Bias Condition:** Apply a small forward bias voltage and measure the resulting voltage across and current through the diode.
- ❖ **Data Collection:** Implement methods to record voltage and current readings.
- ❖ **Plot I-V Characteristic Curve:** Use the collected data to plot the I-V curve.
- ❖ **Identify Forward/Activation Voltages:** Determine forward/activation voltages from the I-V curve.
- ❖ **Plot Forward/Activation Voltage vs.  $1/\lambda$  Curve:** Plot forward/activation voltage against  $1/\lambda$  (wavelength) using the identified forward/activation voltages.



```

1 // C++ code
2 //
3 float R = 220.0;
4 void setup()
5 {
6   Serial.begin(9600);
7 }
8
9 void loop()
10 {
11   float voltageA0 = analogRead(0);
12   float voltageA1 = analogRead(1);
13   float voltageA2 = analogRead(2);
14   float voltageDiode = ((float)voltageA0 - (float)voltageA1)*5.0/1023;
15   float voltageResistor = ((float)voltageA1 - (float)voltageA2)*5.0/1023;
16   float current = voltageResistor/R;
17   Serial.print("DATA");
18   Serial.print(voltageDiode);
19   Serial.print(",");
20   Serial.println(current*1000);
21   delay(100);
22 }
23
24
25
26 }

```

Serial Monitor

UNO:00,14.84  
 DATA:00,14.84  
 DATA:00,14.84  
 DATA:00,14.84  
 DATA:00,14.84  
 DATA:00,14.84

16  
15  
14  
13  
12  
11  
10  
9  
8  
7  
6  
5  
4  
3  
2  
1  
0

Send Clear



# Regression Techniques

**Median values** provide robustness while handling outliers and ensuring reliable central tendency estimation.

## Regression Analysis:

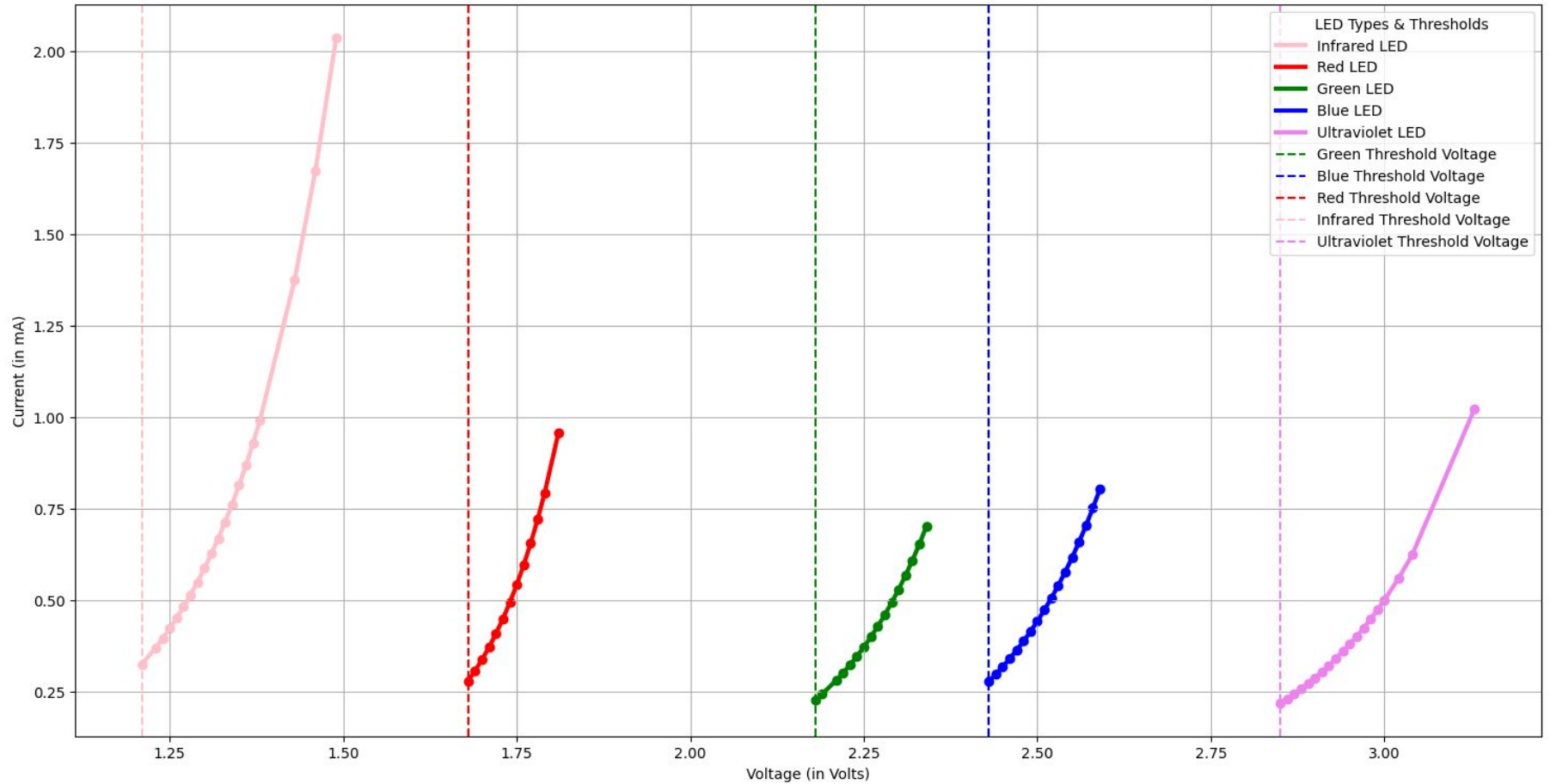
### Least Squares Regression:

- It involved mathematically fitting a linear model to the data using least squares, optimizing the parameters to minimize the sum of squared residuals.
- Critical for accurately determining the slope of Activation voltage v/s  $1/\lambda$  Curve

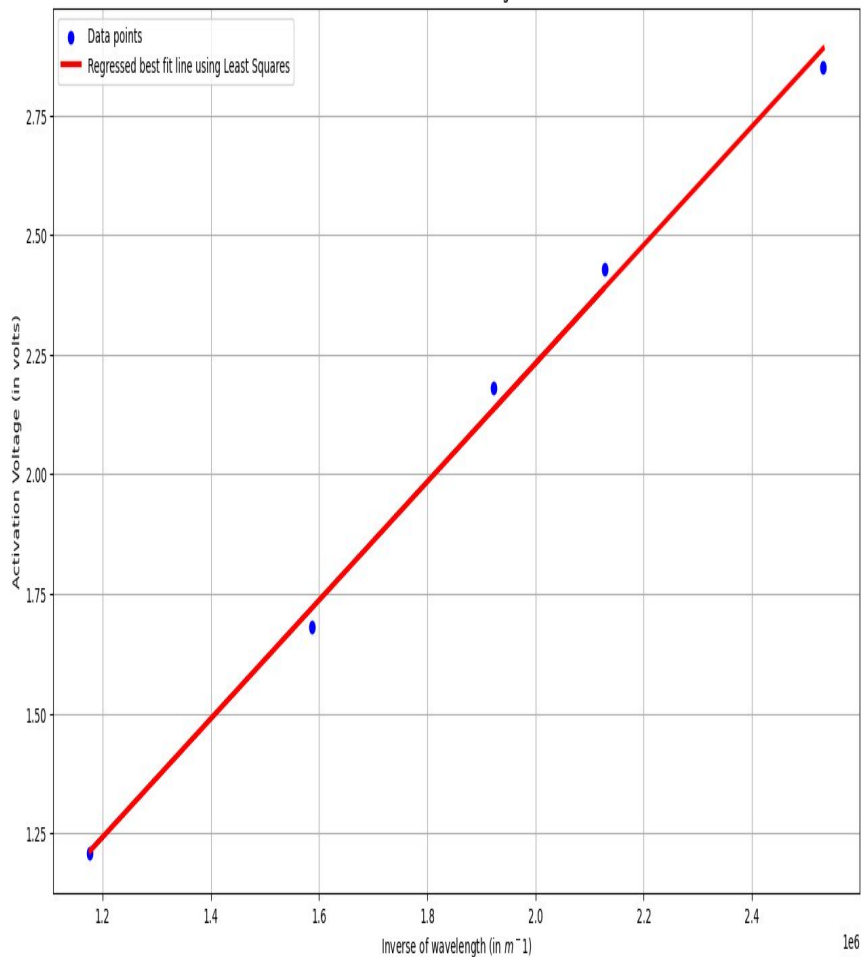
### Gradient Descent:

- Iterative optimization technique used to find the minimum of loss function by iteratively moving in the direction of steepest descent.
- Essential for refining model parameters and improving model fit over multiple iterations.

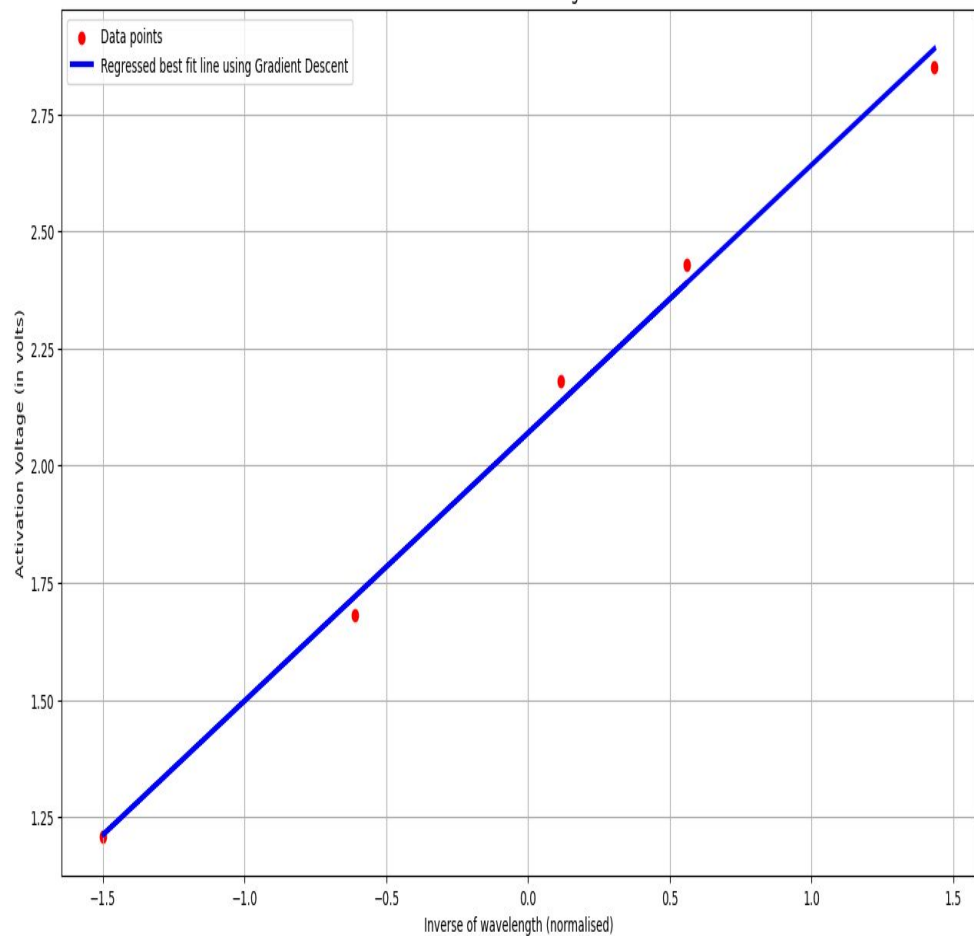
# OBSERVATIONS

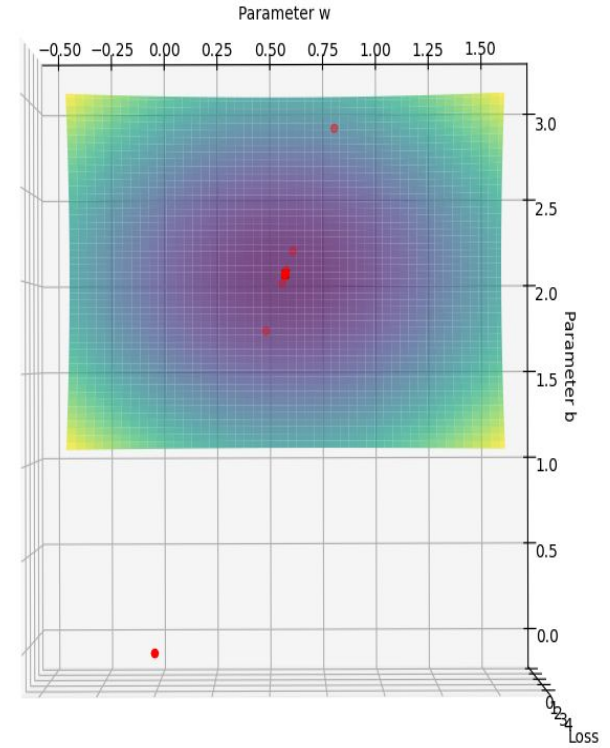
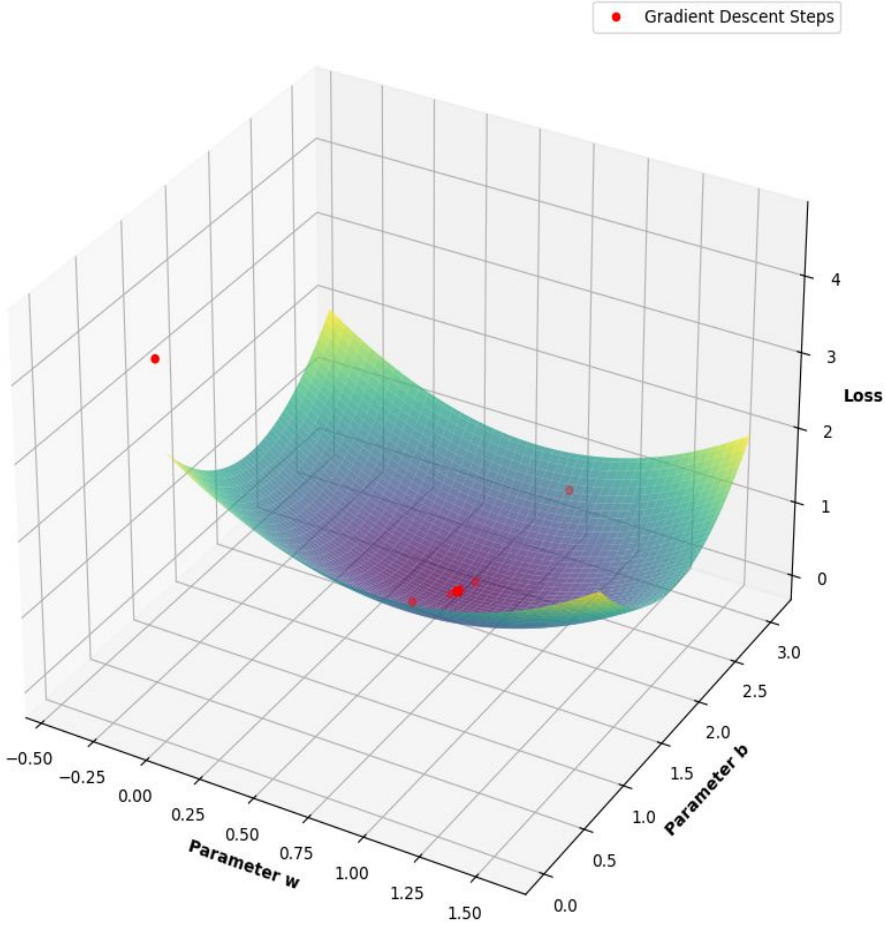


Planck's constant finding curve

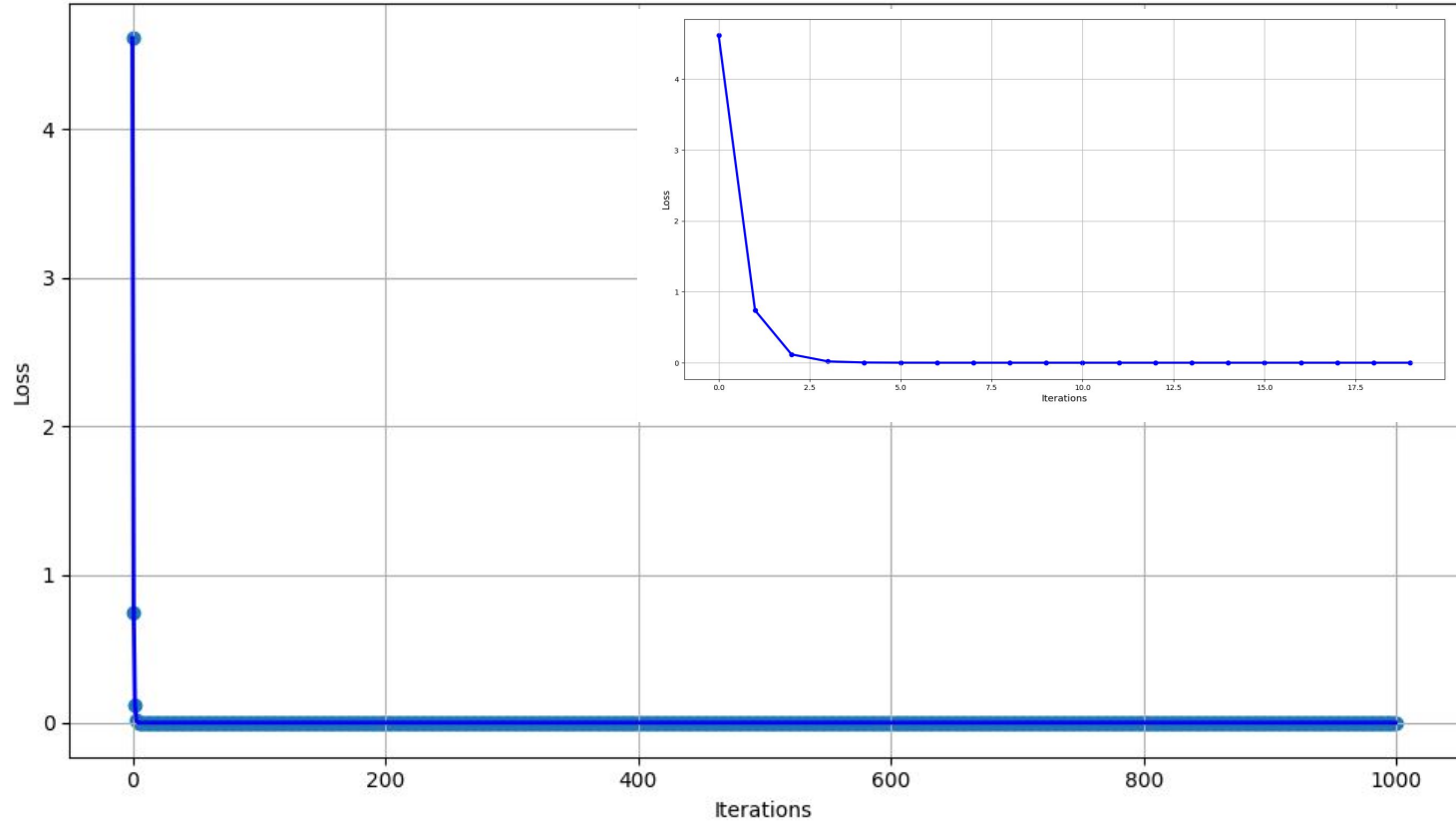


Planck's constant finding curve






Loss vs Iterations



# Computational Framework: Languages, Libraries, and Tools

- Programming Language

-  python™
- Arduino IDE (c++) 

- Libraries

-  NumPy
-  matplotlib
-  pandas
-  PyTorch

# Result

- **After calculating the final value the order of the value obtained by us came out to be  $10^{-34}$ , same as the actual value currently used.**
- **When comparing both the values the significant digit error turned out to be 0.2%**
- **Accounting the instrumental errors, these errors can be mitigated by using better equipments such as wirewound resistors, digipots.**

# Differences b/w Least squares and Gradient Descent

Aspect	Least Squares	Gradient Descent
Method	Analytical	Iterative
Computational Cost	High for large datasets(involves matrix multiplications)	Low for large datasets(depend on the number of iterations)
Implementation	Simple for small datasets	More Complex, requires tuning of hyperparameters(learning rate, iterations)
Precision	Exact solution	Approximate solution
Memory Requirement	High (needs to store matrices)	Low (needs to store parameters)
Convergence	Guarantees global minimum	Might get stuck in local minima
Numerical Stability	Can suffer from numerical instability due to matrix inversion	Generally more stable numerically

<b>Aspect</b>	<b>Our Setup</b>	<b>Laboratories</b>
<b>Setup and Apparatus required</b>	Simple, using Arduino and LEDs. Portable and easy to replicate	Complex Setup, might include photodiodes and spectrometers.
<b>Cost and Relative availability</b>	Low cost, widely available components like LEDs and arduino	Expensive, requires high-end lab equipments not readily accessible
<b>Prerequisites Required</b>	Requires basic knowledge of electronics and programming	Technical knowledge is required to operate and to maintain precision
<b>Complexity Level</b>	Ideal for hands on learning, interactive for beginners	Less interactive for beginners, complex
<b>Result</b>	Reasonably accurate	Extremely high precision and very low uncertainties
<b>Time requirement</b>	Quick data collection and automation	Time consuming due to procedure and manual calibration is required
<b>Human Intervention</b>	Minimal human intervention is required, mostly automated, thus reducing errors	Higher human intervention, including for setup, calibration, and data collection which can introduce errors

# Future Work

To elevate the work from this experiment, we have been working on integrating temperature as a variable to better understand and grasp the underlying feature of how Diode equation plays out its role in determining the planck's constant.



# THANK YOU

## Acknowledgements

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