
# Slope System Manual

# Contents

# Introduction

The Slope-Motion-System is an interactive educational platform designed to help school students intuitively understand key mathematical and physical concepts such as slope, rate of change, and derivatives.

Developed as part of a LSR-HBCSE TIFR (The Learning Sciences Research Group Homi Bhabha Centre for Science Education Tata Institute of Fundamental Research, Mumbai, India) research project, it integrates real-time motion data, graphical visualizations, and an innovative metronome system to connect theory with hands-on exploration.

# Aim - Cognitive learning

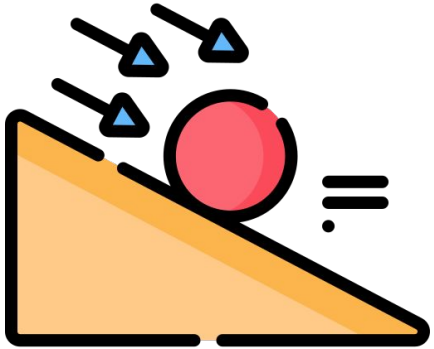
To design and develop an interactive Slope-Motion-System that enables students–especially at school level–to learn fundamental concepts in mathematics and physics, such as:

- Slope as rate of change
- Derivatives and tangents
- Velocity and acceleration

To provide a cognitive, experiential learning environment through motion tracking (using smartphones), dynamic graph plotting, and real-time auditory feedback (metronome system).

To foster active learning, encourage curiosity, and strengthen students' conceptual foundation by transforming abstract equations into tangible, interactive experiences.

# Slope Motion system



## Aim:

To design a Slope Motion System that enables students–especially kids–to learn fundamental physics concepts such as speed, acceleration, and distance-time relationships by recording and visualizing their motion using a mobile device.

## Theory:

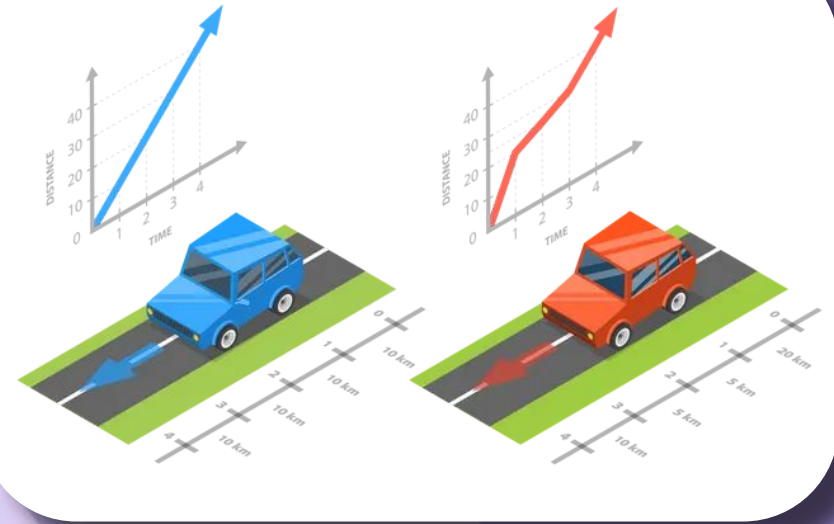
The Slope Motion System leverages real-world motion data captured through a smartphone's sensors (e.g., accelerometer) while a child moves along a defined slope or path. This data is used to generate distance vs. time and speed vs. time graphs in real-time or during post-analysis.

**Speed:** How fast the position changes with time.

**Acceleration:** How speed varies over time; seen as changes in slope on a speed-time graph.

**Uniform motion:** A straight line in a distance-time graph indicates constant speed.

**Non-uniform motion:** Curved or changing slopes represent acceleration or deceleration.



# Slope Motion features

**Separate interfaces** for teachers and students for a tailored user experience.

**Multiple classroom** support using unique class codes for easy student grouping.

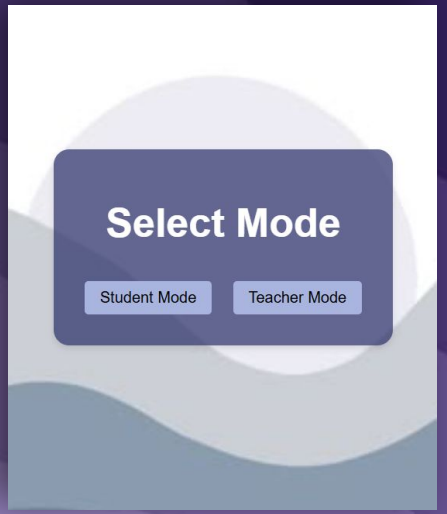
**30-second** motion recording from students, sent to the teacher in real time.

**Custom-graph** creation by plotting points or defining mathematical functions.

Plot up to **10** graphs (student + custom) simultaneously for comparison.

**Download** graphs and data as images or files for offline teaching use.

# Slope Motion UI

# Teacher view

## Slope System

Students Movement Graphs

Enter max value for Y-axis:

60

Choose input type:

Data Points (x,y)

Enter data points (x,y) separated by spaces:

e.g., 1,10 2,20 3,30

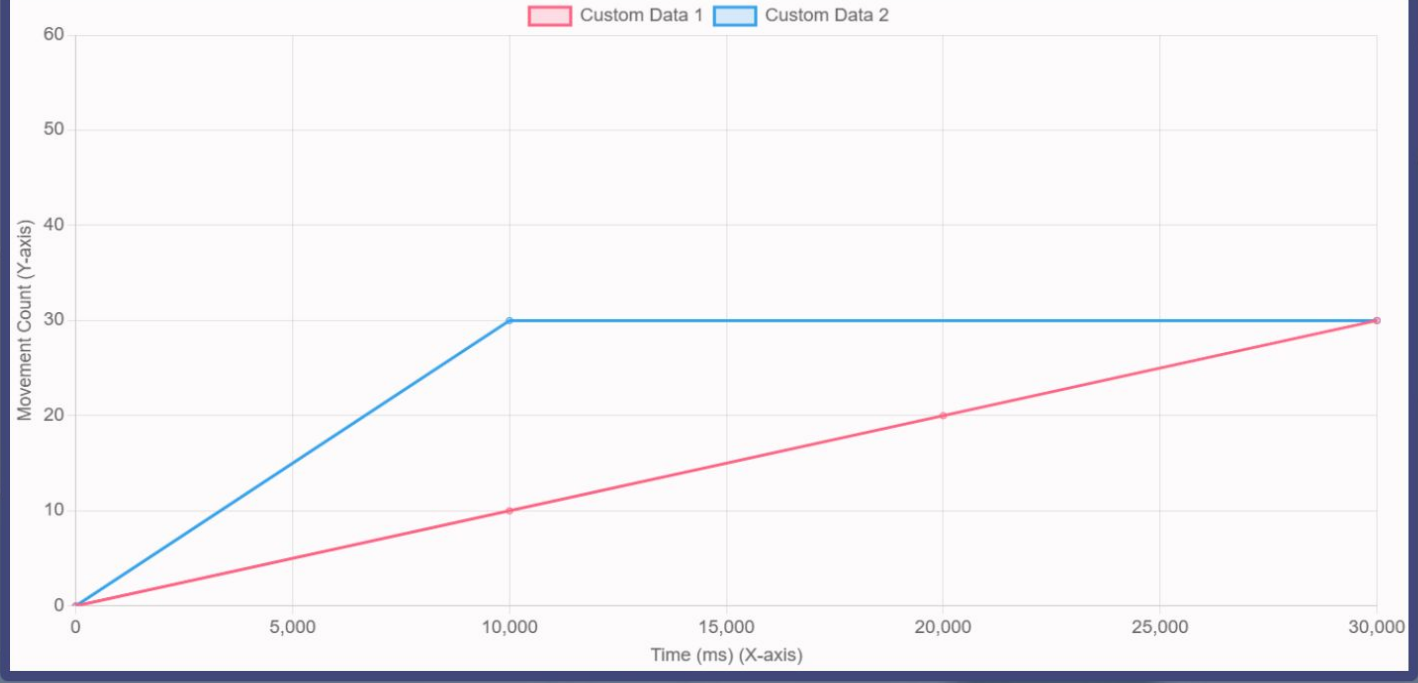
0,0 10000,30 30000,30

Add Data

Generate Classroom Code

Download Data

Refresh Data



# Teacher view

## Slope System

Students Movement Graphs

Enter max value for Y-axis:

60

Choose input type:

Function (e.g., y=x^2+3)

Enter a function of x (e.g., x**2+3):

e.g., x**2+3

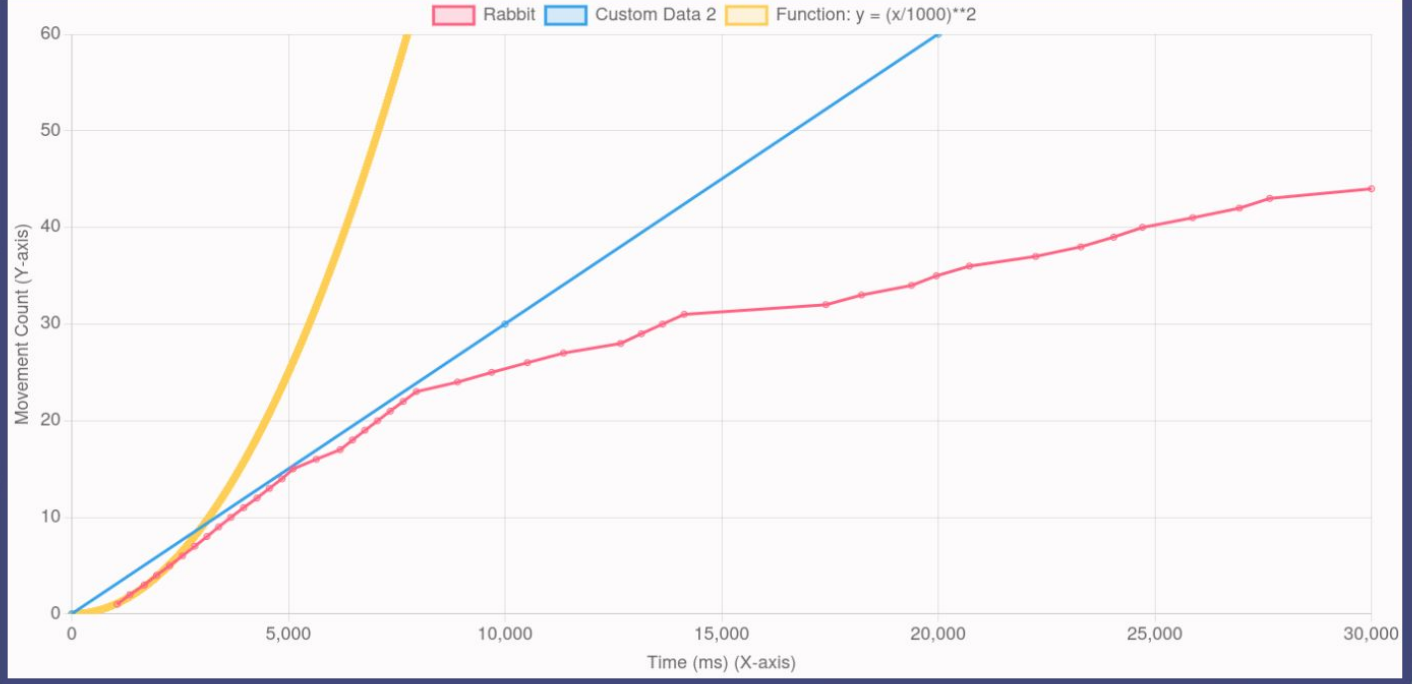
(x/1000)**2

Add Data

Download Data

Refresh Data

Classroom Code: cfa42f



# Teachers content

**Independent classroom** hosting allows each teacher to create and manage isolated environments.

Student motion data is visualized in a clear **movement vs time** graph for easy interpretation.

**Custom data points** can be manually added or predefined to enhance graph analysis.

**Custom functions** can be selected or written to teach how motion relates to mathematical functions.

**Download button** exports both the graph image and CSV data for further use.

**Refresh button** clears all plotted data for a clean workspace.

# Student view & content

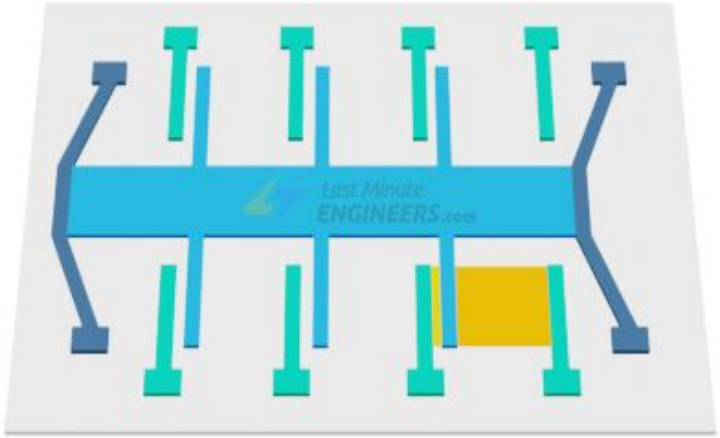
**Class code entry section** to join a specific classroom created by the teacher.

**Initial screen** displays live accelerometer data across all **three axes** (X, Y, Z).

**Preview screen** shows how the recorded data appears before submission.

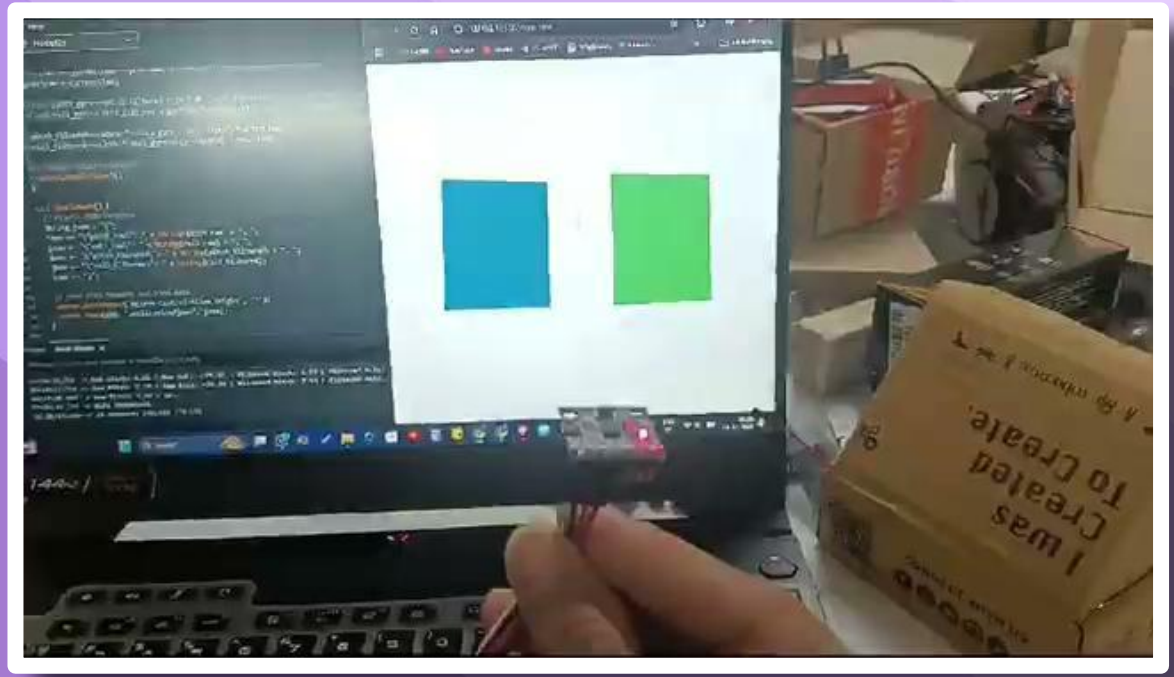
**Start, Refresh, and Send buttons** to control data recording and submission workflow.

# Slope Motion data accusation




## How Does a MEMS Accelerometer Work?

- A MEMS (Micro-Electro-Mechanical System) accelerometer is a tiny micro-machined structure suspended on a silicon wafer by polysilicon springs.
- When the device accelerates along X, Y, or Z axes, the structure deflects, changing the capacitance between its plates.
- This change is processed and converted into an analog voltage, which corresponds to the acceleration.
- MEMS accelerometers are widely used in smartphones to detect motion, orientation, and gestures.




The above video demonstrates how the MPU-6050 (accelerometer) operates as its orientation changes. The rectangular sheet shown in the video represents the top view of the MPU as it moves. A microcontroller is used to acquire the sensor readings, which are then transmitted and visualized on a website by drawing a rectangle using JavaScript.

# Data processing and plotting

The phone has a built-in accelerometer that gives acceleration values along three axes: X, Y, and Z.

Get acceleration data (a) from the accelerometer at each time step.

**Estimate velocity** (v) by integrating acceleration over time

$$v = v_0 + a \times \Delta t$$

Where:

- v0: previous velocity
- Δt: small time interval

**Estimate distance** (d) by integrating velocity over time:

$$d = d_0 + v \times \Delta t$$

Where:

- d0: previous distance

# Metronome system theory

**Active Learning (Constructivism)**

Students explore how tempo (BPM) affects beats and graphs through direct interaction.

**Graph Interpretation Skills**

- Current BPM graph → shows instant rate
- Cumulative Beats graph → shows accumulation
- Builds intuition about slope and rate of change

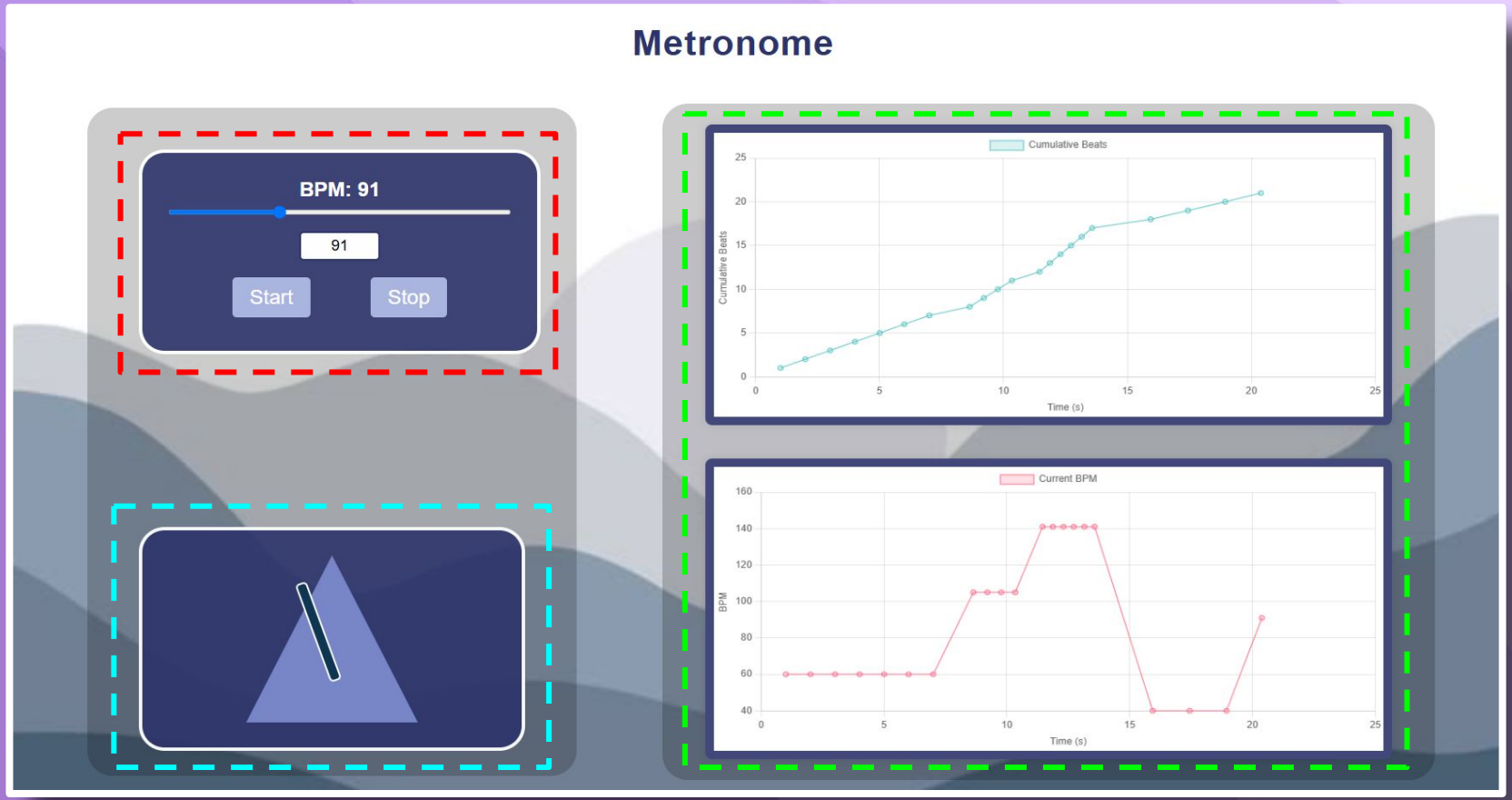
**Real-Time Feedback**

Immediate visual updates help students connect actions to outcomes.

**Cross-Disciplinary Concepts**

Applies to Math (functions), Physics (rate vs. cumulative). Promotes visual, interactive, and applied understanding of time-based data.

# Metronome system view



# Metronome System Contents

### Control System

- Start / Stop buttons control data flow
- Scrollbar adjusts BPM in real-time

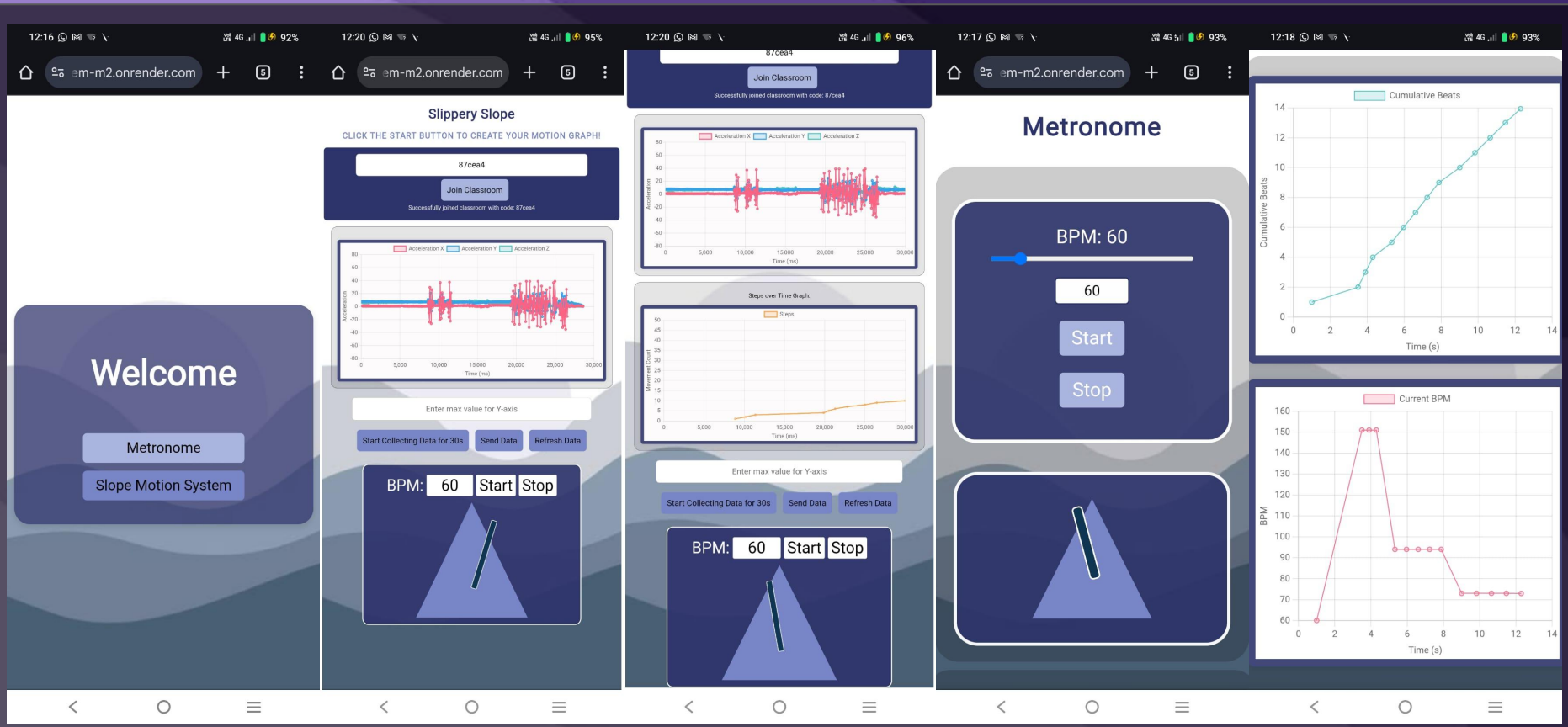
### Visual Feedback

- Live metronome shows current tempo
- Reinforces understanding of beat intervals

### Graphical Insights

- Current BPM Graph: Shows real-time tempo changes (rate)
- Cumulative BPM Graph: Shows total beats over time (accumulation)

# Mobile view


Welcome
Metronome
Slope Motion System
Slippery Slope
CLICK THE START BUTTON TO CREATE YOUR MOTION GRAPH!
87cea4
Join Classroom
Successfully joined classroom with code: 87cea4
Enter max value for Y-axis
Start Collecting Data for 30s
Send Data
Refresh Data
BPM: 60 Start Stop
Steps over Time Graph:
Metronome
BPM: 60
60
Start
Stop
Cumulative Beats
Time (s)
Current BPM
BPM

# Frequently Asked Questions

**How does the system capture motion data?**

It uses a smartphone's built-in MEMS accelerometer to record acceleration along X, Y, and Z axes as students move.

**Do I need any additional hardware?**

No extra hardware is required beyond a smartphone (or any device with an accelerometer) and an internet connection to access the web-based interface.

**Can teachers track student data in real time?**

Yes. Teachers can receive students' motion data live, view graphs instantly, and compare multiple submissions simultaneously.

**Can I download the graphs and data?**

Yes. Graph images and data files (e.g., CSV) can be downloaded for offline analysis, assignments, or further classroom discussion.

# Frequently Asked Questions

**Can multiple classes run at the same time?**

Yes. The system supports unique class codes so multiple classrooms can operate independently without interference.

**How is student privacy handled?**

Data is only shared within the assigned classroom environment and is not stored permanently on external servers.

**What is the main purpose of the Slope-Motion-System?**

The system helps students intuitively understand mathematical concepts like slope, derivatives, velocity, and acceleration through interactive motion experiments and real-time visualization.

**What is the metronome system used for?**

The metronome system provides auditory feedback that helps students understand the concept of rate and periodicity, connecting motion graphs with rhythmic beats

# Team

Name of all ppl in the team and Description