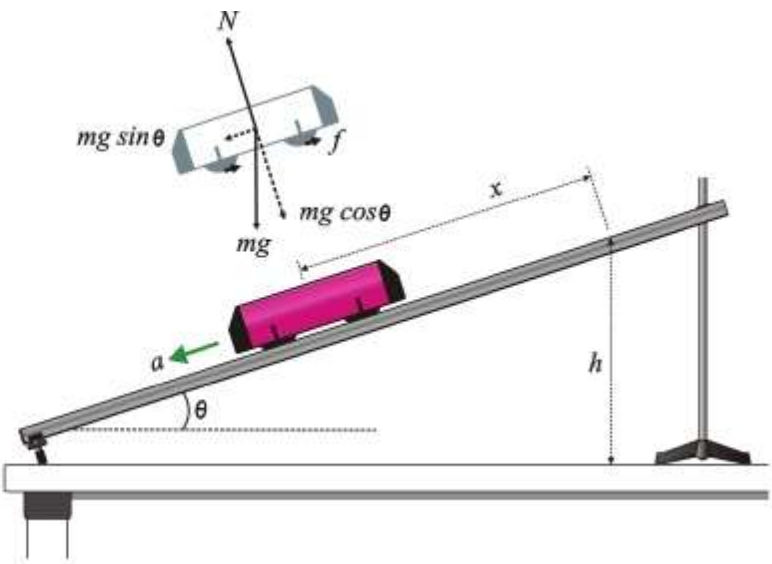
Motion on an Inclined Plane

Draw and compare distance, velocity, and acceleration graphs of a cart based on the angle of the inclined plane..

Fundamental Concept

1. **Motion of a Cart on an Inclined Plane**

A cart on an inclined plane experiences a gravitational force mg. Considering friction f, the force causing the cart's motion and the corresponding acceleration can be expressed as



$$F = ma = ma(\sin\theta - \mu\cos\theta)$$

$$a = \frac{F}{m} = g(\sin\theta - \mu\cos\theta)$$

Let's calculate the position and speed of a cart starting from rest on an inclined plane without considering friction. Let v be the speed as the cart descends the plane, v be the speed immediately after descending, and L be the length of the inclined plane. Since the height $h = Lsin\theta$

$$x = v_0 t + \frac{1}{2}at^2 = \frac{1}{2}gsin\theta t^2$$

$$v = \sqrt{v_0^2 + 2ax} = \sqrt{2gxsin\theta}$$

$$v' = \sqrt{2gLsin\theta} = \sqrt{2gh}$$

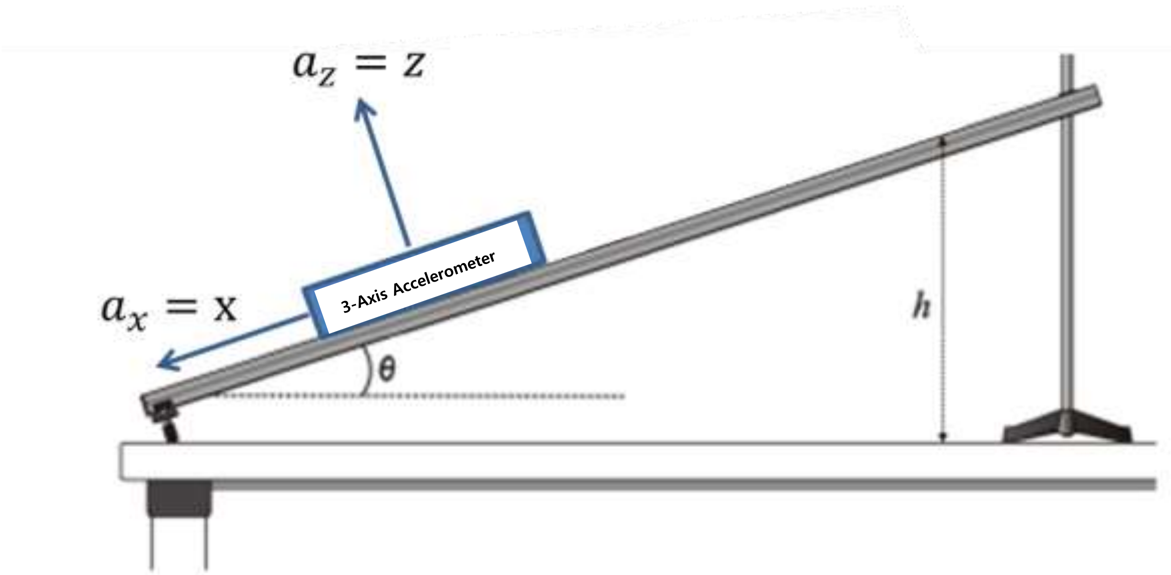
Based on this theory, let's experimentally investigate the relationship between the slope of the inclined plane and the acceleration of the cart.

2. Determining the Slope of the Inclined Plane Using a 3-Axis Accelerometer

When the 3-axis accelerometer is placed on a stationary inclined plane, the y-axis reads 0, and the sum of the x and z-axis readings equals 1g (=9.8 m/s²). The slope θ can be determined using the x and z values.

$$\tan(\theta) = \frac{x}{z}$$

$$\therefore\ \theta = tan^{-1}(\frac{x}{z})$$



Experiment

Materials Needed

Interface, Science# program, Smart device, Motion sensor, Mechanics experiment apparatus, Stand, Ruler

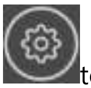
Experiment Preparation

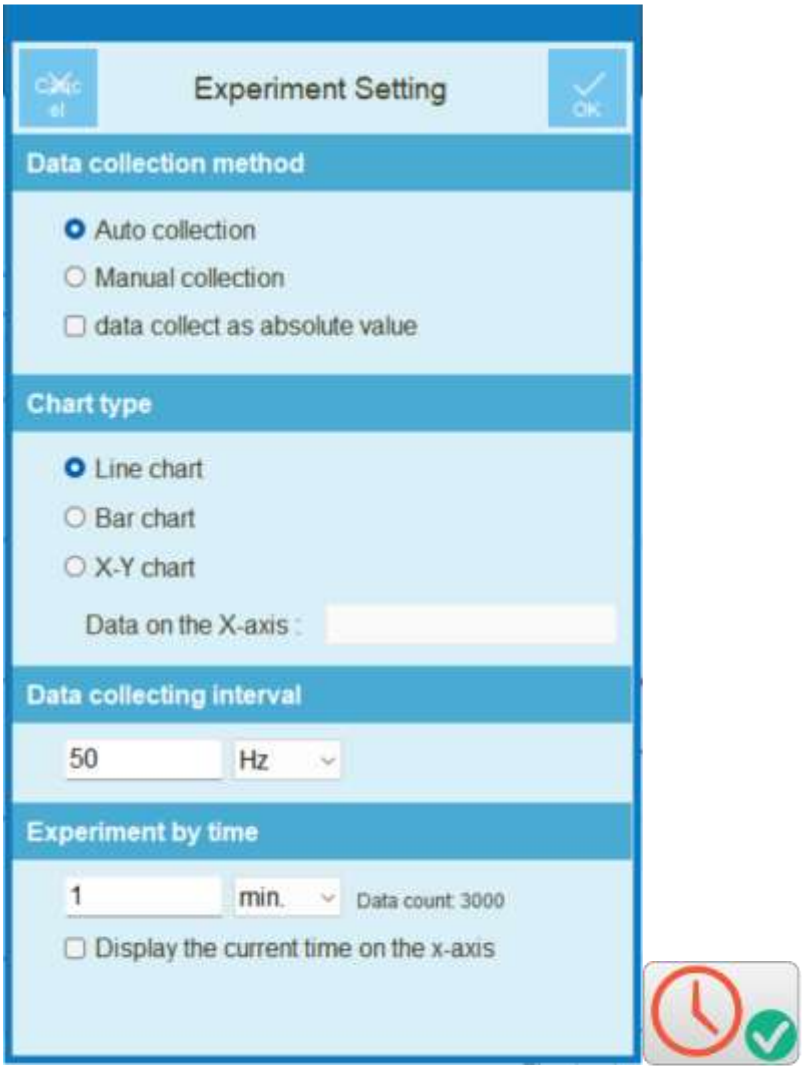
1. Set up the mechanics experiment apparatus and motion sensor as shown in the picture.

2. Calculate the height h of the rail for angles θ of 5°, 10°, and 15° using the length L of the rail and trigonometric functions or a 3-axis accelerometer.

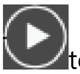
3. Adjust the height h to fix the rail at an angle θ of 5°.

Interface Setup

1.  Run the Science# program.
2. Connect the motion sensor to the interface
3. Press to set up the experimental environment as shown below or press for automatic setup.



Data Collection

1. Press to start data collection.
2. Place the cart 0.15 m away from the motion sensor and release it to measure the time-distance graph of the cart
3. When the cart's motion ends, press to stop data collection.
4. Add a new chart.
5. Using the same method as steps #1-#3, increase the rail angle θ to 10° and 15°, and measure the time-distance graph of the cart.

Data Analysis

Recording Data

1. Using the following formula, predict the acceleration based on the angle θ of the inclined plane.

$$a = \frac{F}{m} = g\sin\theta$$

Angle (°)	5	10	15
Predicted Acceleration (m/s²)			

2. Draw the time-distance graph of the cart for angles θ of the inclined plane (5°, 10°, 15°) on a single chart.

   Combine the three data sets and use [Analysis] - [Data Transformation (X-axis)] to enter the appropriate value in the 'B' field to align the start time of the cart's movement.

Data Application

1. Differentiate the time-distance graph based on the angle θ of the inclined plane using [Analysis] - [Differentiate] to draw the time-velocity graph. Analyze the time-velocity graph again using [Analysis] - [Linear f(x) = Ax + B] to determine the acceleration A of the cart based on the angle θ of the inclined plane..

2. Based on the analyzed graph, record the experimentally obtained acceleration A of the cart for each angle θ of the inclined plane.

Angle (°)	5	10	15
Acceleration (m/s^2)			

3. Explain the relationship between the angle θ of the inclined plane and the acceleration of the cart based on the experimental results.

4. Compare the predicted acceleration with the experimentally obtained acceleration. If they do not match, explain the possible reasons.


Report
(For Teachers)

Report
(For Students)