PCS 211 Lab 2 : Graphical Analysis of Kinematics

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1 Introduction

We shall in the due process of the laboratory experiment, aim to study how motion changes over time through the utilization of motion detectors and video analysis tools.

We then shall aim to understand the graphical and mathematical representations of one-dimensional motion from this laboratory.

2 Theory

Before beginning this investigation we must know the methods and the theory behind the investigation and the due course of action.

2.1 Velocity Measument

We shall be measuring the velocity of the Vernier Dynamics Cart by the use of Vernier Motion Sensor that measures instantaneous velocity by calculating minute changes in position from the reference observer. Mathematically,

$$\overrightarrow{v} = \lim_{\Delta t \to} \frac{\Delta \overrightarrow{x}}{\Delta t} = \frac{dx}{dt}$$

2.2 Acceleration Measurement

We shall be calculating the acceleration of the Vernier Dynamics Cart by the use of data sets of velocity that we obtain from the Vernier Sensors that measures instantaneous velocity.

We shall aim to calculate the acceleration of the cart by considering the ratio of the difference of two velocities of the cart and the time interval between them. Mathematically,

$$\overrightarrow{a} = \frac{\Delta \overrightarrow{v}}{\Delta t} = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

3 Materials Required

- Vernier Dynamics Cart
- Vernier Motion Sensor
- Vernier LoggerPro software
- Vernier Computer interface
- Aluminum Tract
- Lab Jack
- Protractor/angle finder
- Video clip of tossed ball

4 Procedure

4.1 Experiment 1

1. Connect the motion detector software to the computer's hardware, ensure all electronics are switched on and in good working order
2. Utilizing the lab jack and the protractor, angle the track at 15 degrees
3. Adjust the motion detector and cart, so they will not be closer than 15cm from each other
4. Take the cart to the initial position and prepare to release
5. Press play, then release the block. If performed correctly, you should see two graphs on the logger pro software
6. In the data seems inaccurate, try adjusting the cart and re-attempting
7. Using the software to form a line of best fit, then record the data
8. Clear the data once saved and repeat it three more times
9. Save and Export the data once done

4.2 Experiment 2

1. Ensure all technological equipment is switched on and functioning just as before **Experiment 1**
2. Position the cart at the bottom of the ramp, then push it up the ramp hard enough that it reaches the top but not too hard that it hits the sensor
3. Using logger pro press play and record the data
4. Using the software create a linear best fit
5. Save and export the data once done

4.3 Experiment 3

1. Open the bouncing ball video provided
2. Watch the video a few times till you get a general understanding of the motion of the ball
3. Utilizing the pause, play, forward and rewind controls advance the video to an instance where the ball leaves contact with the ball for the first time
4. Play the video and use a painting tool to plot the parabola-shaped motion of ball ascent and descent
5. Once completed, fit a cure to the data on the x data and y data
6. Save and export the data once done

5 Experimental Data

All the collected laboratory data can be found in the files attached consequently with this laboratory report.

Trials	Results
1	$m = 0.9983$ $b = -0.2711$ $r = 0.9909$
2	$m = 1.163$ $b = -0.2814$ $r = 0.995$
3	$m = 1.005$ $b = 0.2814$ $r = 0.9890$
4	$m = 0.9977$ $b = -0.0483$ $r = 0.9884$

6 Analysis

As discussed above there are 3 cases/methods to find the density of the metal block as there are 3 ways to find the volume of the metal block and there is only one way to find the mass of the metal block.

6.1 Experiment 1

6.1.1 Standard Deviation of Uncertainity

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$$s^2 = \frac{\sum (x_i - \bar{x})^2}{n-1} \approx 0.08328$$

6.1.2 Predicted Acceleration using $g \sin\theta$

$$|\overrightarrow{a}| = g\sin\theta$$

$$|\overrightarrow{a}| = 9.81 \sin(15^\circ \pm 0.03^\circ) \approx 2.5m/s^2 \pm 0.03m/s^2$$

6.1.3 Uncertainity

We have,

$$\Delta\overrightarrow{a} = 0.03 \times \frac{\pi}{180} \approx 5.3 \times 10^{-4} m/s^2$$

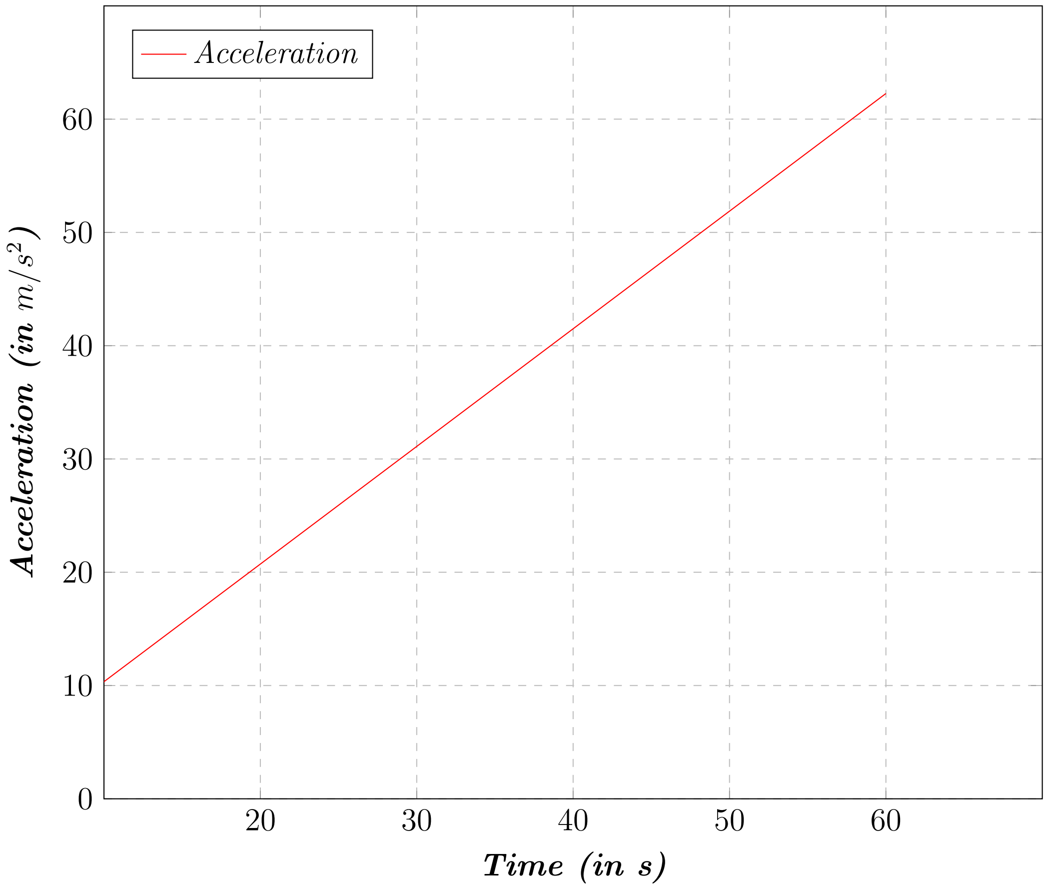

Figure 6.1: *Graph in relation to the **regression line** of **acceleration** versus **time***

6.2 Experiment 2

6.2.1 Experimental Measurement of Acceleration

$$|\overrightarrow{a}| = 1.7 m/s^2$$

Components	Constants
x component	$x = -3.323$ $b = -0.003531$
y component	$a = -4.723$ $b = 6.321$ $c = -0.0265$

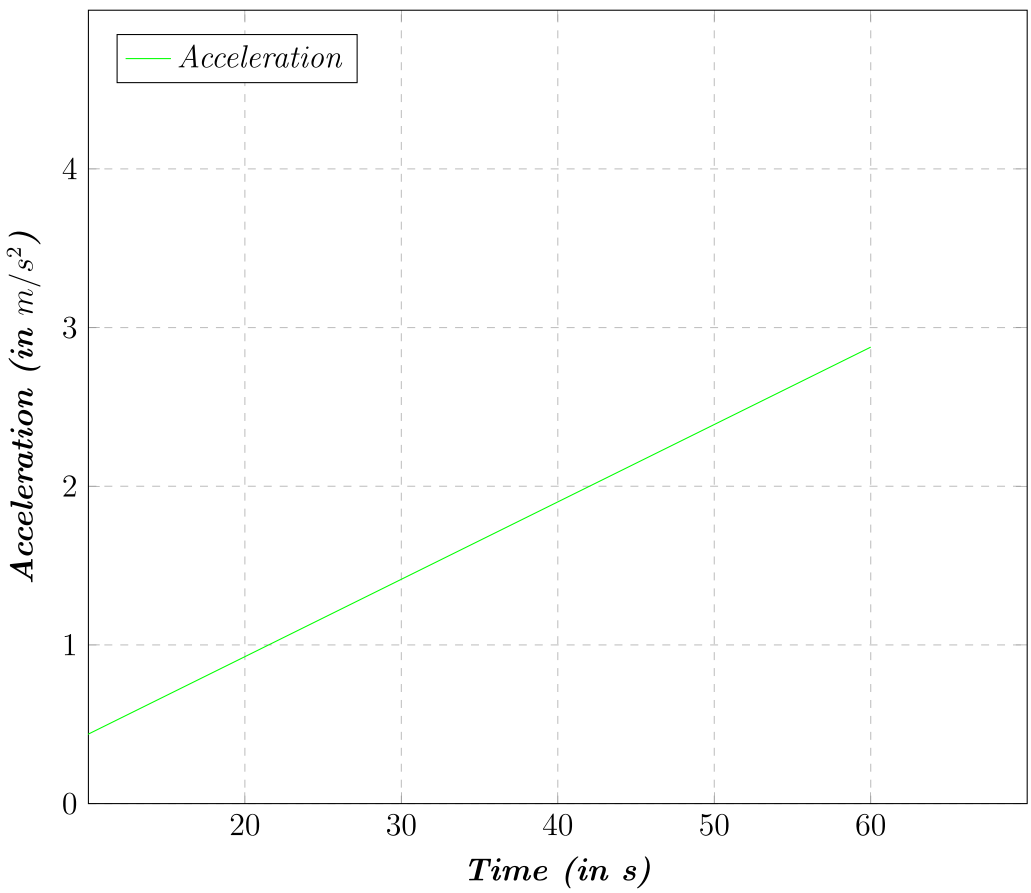

Figure 6.2: *Graph in relation to the* ***regression line*** *of* ***acceleration*** *versus* ***time***

6.3 Experiment 3

6.3.1 Ball's Acceleration while in the air

We can calculate the acceleration by using the kinematic formula using the initial velocity, final velocity and time taken between the two intervals of the recorded velocities.

$$v_f = v_i + at$$

$$a = \frac{v_f - vi}{t}$$

$$\implies a = 2.36m/s^2$$

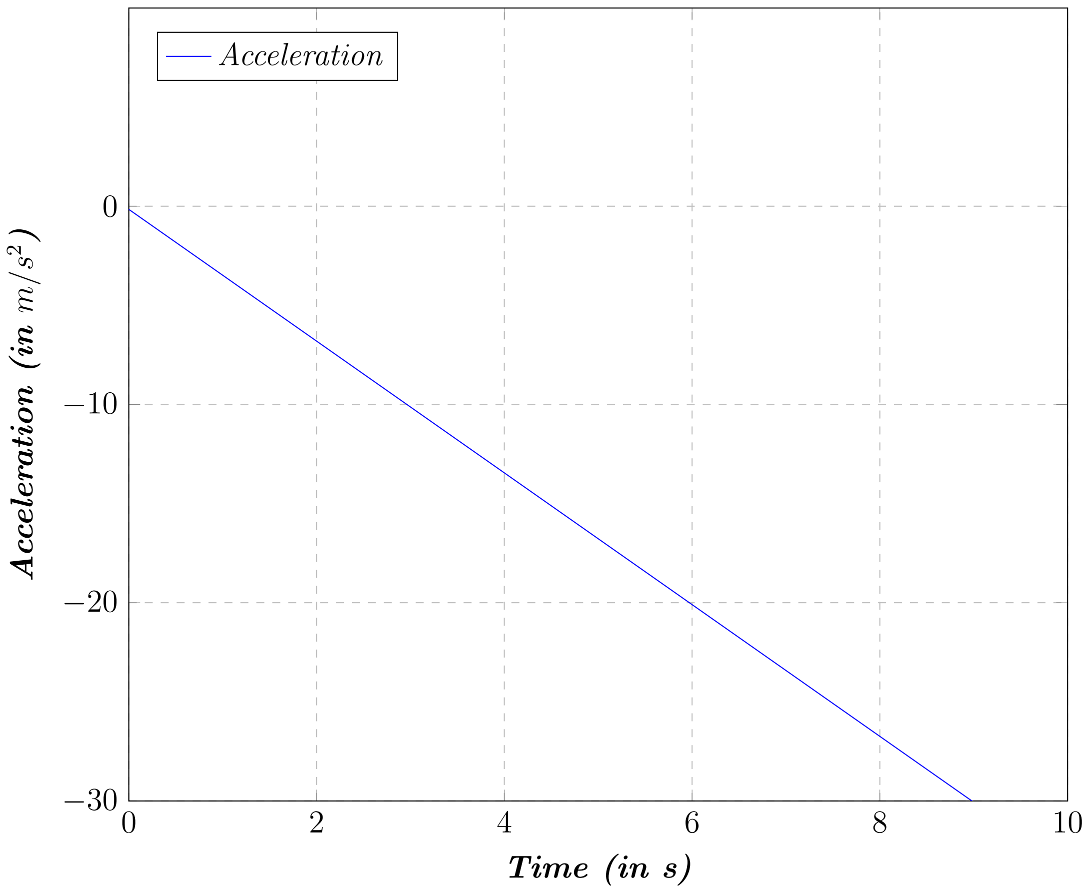

Figure 6.3: *Graph in relation to the* ***regression line*** *of* ***acceleration*** *versus* ***time***

7 Conclusion

In this lab report, we have investigated and studied how one-dimensional motion changes with gradation in time using motion detectors and video analysis tools.

We had further analysed the uncertainties in measurement of the calculated acceleration by estimating and calculating the variation within the theoretical and actual values of acceleration. In this dure process we had come to a conclusion that the actual acceleration was not too accurate when compared to the theoretical values of acceleration. The physical calculation method presented us with great uncertainities that were not intially thought of.

We had finally come to some conclusion that :

1. The accelerations are similar because the equation for acceleration is g sin theta stays constant
2. The first experiment initiates the cart from 0 while the second experiment gradually reaches 0, leaving the acceleration to be very similar
3. The force was used to push the cart up the ramp was inculed in the calculation (thus some uncertainity in measurement) is very similar to the gravitational force that was used to bring the cart down the ramp
4. The predicted and calculated acceleration are not relatively consistent with each other

Bibliography

[1] Serway, R. A., Jewett, J. W. (2018). Physics for Scientists and Engineers. Cengage Learning.