Experiment 4: Momentum and Impulse

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Discussion

Measurement of Momentum and Impulse

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Impulse is the change in momentum of a body. In this experiment, two different methods of calculating impulse of a glider on an air track colliding with a force sensor were employed and the relationship between the methods was investigated. For the first method, the glider was weighed and the initial and final velocities of the glider were recorded before and after the collision using a photogate and flag. Then the impulse was calculated by taking the difference of initial and final momentum. For the second method, the readings on the force sensor were recorded for each time interval and a graph was plotted. The integration of force with respect to time gives the impulse and this was obtained by calculating the area under the graph using middle point Riemann sums. The two methods of calculation gave same results within some experimental margin of error. This experiment was performed for learning how to calculate the momentum and impulse for a moving body and verifying that the two methods give the same result for the value of impulse.

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Measured Values

Mass of glider: 203.0 $\pm$ .05 g

Width of photogate flag: 3.8 $\pm$ .05cm

Calculated calibration constant (Figure 4.1): -6.286$\pm$ .008 N/V

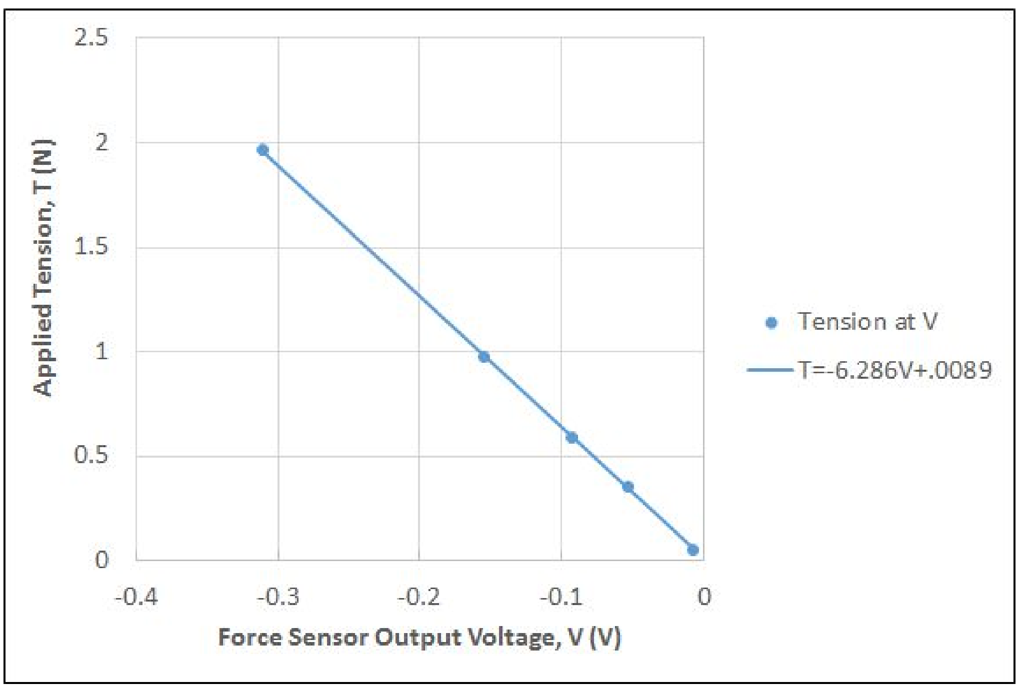

Figure 4.1 Plot of the force sensor output voltage versus the applied tension to calibrate the force sensor. The best fit line has equation: T=-6.286V+.0089. The calibration constant is the slope:-6.286$\pm$ .0008 N/V

Impulse Calculation - Method 1

Velocity of glider towards the force sensor was considered negative and away from the force sensor was considered positive.

Trial 1 - Slow Collision	**Velocity (m/s)**
Initial Velocity	-0.118154$\pm$.0000005
Final Velocity	0.091456$\pm$.0000005
Trial 2 - Fast Collision	
Initial Velocity	-0.395023$\pm$.0000005
Final Velocity	0.210543$\pm$.0000005

Table 4.1 Velocities recorded by the photogate for the two trials.

The mass of glider: .2030 $\pm$.00005 kg

Momentum, P is given by:

$P = mv$ where m is the mass and v is the velocity

Impulse is the change in momentum, it is given by

$\Delta P = P_f - P_i = m\,(v_f - v_i)$

Using this formula and the data recorded in Table 4.1, Impulse for trial 1,

$\Delta P_1 = 0.0425 \pm .00005\ Ns$

Impulse for trial 2,

$\Delta P_2 = 0.1229 \pm .00005\ Ns$

The uncertainty is the same as the uncertainty in mass of glider.

Impulse Calculation - Method 2

Impulse is also given by

$$\Delta P = \int F(t)dt$$

The integration was performed using the method of Riemann Sums using midpoints of rectangles.

$$\Delta P = \int_{t_1}^{t_n} F(t)dt \approx \Delta t \sum_{i=1}^{n} \overline{F}(t_i)$$

Where Δt is the time interval of recording and $\overline{F}(t_i)$ is the average of the force reading at t_{i+1} and t_i.

Thus, $\Delta t = t_{i+1} - t_i = .0005$ and $\overline{F}(t_i) = \frac{F(t_i)+F(t_{i+1})}{2}$

The data recorded by the force sensor was transferred to an Excel sheet. Then the voltage was multiplied by the calibration coefficient and the average background force reading was subtracted. The data obtained was then plotted in Figure 4.2 and Figure 4.3. Using the aforementioned formula, the numerical integration of the force profiles was calculated and the following results were obtained:

Trial 1 (Data plotted in Figure 4.2),
$\Delta P_1 = 0.0427 \pm .00008\ Ns$

Trial 2 (Data plotted in Figure 4.3)
$\Delta P_1 = 0.1192 \pm .00008\ Ns$

The fractional uncertainty is the same as the fractional uncertainty in calibration constant.
$\frac{\delta k}{k} = \frac{\delta P}{P}$

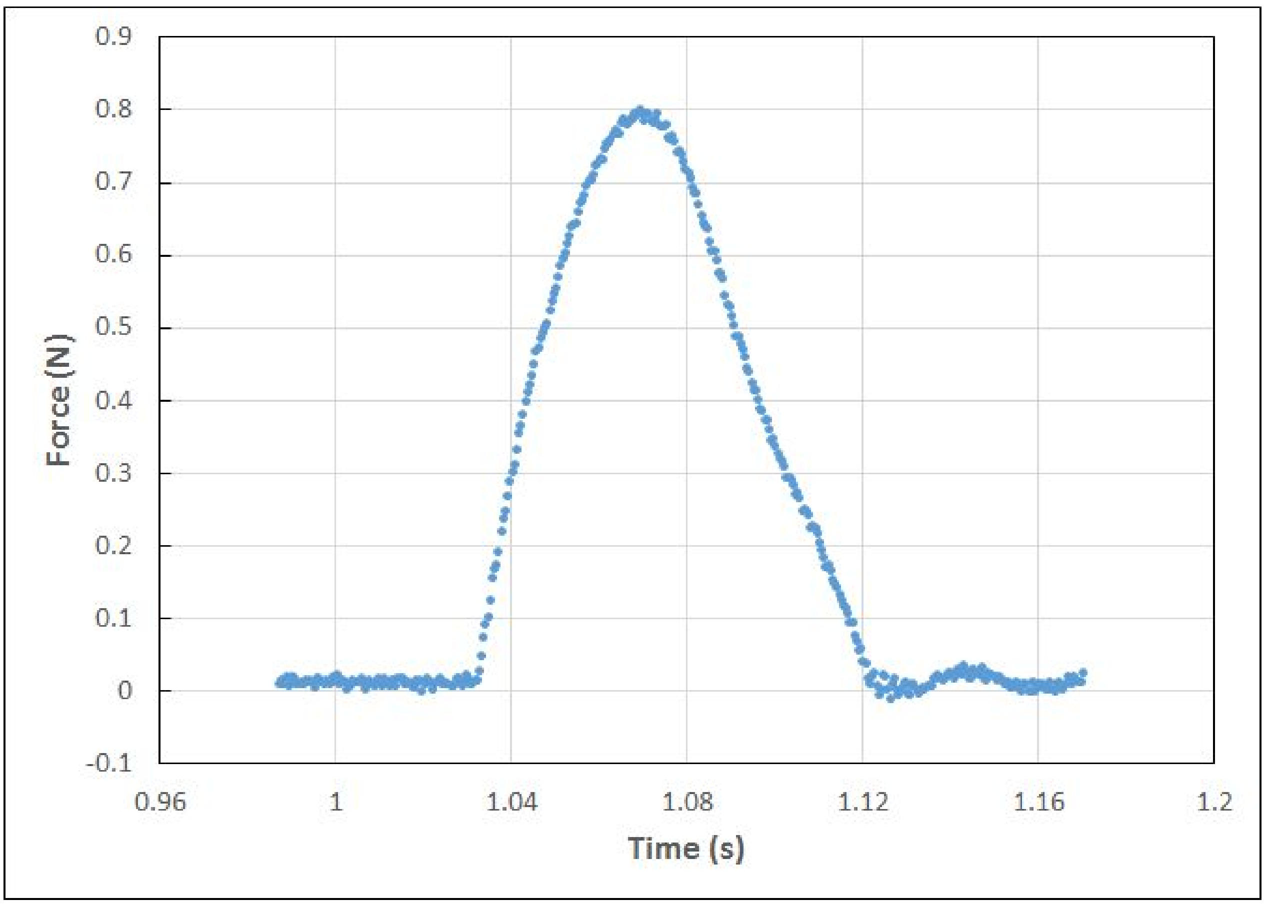

Figure 4.2 Graph for Trial 1, a glider with flag moving with a slow velocity. The points represent the recorded force sensor readings converted to force in Newtons at each time interval for before, during and after the collision. The area under the curve is the measure of the impulse of collision.

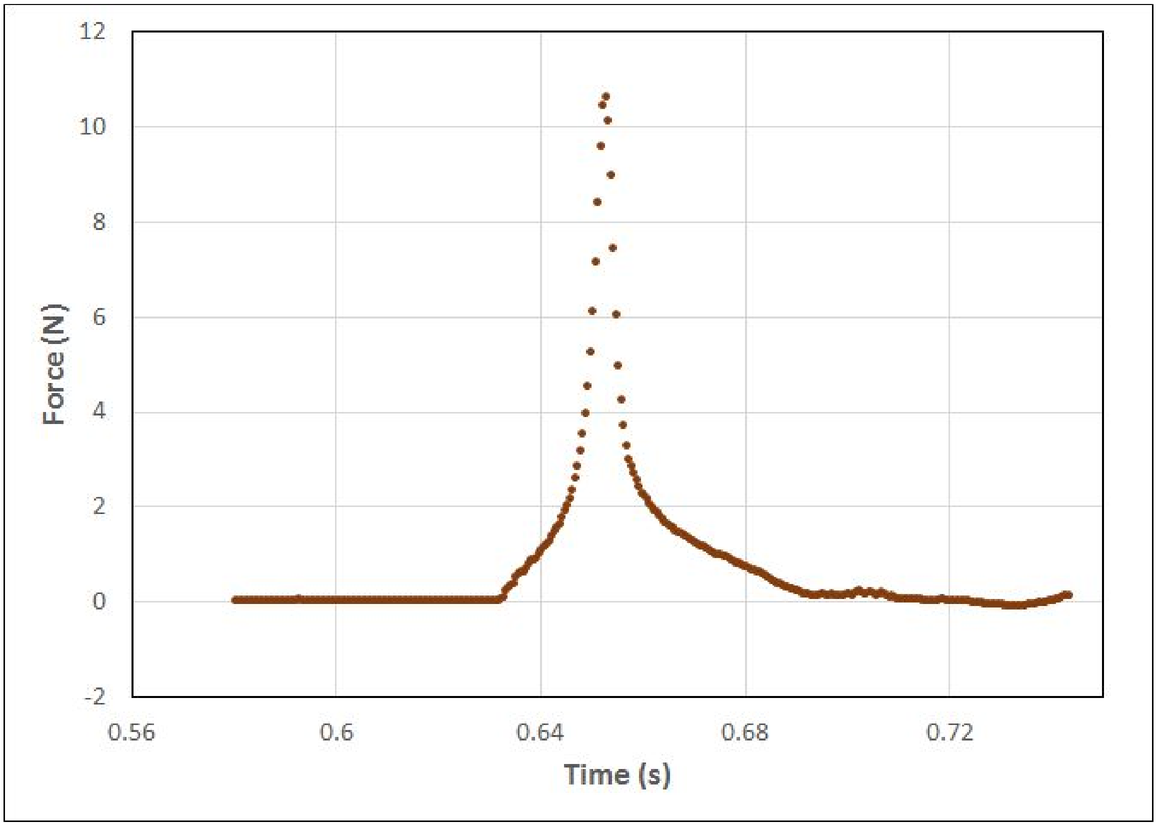

Figure 4.3 Graph for Trial 2**,** a glider with flag moving with a fast velocity. The points represent the recorded force sensor readings converted to force in Newtons at each time interval for before, during and after the collision. The area under the curve is the measure of the impulse of collision.

Results

Method 1 (Change in momentum)	**Impulse**
Trial 1	$\Delta P_1 = 0.0425 \pm .00005\ Ns$
Trial 2	$\Delta P_2 = 0.1229 \pm .00005\ Ns$
Method 2 (Integration using Riemann sum)	
Trial 1	$\Delta P_1 = 0.0427 \pm .00008\ Ns$
Trial 2	$\Delta P_1 = 0.1192 \pm .00008\ Ns$

Table 4.2 Results of the experiment for both trials and for both methods of impulse calculation.

The results in table 4.2 show that the two methods of calculating impulse produce results which are equal within some margin of error. The trial with faster collision has a higher difference in the impulse obtained from the two methods. This might be because of higher "ringing" after collision due to which some error in Riemann sum might creep in.

Presentation Mini-Report

Introduction

In mechanics, impulse is a vector quantity that was first studied along with force and momentum by physicists like Sir Isaac Newton. The S.I. unit of impulse is the same as the S.I. unit of momentum, which is Ns. Impulse is defined as the change in the linear momentum of a body. It is also defined as the integral of force acting on a body over the time period that the force acts. The objective of the current experiment was to learn how to apply these two definitions for impulse calculation and to verify that these two methods produce the same result. For achieving this, a glider on an air track was setup with a flag attached to the glider. Then the glider's collision with a force sensor was observed using a photogate. The velocities measured by the photogate before and after the collision were used for calculating the impulse using the first definition. For the second method, the readings on the force sensor were recorded for each time interval and a graph was plotted. Then the force profile was integrated by using the method of middle point Riemann sums to obtain the impulse. The two values obtained were compared for verifying that the results produced are equal within some margin of error.

Methods

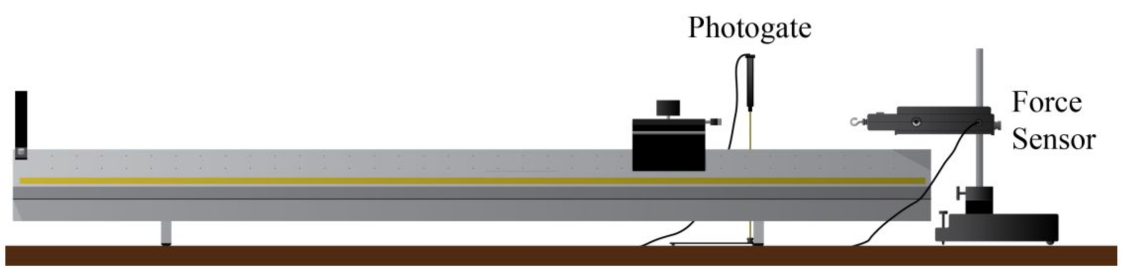

Figure 4.4 Experimental setup for calculating impulse.

The first step for the experiment was calibrating the force sensor. The force sensor was connected to PASCO and 'voltage' was selected as the user defined measurement. Then five masses were weighed (5.1g, 35.8g, 60.3g, 99.8g, 200.6g) and were hung freely one by one and the voltage reading was recorded in an Excel sheet. A graph was plotted for the applied tension versus force sensor reading (Figure 4.1) and the best fit line was obtained. The slope of the best fit line gives the calibration constant that is used for converting force sensor reading to Newtons.

The mass of the glider was weighed using a balance and the width of the flag was measured using a scale. For setting up the experiment to measure impulse, the force sensor, photogate, glider with flag and frictionless air track were set up as shown in Figure 4.4. The force sensor and photogate were connected to PASCO and a pre-configured timer for one photogate was chosen. The width of the flag was input in the input field and the sample rate of the user defined sensor was set to 2kHz. The airtrack was turned on and the glider was slid first gently and then with some force towards the force sensor for a collision. The time, voltage and speed columns were recorded in a table for before, during and after the collision. The recorded readings between the two velocity readings were transferred to an Excel sheet.

Systematic errors were avoided or eliminated by various methods. It was ensured that the air-track was completely level to avoid an acceleration due to gravity of the glider which would result in systematic error in readings. The average background force reading was calculated and subtracted from all the force readings to eliminate the systematic error of the force sensor. While recording the weight of the glider and width of the flag, it was ensured that parallax was avoided by observing the scales perpendicularly.

For the first method of impulse calculation the mass of the glider and recorded velocities were used for subtracting the initial momentum (mv_i) from the final momentum (mv_f). For the second method, the reading of the force sensor were converted to force in Newtons using the calibration constant. Then the average background force reading was subtracted. Graphs were plotted for the Force versus time (Figure 4.2 and Figure 4.3) and the area under the curve was calculated by using mid-point Riemann sums method to give the impulse. The two calculated values of impulse for each trial were compared and it was found that both were extremely close.