ScienceCube

Impulse and Momentum

1. **Explain the relationship between impulse and momentum through experiments.**
2. **Compare and explain the results of impulse experiments using elastic and inelastic strings.**

Fundamental Concept

Impulse-Momentum Theorem

The impulse exerted on an object is equal to the change in the object's momentum, which is known as the impulse-momentum theorem. If the force exerted on the object during the collision is $\vec{F}$ and the collision time is Δt, then the impulse is the product of the force and the collision time, $\vec{F}\Delta t$. When the force is constant, it can be calculated as $\vec{F}\Delta t = m\vec{a}\Delta t = m\Delta\vec{v}$. Generally, even if the force is not constant, using the average force and average acceleration, the impulse-momentum theorem can be derived as follows:.

$$\overrightarrow{F_{av}}\Delta \mathrm{t} = \mathrm{m}\vec{a}\Delta \mathrm{t} = \mathrm{m}\Delta\vec{v} = \mathrm{m}\vec{P}$$

By integrating the force $\vec{F}$ over time, we get the same result:

$$\int_{t_2}^{t_1} \vec{F} dt = \vec{F}(t_2 - t_1) = \vec{F}\Delta t = \Delta\vec{P}$$

In a car collision, for example, the impulse received by the car is the difference between the momentum after the collision and the momentum before the collision. Similarly, in a collision between a large truck and a small car, the force on both vehicles is the same due to action-reaction pairs, and since the collision time is the same, the magnitude of the impulse is identical. Thus, the magnitude of the change in momentum is the same for both the truck and the car.

Impulse involves applying a force to change the state of motion of an object. In this experiment, the elastic force of a rubber band or the resistance to the cart's motion acts as the impulse..

Experiment

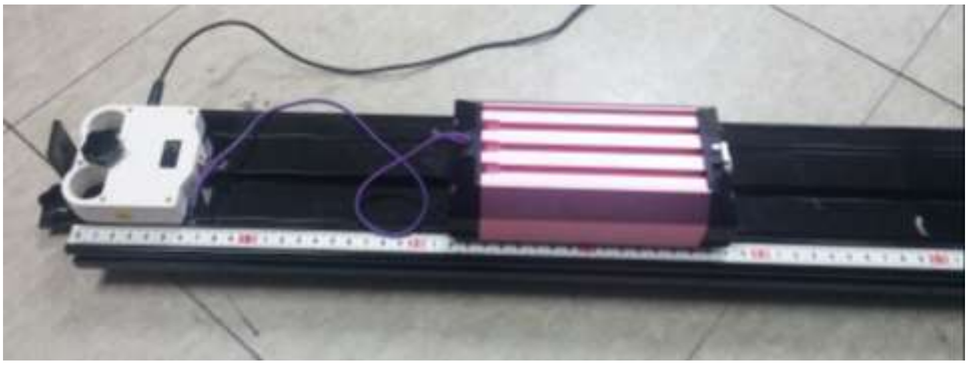
Materials Needed

Interface, Science# Program (Smart Device), Dynamics Experiment Setup, Rubber Band, String, Motion Sensor, Force Sensor

Experiment Setup

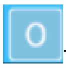
1. Balance the rail well and set it up on a desk or the floor.
2. Fix the motion sensor and force sensor at both ends of the rail as shown in the picture.

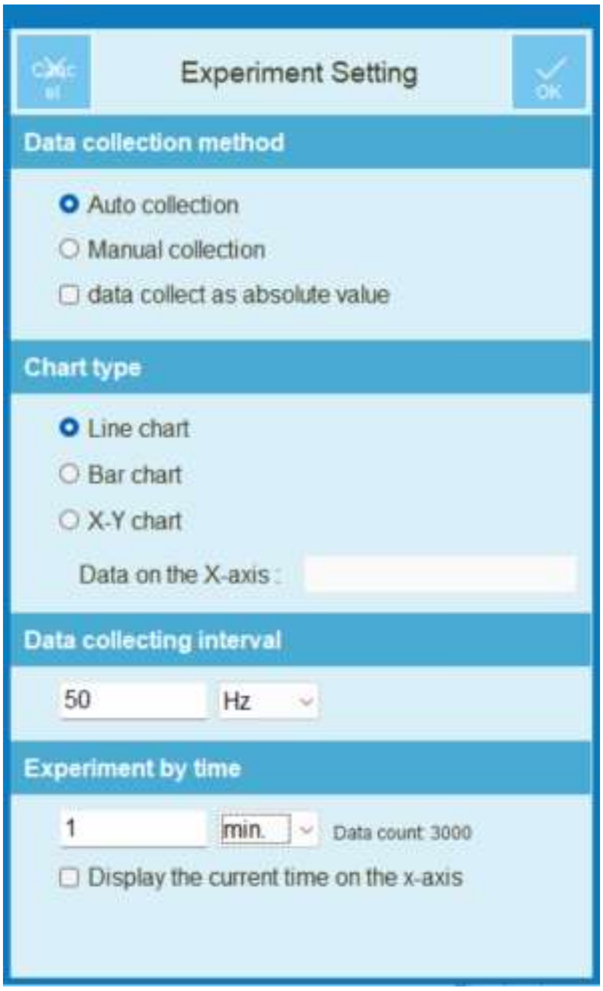

3. Measure and record the mass of the cart.
4. Connect the rubber band to the force sensor loop on one side and to the cart on the other side.



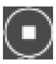
5. Practice gently pushing the cart towards the motion sensor so it slowly returns due to the elastic force of the rubber band. Ensure the force sensor does not move and the cart does not leave the rail. Also, ensure the rubber band does not interfere with the cart's motion.

Interface Setup

1. Launch the Science# program.
2. Connect the force sensor and motion sensor to the interface.
3. Press the button on the force sensor to zero it at 0N when the rubber band is not stretched.
4. Set up the experimental environment as shown below or use the automatic setting option. 



Data Collection

1. Press the button to start collecting data.
2. Push the cart towards the motion sensor.
3. When the cart returns, press the button to stop collecting data.
4. Replace the rubber band with a non-elastic string and repeat the experiment in the same way.
5. Press  the button to end data collection..

Data Analysis

Recording Data

1. Using the elastic rubber band, push the cart and record the time-distance and time-force graphs of the cart's motion.

2. Using the non-elastic string, record the time-distance and time-force graphs of the cart's motion..

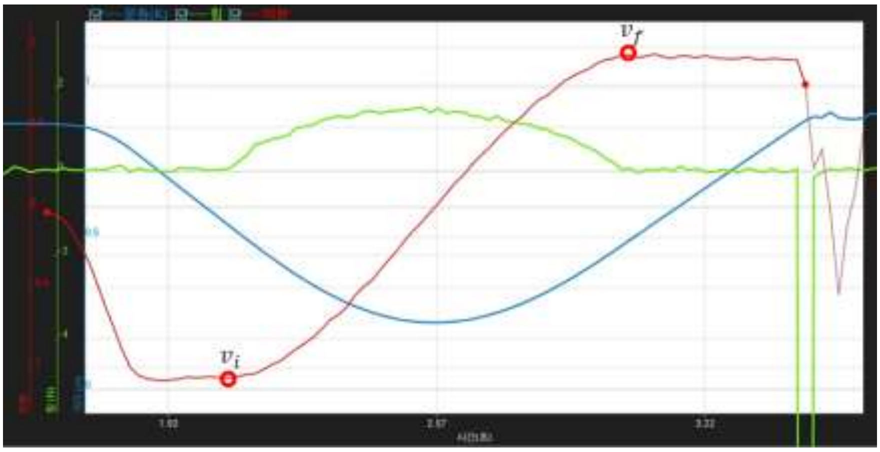
Data Application

1. Measure and record the mass of the cart..

Mass of the cart m	(kg)

2. Differentiate the time-distance graph to get the time-velocity graph, and use statistical analysis on the time-force graph to find the average force in the non-zero force section. Complete the table below using analysis functions.

   [Finding final velocity and initial velocity] – Example



[Finding average force F] – Example

Connection	Final velocity vf	Connection vi	Final velocity F	Connection Δt
Rubber Band	(m/s)	(m/s)	(N)	(s)
String	(m/s)	(m/s)	(N)	(s)

3. Use the data to calculate the impulse and the change in momentum of the cart, and verify if the impulse matches the change in momentum. If they do not match, explain the reasons for the discrepancy.

Connection	Impulse ($\overrightarrow{F_{av}}\Delta$t)	Change in momentum ($\mathrm{m}\Delta\vec{v}$)

Rubber Band	(N·S)	(kg·m/s)
String	(N·S)	(kg·m/s)

4. Compare and explain the differences between the experiments with the elastic rubber band and the non-elastic string.