PCS 211 Lab 5 : Conservation of Momentum

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1 Introduction

We shall, in the due process of the laboratory experiment, aim to demonstrate the validity of the fundamental principle of the conservation of momentum, which states that the sum of the initial momenta before any work done by internal energies is equal to the sum of momenta after work done by internal energies.

We aim to validate this experiment's principle of conservation of momentum by investigating and analyzing the effects of two carts following an elastic collision and an inelastic collision.

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 Momentum

Momentum is defined as the scalar product of mass and velocity. Mathematically,

$$p = mv$$

According to the principle of conservation of momentum, in a closed system, the net change in momentum is always zero. Mathematically,

$$\sum_{i=1}^{n} \Delta p = 0$$

Rewriting this expression mathematically we have,

$$\sum_{i=1}^{n} p_i = \sum_{i=1}^{n} p_f$$

Applying the above equation to our experiment we have,

$$m_1 v_{i_1} + m_2 v_{i_2} = m_1 v_{f_1} + m_2 v_{f_2}$$

In a special case where if we are to have a inelastic collision (same final velocity for both the masses), our expression would reduce to,

$$m_1 v_{i_1} + m_2 v_{i_2} = (m_1 + m_2)\, v_f$$

2.2 Kinetic Energy

Kinetic Energy is defined mathematically as,

$$K = \frac{1}{2} m v^2$$

3 Materials Required

- Vernier Computer Interface
- Logger Pro Software
- 2 Vernier Carts with magnets & velcro attachments
- Aluminum Track
- 2 Vernier Motion Sensor
- Additional mass (500g)

4 Procedure

1. Each cart's mass, including the weight of any attached items, was measured and recorded, along with an estimate of its uncertainty.
2. The Vernier Computer interface's CH1 and CH2 ports were used to connect the two motion sensors.
3. On both ends of the track, sensors were positioned. The sensors' swivelling heads were turned such that they now faced away from the table.

4. LoggerPro was configured with the necessary options. In order to make sure everything was operating as it should, a few test runs were performed.
5. For the velcro pads on the two carts to adhere to one another when they collided, they were positioned to face one another.
6. We extracted cart "1"'s pre-collision velocity and both carts' post-collision final velocities using LoggerPro.
7. A sufficient amount of mass was added to cart 1 such that its mass increased by at least 50%. Uncertainty was used to record the new cart's mass to get the initial and final velocities for this set of masses.
8. The mass on cart 1 was taken off and put on cart 2. Uncertainty occurred when the two new masses were recorded to get the initial and final velocities for this set of masses.
9. The magnets on the ends of the carts should be positioned, so they face one another. When we were confident that our strategy was sound, we hit play on LoggerPro to start collecting data and sent cart "1" hurtling into cart "2".
10. As was done for the perfectly inelastic collision, LoggerPro software was used to measure the velocity of cart "1" before the collision and the final velocity of each cart after the impact.
11. Mass was added to cart 1 to raise its overall mass by 50%. The cart's updated mass was noted. Repeating the steps, we can see that we measured and recorded this group of masses' initial and final velocities.
12. Take the weight out of cart 1 and put it in cart 2. Cart 2 now has a heavier weight as a result. After recording the new masses of each cart, we repeat the steps to determine the initial and final velocities for this set of masses.

5 Experimental Data

Please find attached the experimental data in a seperate file alongside the report.

6 Analysis

In this particular lab experiment, the component of physics known as circular motion was introduced. This area of physics analyzes the fundamental behavior and laws that an object adhere's to when the object moves around a circular path. An important part of this is circular acceleration, or as it's known as centripetal acceleration. Therfore we have,

$$a_c = \frac{v^2}{r}$$

Where v is the velocity and r is the radius of the circular motion.

Combining Newton's 2nd law with the above experession, we have,

$$F = ma = \frac{mv^2}{r}$$

The circular motion also comprises circular velocity, which is the velocity of the object moving along the circumference of a circle. Through the circular velocity the relationship between velocity and period(T) is found to be,

$$v = \frac{\Delta x}{\Delta t}$$

The equation can be expressed in terms of a circle. For example, the distance(x) can be further denoted as the perimeter of the the circle's circumference which $2\pi r$. The time(t) can also be denoted as period(T) which is the time taken to complete one cycle specified by a given point. Therfore we have,

$$v = \frac{\Delta x}{\Delta t} = \frac{2\pi r}{T}$$

In this experiment to determine the spring force(F_s), the mass meter was used. The mass meter was attached to the mass(m), and the spring and the mass were pulled directly over the pin; the readings of the mass determined by the mass meter was denoted as M.

In order to calculate the force of the spring, the M value must be converted into F_s. To do this, it must be understood that the mass meter is no different than a hanging scale. A hanging scale measures the force of gravity of an object from the object's mass, the mass is hung on the scale and it is measured. Similarly, in this situation, the mass was hung on the scale, but instead a pulled force was applied, however the same instrument mechanics were applied. This implies that,

$$F_s = Mg$$

As it could be seen from the experiment, the results were calculated with fixed variables, to ensure accuracy. For example, for each time variable determined, there were 20 revolutions made. So although time is given, it is based on time required for 20 revolutions. However, period(T) is defined by the time required for a single revolution.

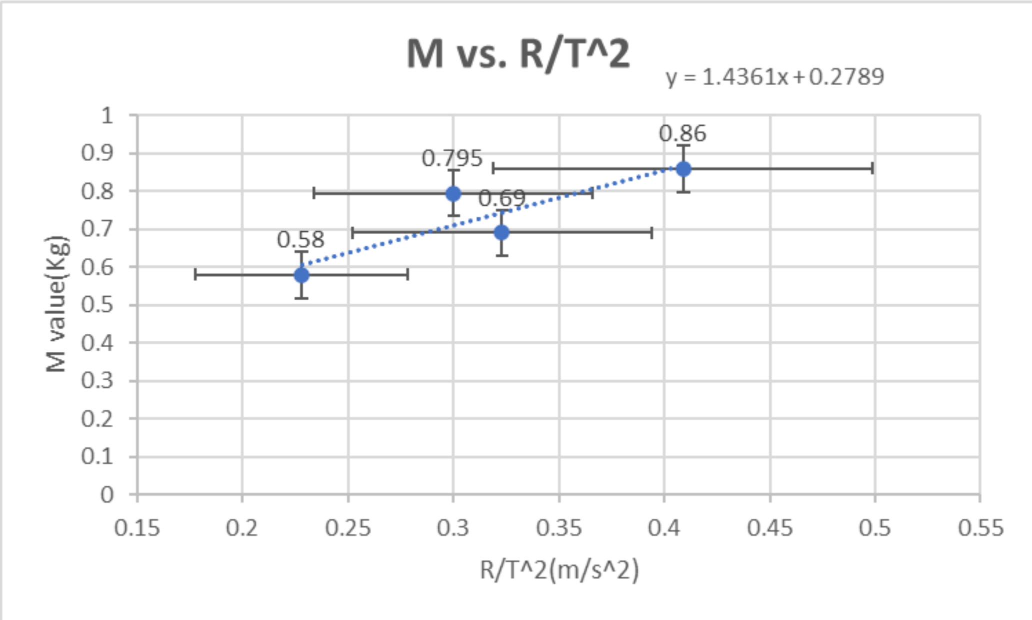
Using the given data, for the three main variables, T(period), R(radius), and M(mass of object stretched to equilibrium with applied force), we can establish the relationship between them, and express it through a graph. The following relationship requires a equation that combines all of these elements into a single equation. Therefore we have,

$$Mg = \frac{mv^2}{r} = \frac{\frac{4m\pi^2 r^2}{T^2}}{r} = \frac{4m\pi^2 r}{T^2}$$

$$\implies M = \frac{4m\pi^2 r}{gT^2}$$

Thus, the relation between the three variables is solved with M on one side, and the other two variables on the other side. However to demonstrate the relationship using a graph we must separate the equation to the graph form of $y = mx + b$. Where the M is proportional to the variables T and r by some factor, that is the slope m.

$\frac{r}{T^2}$(m/s^2)	Error propagation($\frac{r}{T^2}$)	M value(Kg)	Error propagation(M)
0.228	0.123	0.58	0.05
0.323	0.162	0.69	0.05
0.30	0.135	0.795	0.05
0.4090	0.221	0.86	0.05



To be able to find the predicted slope of the graph, for the constant 'm' value, the previous combined equation must be examined. Through the formula for the relationship between M, T and R, in the slope-intercept form for a straight line, the slope value can be determined as,

$$M = \frac{4m\pi^2 r}{gT^2}$$

Therefore we have,

$$m = 1.8531\frac{kgs^2}{m}$$

As it could be seen from the results, the measured slope based on our graph is 1.4361, while the predicted slope which is derived from various physics concepts and laws is 1.8531.

Although the results have a small difference, there were multiple factors that accounted for this. Such as inaccurate readings, instrumental inaccuracies, and unintended interference in the lab. The percentage error is figured out to be,

$$\Delta M = 17\%$$

However, as evidently proved the slope determined from the lab experiment with the practical results well complemented the theoretical and mathematical approach to calculate the slope.

Both methods relied on fundamental concepts, and abided by the physics laws, thus both methods are valid and play a key role in determining the results.

7 Conclusion

This laboratory experiment helped examine the various outcomes that may be attained while dealing with elastic and perfectly inelastic collisions. The carts remained grouped together and always had the same ultimate velocity during the perfectly inelastic collision. Greater m_1 values would lead to a faster ultimate velocity, while greater m_2 values would result in a considerably slower velocity between the two carts. The two carts were able to repel one another and not "stuck together" due to the elastic collision.

This led to The fact that cart one only experienced a "negative" velocity (bounced backwards) during the elastic impact is another intriguing feature of this experiment. This happened when cart two (the stationary cart) had a mass significantly higher than cart 1. This makes sense given that cart two, compared to the other two trail runs, is much harder to move forward and necessitates more kinetic energy. Also, the KE lost during inelastic collisions is significantly higher than the momentum lost.

This is because, theoretically, momentum is stored during inelastic collisions, and KE is lost. In elastic collisions, the momentum lost and the kinetic energy lost is lower than inelastic collisions. This is because, theoretically, during elastic collisions, momentum and KE are conserved. These different values occur due to slight human and lab errors that do not get the exact value as expected by theory.

Bibliography

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