

SC 130 Physical Science Laboratory Four: Momentum

Marble Momentum

Introduction

This laboratory explores the concepts of conservation of momentum. Equipment needed included marbles, rulers that function as marble tracks, wide masking tape to hold down the track, books to wedge up one end of the track, and stopwatches.

Terminology: Large, shooter marbles are called taws. Small marbles are called ducks. What do you call marbles? What do you call shooter and player marbles?

Questions

Can we show that momentum is conserved in a simple systems?

Introduction

Existing theory asserts that momentum is conserved. In the first part of this three-part laboratory you will explore qualitatively the conservation of momentum. In the second part you will calculate the momentum before a collision and the momentum after a collision of a duck marble and another duck marble. In the third part you will repeat part two, but using a taw colliding with a duck.

Part One: Conservation of Marble Momentum: Rolling Ducks

Hypotheses

Marbles in equals marbles out. Mass in equals mass out. Speed in equals speed out. Momentum in equals momentum out.



Procedure

Place a set of five duck marbles touching each other on the flat stretch of ruler track. Release a single duck down the ruler ramp. How many marbles come off the end of the track? Release two ducks down the track. How many ducks come off the end of the track? Continue on for sets of three, four, five and more marbles. What happens when the number released exceeds the number on the flat part of the track? Are marbles in equal to marbles out?



Set up five marbles on the flat part of the track. Release a single marble, but this time give it a gentle extra push to start the marble so it is traveling faster than a simple release. Do more marbles come off the track? Is there a speed difference? Experiment. Is speed in equal to speed out? Play gently – marbles can and do break.

How do the marbles know how many marbles should be "kicked off" the track each time? How do the marbles count? Just how smart is a marble?

Data tables | Data Analysis and Results | Data Display/Diagrams

Design your own. You decide how to best record and present the data you have gathered.

Part Two: Conservation of Momentum in a Duck-Duck Collision

The momentum p is defined as the product of mass and velocity (speed). Both momentum and velocity have directions associated with them, both are vector quantities. This means they are usually written with an arrow on top of the symbol for them. Marbles have a mass, their velocity is a speed in a particular direction. The tracks keep the marbles moving in the same single direction. In the world of science this is a one-dimensional model and keeps the mathematics much simpler.

Introduction

Momentum is said to be conserved. This means that the momentum before an event should be equal to the momentum after an event. The momentum of the duck coming into the collision should be equal to the sum of the momentum of the ducks leaving the collision. The inbound duck is mass m_1 and the duck that is hit on the track is mass m_2 in the formula above.

$$p_{\text{before}}^{\rightarrow} = \sum p_{\text{after}}^{\rightarrow}$$
$$m_1^{\text{before}} v_1^{\text{before}} = m_1^{\text{after}} v_2^{\text{after}} + m_2^{\text{after}} v_3^{\text{after}}$$

Hypothesis

The momentum before the collision is equal to the momentum after the collision.

Procedure | Data tables | Data Analysis and Results

Find two ducks that are close to the same mass. Be careful – each duck has a different mass. How can you tell by looking whether two ducks might have the same mass? Determine the mass of each duck with a balance.

Roll the inbound m_1 duck down the track by itself, releasing the duck from 0.0 cm at the top of the ramp track. Measure the time for the m_1 duck to cover the 30.0 cm along the flat track. The two marbles below show the distance over which the measure the time for the m_1 duck.



Determine the velocity of the inbound m_1 duck by dividing the distance by the time. Calculate the momentum of the inbound m_1 duck.

mass m1 inbound duck (g)	distance for inbound duck (cm)		time for inbound duck (s)		velocity v1 inbound duck (cm/s)	momentum inbound duck (g cm/s) (mass × velocity)
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Table 1: Momentum before collision

Now set up the ducks to collide.



Place the m1 duck at 0.0 cm on the ramp track. Place the m2 duck on the flat track at 0.0 cm. In the image above m1 is on the right, m2 is on the left.

The ducks will collide and both ducks will roll off the track. Run the collision a few times. During separate runs, time each duck and determine each duck's velocity over the 30 cm flat stretch of ruler track. Calculate the momentum for each duck after the collision using the following tables.

mass m1 duck (g)	distance for m1 duck (cm)	time for m1 duck after (s)	velocity m1 duck after (cm/s)	momentum m1 duck after (g cm/s)
mass m2 duck (g)	distance for m2 duck after (cm)	time for m2 duck after (s)	velocity m2 duck after (cm/s)	momentum m2 duck after (g cm/s)
			Sum of the momentums after:	

Table 2: Momentum after collision

Is the momentum of the inbound m1 duck equal to the sum of the momentums of the two ducks after the collision? How close are the results? Use the percentage change formula to determine the change in momentum:

$$\text{percentage change in momentum} = \frac{(\text{momentum after} - \text{momentum before})}{\text{momentum before}}$$

If the percentage change is less than 10%, then based on our very basic experiment we cannot rule out conservation of linear momentum.

The momentum after is not usually exactly equal to the momentum before. Was momentum gained or lost from before to after? Why do you think this happened?

Data Display | Diagrams

None.

Part Three: Conservation of Momentum in a Taw-Duck Collision

Repeat part two using a taw as the inbound marble and a duck sitting at rest on the track. Make the same measurements and calculations as part two.

What did you find – was momentum conserved? What is the percentage gain or loss in momentum? Where is the momentum coming from or going to – if anywhere. Is your result within the 10% uncertainty we tend to expect in our laboratory measurements? Can the duck have more speed after the collision than the taw had before the collision?

Conclusions

Wrap up these three activities with an essay that addresses each of the three activities and the results you observed and measured. Comment on whether the hypotheses held for your team. Discuss anything unusual, new, or different you encountered. Discuss what the conservation of momentum and energy means for you in light of the above activities. Be thorough and complete. Use correct grammar and spelling.

[Notes from the field for instructors: In this laboratory we explore conservation of linear momentum. Another momentum that is conserved is angular momentum. Angular momentum is the momentum of spinning. Spinning objects tend to continue to spin. Objects that are not spinning tend to remain at rest – to not spin. Think of a child's toy top. In the experiments above we considered only linear momentum, but the marbles are spinning as they move on the track. In part two a spinning m_1 duck hits a non-spinning m_2 duck. The m_1 duck loses speed and thus spin, the m_2 duck goes from not spinning (sitting still on the track) to spinning very quickly. These changes in spin momentum are related to why linear momentum is consistently "lost" in these collisions.]

Where linear momentum is $p = mv$, the angular momentum $L = I\omega$ where $I = 0.4mr^2$ and $\omega = v/r$. Thus the angular momentum of a marble is $L = 0.4mrv$. One cannot just add all the momentums and hope for the best: the units are different. Ultimately one has to retreat to an energy position noting that the potential energy must appear as both linear and rotational kinetic energy in both of the marbles post-collision, along with losses to friction, sound, and any heat produced in the collision.

One thought occurs as to what to try to reduce the impact of external torque exerted by the track: lubricate the ruler track with some form of greaseless lubricant such as WD-40®.

Marbles on a track are very complex!]