DOINGWHATWORKS

SAMPLE MATERIAL

Lab Lesson Plan: Conservation of Momentum

Hillcrest High School, Texas

Topic: Encouraging Girls in Math and Science

Practice: Sparking Curiosity

Pre-AP physics students at Hillcrest High School participate in this hands-on lab experiment using cars on an air track to learn about the conservation of momentum. Students experiment with collisions between the cars to "study the energy and momentum of two masses as they collide." The teacher engages the students by requiring them to complete the experiment in small groups (3-4 students each). In each group, one or two students manipulate the cars and one or two students work with a computer software that records and plots the data. The teacher emphasizes the connection between conservation of momentum and real-life applications such as forensic investigations and careers in automotive engineering.

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Lab Lesson Plan: Conservation of Momentum

Introduction

Collisions of two frictionless objects (gliders on a track, also referred to as carts or cars) can be described in terms of momentum (and sometimes energy) conservation. There are three types of collisions: "elastic" (kinetic energy is conserved), "inelastic" (kinetic energy is lost), and "completely inelastic" (the objects stick together). If kinetic energy is gained, the collision is "super-elastic."

The lab experiment below allows you to observe most of these types of collisions and to test for the conservation of momentum and energy.

Conservation of momentum in everyday life

Momentum is very practical and applicable to everyday life. There are a lot of professions in which you have to have a thorough understanding of momentum. One example is a police officer who would go and investigate an accident scene. They have to use the momentum of the cars, by looking at the evidence and the skid marks, and they can work backwards and find out exactly how fast those cars were going. Also, momentum is extremely important in the different kinds of collisions that are possible.

In driver's ed, you may have learned that a head-on collision is the worst kind you can have. We're going to see why that is in the lab today. It's because the exchange of momentum is the highest. An immovable object is also bad; we'll talk about the exchange between the time of impact and the amount of momentum that you receive as a driver.

If you're an engineer designing cars, you need to consider things like airbags, but the entire vehicle itself is a structure to allow all that momentum not to pass into the passengers when they're in a traffic accident.

Experiment objectives:

1. Observe collisions between gliders and test for conservation of momentum
2. Measure energy changes in different types of collisions
3. Classify collisions by type (elastic, inelastic, completely inelastic)

Equipment:

The equipment we will be using is called an air track. It consists of a hollow extruded aluminum beam with small holes drilled into the upper surface. Compressed air is pumped into the beam and released through the holes. This forms a cushion of air supporting a glider (also referred to as a cart or car) on a nearly frictionless surface. The glider can move with almost frictionless horizontal motion.

Attached to the air track are two sonic motion sensors which are controlled by the computer. The computer signals a motion sensor to emit a sound pulse. The pulse reflects off the plastic card attached to the glider and returns an echo to the motion sensor. The computer receives the signal and calculates the position of the glider from the time delay between sending the pulse and receiving the echo. Computer software plots the data and can use the data to calculate velocity and acceleration. [Note: to add more potential variations, students can use a known mass for the gliders (e.g., 0.5 kg), and then place additional material of known mass on top of the gliders.]

The appropriate computer program should be running when you arrive at the laboratory [note: the software being used is Vernier Logger Pro 3.5]. Click on "create experiment" and scan through the sensors, double clicking on the sensor set up that virtually connects the motion sensor to the 750 interface to match the physical set up on the lab table. Click on the motion sensor icon a second time to set up the interface for the second motion sensor. Double click on the graph icon to open a graph window. Drag the velocity from the data window into the graph window to plot the velocity of the glider. Drag the second velocity icon from the data window for the second glider. Now we are ready to take data.

Preparation questions

Following is a list of questions intended to help you prepare for this laboratory session. If you have read and understood this write-up, you should be able to answer most of these questions. The teacher assistant may decide to check your degree of preparedness by asking you some of them:

1 What is mass?
2 What is the formula for momentum?
3 What is the physical definition of Impulse?
4 What is a completely inelastic collision?
5 How does the Motion Sensor determine the location of the glider?
6 Why is the air track used in this experiment?
7 What is conserved in a perfectly elastic collision?
8 What is conserved in a completely inelastic collision?
9 Under what conditions is the momentum conserved?

Experiment 1: Elastic collisions

In this experiment we will measure the speeds of two air gliders before and after they collide with each other.

Set one glider at rest near the center of the air track. You may have to keep a hand on it until just before the collision to keep it at rest. Give the second glider a velocity directing it away from the first glider. The glider will bounce off the end of the track and rebound reaching a stable speed before colliding with the first glider. The extra time will give you a chance to hit "Start" before the collision occurs. Be sure to move out of the way of the motion sensor. It might mistake reflections off your hand as signals from the glider. If this happens merely retake the data. Continue taking data as the gliders bounces off one another. Then hit the "Stop" button using the cursor.

Scan the data and look for the collision event which should show a sudden exchange of velocity between the gliders. Use the curse tool (x,y) in the tool bar to read the velocities of each glider before and after the collision. One of the gliders should have an initial velocity very nearly zero. Use these velocities and the mass of the glider obtained by massing it on the lab electronic scale to calculate momentums both before and after the collision. Calculate the total momentum of the system by adding the momenta of each glider before and after the collision. Determine to what extent momentum is conserved. Also calculate the kinetic energy of the system before and after the collision. Verify to what extent kinetic energy is conserved.

Experiment 2: Moving Target, Elastic Collision
Repeat the above procedure for both gliders in motion, with elastic bumpers in place. Add masses to one of the gliders. Is momentum conserved? If not, is the error within tolerances given the uncertainty of the measurement? Is the velocity of separation conserved? That is, does the difference between the velocities of the two gliders remain a constant before and after the collision?

Experiment 3: Ineleastic Collision
Repeat the above procedure for an inelastic collision. To do this, replace the bumper on one glider with the needle-point and equip the other glider with the clay pot receptacle. This should cause the gliders to stick together when they collide. Determine the total momentum and kinetic energy before and after the collision. If either is not conserved, are the errors within limits of the accuracy of the experiment. If any large discrepancy is noted, explain.

Additional materials and potential study questions

Change in velocity

Mass of glider 1 (kg)	Mass of glider 2 (kg)

Run number	Velocity of glider 1 before collision (m/s)	Velocity of glider 2 before collision (m/s)	Velocity of glider 1 after collision (m/s)	Velocity of glider 2 after collision (m/s)
1		0		
2		0		
3		0		
4		0		
5		0		
6		0		

Conservation of momentum

Run number	Momentum of glider 1 before collision (kg·m/s)	Momentum of glider 2 before collision (kg·m/s)	Momentum of glider 1 after collision (kg·m/s)	Momentum of glider 2 after collision (kg·m/s)	Total momentum before collision (kg·m/s)	Total momentum after collision (kg·m/s)	Ratio of total momentum after/before
1		0					
2		0					
3		0					
4		0					
5		0					
6		0					

Conservation of energy

Run number	KE of glider 1 before collision (J)	KE of glider 2 before collision (J)	KE of glider 1 after collision (J)	KE of glider 2 after collision (J)	Total KE before collision (J)	Total KE after collision (J)	Ratio of total KE after/before
1		0					
2		0					
3		0					
4		0					
5		0					
6		0					