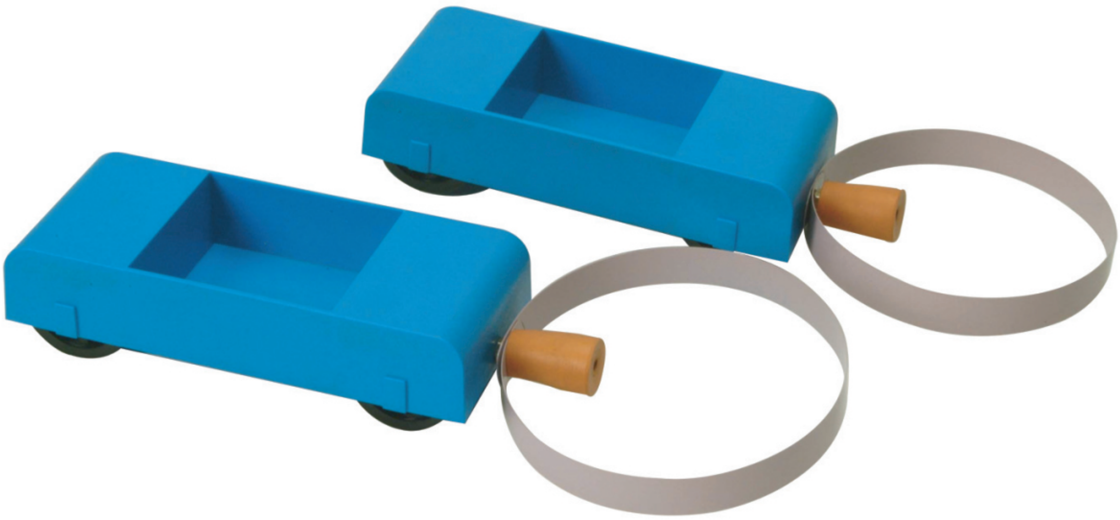
HALLS CAR

CAT NO. PH 0351APL



Experiment Guide

GENERAL BACKGROUND:

The Halls cars are a set of two simple cars that can each carry a variable amount of weight. They can be used to easily demonstrate properties of static and kinetic friction, momentum conservation, Newton's laws, and the conversion of energy such as (potential, kinetic, and heat, for example).

The cars each have a ring attached to the back of the car. These rings are designed be used so that the cars collide elastically. They can also be used to attach the cars to a pulley system for use in an inclined plane experiment.

Friction:

The Halls cars can easily be used to demonstrate the effects of moving (kinetic) friction. Students will notice that the cars travel different distances on different surfaces and that the kinetic energy of the cars is transferred to heat (“lost” through friction).

Elastic Collisions:

When two objects collide elastically, the total kinetic energy of the system is conserved. In an inelastic collision, some kinetic energy is lost in the collision as the objects become deformed and kinetic energy is converted into heat. The attached rings on the Halls cars help ensure the cars bounce off of one another elastically so that the kinetic energy is the same before and after the collision.

Momentum:

The total momentum in any closed system is conserved. By adding masses into the slots on the top of the Halls cars and using the definition of momentum, $P = mv$, students can observe how objects with the same momentum move at different velocities if their masses are different.

NEXT GENERATION SCIENCE STANDARDS

MS.PS-FM Forces and Motion

a. Formulate questions arising from investigating how an observer's frame of reference and the choice of units influence how the motion and position of an object can be described and communicated to others.

b. Communicate observations and information graphically and mathematically to represent how an object's relative position, velocity, and direction of option are affected by forces acting on the object.

d. Use mathematical concepts and observations to describe the proportional relationship between the acceleration of an object and the force applied upon the object, and the inversely proportional relationship of acceleration to its mass.

f. Analyze and interpret data to determine the cause and effect relationship between the motion of an object and the sum of the forces acting upon it.

HS.PS-FM Forces and Motion

a. Plan and carry out investigations to show that the algebraic formulation of Newton's second law of motion accurately predicts the relationship between the net force on macroscopic objects, their mass, and acceleration and the resulting change in motion.

c. Use algebraic equations to predict the velocities of objects after an interaction when the masses and velocities of objects before the interaction are known.

e. Construct a scientific argument supporting the claim that the predictability of changes within systems can be understood by defining the forces and changes in momentum both inside and outside the system.

Cross cutting Concepts:

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (a), (b)

Science and Engineering Practices: Constructing Explanations and Designing Solutions

Use qualitative and quantitative relationships between variables to construct explanations for phenomena. (a) Construct explanations from models or representations. (b)

Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints. (g)

Planning and Carrying Out Investigations

Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables, or effects, and ensure that the investigation's design has controlled for them. (a)

Using Mathematical and Computational Thinking

Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (c)

Standards: (Taken from the May 2012 draft of the Next Generation Science Standards)

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Halls cars	2

RECOMMENDED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Motion sensors or video recorder and video analysis software	
Slotted mass set or other weights	Varied
Ruler/Meter stick	1

Activity 1: Conservation of Momentum (Teacher answers)

Collide two Halls cars, determine whether momentum is conserved in the collision, and practice using graphs of displacement, velocity, and acceleration.

PROCEDURE:

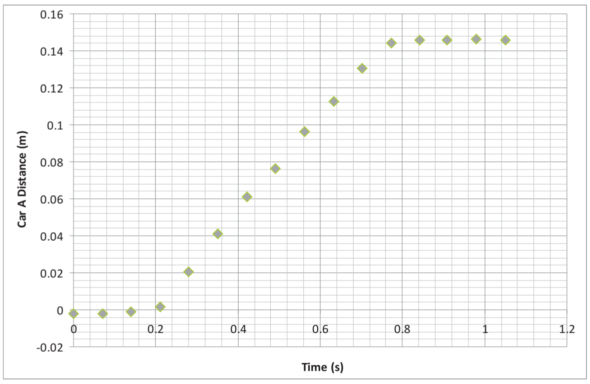
1. Weigh the Halls cars and record their mass.
2. Place the cars about a foot apart with the rings facing one another, so that they will collide head-on. Gently push one car (Car A) into the other, stationary car (Car B)
3. Set up motion sensors to record the collision between the cars or take a video using a high-speed camera, a computer camera, or even a smartphone (a side-view of the collision works best).
4. Collide the cars again and record the collision.

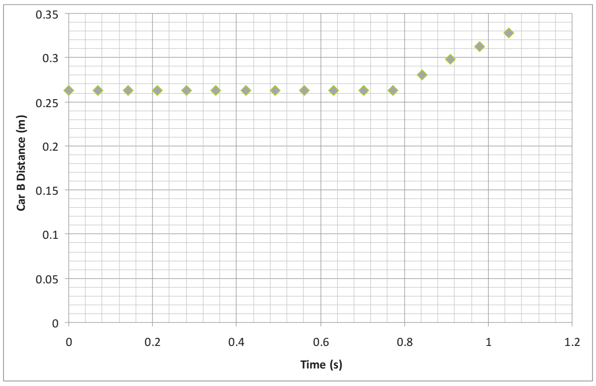
DATA:

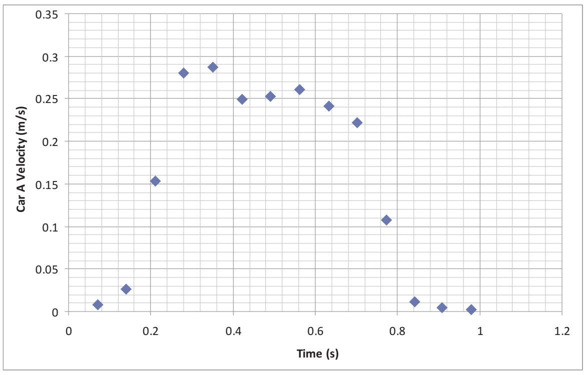
Mass of Car A ____0.70kg___
Mass of Car B ____0.70kg____

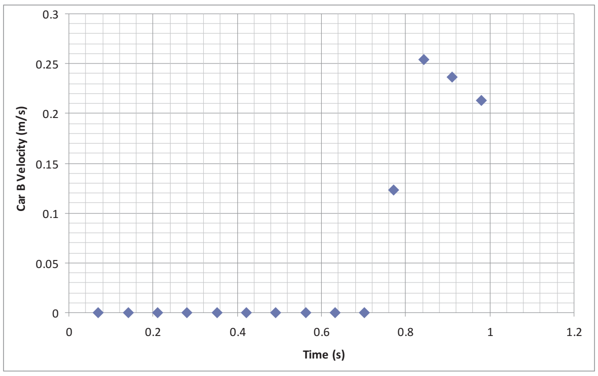
DATA ANALYSIS:

1. Create graphs of the displacement, velocity, and acceleration of Cars A and B and attach them to the end of this laboratory report.

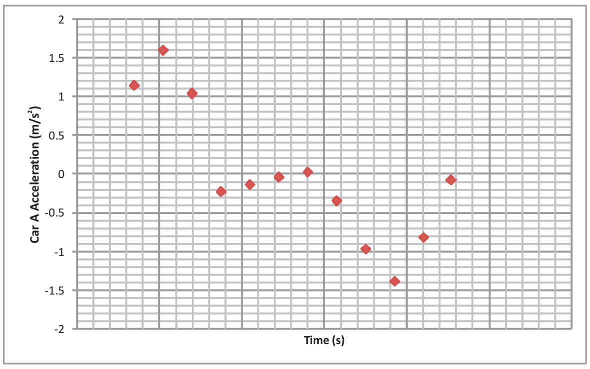


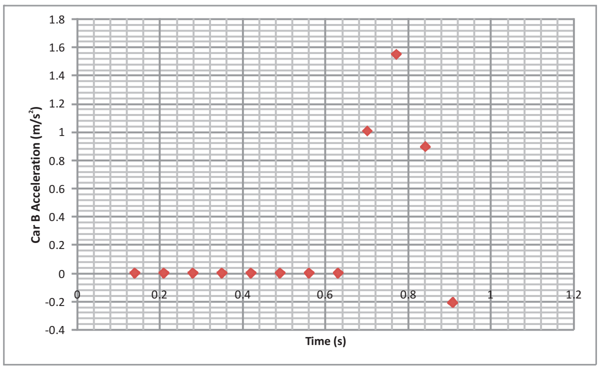






Car A Acceleration (m/s²)





2. Use your graphs and your video to find data points just before and just after the collision. What are the velocities of Cars A and B at these times?

Before Collision:

t = 0.70s
Car A: v_x = 0.22 m/s
Car B: v_x = 0.00 m/s

After collision:

t = 0.84 s
Car A: v_x = 0.01 m/s
Car B: v_x = 0.25 m/s

3. Use your data to calculate the momentum of each car before and after the collision? Show all work including formula and substitution with units.

Momentum = (mass)(velocity)

Before Collision:

Car A: mv_x = (0.07 kg)(0.22 m/s) = 0.0154 kg m/s
Car B: mv_x = (0.07 kg)(0.00 m/s) = 0.00 kg m/s

After Collision:

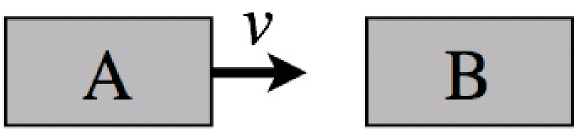
Car A: mv = (0.07 kg)(0.01 m/s) = 0.0007 kg m/s
Car B: mv = (0.07 kg)(0.25 m/s) = 0.0175 kg m/s

CONCLUSIONS:

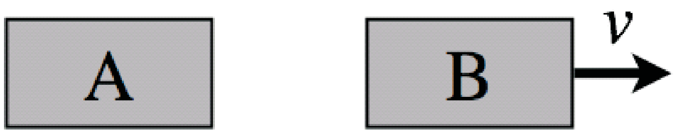
1. Assume the cars collide perfectly elastically. Thinking about conservation of momentum, what did you expect the velocities/momenta of the cars to be immediately after the collision? Draw a picture of what you expected to see just before and just after the collision.

   The total momentum of the system should be conserved. Since the masses of the cars are equal, that means that the sum of the velocities before and after the collision should be the same. If the cars collide elastically, then no kinetic energy is lost in the collision.

   Before the collision, Car B was at rest and Car A had some velocity, v.



   After the collision, since none of the kinetic energy is lost, all of the momentum must be transferred completely from Car A to Car B, so Car A should stop totally.



2. Did your data show that momentum was conserved in the collision? If not, by how much did the momentum change? Calculate the percent difference below.

$$\% \text{ Difference} = \frac{(\text{Before - After})}{\text{Before}} \times 100$$

Before collision: Total momentum = 0.0154 kg m/s + 0.00 kg m/s = 0.0154 kg m/s
After collision: Total momentum = 0.0007 kg m/s + 0.0175 kg m/s = 0.0182 kg m/s

% Difference = 100% (0.0154 kg m/s - 0.0182 kg m/s)/ 0.0154 kg m/s = -18%

3. Did your data show that momentum increased, decreased, or stayed the same? Can you explain how what you observed may differ from what you expected to see?

The experiment showed that the total momentum increased. This is most likely due to inaccuracies in how we tracked the velocity of the cars - user error in marking the car's position throughout the video, and the incline of the floor. The cars probably accelerated slightly as they moved down the slightly inclined floor.

4. Which car experiences a greater change in momentum?

The cars experience equal and opposite changes in momentum - that's how the total momentum is conserved.

5. Which car experiences a bigger force in the collision?

The forces are equal. Newton's third law tells us that the force that Car A exerts on Car B is equal and opposite to the force that Car B exerts on Car A.

6. Looking at your graph of the acceleration of the cars during the whole demonstration, what can you say about the forces acting on the cars? Try to make comments about the cars at distinct times (when was it being pushed, when was friction an important factor, etc).

Car A:
At the beginning of the demonstration, Car A is being pushed by the experimenter and so there is a net positive acceleration acting on the car (because the applied force is larger than the force of friction acting in the opposite direction). After that, friction is the

only force acting to change the acceleration of Car A. It begins to slow the car down before the collision occurs (around t = 0.70s). After the collision, Car A stops moving completely and so the total acceleration is zero.

Car B:

Since the car is initially stationary, there are no net forces acting on it and the total acceleration is zero. The acceleration finally changes when Car A exerts a net force on Car B by colliding with it (pushing it forward). The acceleration drops to zero after the collision because there is no longer any applied force. The car moves at a constant velocity for the rest of the video. If we watched the cars longer, we would observe friction exerting a net force on Car B, causing a negative acceleration, and finally bringing Car B to a stop.

EXTENSIONS

(Teacher answers)

There are many very simple demonstrations possible using Halls cars that highlight fundamental physical principles. A few are listed below.

1. Use the cars to highlight the effects of kinetic friction. Push the car on different surfaces, trying to exert the same initial force each time (releasing them from an inclined plane can help). Have students observe the distance the car travels on a low-friction track, a waxed floor, a carpet or rug, or a newspaper.
2. Demonstrate how cars with the same momentum travel at different velocities if they have different weights. Repeat the activity above, but put weights one or both of the cars. Ask students to predict how the momentum will be split between the cars after the collision and compare their predictions to the experiment.
3. Use the cars to explore conservation of energy. Using an inclined plane, a car can be used to demonstrate the conversion from gravitational potential energy to kinetic translational and rotational energy. Different amounts of mass can be added to the cart to verify that the rate at which objects fall (slide down the ramp) is independent of mass.

Name:____ Date:____________

Lab Section:____________

ACTIVITY 1: CONSERVATION OF MOMENTUM

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4. Collide the cars again and record the collision.

DATA:

Mass of Car A __________

Mass of Car B __________

DATA ANALYSIS:

1. Create graphs of the displacement, velocity, and acceleration of Cars A and B and attach them to the end of this laboratory report.

2. Use your graphs and your video to find data points just before and just after the collision. What are the velocities of Cars A and B at these times?

Before Collision:

After collision:

3. Can your data to calculate the momentum of each car before and after the collision? Do so below.

Momentum = (mass)(velocity)

Before Collision:

After Collision:

CONCLUSIONS:

1. Assume the cars collide perfectly elastically. Thinking about conservation of momentum, what did you expect the velocities/momentum of the cars to be immediately after the collision? Draw a picture of what you expected to see just before and just after the collision.

2. Did your data show that momentum was conserved in the collision? If not, by how much did the momentum change? Calculate the percent difference below.

$$\% \text{ Difference} = \frac{(\text{Before - After})}{\text{Before}} \times 100$$

3. Did your data show that momentum increased, decreased, or stayed the same? Can you explain how what you observed may differ from what you expected to see?

4. Which car experiences a greater change in momentum?

5. Which car experiences a bigger force in the collision? How do you know?

6. Looking at your graph of the acceleration of the cars during the whole demonstration, what can you say about the forces acting on the cars? Try to make comments about the cars at distinct times (when was it being pushed, when was friction an important factor, etc).

Car A:

Car B:

Manufactured by :
EISCO
www.eiscolabs.com

U.S. Distributor :
Eisco Scientific
850 St Paul St, Suite 15, Rochester, NY 14605
Email : www.eiscosci.com