Collision I: Teacher Notes

Introduction

The focus of this investigation is the study of the forces during a collision with a stationary object. Students will explore quantitative factors that influence a collision (e.g., impact force, impact time, etc.) by analyzing the resulting shape of a line graph. By using a stationary Force probe connected to their handheld computer, the students will investigate the collision of their cart as it impacts the Force probe. By engaging with relevant phenomena from their everyday life, the students are encouraged to question their surroundings.

In addition, students will gain experience with inquiry skills, including:

- knowing that an object's motion can be described by tracing and measuring its position over time;
- realizing that an object's motion can be described and represented graphically according to its position, direction of motion, and speed;
- knowing that when a force is applied to an object, the object either speeds up, slows down, or goes in a different direction;
- understanding the relationship between the strength of a force and its effect on an object (e.g., the greater the force, the greater the change in motion; the more massive the object, the smaller the effect of a given force);
- knowing that an object that is not being subjected to a force will continue to move at a constant speed and in a straight line;
- identifying variables that can affect the outcome of an experiment;
- understanding effects of balanced and unbalanced forces on an object's motion (e.g., if more than one force acts on an object along a straight line then the forces will reinforce or cancel one another, depending on their direction and magnitude; unbalanced forces such as friction will cause changes in the speed or direction on an object's motion);
- using technology (e.g., hand tools, measuring instruments, calculators, computers) and mathematics (e.g., measurement, formulas, charts, graphs) to perform accurate scientific investigations and communications;
- knowing that scientific investigations involve asking and answering a question;
- planning and conducting simple investigations (e.g., formulating hypotheses, designing and executing investigations, interprets data, synthesizing evidence into explanations, proposing alternative explanations for observations, critiquing explanations and procedures);
- establishing relationships based on evidence and logical argument (e.g., provides causes for effects);
- knowing that scientific inquiry includes evaluating results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists (e.g., reviewing experimental

procedures, examining evidence, identifying faulty reasoning, identifying statements that go beyond the evidence, suggesting alternative explanations).

Discussion Guide

Using this Guide

This guide is designed to help you convert the investigations your students experience into solid learning. The "Overview" section mentions some of the learning issues raised by this content. These issues might come up in conversations with students anytime. The "Setting the Stage" section provides ideas for a discussion you might hold before beginning the investigations. This discussion is important to motivate and alert students to observations that might answer their questions. The "Wrap Up" section can be used after the investigations to help student reflect on what they have done. Taking time to reflect while the investigations are fresh in students' minds has been shown to substantially increase learning.

Overview

This investigation looks at two collisions of a cart with a fixed object. One is a hard collision with the wall. Although it happens quickly, students can capture the time history of the force of the wall on the cart by mounting the force detector on the cart. A much more gentle collision is caused by rubber bands. Students might not see this as a collision without a discussion of what a collision is.

The acrobat provides an informal way to OBSERVE forces and how quickly they change. A constant force will cause the acrobat to hang at an angle. If the force on the cart changes quickly, the acrobat will fly around. If the force changes slowly, the acrobat will rock gently.

Setting the Stage

Collisions are more common than students may think. The air around us consists of molecules that are each colliding 100 million times per second. The air in a cube about one foot on a side has 50 million trillion trillion collisions per second. Every one of those collisions obeys the same laws that are explored in this investigation.

To stimulate interest in collisions, ask students:

[Examples: two cars, baseball and bat, boat with its dock, asteroid and the earth, two galaxies, two electrons in a wire.] [No] [No. Imagine two carts with repelling magnets.]

To stimulate reflection about collisions, ask:

[It often drops to zero quickly.] [Yes. Each of the colliding objects pushes on the other.] [Large forces.] [The velocity of each object changes and because there is some force between the objects. Larger velocity changes are associated with larger forces.] [It depends on how quickly the velocity changes. A hard collision causes a fast velocity change that will cause the acrobat to rock violently.] [Yes. When it rocks violently it is modeling a dangerous collision.]

To focus student attention on the force detector, ask:

[Students can experiment with a paperclip or other iron object.] [They can verify that the detector is sensitive to magnetic fields by bringing a magnet near the sensor and observing the resulting "force" graph on the computer. They can also rotate the

Force probe and detect changes due to the Earth's magnetic field.] [When the eye bolt is near the end of the beam, a small force is required to bend the arm, making it most sensitive. It can measure the weight of a dime. At the other location, a big force is needed to bend the beam. You can weigh a student there.]

It is important to bring students back to considering the forces and velocity changes in collisions. First, address some difficult points in the investigations:

[For all collisions, a force causes a change of velocity in a short time. The rubber bands cause this to happen, just over a longer time than usual, because of a much smaller force.] [No, they are the same. This is the point of Trial I.] [No, they are the same.]

Now encourage students to think about the forces and velocity changes in different collisions by asking: "What are the relative sizes of the forces caused by the propeller, rubber band, and bumper?" [The bumper caused a force that is many times that of the rubber band, and the propeller's force was much smaller. (You might calculate these ratios, but the calculations might distract students, too.)]

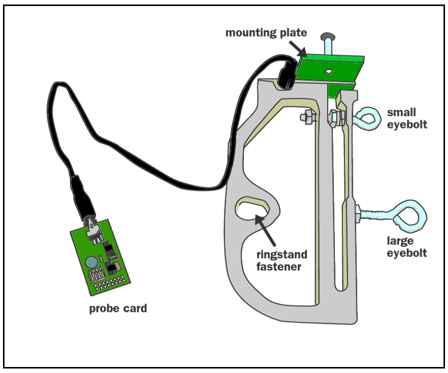
Wrap Up

Cover some optional finer points by asking: [Weight is the force of gravity on an object. We can use a force probe to measure weight, but not mass.] [The weight of an object in newtons is 9.8 times its mass in kilograms, on earth.] [On the moon, in space, anywhere gravity is different from its value on the surface of the earth.] [A larger force is required to stop or turn around a more massive cart. This is why a heavier car causes more damage.]

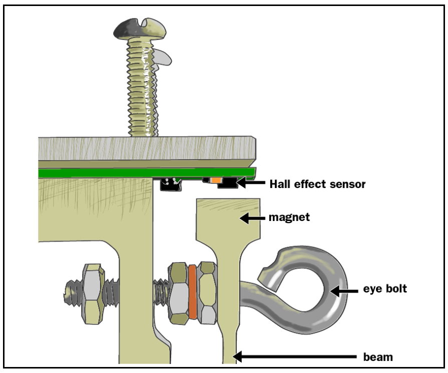
Additional Teacher Background

This investigation shows how we can learn a lot by looking closely. The probes allow students to slow down a very fast event-a collision-and look at what happened every few thousandths of a second. It's like having a microscope for time. What is happening is that forces due to contact change the velocity. The ideas students learned about the effect of force on carts can be applied to collisions. If the velocity changes quickly, there is a big force. This is what causes damage. If the collision is softer, the velocity changes more slowly, indicating that there is less force.

The Force probe works on the simple principle that a rigid beam will bend an amount that is proportional to the force exerted on it. Instead of trying to define "force", you can simply say that it is what the force probe measures. In this case, the beam is aluminum, it can be either pushed or pulled, and it has stops so that it won't be bent beyond its elastic limit. There are two eye bolts at different distances along the beam. The one that is nearer the end gives a more sensitive reading, because it takes less force to move the beam a certain amount. The lighter range is + or - 20N, and the heavier range is + or - 200N.



The deflection of the beam is measured with a little chip called a Hall effect sensor, which measures magnetic field. A strong magnet is embedded in the end of the beam, and the Hall effect sensor is next to it. As the beam moves, the magnetic field changes and the sensor's output changes too.



If the sensor card is unscrewed from the Force probe, it can be used as a general-purpose magnetic field sensor. It can easily detect the Earth's magnetic field, which you will notice if you rotate it and expand the graph.

Suggested Timeline

The amount of time you spend on introductory discussions, data collection, and analysis, will determine your overall timeline. The following represents a possible timeline.

One class period - "Setting Up" discussion

One class period - Trial I: Weighing the cart with the Force probe

One class period - Trial II: Colliding a cart with a wall

One class period - Trial III: Adding a bungee cord

One class period - Analysis and "Wrap Up" discussion

Additional days can be used for Further Investigations.

