Collision II: Teacher Notes

Introduction

The focus of this investigation is on equal and opposite actions and reactions. Students gather and analyze data resulting from a tug-of-war between two Force probes and the collisions of two moving carts. Students will explore quantitative changes (e.g., impact forces, impact times, resulting velocities, etc.) by analyzing the resulting shape of a line graph during collisions of carts of different masses. By engaging with relevant phenomena from their everyday life, the students are provided with a sense of connection between science and the world around them.

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 continues the exploration of collisions. The last investigation involved single carts colliding with fixed objects; here two carts collide. This is much closer to the collisions between molecules in a gas or between two cars. Because two carts are needed, pairs of student groups will need to work together.

This investigation provides yet another situation in which force is related to change in velocity. It may seem repetitive, but it is worth hammering home this relationship because it is central to the study of force and motion. The other important idea in this investigation is that the forces on the two colliding carts are the same. The force of cart A on B is exactly the same as the force of B on A, even if they have different masses. Students saw this idea in the previous investigation, but it is worth repeating in this new context. Most students think that the more massive cart will exert a larger force on the lighter cart, but this is wrong.

This idea is most dramatically shown in Trial I, where students with force probes play tug-of-war. No matter what they do - who pulls "harder", who pulls and who stands still - the force probe graphs will be identical. Most people find this quite surprising, and it's worth discussing many examples: a car and a truck, standing on a table, a fly and a fly-swatter.

Setting the Stage

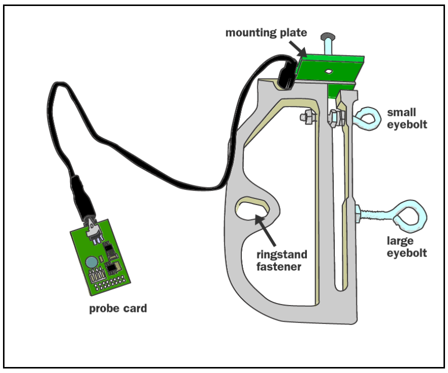
A discussion on automobile collisions can provide context for this investigation. Focus on the role of devices that save people, including bumpers, seat belts, and airbags. The operation of each of these safety devices can be explained in terms of forces and velocity change. The key is realizing that you want to avoid large forces. Large forces are what maim and kill. After introducing this idea, ask to explain in terms of what they have learned about forces and velocities: [All other things being equal, a high speed collision results in a larger change in velocity. This requires a bigger force that the wall, tree, or other car you collide with will provide.] [A bumper is designed to increase the time of collision by slowly giving away. This reduces the rate of change of velocity, resulting in less force.] [The seatbelt stops you from hitting the dashboard or window. Because those are hard, collisions with them generate huge forces. When your head hits the windshield, its velocity changes very quickly and the resulting force is huge.] [When it inflates, it applies a force on you to slow you down quickly but much more gently than the windshield would. Spreading the force over a longer time means that the maximum force is smaller.]

Wrap Up

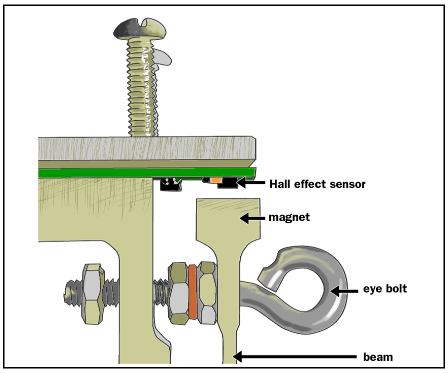
Because this investigation concludes the study of force and motion, lead a discussion that draws from all five investigations. One way to do this is to introduce Newton's Laws and ask for evidence from these experiments for each law: [The rolling cart that continues at almost a constant speed on a level surface. Of course it does slow down a bit, the result of some frictional force.] [Yes. Zero velocity is a constant velocity, too. If there is no force on a cart at rest, it stays at rest.] [The following forces have all caused velocity changes that we have measured: the force of gravity on the ramp, the force of the propeller, the force of friction from the sled, the force of the wall in Collision I, the force of the rubber bands, and the force of the other cart in Collision II.] [Yes, if you count only one force that was balanced by another. For instance, if you hold the cart while the propeller is going, or oppose the propeller's force with a sail, there are two opposite forces. The net force is zero, so there is no change in velocity and Newton's Second Law is still true.] [In Collision II, two force probes push or pull on each other, and their force graphs are the same.] [There are no exceptions.]

Additional Teacher Background

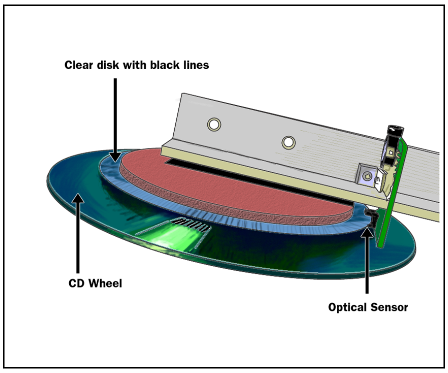
The Force probe works on the simple principle that a rigid beam will bend an amount that is proportional to the force exerted on it. Instead of trying to define "force", you can simply say that it is what the force probe measures. In this case, the beam is aluminum, it can be either pushed or pulled, 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 +/- 20N, and the heavier range is +/- 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 beamm moves, the magnetic field changes and the sensor changes its output.



If the sensor 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. This also means, however, that the Force probe should be recalibrated to zero whenever its position or orientation is changed.



The SmartWheel is also used in this investigation. Some sophisticated electronics are used to sense the rotation of the wheel and use that to generate a graph on the computer. An invisible infrared beam is directed through the clear plastic disk that has regular black lines printed on it. A sensor detects when a black line blocks the beam. Each time the beam is blocked means the wheel is turned a bit. The computer simply counts how many times the beam is blocked. There are actually two beams and this allows the computer to figure out which way the wheel is turning. If the wheel is turning one direction, the computer adds 1 each time the beam is blocked, but if it turns the other direction, it subtracts 1. The computer program interprets this information either as position (how many black lines go by) or as velocity (how fast the black lines go by).

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: Action and reaction

One class period - Trial II: Forces on colliding carts

One class period - Trial III: Velocities of colliding carts

One class period - Analysis and "Wrap Up" discussion

Additional days can be used for Further Investigations.

