Propeller: Teacher Notes

Introduction

The focus of this investigation is the study of the effect of forces on motion. Students will explore quantitative changes (e.g., velocity, force, acceleration, etc.) over time on a line graph that results from a mounted propeller on the air cart with or without an attached sled. By using a SmartWheel and Force probe connected to their handheld computer, the students will investigate resulting motions. By exploring a somewhat puzzling situation, the students are encouraged to explain their ideas through clarification, justification, and representation.

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

Ask students to debate what effect forces have on motion. The simplest answer is that a force can speed up or slow down an object, but students are unlikely to know that right at the beginning. If they say this too quickly, perhaps they have memorized this rule without thought. Push them for examples and ask them to explain why a bike going fast on a level road requires force just to keep a steady velocity. Why does it take more force to maintain a greater velocity? The answer is that air resistance increases rapidly with velocity, so higher speeds need more force to balance it.

At the right moment, you need to point out that in science, the word "force" has a restricted meaning. We are not talking about usage such as "forceful personality" or "a military force." Our use is restricted to pushes and pulls. In the same vein, we use "motion" only to refer to the way something moves from point to point. It is not about "a motion to adjourn."

Setting the Stage

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The central point of this investigation is that the propeller provides a constant force and this force causes a constantly changing velocity. This appears as a slanted straight line on a velocity graph. On a position graph a constant force generates a parabola.

To develop these ideas, ask students:

[Straight, slanted line segments while the propeller was operating.] [It is changing at a constant rate, or it is constantly changing.] [The line is more horizontal, it slants less.] [More steeply slanted straight lines.] [You would see two straight lines, one going up and the other going down at the same slant.] [They all have parts that are curved upward or downward. These are all parts of a parabola.] [It is constantly increasing.]

Wrap Up

The sled increases the friction on the cart and creates a force that opposes the force provided by the propeller, and the result is a straight-line velocity graph with a reduced slope. Have the students predict what happens to the slope of the velocity versus time graph as you add mass to the sled? [It slants less and appears more horizontal]

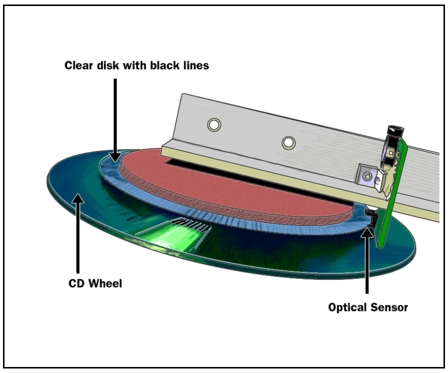
Additional Teacher Background

This investigation introduces force. A battery-operated propeller is used to generate a light, constant force and a new sensor is used to measure the forces. In many respects, this unit is central to the entire set of five force and motion units. The key point is that force causes a change in velocity. If you observe a velocity change, there must be some force acting. If velocity is constant, then no force is present. If there is more than one force on an object, it is the NET force that matters; two opposite forces can cancel out.

If you tossed a ball straight up and let it fall, what would the velocity versus time graph look like? The result is very surprising. The velocity versus time graph is a downward-sloping straight line the whole time. It passes through the x-axis at the moment when the ball is at its maximum height. You can observe this by pushing a cart up a ramp, then letting it roll down again. The position versus time graph is a parabola, and the velocity versus time graph is a straight line with negative slope.

The sled adds back the friction we worked so hard to get rid of in the cart, but now instead of being hidden from view, it can be adjusted at will. The propeller pulls one way, and the sled pulls the other. This reduces the net force on the cart, and it will change velocity more slowly as weight is added to the sled.

Surprisingly, the kinetic friction provided by the sled is roughly constant regardless of velocity, just like the force provided by the propeller. This is demonstrated by the fact that when you give the cart a push and let the sled bring it to a stop, the velocity versus time graph is a straight line. Constant change in velocity implies constant force. This isn't completely true, however. Is it possible to identify a terminal velocity for a cart with a weighted sled? Yes, this is the point where the drag force just equals the driving force, and the velocity stops increasing.



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 half class period - Trial I: Adding a propeller to a cart

One class period - Trial II: Measuring the motion of a propeller-driven cart

One class period - Trial III: Adding a friction sled to a propeller-driven cart

One class period - Analysis and "Wrap Up" discussion

Additional days can be used for Further Investigations.

