Air Cart: Teacher Notes

Introduction

The focus of this investigation is on the observation of motion. The students will construct a low-friction cart that they will use throughout the Motions and Forces and one of the Transfer of Energy investigations. Students use qualitative observational skills to explore the causes (e.g., inertia, force, etc.) and results (e.g., friction, velocity, etc.) of motion, alerting the teacher to commonly held student ideas.

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;
- 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);
- 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 is important because students build a low-friction cart and ramp that will be needed later. Most of this investigation is devoted to construction and testing. This can be most absorbing, but to get the most out of the time, you should encourage students to think about the goal of friction reduction and how the cart design achieves this.

Students get confused about the effects of forces because friction is present in most situations they encounter. Students do not understand that forces cause a change in velocity, since everyday experiences suggest to them that forces are needed just to keep velocity constant.

An example of this comes from biking on a level road, where it is obvious that one has to work hard providing a force just to keep going at a steady rate. Does this show that force does not change velocity? No, because there is no net force on the bike. At constant speed, the force of friction exactly balances the force the biker supplies. If there were no friction from the air, bike, and road, then no force would be needed, but students usually do not realize this. What actually causes friction at a molecular level is a very complicated subject, still not perfectly understood. More important at the beginning level is the idea that friction is a force that opposes motion. The friction force always acts to slow down a moving object.

Setting the Stage

Before beginning the construction, engage students in a conversation about friction. A good first discussion can be about what it would be like to exist in a world without friction. Here are some questions you might ask, followed by possible responses. [Roller-skating, ice skating, skateboarding. Not swimming] [It would be hard to stand up. Going down stairs would be very dangerous--hanging on the banister would not help much because your hands would slip, too.] [No. You couldn't start because the wheel would slip. You couldn't turn without falling over.] [Pushing with your foot against the ground wouldn't work. Pushing against a heavy or fixed object would work.] [Friction confuses the situation. Motion is easier to understand without friction. We can always add friction later.]

Wrap Up

If students investigate the effect of mass, they might be in for a surprise. It is natural to assume that the heavier cart will zoom down the ramp faster. Ask students: [Yes. This can be perceived by simply feeling the force on a stationary cart.] [The greater force down the ramp is exactly balanced by the increased force needed to move the heavier cart. This is the same effect as the famous but apocryphal story about dropping heavy and light balls off the Leaning Tower of Pisa.]

To focus students on the role of friction, ask them to design high-friction carts. How many ways could they design a cart that would roll down the ramp but stop within one cart length?

Additional Teacher Background

The energy lost to friction always ends up as heat energy in the form of random molecular motion. This will come up in later investigations, when the question "where did the energy go?" will be asked again and again. There can be many sources of friction. In the case of the cart, the axle rubs in the straw when it turns. There is some rolling friction as the wheel surface touches and then lifts from the floor. This is much less than if the wheels were locked and dragged across the floor, however! That's why car brakes work: when the wheel is braked, it is dragged along the road instead of being free to roll. It's also why you can steer: it's easier for a wheel to roll in the direction it's steered than to slide sideways, so the car tends to go in that direction, unless the road is icy.

A distinction can be made between starting or static friction (the force between surfaces before the object moves), and sliding or kinetic friction (which is the force between surfaces as the object slides along). These could be measured with the Force probe as an extension activity. For instance, one could put a loop of string through a book and pull it across a table. The static friction would be the force needed just to get the object moving, and the kinetic friction would be the force needed to keep it moving at a constant speed. Kinetic friction is roughly constant regardless of how fast the object is sliding.

Students should also consider the effect of air resistance that results from the cart hitting air molecules and pushing them out of the way when it is moving. A wind tunnel isolates the effect of air resistance. Air resistance increases with increased velocity, so the force needed to keep a car going at 60km/hr is much greater than for 20km/hr.

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 and half class periods - Trial I: Building an air cart

One half class period - Trial II: Building a test ramp

One class period - Trial III: Performing a coasting test

One class period - Analysis and "Wrap Up" discussion

Additional days can be used for Further Investigations.

