Invention Lab

Race-Car Construction

OBJECTIVES

Students will

- use appropriate lab safety procedures.
- use the scientific method to solve a problem.
- design and implement their procedure.
- construct a model car to meet assigned criteria.
- use concepts in physics to measure the performance of the car.

Planning

Recommended Time

One lab period is necessary to test the car. Students can design and construct the car at home or use one more lab period to design and construct the car. Students should have their plan approved before the class begins.

Materials

[for each lab group]

- ✔ aluminum sheet
- ✔ 2 bamboo skewers
- ✔ drinking straws
- ✔ glue
- ✔ 2 large, wide rubber bands
- ✔ masking tape
- ✔ meterstick
- ✔ 3 plastic film canister lids
- ✔ scissors
- ✔ 4 small rubber bands
- ✔ stopwatch
- ✔ 2 support stands with clamps
- ✔ table clamp
- ✔ 5 tongue depressors
- ✔ inclined plane

Optional

- ✔ 1.5 V–3.0 V dc motor
- ✔ 15 cm insulated wire
- ✔ 2 AA batteries

Materials Preparation

Teachers should specify which motor the class should use to avoid the electric car contest just becoming a question of which motor is largest. Motors can be bought from an electronics store for about $2–$5. This lab was bench tested using the 3 V Mabuchi "Cer-Mag" model RE 280 motor, which is widely available. For the gravity-powered car, a steep incline works well to accelerate the car only if there is a smooth transition between the incline and the floor. A smooth transition can be easily obtained by taping a thin aluminum sheet to the bottom of the incline and to the floor. The type of sheet sold in hardware stores as roof flashing or for air conditioning equipment works well.

Classroom Organization

- This lab may be performed by students working alone or in pairs.
- **Safety warnings:** Students should be especially careful while using sharp objects, as they can cause serious injury. They should wear eye protection and perform this experiment in a clear area. When a sharp tool is not in use, it should always be covered with its protective sheath and kept in a safe place.

Techniques to Demonstrate

You may wish to make a sample car of your own in each category to inspire your students. Follow the steps in the Proposed Procedure section.

Pre-Lab Discussion

Discuss with students some of the following issues:

- how the angle of the ramp influences the speed of a nonmotorized car
- how the size of the tires influences a car's speed if it moves at a constant speed
- where friction should be minimized on the car and what materials can be used to decrease friction
- where the force of friction helps the car move faster, and what materials can be used to increase friction
- different ways to design a motorized car (that is, direct drive, belt driven) and how this design would influence the car's speed

For a car to move in a straight path, students should align the center of mass with the drive wheel(s). There are many ways to do this, depending on the design of the car.

Gravity-powered car: mass will not affect the speed, but it might keep it from slowing down as much on the horizontal. However, greater mass increases the normal force, which increases friction.

Car with a motor: there are two common methods to design the car.

Method 1: connect the wheel directly to the motor shaft (as described in the Proposed Procedure section).

Method 2: Wrap a rubber band around the motor shaft that then goes around the wheel axle to power the car.

Tips for Evaluating the Pre-Lab Requirements

Students' plans should include the category they plan to enter, a materials list, a diagram illustrating the design of the car, and the name they have chosen for the car. A procedure should be described for measuring the speed of the car and analyzing the average speed of the car. The direct-drive apparatus is simpler to construct and more reliable than the rubber-band apparatus.

Proposed Procedure

Part I: The Design of the Car

Examples of designs are provided below.

Gravity-powered car: mount and tie a brick to an old roller skate with cord.

Motorized car: cut tongue depressor down to three-fourths its original length. This will serve as the body of the car. Cut one straw in half. Clean the bamboo skewers of loose fibers to reduce friction, and place it inside this straw. Cut the bamboo skewer so that it is 2.5 cm longer than the straw piece. This will serve as an axle of the car. Cut tiny holes directly through the centers of two film canister lids for the rear wheels. Connect a lid to each end of the bamboo skewer, and secure them in place with hot glue. Center the straw perpendicular to the tongue depressor, and hot glue it to one end of the tongue depressor. Mount the motor sideways on the other end of the tongue depressor. The motor shaft should be mounted so that it is parallel to the bamboo skewer at the opposite end. Cut a tiny hole in the middle of the third film canister lid and shove it onto the motor shaft so that it fits tightly. Play around with this lid until it spins evenly on the motor shaft. When this happens, hot glue the lid to the shaft. This will serve as the front drive wheel and the motor of the car. The car should now be able to roll along the floor supported by three wheels, and no parts should drag.

Mount the two AA batteries on top of the tongue depressor using rubber bands. To ensure contact between the batteries and the motor, place a large, wide rubber band end to end around both batteries. This keeps the batteries firmly pressed together and holds the bare ends of the motor wire against the battery terminals. The car will run in a straighter line if the batteries hang over the edge of the tongue depressor on the side opposite the motor.

Tightly mount rubber bands to serve as tires on the wheel perimeters for added traction. Connect wires from the batteries to the motor and you are ready to race. Thread beads through the bamboo skewer axle to help guide it and reduce its friction.

A sample design uses 15 cm wooden plant labeling sticks rather than tongue depressors. The key to having the car run straight is to make sure that the line of thrust of the drive wheel passes through the center of mass of the car. One disadvantage of the direct-drive method is that it places one of the largest masses on the car, the motor, off the line of thrust. This can be balanced by placing the other large mass, the battery pack, on the other side of thrust on an outrigger. For sample data, the motor had a mass of 46 g and the batteries had a mass of 48 g. The rest of the sample car massed 24 g. Using this type of assembly, the car is started by twisting the free ends of the wires together to close the circuit.

Part II: Measuring the Car's Speed

Use tape to mark a starting line at 0.00 m and a finish line at 1.00 m. The stopwatch should be started at the 0.00 m mark and stopped at the 1.00 m mark. Gravity-powered cars should roll down an inclined plane at the steepest angle possible without causing the car to tumble. The 0.00 m mark should be made at the base of the inclined plane and a distance of 1.00 m should be measured from this mark. Motorized cars should follow steps 1–3 in the Chapter 2 Discovery Lab. A distance of 1.00 m should be measured from the 0.00 m mark.

Post-Lab

Tips for Evaluating Patent Application Lab Report

Student lab reports should include clearly drawn and labeled diagrams of the car and the method used to measure the average speed of the car over 1.00 m for three trials. There should be a section describing each diagram and explaining why certain features of the car's design were chosen. Reports should include a detailed procedure and the data, and they should clearly indicate how students calculated the average speed of the car.

Additional Notes

Motion in One Dimension

HOLT MCDOUGAL PHYSICS

Invention Lab

Race-Car Construction

U.S. RACING ASSOCIATION
LYNCHBURG, SOUTH CAROLINA

September 27, 1999

Mr. Steve Thorpe

1% Inspiration Laboratories
14557 West Post Road
Tempe, Arizona 85289

Dear Mr. Thorpe:

To celebrate our 25th anniversary, we are promoting auto racing this season by having a contest to develop an inexpensive race car. Cash awards and free tickets to the U.S. Racing Association Silver Cup race are going to be awarded in each category to the fastest car that meets the criteria.

The contest will include judging a motor-less cars that will need to accelerate to top speed using only a ramp or a similar physical structure and should travel a displacement of 4.0 m. The car may not be pushed, launched, or pulled. You should also include a complete description of the device used to accelerate the car.

All cars should be composed of scrap materials found around the home. The appearance of the car will not be judged, but contestants should pay careful attention to physical design elements that affect the ability of the car to travel in a straight line at high speeds. Each contest entry should include an analysis of the car's speed, using appropriate SI units accurate to three significant digits. The analysis should average the speeds over three trials, traveling a horizontal distance on a smooth surface, such as tile or a similar surface. The speed must be calculated only on the horizontal path of the car's travel. Each contest entry should use the format of a patent application and include the name of the car. Good luck in the design of your contest entry.

Sincerely,

Billy Joe Greenfield

Billy Joe Greenfield

More information about the design is on page 12.

1% Inspiration Laboratories

MEMORANDUM

Date: September 28,1999
To : Development Team
From: Steve Thorpe

This project reminds me of some of the soapbox derbies I entered when I was a kid. This really sounds like fun! The U.S. Racing Association car design contest could result in some great prizes, so we will need to do careful planning.

Before you go into the lab, prepare a plan for the design of the car. Your plan should include a list of materials needed and a diagram of the car. Remember to include all of your testing and development procedures. I have included a newspaper clipping with this memo that may be helpful to your design and setup. Your plan should also include a design of a car that will move in a straight path.

- An easy way to do this is to make sure that the car is stable and that it does not pull to either side. Your design should take into account the size and shape of the car.
- For the car without a motor, take into consideration that the car will begin to slow down at some point along its horizontal path.
- Determine the average velocity your car will travel over three trials, and show your calculations.

I will approve your plan before you start work on your project, so turn it in to me soon. When your car is ready, prepare your report using the format of a patent application. Be sure your report includes all parts of the application, and pay close attention to the number of significant figures throughout the lab. Good luck!

14557 West Post Road • Tempe, Arizona 85289

See next page for safety requirements and more hints.

SAFETY

- Wear eye protection and perform this experiment in a clear area.
- Cut carefully, and be aware of those around you. When working with a knife, do not draw it toward you. After using a sharp tool, cover it with its protective sheath and return it to a safe place. Sharp objects can cause serious injury.

Coaster cars gravitate to a winning speed

In an event that combines elements of automobile racing and downhill sledding, coaster cars zip down a hill under the pull of gravity to pick up speed for the timed run on the flat surface of the track. Cars that win tend to be heavy, narrow, and low to the ground.

Races will be held today at Coaster Lanes. The track measures 50 meters from the starting line at the bottom of the hill to the finish line. The slope of the hill is 20 degrees.

Manuel Sanchez, last year's winner, explains that there are many tricks to building a successful coaster car. "Wheel alignment is important in making sure that the car will move in a straight path," he says, "Also, knowing how to distribute the mass is critical to building a winning car. You have to make sure the car does not slow itself down."