Drexel-SDP GK-12 ACTIVITY

Activity: Max Your Ride

Subject Area(s) Data Analysis & Probability, Measurement, Number & Operations, Physical Science, Problem Solving, Science and Technology

Associated Unit Forget the Chedda!

Associated Lesson Energetically Challenged

Activity Title Max Your Ride

It's always a good idea to revisit the drawing board (or table).

Grade Level 7 (6-12)

Activity Dependency
Construct A Car, Quantify It, Convert It, Dragged Racers, Spinners

Time Required 45 minutes

Group Size 2 people

Expendable Cost per Group US$0

Summary

Students will use the concepts and results from previous lessons and activities to calculate the work done by friction and torque on their car as they work through the associated worksheet. Information about the work done by forces acting on the car can be used to compute the efficiency of the car and identify ways that the design of the car could be improved.

Engineering Connection

Efficient designs make the most out of energy that is transferred. Hybrid car designs achieve better fuel consumption than other types of cars because of their small size, low weight, and aerodynamic body. Contrast these designs with large, boxy sport utility vehicles that earn the nickname "gas guzzlers."

A work and energy analysis may provide information about which parts of a system should be improved so that experimental results can be as close as possible to theoretical bounds.

Keywords

mousetrap, car, forces, torque, moment of inertia, angular acceleration, linear acceleration, rotational motion, linear motion, design, efficiency, work, energy, conservation, optimize

Educational Standards

- PA Science:
  - 3.1.7 – Unifying themes
  - 3.2.7.B – Apply process knowledge to make and interpret observations
  - 3.2.7.D – Know and use the technological design process to solve problems
  - 3.7.7.D –Apply computer software to solve specific problems
- PA Math:
  - 2.1.8.D – Apply ratio and proportion to mathematical problem situations involving distance, rate, time, and similar triangles
  - 2.3.5.D – Convert linear measurements within the same system
  - 2.3.8.A – Develop formulas and procedures for determining measurements
  - 2.4.5.B – Use models, number facts, properties, and relationships to check and verify predictions and explain reasoning
  - 2.5.8.B – Verify and interpret results using precise mathematical language, notation and representations, including numerical tables and equations, simple algebraic equations and formulas, charts, graphs, and diagrams
  - 2.5.8.C – Justify strategies and defend approaches used and conclusions reached
  - 2.6.5.A – Organize and display data
  - 2.6.8.F – Use scientific and graphic calculators and computer spreadsheets to organize and analyze data
  - 2.7.8.D – Compare and contrast results from observations and mathematical models

- 2.8.8.B – Discover, describe, and generalize patterns, includeing linear, exponential, and simple quadratic relationships

Pre-Requisite Knowledge

Students should have completed the “Dragged Racers” and “Spinners” activities and have values calculated for the coefficient of friction for the wheels and the moment of inertia for their axle.

Learning Objectives

After this activity, students should be able to:

- Identify energy sources and sinks
- Calculate the magnitude of the energy sources and sinks
- Calculate the efficiency of a system
- Compare the work done by different forces
- Interpret usefulness of modifications using work and energy principles

Materials List

Each group needs:

- String
- Meter stick
- Duct tape
- Mass/weight set or coins and plastic bags
- Wire twist ties
- Ruler or measuring tape

To share with the entire class:

- Motion Sensor
- Force Sensor
- PASCO Explorer GLX (or sensor interface with computer)
- “Max Your Ride” worksheet in DataStudio file

Introduction / Motivation

[Reiterated from “Energetically Challenged”]

Each of you has a mousetrap as your energy source, so you all have about the same energy to work with. If your car is too heavy or not properly weighted, it will use energy at a faster rate than one that is light and balanced correctly. All of your cars can be analyzed to make the most of the energy stored in the mousetrap – by doing this, you’re increasing the efficiency of your car.

Use the values for frictional force that you’ve calculated in the “Dragged Racers” activity, and find the work done by friction for one revolution of the wheel. Compare this with the work done by the torque on the axle to calculate the efficiency. You may need to use the force sensor to test the force from the mousetrap arm. Comparing these values may give you hints about which parts of the mousetrap car should be changed.

Vocabulary / Definitions

Word	Definition
Work	The energy transferred by the action of a force. Work from a force is calculated as the product of the force and the distance through which it acts. Work from torque is calculated as the product of the torque and the angle (in radians) through which it acts.
Energy	The physical quantity that is expended when an object is in motion.
Potential Energy	Energy possessed by an object about to go into motion.
Kinetic Energy	Energy possessed by an object in motion.
Conservation of Energy	Another name for the first law of thermodynamics, which states that the total energy of the universe is constant. Therefore, energy can be transferred from one form to another, but it cannot be created or destroyed.
Conservative Force	A force whose work is reversible. Work done by body forces and springs are conservative forces; body forces depend on the height through which the gravitational force acts, and springs return to their original energy state after they are compressed or extended.
Non-conservative Force	A force whose work is not recoverable. Friction and drag are non-conservative forces – the path of the work is always opposes the direction of the motion.
Joule	SI unit for energy. 1 joule (J) = 1 N*m. Used in the MKS unit system.
Calorie	Unit defined as the energy needed to heat 1 g of water by 1°C. 1 cal = 4.2 J. Used the CGS unit system (centimeters, grams, seconds).
Efficiency	A measure of how well the energy is transferred from one form to another. $E = \frac{\text{Work Output}}{\text{Work Input}}$

Procedure

Background

See associated lesson, **Energetically Challenged**.

Before the Activity

- Interface computer with PASCO Explorer GLX (or other unit) using USB port
- Plug Force Sensor and Motion Sensor into GLX sensor ports.

With the Students

1. Open "Max Your Ride" worksheet in DataStudio file based on chedda_456_activity_worksheet.ds *corresponding to student's or group's initials*.
2. Help students measure the force exerted by the mousetrap arm/spring with the force sensor
3. Follow instructions contained in "Max Your Ride" worksheet. Work through worksheet questions and input necessary parameters
    a. Note that you use values for frictional force that you have measured in the "Dragged Racers" activity, and frictional work for one revolution of the wheel is calculated from this value.

   b. Note the work done by torque on the axle.
   c. Double-check the computed value for the car's efficiency.
4. Help groups troubleshoot their problems. If necessary, help explain concepts related to:
   a. The required angular acceleration for the wheel so that it does not slip
      i. Find the maximum acceleration before slipping occurs by using Newton's 2nd law (F=m*a), substituting the frictional force and the car's mass.
      ii. Convert the linear acceleration a into angular acceleration α
   b. The force needed to produce the torque that causes the angular acceleration calculated in (2a)
      i. Substitute the moment of inertia, I, calculated in "Spinners" into the torque-angular acceleration relation (T=I*α)
      ii. Substitute the torque and the radius of the axle into the Force-Torque relation (T=F*d) to compute the Force needed from the mousetrap arm.
   c. Extending the mousetrap arm so that the force you calculated in (2b) is achieved.
      i. Use trial and error with the force sensor
      ii. Solve for proportionality: the force of the mousetrap arm and its length are proportional.
5. If requested, help students set up and repeat the exercises in "Dragged Racers" and "Spinners."

Attachments
chedda_456_activity_worksheets.ds
(contained in chedda_456_activity_worksheets.zip; see **Curricular Unit: Forget the Chedda!**)

Assessment
Check last page of "Max Your Ride" for a calculated *Efficiency* value.

Owner
Drexel University GK-12 Program

Contributors
John C. Fitzpatrick, Mechanical Engineering and Mechanics, Drexel University

Copyright