



Drexel-SDP GK-12 LESSON

Lesson: Energetically Challenged

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

Associated Unit Forget the Chedda!

Lesson Title Energetically Challenged

Header



Weight is a conservative force: its work on an object is reversible.

Grade Level 7 (6-12)

Lesson # 5 of 5

Lesson Dependency

Quantify It; Convert It; Forces, Forces Everywhere; Torqued

Time Required 20 minutes

Summary

This lesson concludes the unit by combining the principles discussed in the previous lessons to end at a final lesson on work and energy, applied to the mousetrap car model.

Engineering Connection

The recurring theme throughout this unit has been efficiency. As the United States makes strides towards energy independence, we must not only consider how to produce energy but also how to use these resources wisely. Because energy cannot be created nor destroyed (this is the first law of thermodynamics), it can only be transferred in one form to another. In the process of this energy transfer, we rarely get all of the energy into the desired form – in mechanical processes, energy loss occurs as heat or sound. Engineers seek to minimize these losses and maximize the amount of energy transferred, no matter which physical system we consider.

The mousetrap car model runs on energy transferred by the mousetrap. This mousetrap has to be set, however, so when we set the mousetrap we use energy that has been metabolized from food. The food had to be delivered and prepared before we consumed it, so more energy was used for these tasks. The processes that transfer energy may vary (i.e. mechanical to mechanical, chemical to mechanical, electrical to mechanical), but the overall efficiency is defined as the fraction of the work that is output based on the input energy.

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

torque, force, rotation, mass, moment of inertia, work, energy, conservative force, nonconservative force, path dependence

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
- 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
 - 2.7.8.D – Compare and contrast results from observations and mathematical models

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

Pre-Requisite Knowledge

Students should have been introduced to concepts of force and torque.

Learning Objectives

After this lesson, students should be able to:

- Recall the difference between conservative and nonconservative forces
- Identify energy sources
- Discuss how forces acting on a system impact its energy
- Relate the forces on a system to the energy they use

Introduction / Motivation

So far we've talked about torque, weight, and friction, which are the primary loads we have to consider when analyzing the motion of our mousetrap car. We can put these concepts together and figure out a better design if we consider the work and energy of our mousetrap car system.

Let's say that you weigh 120 lbs and decide to go hiking up a mountain with a friend who weighs 150 lbs. You are both in good physical condition and both of you eat half of a pizza before leaving. Who do you think is going to use more energy as they are hiking? (Your heavier friend). Who do you think will be able to go farther before they get tired? (You, at 120 lbs). Why do you expect this? (Because both you and your friend ate the same amount of pizza beforehand).

When people are on diets, what do they say they're trying to limit? (Calories). Calories are a measure of energy content, so if we take in more energy than we use, it's stored as fat. If the opposite is true, then we burn those reserve calories stored as fat.

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.

We consider the work done by a force to be equal to the product of the force and the path length through which the force acts, so if our car moves 2 meters and the total frictional force is 0.5 Newtons, the total work done by friction is 1 Newton-meter.

The units for torque are already Newton-meters, so we calculate the work for torque as the product of the torque and the angle through which the object rotates. If a torque of 2 N*m acted through a full turn of the wheel, or 2π radians, the total work done by the torque would be 4π N*m.

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. $E = \frac{\text{Work Output}}{\text{Work Input}}$

Lesson Background & Concepts for Teachers

Energy principles are the cornerstone for efficient design strategy. Up to now, lessons have introduced the concepts that must be used to calculate the energy of a car. Students should be encouraged to revisit past lessons and repeat the activities when optimizing their car, since there are multiple design options and several methods to optimize their design.

The mousetrap car itself illustrates a mechanical-mechanical energy transfer, since the potential energy in the loaded spring is connected to the wheels in some way, and causes the wheels to propel the car. Solar cars use an electric-mechanical energy transfer, as the photovoltaic (solar) cell converts ambient light into an electric current. Actual cars (and scaled models used by extreme hobbyists) use a chemical-mechanical energy transfer; gas or diesel is burned (the engineering term is combustion) to produce a series of explosions that cause a crankshaft to turn the transmission. The work output of the engine, and the energy it uses, depends on the number of cylinders: 4, 6, or 8 (as in V6 or V8). A mechanical-electrical energy

transfer is used to create electricity, such as wind and hydroelectric, and generators and nuclear power uses a chemical-mechanical-electrical energy transfer.

Possible extensions from this lesson may include comparing the efficiency of the optimized mousetrap cars with electric or solar-powered cars. The total energy used for the systems can be compared, *i.e.* include the biological energy (calories and food) needed by a student to set the mousetrap, which may lead to the principle behind the “green” push for human-powered vehicles (HPVs): human power is more efficient than engine power and produces biodegradable waste products.

Associated Activities

Max Your Ride

Lesson Closure

Segue into associated activity.

Assessment

Check **Max Your Ride** workbook: is *Efficiency* calculated?

Additional Multimedia Support

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