Science Unit: *Physics Ideas*
Lesson 4: *Modifying Forces*

School year:	2006/2007
Developed for:	Tecumseh Elementary School, Vancouver School District
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Grade level:	Presented to grades 6-7; appropriate for Grades 5-7 with appropriate modifications.
Duration of lesson:	1 hour and 20 minutes
Notes:	These activities are likely to take longer than the estimated duration. Originally they were set up in a station approach with an instructor. Students continued to work on science activities during the week following the lesson.

Objectives

1. Learn about how to use mechanical systems to modify speed and forces.
2. Learn to use pulleys to increase pulling force by decreasing the pulled distance.
3. Learn to use a lever to increase force by decreasing movement distance (and vice-versa).
4. Learn that gears are equivalent to rotating levers that modify rotation speed and force.

Background Information

Our oldest tools are levers and ropes. Modern apes still use simple tools made from rocks, sticks, and vines to hunt for food and crush nuts. The oldest known fossilized ropes are approximately 17,000 years old, while ancient Egyptians developed specialized rope-making tools in 4,000-3,500 BC. These ropes were used in building the Pyramids and are well documented within the Pyramids and other tombs. Ancient Egyptian sailboats used ropes and levers for controlling the sails and steering.

The oldest known complex geared device is the Antikythera Mechanism: an ancient mechanical astronomical computer. Found in a shipwreck off the Greek island of Antikythera, this remarkable mechanical computer calculates the locations of planets, stars, and phases of the Moon, and is dated to 150-100 B.C. The technology behind the mechanical design and metal manufacturing of this machine were lost with the fall of ancient Greece, not to be seen for millennia. Similar mechanical devices were not built until the 18th century, and no contemporary devices have approached its complexity and accuracy until the modern digital computer.

Vocabulary

Tension	A pulling force acting to elongate or stretch an object.
Pulley	A simple machine with a grooved wheel used to change the direction of rope force.
Compression	A pressing force acting to compress or shorten an object.
Lever	A simple machine made from a rigid bar pivoting around a fixed point.
Gear	A toothed wheel meshing with another part to transmit motion
RPM	Revolutions per minute: measure of rotation speed

Materials

- 8 single pulleys
- 3 double pulleys
- Length of string or twine
- Weights of given units: example 5x 100g, 1x 200g, 1x 300g, 1x 400g, or 14x of one single unit.
- 3 pairs of pliers and samples of wood or metal strips to compress and bend.
- Wooden rulers and assorted weights
- Pencils or dowels to act as pivot
- Gear and shaft set: LEGO Technic set with motors, gears, shafts, chains, etc.

In the Classroom

Introductory Discussion

1. Demonstrate and discuss the different types of forces found in common objects: scissors, pliers.

- Pulleys: how can one person lift an object many times their mass? Students use a single common mass to lift an equivalent mass, twice, three, or four times the common mass.
- Levers: press on the sample piece of metal. Can you dent it? Try pressing again with the pliers, why can you do it now?
- Levers: balance the rulers with pivot in the center. Put equivalent masses on either side and adjust until they balance. What are the distances from the center pivot? Put different masses on either side of the ruler and move them to make it balance. How are the distances from the pivot and masses related?
- Gears: the electric motor turns at 300 revolutions per minute (rpm). Assemble a combination of gears to reduce the speed so the final shaft turns at 60 rpm, and 1 rpm. How many times have you multiplied the available force of the motor (ignoring friction)?

2. Short description of other items to discuss or review.

- Look at a variety of balance beams: scales of justice, Mediterranean marked scales, etc.

3. Summary of instructions for science experiment/activity.

- Measure the length of each lever arm, from pivot point to point of contact, for each of the levers.
- Measure the length of each gear tooth, and the number of teeth on each gear.

4. Briefly describe safety guidelines.

- Be very careful with the cutting shears.

Science Activity/Experiment

Stations are set up in the classroom. One or two adults can run the entire class.

Divide the students into three or four equal groups. Save some time at the end of each station time to discuss the student observations.

Part 1 – Pulleys

- Students try to balance masses on each of the four pulley systems.
- What is the relationship between the number of vertical lines and the mass that can be lifted.
- Is the tension in the string the same for all four pulley systems?

Part 2 – Levers

- Balance given masses at given distances on the rulers.
- Balance the mystery mass on the ruler; calculate its mass given the known mass.

Part 3 – Gears

- Count the number of teeth on each of the three sizes of gears. Put two gears on the platform and count the numbers of times you need to rotate the small gear to make the larger gear rotate once. What is the relationship between number of teeth and the number of needed rotations?
- Put the special white gear (safety clutch) on the electric motor. Grab the outside of the white gear and turn on the electric motor. The safety clutch exerts a rotational force of only 2-5 Newton-centimeters.
- Use the gears and shafts to reduce the speed of the motor from 300 rotations per minute (rpm) to 60 rpm, and 1 rpm.

Science Journal: Students will record their observations at each station to understand the relationships between each of the simple machines.

Closure Discussion

Examples of questions to ask students

1. How do bicycles change gear? What system do cars use?
2. What is the numeric advantage of the compound shears?
3. Identify lever and pulley systems in and around the school that have not already been covered.