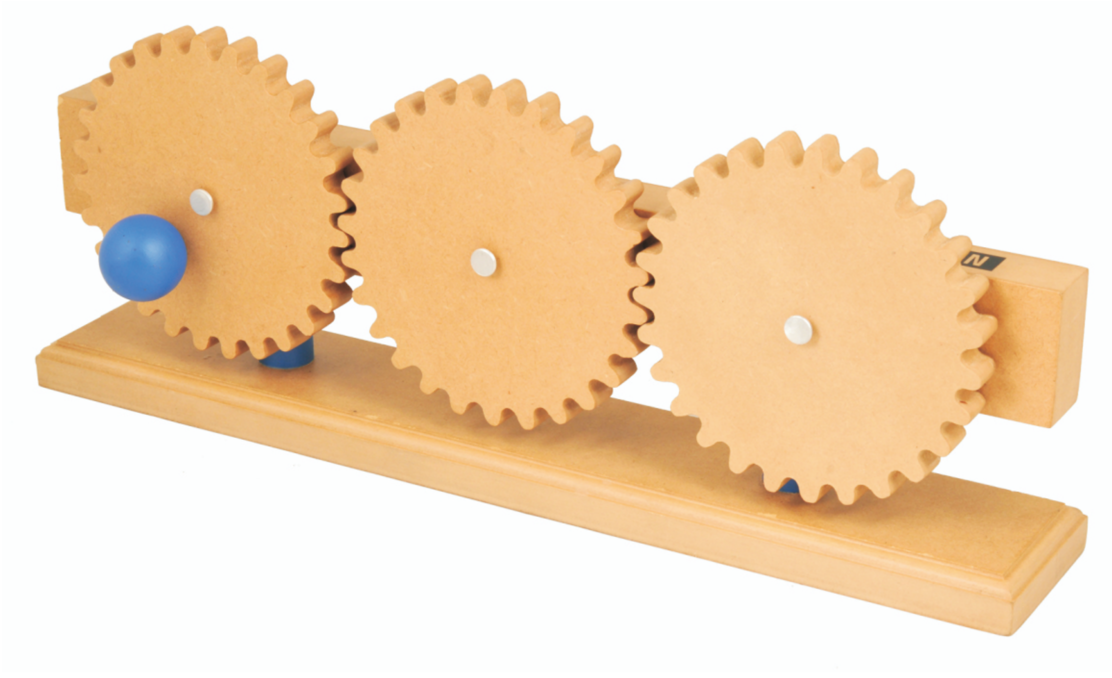
WOODEN SIMPLE MACHINES : GEAR TRAIN

CAT NO. WDMS11



Experiment Guide

GENERAL BACKGROUND :

There are six simple machines that all other machines are made out of. Even complex machines like an automobile really consist of simple machines that all convert energy in order to do work. Machines are used to make work easier. Here work is defined as a force applied over a given distance. The force applied and the distance traveled must be in the same direction.

To do a given amount of work on an object, it takes a certain amount of energy. When using simple machines, the amount of force used is decreased in order to increase the amount of distance travelled or vice versa while keeping the amount of work done the same. Written mathematically we can get the following relationship.

$$\left[\text{Force applied or weight of the load}\right]\left[\text{Distance moved}\right] = \left[\text{Force applied by the effort}\right]\left[\text{Distance moved}\right]$$

$$F_l \times d_l = F_e \times d_e$$

Simple machines can either change the direction the force is applied, or increase the mechanical advantage by doing the same amount of work over a longer distance and therefore decreasing the amount of force needed.

Mechanical advantage is a way of measuring how much easier it is to do work or how much less force is required. Written as a formula:

$$\text{Mechanical Advantage} = \frac{\text{Output force (load)}}{\text{Input force (effort)}}$$

The load is the amount of force or weight that is being lifted
The effort is the amount of force or weight being applied to the rope in order to move the load.

The six simple machines are pulleys, levers, wedges, inclined planes, screws and wheels & axles. Compound machines have two or more simple machines that when used together make work easier.

Wheels and axles increase mechanical advantage by covering a longer distance using less force; the larger the wheel the greater the mechanical advantage. The famous Penny Farthing bike increased the distance traveled for each rotation of the petal. A rider needed to run alongside the bike to get it started before jumping aboard since the pedals were too difficult to push from a standstill. Here a greater force at the pedal over a smaller distance was traded for a smaller force on the wheel, covering a greater distance.

As a wheel turns the distance traveled by the one rotation of the wheel is directly proportional to the diameter of the wheel. For the penny farthing bike one rotation of the pedal equals one rotation of the bike's wheel. However the distance covered by the person's foot is much smaller than the distance covered by the bike's wheel.

Examples of wheels and axels include bike tires, car tires, windmills, and steering wheels.

In diagram 1 there is a red string wrapped around two different diameter wheels. As each wheel is pushed forward with the same force it turns one complete rotation and rolls the red string out on the ground. Compare the distance traveled by each wheel.

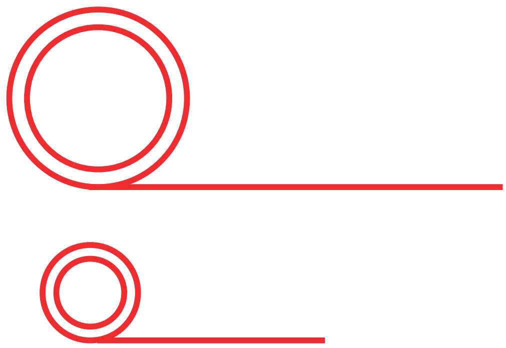


Diagram 1

As you can see the distance traveled by the larger wheel is farther than that of the smaller wheel. The bigger the wheel, the less force is needed to do the same amount of work.

Gears are a variation of a wheel and axle in which the wheel has teeth along the outside edge and works with another gear. There are four basic purposes for using gears.

1. To reverse the direction a gear or object is rotating.
2. To change the speed of a rotating object.
3. To change the position of a rotating axis.
4. To keep two things in rotational motion synchronized.

A gear ratio is the way of measuring the size of one gear compared to another. Two gears of different sizes will rotate with different speeds compared to one another. Look at diagram 1. Let's say the top wheel has a diameter of 10 centimeters, so if the top gear makes one complete rotation, then the distance covered by the circumference is times diameter = 3.14 x 10cm = 31.4 cm.

Let's say the bottom wheel has a diameter of only half that of the top wheel. So 5.0cm x 3.14 = 15.7 cm of distance covered, so the bottom gear would have to rotate twice for each time the top gear rotated once. Therefore the gear ratio would be 2:1.

There are gears in your car engine and in analog clocks and even in a music box. Some of the most easily visible gears are in bicycles.

Gears use teeth, the ridges along the circumference of the gear. The teeth prevent slipping between the gears and allow for more precise gear ratios. By simply counting the teeth the gear ratio can be determined. If the top gear has 30 teeth and the bottom gear has 15 teeth, then the gear ratio is exactly 2:1. The teeth also allow for minor imperfections in the diameter of the gear not to matter. It would be very difficult to make two gears that are exactly some ratio of each other. Over many thousands of rotations even the smallest imperfection would cause the ratio to be off. The teeth keep the ratio exactly perfect and constant.

The driving gear or the primary gear is the gear that gets rotated by a hand or crank and then the gear after that is called the follower gear.

The force on the primary gear can also be increased or decreased. If you double the size of the follower gear, the force on the follower gear axle is twice what it used to be.

You can calculate the increase in force by simply dividing the number of teeth on the follower by the number of teeth on the driver to get the increase in force. Example the follower has 40 teeth and the driver has 10, so the increase in force is 4. This also means that you have to turn the driver gear around four times to get one rotation of the follower gear. Again you are trading force for distance so energy (the amount of work done) is conserved.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Gear Train Base	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Broken gear trains in music boxes, analog clocks, drills, etc	Several

ACTIVITY 1: GEAR TRAIN (TEACHER ANSWERS)

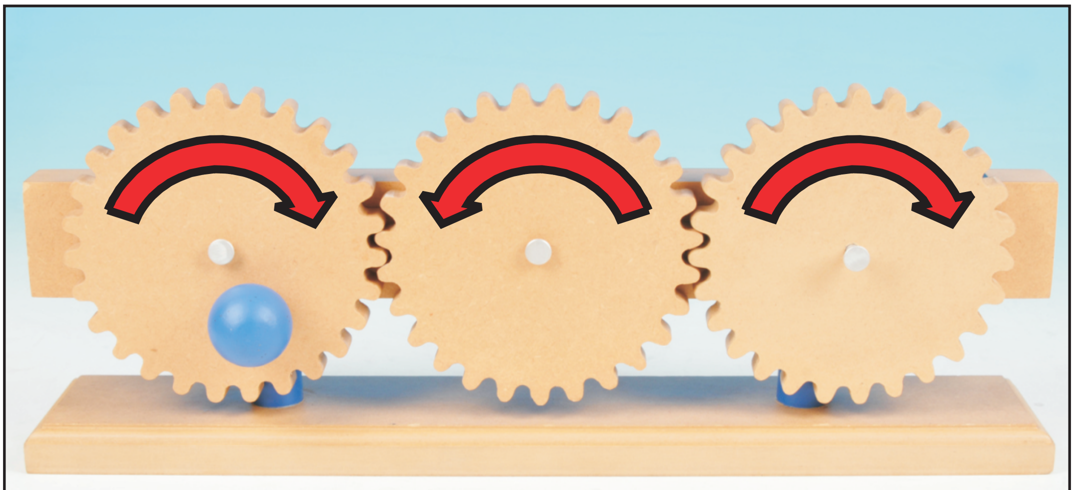


Diagram 2

1. Use the hand crank to turn the primary gear clockwise as shown in diagram 2. What direction does the second and third gear turn respectively? Draw an arrow showing the direction of motion on diagram 2 above.

   (The second gear turns counterclockwise and the third gear turns clockwise.)

2. If you added a fourth gear to the end of the gear train, what direction would that gear turn?

   (The fourth gear would turn counterclockwise, each gear in a gear train turns in the opposite direction of the proceeding gear.)

3. How many teeth are in your gear model? ___27 in each gear____

4. Is there any mechanical advantage to this apparatus? Justify your answer using the terms force and distance.

   (There is no mechanical advantage to this apparatus. The distance traveled by each gear is the same for one complete rotation because there are 27 teeth in each gear.)

5. There are four basic purposes for using a gear listed above. Which of these four things does this gear train demonstrate?

   (This gear reverses the direction of rotation, changes the position of the rotating axis and keeps the first and third gear in synchronized motion.)

ACTIVITY 2: EXPLORING REAL GEAR TRAINS

Have students take apart a broken analog clock, or music box, a broken electric drill, even a VCR and find a gear train (a series of gears, at least two in contact with each other) Have students rotate the gears by hand and see if they can figure out the purpose of the gears.

QUESTIONS FOR STUDENTS TO ANSWER

1. How many gears are there in a row ?

2. Rotate the gears by hand. What direction does each gear rotate in?

3. Are the gears the same size? If not try counting the teeth of gears to find the mechanical advantage.

4. What do you think the purpose of the gears is? Think of the four basic purposes of using gears. What do these gears do? Do they allow rotation on a separate axis? Do they cause the speed of rotation to increase or decrease? To they increase the force of rotation?

You can use the information in the background section to help students explore and learn more about how gears work and what combinations are useful.

NAME:____ DATE:_______________

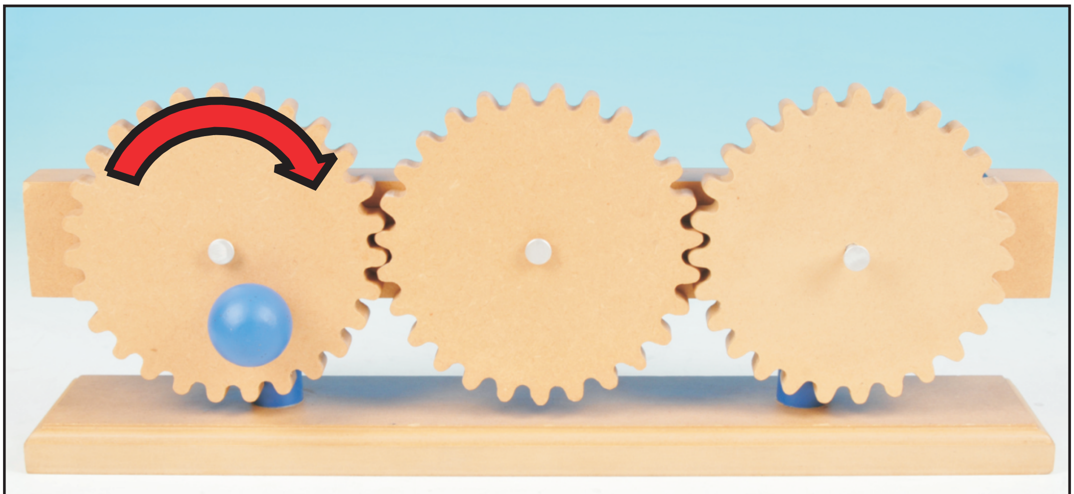
ACTIVITY 1: GEAR TRAIN

Gears are a variation of a wheel and axle in which the wheel has teeth along the outside edge and works with another gear. There are four basic purposes for using gears.

- To reverse the direction a gear or object is rotating.
- To change the speed of a rotating object.
- To change the position of a rotating axis.
- To keep two things in rotational motion synchronized.

Gears use teeth, the ridges along the circumference of the gear. The teeth prevent slipping between the gears and allow for more precise gear ratios. By simply counting the teeth the gear ratio can be determined. If the top gear has 30 teeth and the bottom gear has 15 teeth, then the gear ratio is exactly 2:1. The teeth also allow for minor imperfections in the diameter of the gear not to matter. It would be very difficult to make two gears that are exactly some ratio of each other. Over many thousands of rotations even the smallest imperfection would cause the ratio to be off. The teeth keep the ratio exactly perfect and constant.

The driving gear or the primary gear is the gear that gets rotated by a hand or crank and then the gear after that is called the follower gear.



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