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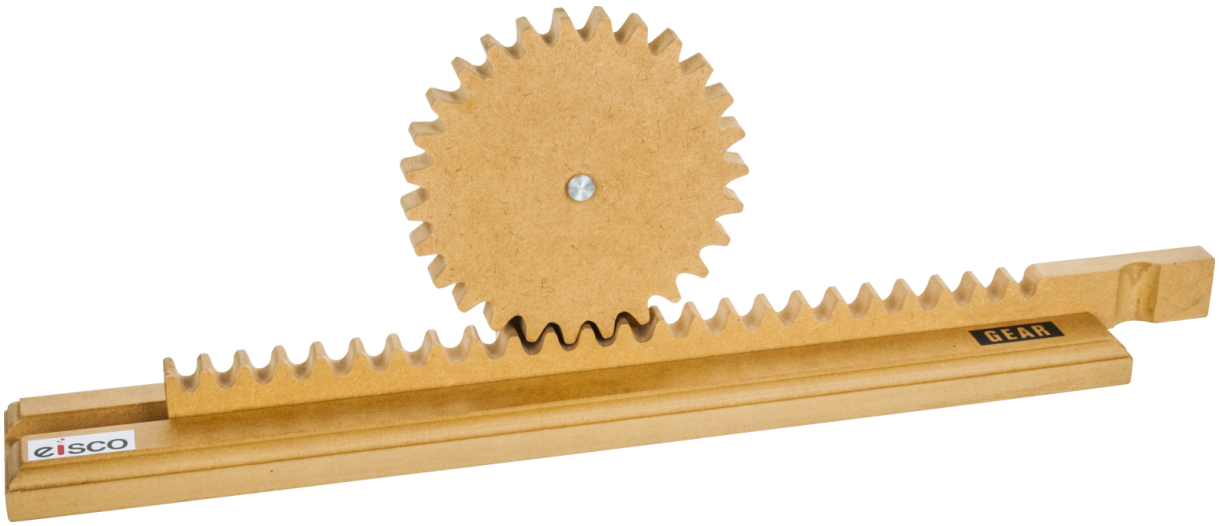
SIMPLE MACHINES : GEAR

CAT NO. WDMS15



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.

[Force applied or weight of the load] [Distance moved] = [Force applied by the effort] [Distance moved]

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

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 petals 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.

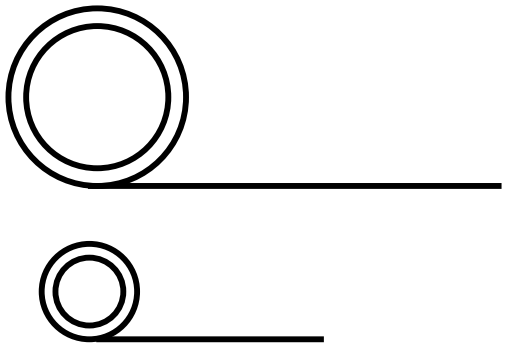


Diagram 1

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 Base	1
Pole with teeth	1

ACTIVITY 1: STEERING WHEEL (TEACHER ANSWERS)

A gear is a wheel and axle with teeth on the outside circumference. Gears can be used for several different purposes, one of which is to turn translational motion into rotational motion or turn rotational motion into translational motion.

1. In a car, a steering wheel is used to rotate the front tires. Rack and pinion steering is a common type of steering system in many cars. Look at diagram 2 of a rack and pinion steering. Identify the gear in this diagram by circling it.

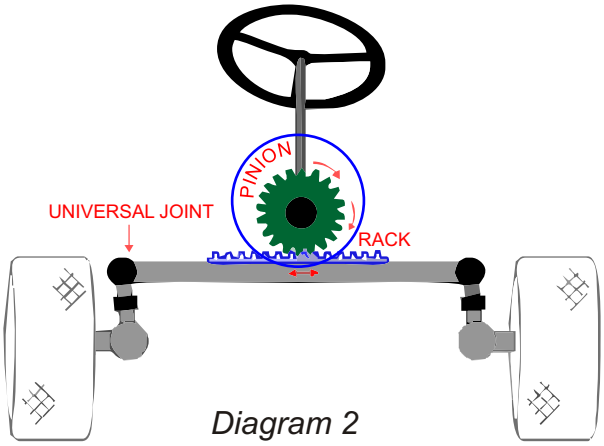


Diagram 2

2. In the case of rack and pinion steering, is rotational motion being converted to translational motion, or is translational motion being converted into rotational motion?

   (Rotational motion is being converted into translational motion.)

3. How many teeth are in your gear model? *27*

4. How many teeth are in your post? *24*

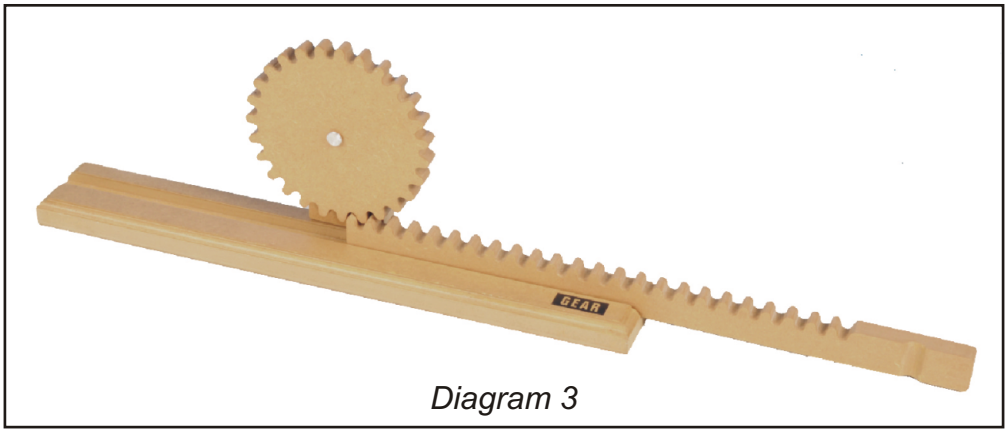


Diagram 3

5. Set up your gear as shown in diagram 3. The tooth that is at the bottom of the gear is the tooth you should keep your eye on. Rotate your gear one half rotation until the gear tooth at the bottom is now at the top. Measure the distance the post traveled. Compare the distance the post traveled to the distance one gear tooth traveled.

   (The distance the gear tooth traveled is equal to the distance the post traveled.)

6. 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 the post is the same as the distance traveled by the gear. Therefore the force is the same and the mechanical advantage is zero. This is assuming no frictional forces in the apparatus.)

7. Is it possible to add a steering wheel to increase the mechanical advantage of my rack and pinion steering? If so, what size would the steering wheel need to be compared to my pinion?

(It is possible to add a steering wheel and increase the mechanical advantage.I would need to cover a greater distance with one rotation of my steering wheel than the distance the pinion covers. A greater distance covered means the diameter of my steering wheel would need to be bigger than the diameter of my pinion.)

NAME:_____ DATE:_____

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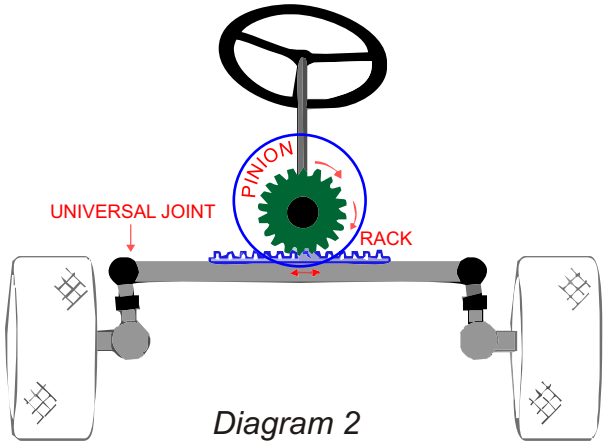

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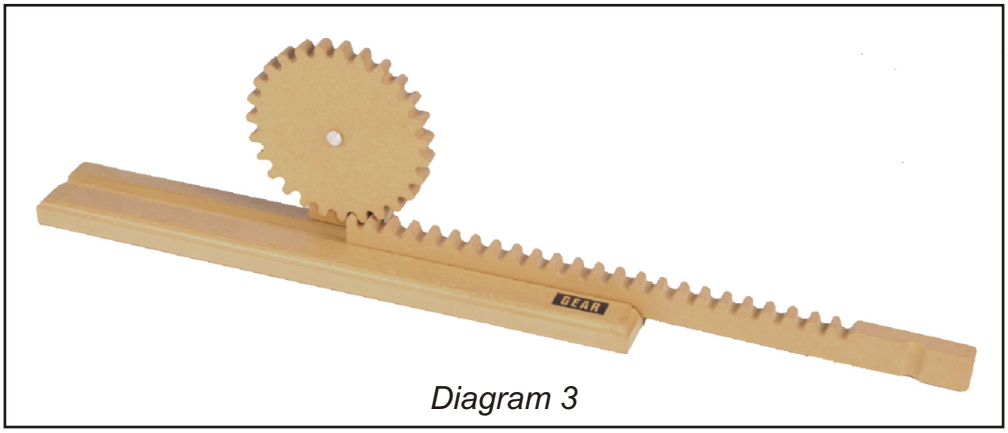
4. How many teeth are in your post? _____



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7. Is it possible to add a steering wheel to increase the mechanical advantage of my rack and pinion steering? If so, what size would the steering wheel need to be compared to my pinion?

ACTIVITY 2: BIKE GEARS

Bikes have easily viewable gears. The simplest kinds of bikes have the fewest gears. What do the gears do? The pedals rotate the front gear, which in turn rotates the back gear and also rotates the back tire.

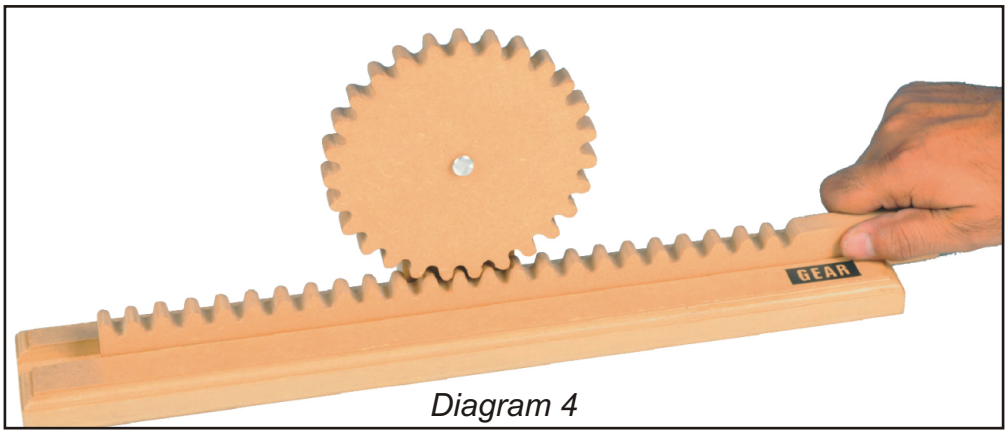

Diagram 4

Move your post in your apparatus as shown in diagram 4. As the post moves from left to right, the gear rotates counterclockwise.

1. The motion of your gear model is similar to what part of a bicycle?
   (The motion of the gear model is similar to the chain and back wheel gear in our bicycle.)

In diagram 5 is a picture of a simple children's bicycle. In a system of gears there is a driving gear (also called a primary gear) and then a follower gear that gets rotated by the driver gear. These two gears teeth normally touch in a gear train but do not touch in a bike.

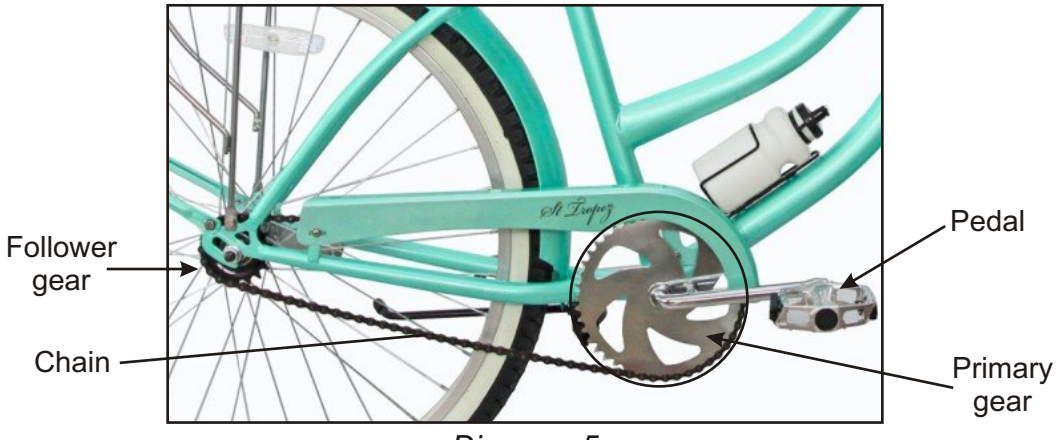

Diagram 5

2. What allows the driver gear to rotate the follower gear?
   (The bicycle chain connects the two gears together.)

3. How is the wooden simple machines gear like a bicycle?

   (The rotating gear transfers motion to the post, just like the front gear transfers motion to the chain when the bike is pedaled. The chain then transfers motion again to the back gear which rotates the back wheel.)

4. Label the driver gear and the follower gear in the bicycle in diagram 4 and then circle the larger of the two gears.

5. When two gears are in contact with one another the primary gear turns in the opposite direction as the follower gear. This is not the case with the bicycle. If the driver gear rotates clockwise, the follower gear does too. What allows this to happen?

   (The bike chain allows both gears to move in the same direction, while the chain itself rotates in the same direction as both gears.)

6. Count the teeth in the first gear and the teeth in the second gear and use that information to come up with the mechanical advantage of these bicycle gears.

   There are 50 teeth on the front gear and 20 on the back gear.

$$\textit{Mechanical advantage} = \frac{\textit{number of teeth on the follower}}{\textit{number of teeth on the driver}} = \frac{20}{50} = 0.4$$

7. Do the gears increase or decrease the mechanical advantage in this case? What possible reason would the bike manufacturer have to design the bike this way?

   (The gears decrease the mechanical advantage in this case because the follower gear is smaller in diameter than the driver gear and the mechanical advantage is less than one. Small children do not have very much strength. It would be easier to pedal and require less force from a child to ride this bicycle.)

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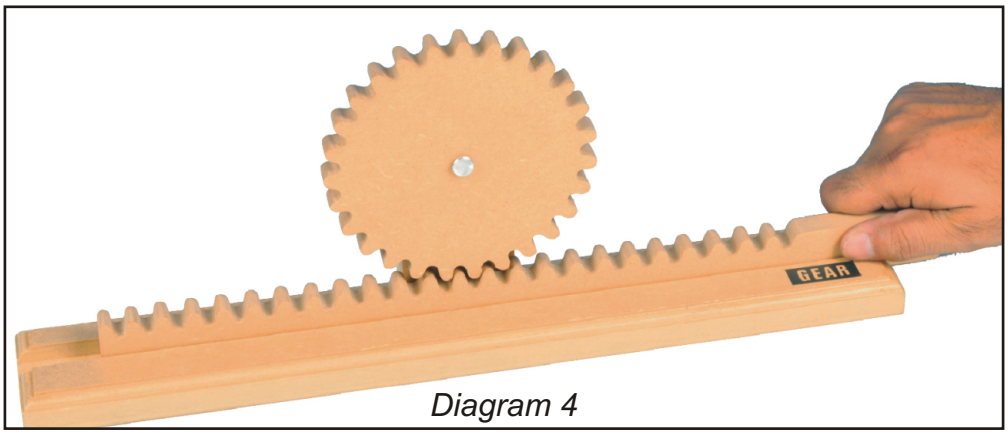

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