NAME: ______________ HOUR: _____________

Activity 1.1.3 Gears

Introduction

You do not have to look far to see gears. You might not think of an object such as a computer as having a lot of moving parts, but the CD tray on your computer is likely controlled by gears. A traditional watch is full of gears. The watch has one source of power or input that must move multiple hands continuously and at different speeds. Some watches also keep track of the day of the month. This may be low-tech by today's standards, but imagine the challenge of choosing just the right gears to keep a watch synchronized. In a watch the gears are used to manipulate rotational speed. Gears are also used in many applications to control torque and rotational direction.

Procedure

In this activity you will learn about gear ratios and how they affect speed and torque within a system.

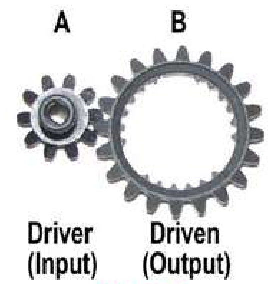


Figure 1

Functions of Gears

- Gears change the speed of rotation.
- Gears change the direction of rotation.
- Gears change torque values.

Gear Ratios

By joining together two or more gears of different sizes, both the speed and the torque are changed from the input gear to the output gear. The larger gear within a system will always move slower and have more torque than the smaller gear. Gear Ratio (GR) is a comparison between the driver gear, also called the input (connected to the power source), and the gear being driven, or the output. Below are four examples of ways to determine the gear ratio in figure 1.

Method 1**:** The gear ratio can be determined by counting the number of teeth on each gear. The ratio is expressed by dividing the number of teeth on the output gear (n_{out}) by the number of teeth on the input gear (n_{in}).

$$GR = \frac{n_{out}}{n_{in}} \rightarrow GR = \frac{20}{10} \rightarrow GR = \frac{2}{1}$$

Gear ratios are often expressed using a colon. In this example the ratio is 2:1 (pronounced two to one). The gear ratio of 2:1 indicates that the driver gear is half the size of the driven gear, and that the driver gear will make two revolutions for every one made by the driven gear.

Method 2: The gear ratio can be determined using the diameter of each gear. Assume that the diameter of gear A is 2.5 in. (d_{in}), and the diameter of gear B is 5 in. (d_{out}).

$$GR = \frac{d_{out}}{d_{in}} \rightarrow GR = \frac{5\,\cancel{in}.}{2.5\,\cancel{in}.} \rightarrow GR = \frac{2}{1}$$

Method 3: The gear ratio can be determined by recording and comparing the angular velocity or speed at which each gear is turning. The lower case Greek letter ω is used to represent angular velocity. A common way to measure angular velocity is using revolutions per minute (rpm). Assume that the rpm of the input gear is 446 rpm and the rpm of the output gear is 223 rpm.

$$GR = \frac{\omega_{in}}{\omega_{out}} \rightarrow GR = \frac{446\ \cancel{rpm}}{223\ \cancel{rpm}} \rightarrow GR = \frac{2.00}{1}$$

Method 4: The gear ratio can be determined by recording the torque at each gear. Divide the torque at the output gear (τ_{out}) by the torque at the input gear (τ_{int}). A common way to measure torque is to use foot pounds (ft·lb). Assume that the torque force at the driver gear is 4 ft·lb and the force at the driven wheel is 8 ft·lb of torque.

$$GR = \frac{\tau_{out}}{\tau_{in}} \rightarrow GR = \frac{8\ \cancel{ft-lb}}{4\ \cancel{ft-lb}} \rightarrow GR = \frac{2}{1}$$

The above equations all solve for the gear ratio of the driver gear to the driven gear. Based upon these formulas, the following is true.

$$\frac{GR}{1} = \frac{n_{out}}{n_{in}} = \frac{d_{out}}{d_{in}} = \frac{\omega_{in}}{\omega_{out}} = \frac{\tau_{out}}{\tau_{in}}$$

Mechanical Advantage of a Simple Gear Train

In a group calculate the mechanical advantage of a simple gear train that consists of four meshed gears each with its own axle. Assume that the first gear, gear A, is the driver as seen in Figure 4.

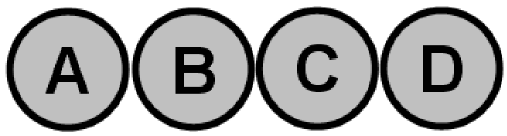


Figure 4

Complete the following tables based upon simple gear train info from Mr. Bayer:

Number of Teeth Per Gear				
	A (n_{in})	B	C	D
n (teeth)				

	B:A	C:B	D:C		
Gear Ratio (reduced)					
Gear Ratios as Fractions				Product of Fractions	Final Gear Ratio

By multiplying the gear ratios between each set, you discover the ratio between gears A and D.

Simple Gear Train Conclusion

1. How many times will gear A rotate compared to gear D? How does this compare to the gear ratio you just calculated in the table?

2. If 10.0 ft·lb of torque is applied at gear A, then what is the output at gear D?

Formula	Substitute / Solve	Final Answer

3. How can you make gears A and D rotate in the same direction?

4. What will the gear ratio be if A is connected directly to D?

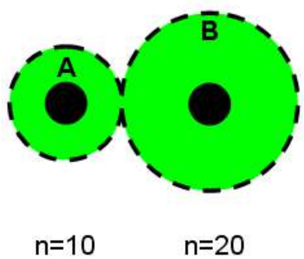
5. How does the ratio between A and D compare to the entire system?

6. If gear D is the final output, or where the load is attached, then how did gears B and C impact the system?

Compound Gear Trains

A compound gear train connects gears that may share axles or shafts. Two gears on the same shaft share the same torque and speed although they are different sizes. This allows more efficient manipulation of speed and torque throughout the system.

Figure 5 represents two simple gear trains and gear ratio for each set. The input for the first set is gear A. The input for the second set is gear C.



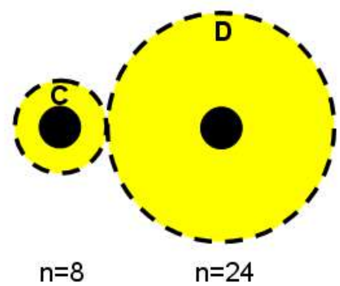


Figure 5

Gear Ratio of Set 1

$$GR = \frac{n_{out}}{n_{in}} = \frac{B}{A} = \frac{20\not{n}}{10\not{n}} = \frac{2}{1}$$

Gear Ratio of Set 2

$$GR = \frac{n_{out}}{n_{in}} = \frac{D}{C} = \frac{24\not{n}}{8\not{n}} = \frac{3}{1}$$

Figure 6 represents the two simple gear trains above with gears B and C sharing the same shaft. Gear A is the driver.

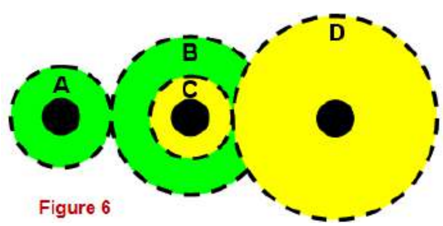


Figure 6

Solving For Compound Gear Trains

To solve for a compound gear train, determine the gear ratio of each simple gear train. Next find the product of all sets. We know from the previous example that the ratio between gears A and B is 1:2 and that the ratio between gears C and D is 1:3.

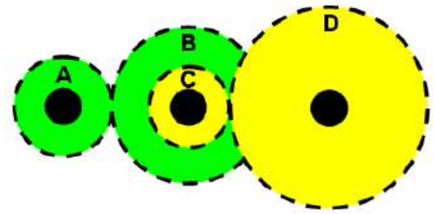
Gear Ratio of A : D

$$GR = \frac{B}{A} \times \frac{D}{C} = \frac{2}{1} \times \frac{3}{1} = \frac{6}{1}$$

The gear ratio of 6:1 indicates that the driver gear A will make six revolutions for every one by the driven gear D, and that gear D will have 6 times more torque than gear A.

Mechanical Advantage of a Compound Gear Train

In a group calculate the mechanical advantage of a gear train that consists of four different-sized gears. The two gears in the middle must share the same shaft. Once the gears are arranged, assume that the driver is Gear A. Gear A is connected to gear B and will share the shaft with gear C, which is connected to gear D.



Complete the following tables based upon simple gear train info from Mr. Bayer:

Number of Teeth Per Gear				
	A (n_{in})	B	C	D
n (teeth)				

	B:A	D:C		
Gear Ratio (reduced)				
Gear Ratios as Fractions			Product of Fractions	Final Gear Ratio

Compound Gear Train Conclusion

7. How many times will gear A rotate compared to gear D?

8. If 7.0 ft·lb of torque is applied at gear A, then what is the output at gear D?

Formula	Substitute / Solve	Final Answer

9. Why might compound gear trains be better than two gears alone?

10. Name and describe an application of a compound gear train.