Introduction to Gears & Gear Ratios

Grade(s): 6-8

Learning & Activity Goals/Objectives

- What is a gear and how does it work
- How do you determine a gear ratio
- What is torque vs. speed and how do they impact the way gears operate

Overview

What is a gear? How does it work? How does the size of the gear and different gear arrangements impact the overall performance of the gears?

In this lesson we answer all of these questions and more. Students will be introduced to gears, and gear ratios. Students will also learn about torque and speed and how to determine if the gear ratio that they are using is utilizing either of these.

The second part of the lesson, after the students are familiarized with gear ratios, focuses on how to incorporate these concepts into their Junior Solar Sprints vehicles. During this portion of the lesson we will discuss how wheel size directly impacts the gear ratio needed to move the vehicle and how to best find the proper ratio to use.

Curriculum Standards

Health & Physical Education

Grade 6

- 2.1.6.A.2
- 2.1.6.D.1
- 2.2.6.A.1
- 2.2.6.B.1
- 2.2.6.D.2

Grade 8

- 2.1.8.A.2-3
- 2.1.8.C.2
- 2.2.8.D.1-2

Science

- 5.1.8.A.1
- 5.1.8.A.2
- 5.1.8.C.1
- 5.1.8.C.2
- 5.1.8.D.1
- 5.2.8.C.2

Technology

- 8.2.4.B.3

Life & Career Skills

- 9.1.8.A.2
- 9.1.8.B.[1 & 2]
- 9.1.8.D.3

Mathematics

- CCSS.Math.Practice.MP4
- CCSS.Math.Practice.MP7
- CCSS.Math.Content.6.NS.B.3

Social Studies

- 6.3.8.A.1

Advanced Gears and Gear Ratios

Grade(s): 6-8

Learning Objectives:

- What do the different gear ratios mean, practically?

Overview

As a follow-up to the Introduction lesson students are provided with an opportunity to test different gear ratios. Utilizing equipment supplied by goHunterdon the students will build and test a working prototype and will have the opportunity to see how gear choices impact their car.

This workshop is designed for the students to design and build a working prototype which will help them in refining their actual design.

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Health & Physical Education

Grade 6

- 2.1.6.A.2
- 2.1.6.D.1
- 2.2.6.A.1
- 2.2.6.B.1
- 2.2.6.D.2

Grade 8

- 2.1.8.A.2-3
- 2.1.8.C.2
- 2.2.8.D.1-2

Science

- 5.1.8.A.1
- 5.1.8.A.2
- 5.1.8.C.1
- 5.1.8.C.2
- 5.1.8.D.1
- 5.2.8.C.2

Technology

- 8.2.4.B.3

Life & Career Skills

- 9.1.8.A.2
- 9.1.8.B.[1 & 2]
- 9.1.8.D.3

Mathematics

- CCSS.Math.Practice.MP4
- CCSS.Math.Practice.MP7
- CCSS.Math.Content.6.NS.B.3

Social Studies

- 6.3.8.A.1

Introduction to Gears and Gear Ratios Lesson Plan: 2020

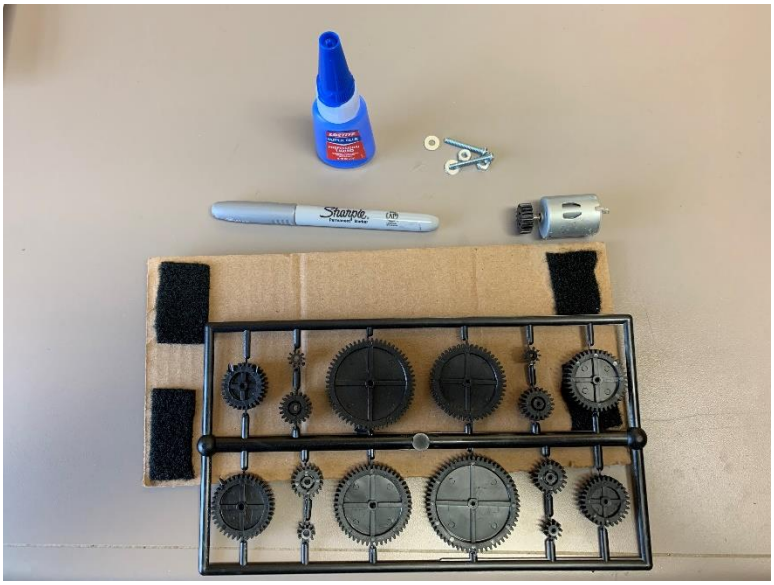
Objective: Students will know what a gear is and understand what it is used for. They will also understand gear ratios, how to find them, and what the differences are in how they work. They will be introduced to the concept of torque and speed and be able to identify a gear setup as such.

Time: 30 – 45 minutes

Materials: Introduction to Gears PowerPoint, gear setups

Making the Materials:

You are going to start off with a few different pieces of cardboard, corrugated plastic, or something like that. As you can see from the photo on the right you will also need gears, nuts and bolts, and a marker.



Next you want to push the bolt through the cardboard and put the gear on the other side and secure with a bolt. Using the marker you want to draw a straight line across one of the ridges on the gear.

Finally you are going to do the exact same thing with the second gear and make sure that the lines are even with one another. [To get the right spacing put the gear where you want it and mark where the hole will be so that you can push the bolt through in the right spot]

Procedure:

1. Begin by having the students tell you what a gear is. Follow-up this question by asking them where they might be able to find gears. Then work your way through the next few slides which talk about where gears are found and some different types of gear setups. Make sure to point out that <u>Spur Gears</u> are what they will be using to build their cars.
2. Over the next few slides you will be defining what a gear ratio is. Make sure that the students understand what everything means before moving on. There are also some examples to work through as a class. Slide #9 will explain the trick question in the previous examples by showing that gears used to move the rotations don't factor into the overall ratio. Only gears that are attached to the source of the rotation [i.e., the motor] and the final gear that is performing work [i.e., the axel of their car]. Point out once again that the ratio is [MATH PROBLEM]
3. Slides 10 – 13 will talk about torque and speed. Have the students try to define both of the terms. A good example of torque, if the kids don't understand the definition, is screwing a screw in by hand with a screwdriver. Torque is the amount of force you need to use to turn the screw.
4. The following are some equations that should help explain the relationship of torque, speed and power.

   <u>Torque</u>
   Torque, when being measured in the US, is pounds feet. For example a 2020 Ford Mustang has 350 lb-ft of torque. In the rest of the world torque is measured in newton metre (Nm) Which would put the same Mustang at 447 Nm. This is the measurement we would use in our equation of:

$$Power(kW) = \frac{Torque\ (Nm) * Speed\ (RPM)}{9.5488}$$

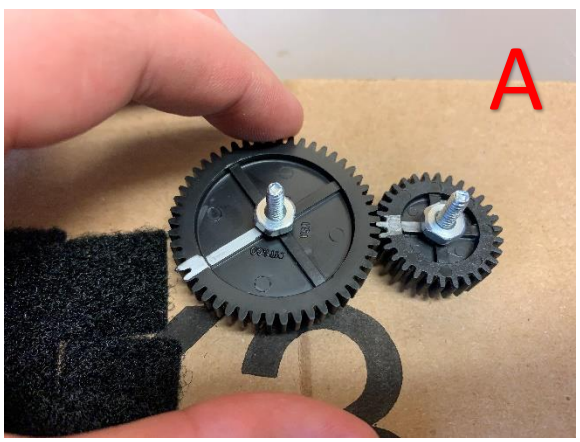
If you were to rearrange the equation it would look something like:

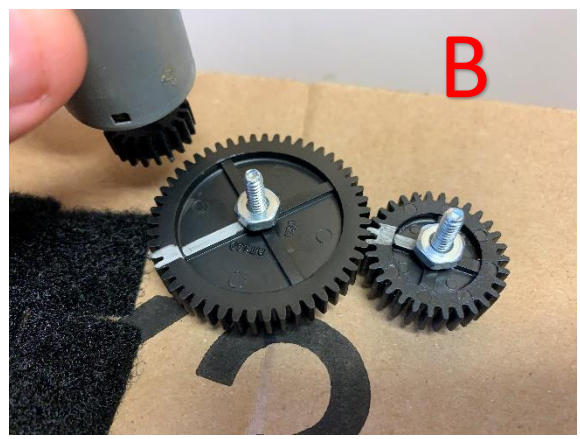
$$9.5488 * Power\ (kW) = Torque\ (Nm) * Speed\ (RPM)$$

5. On slide #11 the constant (9.5488) has been applied to the equation so that the students can more easily see the change that torque and speed make relative to one another. Have the students solve the equation assuming the power of the motor stays constant but you increase the torque. Then do the same thing with increasing the speed.
6. The equation on slide #11 is the standard for the motor that the students will be using. Obviously don't discuss the ability to change the power output to the students at this point. We want them to see that applying different gear ratios to their cars, increasing torque or speed, it will have an impact on their car.

Activity:

You will have two different ways that you can have the students utilize the gears. They can either turn them by hand an watch the two different lines[A]. Or, they can utilize a motor with a gear on it to see what the torque and speed look like with the motor they will be using[B].





Extra Material – [Math Heavy]

If you would like to challenge your students have them attempt to work out what will happen to their car, mathematically speaking, if they are able to generate additional kW by having a better angle to the sun. So below are some scenarios that you can provide to them, be sure to give them the full equation at this point:

$$Power(kW) = \frac{Torque\ (Nm) * Speed\ (RPM)}{9.5488}$$

<u>Scenario #1</u>

Your car has been running at 1,200 kW for most of the morning, but the sun suddenly goes behind a cloud as you are about to race. The race officials say that there is still enough sunlight to run your race on solar power. Your power output drops to 800 kW. You know that your gear

ratio provides your car with 8 Nm of torque and 1,437 RPMs at 1,200 kW. How does this change impact your car?

Solution:

1) If the following is your normal equation:

$$1{,}200\ kW = \frac{8\ Nm * 1{,}437\ RPM}{9.5488}$$

2) You would have to solve for *x*, being [torque * speed]:

   So I would need to set up my new equation in the following way:

$$800\ kW = \frac{x}{9.5488}$$

3) Completing both of my equations for [torque * speed] I get the following:

   At 1,200 kW I have 11,496 Nm*RPM

   At 800 kW I will have 84 Nm*RPM

4) Since your ratio has not changed you can use it to get the same ratio with your decreased power. Here is how I found it. Solve for x Nm:

$$\frac{x\ Nm}{84Nm * RPM} = \frac{8\ Nm}{11496\ Nm * RPM}$$

$$[11496\ Nm * RPM] *\ x\ Nm = 672\ [Nm * RPM] * Nm$$

5) Divide both sides by [11496 Nm * RPM]:

$$x\ Nm = 0.06\ Nm$$

6) Now using this new number I can plug it into my equation for my new power output. And I get:

$$800\ kW = \frac{0.06\ Nm * x\ RPM}{9.5488}$$

7) Solve for x and you should get 1,396 RPMs.

In conclusion the decrease in power from the sun significantly altered the amount of torque available for your vehicle. This is a good thing to know as you might conclude being able to change your ratio depending on the sun's output would be beneficial to the speed of your vehicle.

Calculating Speed Output

Another interesting mathematical exploration is how the change in gear ratio alters the speed of the vehicle or the (output speed). We can use this formula to find out how our ratio is going to impact the actual output of speed for our car. This formula is:

$$Output\ Speed(RPM) = \frac{Input\ speed(RPM)}{Speed\ Ratio}$$

The motor has a maximum output of 5,200 RPMs so we can use that as our baseline. If we have a gear ratio of 3 (a small driver gear that is 1/3 the size of the driven gear), we would set this up in the following manner:

$$Output\ Speed(RPM) = \frac{5{,}200(RPM)}{3}$$

We get an output ratio of 1,733 RPMs. You can have the students try and figure out the speed output for their vehicle if their motor is working at full capacity, half capacity, and more. You could also ask the students to utilize all of this information to figure out the necessary power output to get them the optimum ratio. The mathematical information needed to do this is within the Solar Lesson.