Introduction to Gears and Gear Ratios Lesson Plan: 2022

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: 45 minutes

Materials: Introduction to Gears PowerPoint, gear setups
Remote: Use www.geargenerator.com for gear simulation

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 Spur Gears 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.
3. Slides 9 – 12 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.

   Torque
   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-meter (N-m) which would put the same Mustang at 447 Nm. This is the measurement we would use in our equation of:

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

   Where 9.5488 is a conversion factor for angular velocity

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

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

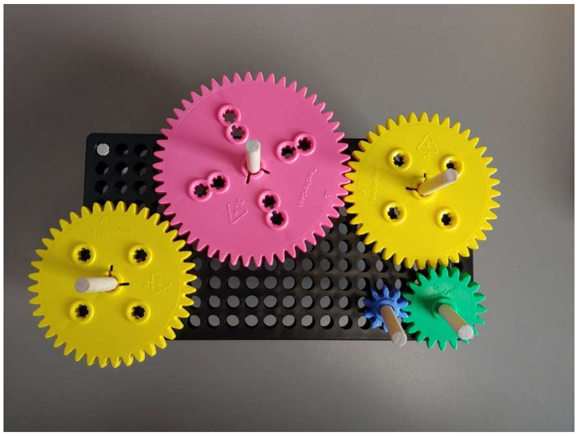
5. On slide #10 the conversion factor (9.5488) has been applied to the equation so that the students can more easily see the change that torque and speed make relative to one another.

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 #10 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, will have an impact on their car.

Activity:

Each gear set includes 1 large gear with 50 teeth, 2 gears with 40 teeth, 1 gear with 20 teeth, and 1 gear with 10 teeth along with a base. These supplies are needed to complete the Ratio & Proportion Lab and Mechanical Advantage worksheets which will help students to understand how gears work and how the set up chosen will affect torque and speed for their vehicles.



For those students who are working remotely using the online gear generator program, there is a separate worksheet with instructions on how to use the gear generator and gear ratios to try. Then they will indicate on the worksheet whether the gear ratios are better for torque or for speed.

Extra Material

Calculating Speed Output

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

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

The motor has a maximum output of 5,200 RPM with no load so we can use that as our baseline. If we have a gear ratio of 3:1 (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 a maximum output axle speed of 1,733 RPMs. This is with no load, so actual rpm's will be less than this. You can have the students try and figure out the output speed for their vehicle if their motor is working at full capacity, half capacity, and more.

If your students would like to use the output speed of the axle to calculate actual vehicle speed, you need to measure the circumference of the driven wheel and use that to convert revolutions to distance traveled.

$$Output\ Speed\ (RPM) * drive\ wheel\ circumference\ = vehicle\ speed$$

Where output speed is 1733 rpm

Using provided car kit wheels, circumference is 5 inches

Multiply by a 0.000947 unit conversion factor to go from inches per minute to miles per hour

So, entering all of these numbers into the equation above gives the following:

$$1733\ RPM * 5\ in * 0.000947 = 8.2\ miles\ per\ hour$$

This is the maximum theoretical vehicle speed using the provided motor and wheels at a gear ratio of 3:1. Actual rpm's will be less than this, so you could have students use 5,000 rpm as the maximum and then vary the gear ratio and see how it affects the speed of the vehicle. Remind students that if they use a higher torque gear ratio, that they cannot use the maximum output speed of 5,200 rpm because as torque increases, speed decreases for a fixed motor power output.