Unit 2 Gears and Drivetrain Speed

Class Flow

Unit 2 should take approximately 10 hours.

Lesson 2.0 (Approximately 30 minutes)

Objectives

1. Describe the relationship between radius, diameter, circumference, revolutions and distance for a wheels

In this lesson, students will understand that the diameter of the wheel can be used to calculate a specific distance travelled. You will want to have each student take a wheel and a piece of string to measure the circumference of the wheel. They will then calculate the circumference of the wheel and see that they are the same. Then you will walk them through the math of figuring out how far a robot can travel based on number of rotations.

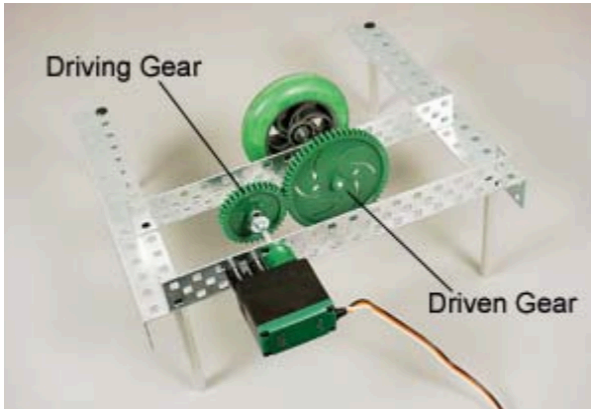
Lesson 2.1 (Approximately 1 hour)

Objectives

1. Identify the different types of gears
2. Explain the difference between speed, power and torque and vary the gear ratio (and the mechanical advantage) in a system, which gives them the versatility necessary to accomplish whatever work needs to be done.
3. Demonstrate the correct use of the calculations needed to choose a gear reduction.

You should go over the slides and give the handouts when indicated on the slides. Be very careful to note the difference in gear ratio and gear reduction. Gear ratio is not something you can really use mathematically because it's a ratio. If you have a 60 tooth driving gear and a 30 tooth driven gear, the gear ratio is 2:1. However, gear ratio is not used generally when trying to calculate distance travelled or torque output. All of the equations refer to the gear reduction. The gear reduction in the previous example is driven/driving which is ½. Therefore, if you have input speed 100 RPM, input speed = output speed/Gear reduction, the equation is 100/(1/2) which is 200 RPM. Just be very careful with the words

you use and make sure you use the correct one. I warned the kids that I would likely mess it up a few times and to bear with me. I also encourage them greatly to just think of it logically. If the 60 tooth gear spins one time, then the 30 tooth gear would spin 2 times. That means if the 60 tooth gear is going around 100 times, the 30 tooth gear would go around 200 times. Most kids get this concept but get tripped up on the formulas and on the terminology. Consider bringing in a real gear set (if you had a 3D printer, you can print one from thingiverse https://www.thingiverse.com/thing:185912) to help them understand. Or have the kids build a gear chain with VEX parts with tape denoting the starting point so they can see that as you turn one gear a full rotation, the other one does more (or less) than one rotation. If you have time, you could even go to the next step which would be to have the kids attach a motor to one of the gears and also attach a wheel (see picture below).



Lesson 2.2 (Approximately 1 hour)

Objectives:

1. Describe the relationship between radius, diameter, circumference, revolutions and distance for a wheels using a gear reduction to increase speed or torque.

In this lesson, students will take what they've learned about gear reduction and speed and apply it to calculate distance travelled. They will also learn about compound gear reductions if you need even more speed or torque. You will lose some kids here which is why the picture above could be really helpful. Try to get a piece of string and put it around a wheel and show how the circumference of the wheel is the distance that is travelled in one revolution. I had kids at the

end of the year who still just couldn't intuitively get this concept but they were able to memorize the formulas. Keep trying to get them to understand it intuitively because it will make it much easier! There is also homework to hand out. There is time built into class to allow most of them to complete it during class.

Lesson 2.3 (Approximately 7 hours)

Objectives:

1. Analyze the features of their robot and identify/synthesize how to change them to get different results for high speed or low speed
2. Graph the results of their experiment in a meaningful way and discuss situations where the results did not follow the expectation.

The kids should build 6 iterations of their robot using a variety of gears and wheels. The point is to show them that the smaller the wheel diameter, the less distance it travels per revolution. Also, the varying gear reductions will give them very fast or very slow robots and they should see a decrease or increase in accuracy. See reasons listed below in report discussion. If you want to create an extension to this, you could also have them try to pull or push an object with various gear reductions. They should see that the robots that can go faster and farther in 3 seconds can also not push or pull as much weight as the slower robots.

Quiz (approximately 1 hour)

The quiz should be given at the end of the project after they have turned in the lab report. There is a quiz practice sheet as well as a kahoot you can do with the kids. https://play.kahoot.it/#/k/38c0e5b6-7254-43ae-9195-a2049f37b460

General Information:

The teacher should load the robot with the program that makes the robot move forward for 3 seconds. Open RobotC and go to File>Open > ROBOTC Development Environment 4.X\Sample Programs\VEX2\Basic Movement\Moving Forward.c. Please note that the motors must be plugged into ports 2 and 3 which means the kids will need a motor controller. If your kids want to use ports 1 and 10, that's totally fine by they will need to update the code to match. Also, using ports 1 and 10 mean that you have to change the code if you find that one side is moving in the wrong direction. If you use a motor controller, then all you have to do is flip the connection between the motor and the motor controller

and that will flip the polarity of the motor and make it spin in the opposite direction. I would recommend using the motor controller.

Be sure the RobotC environment is in VEX2 not VEXIQ. The students should test their robot after each build iteration and record their results in the last column of the table. They should also write down their observations in their notebook.

If you've never worked in RobotC before, see if you can get with someone who can because it helps just to see it a few times. Learning a new software environment is all about practice. If you aren't comfortable with it, just roll with it and maybe even tell your kids to bear with you because it's new. Your kids will understand. Don't be ashamed if the kids figure something out before you; use that as a tool and resource. The great thing about VEX and RobotC is that there are a ton of online resources to help you. Carnegie Mellon is a fantastic resource.

As the kids are going through the project, talk to them about the main points that they should be observing: that a gear reduction of ½ goes way faster than a gear reduction of 2:1 and that robots with the same gear reduction but with bigger wheels will travel further (because the circumference is larger). See discussion points below for more detailed observations.

Lab Report Information

Results:

Column D is given by the specs of the motor. New motors from the package will come geared for 100 RPM. If you are using old motors, there is the possibility that the internal gears have been changed to be gears for high speed (160 RPM). If your teams have a robot that veers wildly off course, it's possible they are using an old motor that has had the gears changed out. Google how to change the gears on a VEX motor to find the instructions. The gear and wheel combinations shown here are samples. However, each team should have one set up geared for speed and one for torque.

A	B	C	D	E	F	G	H	I	**J**	**K**	**L**

Driven Teeth*	Driving Teeth*	Gear Reduction	Input Speed (RPM)	Output Speed (RPM)	Output Speed (RPS)	# of revolutions in 3 secs	Wheel Diameter**	Circumference	**Predicted** Distance Travelled in 3 secs	**Actual** Distance Travelled in 3 secs	**% Error**
24	60	=A/B	100 RPM	=D/C	=E/60	=F*3	4"	=H*3.14	=I*G	Measured	=(J-K)/J*100
60	60						4"				
60	24						4"				
24	60						2.75"				
60	60						2.75"				
60	24						2.75"				

Discussion

For the most part, they will find that the robot will not go as far as their calculations predicted. This is because the 100 RPM for the motor output is based on a full 7.2 V battery charge. If their battery isn't fully charged, it won't be able to reach the spec level of 100 so any gear reduction will also be affected. Also, the 100 RPM is free speed meaning there is no countering torque but the motors are not spinning at free speed.

Also, the robots that are geared for speed (ie anything where output speed is over 100), will take some time to accelerate and therefore will not reach the speed instantly causing the actual value to be lower (sometimes much lower) than the predicted value. For some robots that go past the predicted distance, it can be caused by the fact that the robot doesn't stop dead in its tracks when the program ends because of momentum. The heavier the robot, the more likely this phenomenon will happen. Students should observe that robots that are gear for speed instead of torque will have less error. This is because the lack of acceleration at the beginning matters less and the robot will not overshoot the end by continuing to move after the program has stopped.

Another observation is that with the same gear ratio, your robot with bigger wheels should travel further than with the smaller wheels. It may be that the factors causing errors may make it hard to notice the difference, especially if you use 4" and 5" wheels. The larger the difference in wheel size, the more likely you are to see a difference.