Overview:
In this lesson, students will learn how gears can be used to increase torque or speed. Students will build, modify, and analyze a simple gear train and then work as a team to create a custom design.

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Learning Objectives & NGSS Alignment:
- Build and modify a gear train to increase torque or speed.
- Determine the gear ratio and output speed of a gear train.
- Use Kid Spark engineering materials to create a custom design.

Scientific/Engineering Practice - Using mathematics
Crosscutting Concept - Scale, proportion, and quantity

Convergent Learning Activity:
1. What is a Gear?
A gear is a toothed wheel designed to work with another toothed component to increase torque (a twisting force that causes rotation), increase speed, or change direction.

2. What is a Gear Train?
A gear train includes at least two gears that work together to increase torque, increase speed, or change direction. A gear train includes a driver gear and a driven gear. Power is applied directly to the driver gear which causes it to rotate. As the driver gear rotates, the driven gear rotates in the opposite direction.
Instructions:
Follow the step-by-step instructions to assemble a simple gear train.

1. 2x Beams, 5x Half Beams, 6x Blocks
2. 4x Beams, 4x Blocks
3. 1x Motor Module, 1x Bearing Module
4. 4x Mini Curved Beams, 4x Risers, 1x Single Snap Block
Instructions:
Follow the step-by-step instructions to assemble a simple gear train.

Instructions:
Place the small and large gears on the structure as shown.
**Instructions:**
Follow the step-by-step instructions to assemble a simple gear train.

**Step 1:** Power on the Maker ROK-Bot.
**Step 2:** Sync the ROK-Star Controller to the Maker ROK-Bot.
**Step 3:** Press the X/Y buttons on the ROK-Star Controller to activate the gear train.
3. **Increasing Torque**

In a gear train, the gear that is connected directly to the power source (your hand or a motor) is called the driver gear. The gear being driven by the driver gear is referred to as the driven gear. The main purpose of a gear train is to increase torque or speed. The arrangement of the driver and driven gears determine if the gear train will increase torque or speed.

To increase output torque using a gear train, a power source should be directly connected to a smaller gear and used to drive a larger gear.

4. **Determining Gear Ratio and Mechanical Advantage**

A gear ratio is a relationship between the number of gear teeth on the driver gear to the number of gear teeth on the driven gear. The formula for gear ratio is:

\[
\text{Gear Ratio} = \frac{\text{Number of teeth on driven gear}}{\text{Number of teeth on driver gear}}
\]

In this example, there are 28 teeth on the larger driven gear and 16 teeth on the smaller driver gear. Divide 28 ÷ 16 to get a gear ratio of 1.75. This means the smaller driver gear has to rotate 1.75 times in order for the larger driven gear to rotate 1 time. This relationship can be written as a ratio of 1.75:1. The gear ratio also defines how much mechanical advantage (the amount a machine multiplies force) is being created in a gear train. In this example, the larger driven gear has an output force that is 1.75 times greater than the input force that is being applied to the smaller driver gear.

**Instructions:**

**Step 1:** Adjust the gears so both snap-in wheels are at top dead center as shown in the figure above.
**Step 2:** Press the X button on the ROK-Star Controller.
**Step 3:** Observe how the smaller driver gear has to rotate 1.75 times in order for the larger driven gear to complete one complete revolution.

5. **Determining Output Speed**

To determine the output speed of a gear train (how fast the driven gear is rotating), the following formula can be used:

\[
\text{Output Speed} = \frac{\text{Input Speed}}{\text{Gear Ratio}}
\]

In order to determine the output speed, the input speed must first be determined. The speed of a gear is usually determined in how many complete revolutions it makes in one minute (RPM - revolutions per minute).

**Instructions:**

**Step 1:** Adjust the small driver gear so the snap-in wheel is at top dead center.
**Step 2:** Locate a timing device (clock, stopwatch, etc.).
**Step 3:** Press the X button on the ROK-Star Controller and count the number of complete revolutions the small driver gear makes in one minute.

In this example, the small driver gear makes around 23 revolutions in one minute. Divide 23 ÷ 1.75 (Gear Ratio) = 13.14 RPMs. This means the output speed of the large driven gear is around 13 revolutions per minute.
6. **Increasing Output Speed**

To increase speed using a gear train, a power source should be connected to a larger driver gear and used to drive a smaller gear.

**Instructions:**

**Step 1:** Disconnect both gears from the structure.

**Step 2:** Connect the large gear to the motor module.

**Step 3:** Connect the small gear to the bearing module.

**Step 4:** Since the larger gear is now the driver gear, the gear ratio has been changed. Work as a team to determine the gear ratio and output speed of the gear train.
Divergent Learning Activity:

Scenario:
Kid Spark Engineering is currently accepting proposals for new and creative product inventions or innovations that serve a specific purpose.

Design & Engineering Challenge:
Develop a new product or design that includes a gear train. See example below.

Specifications/Criteria:
1. Students will work in teams of up to 4 to design and engineer a new product or design that serves a specific purpose. Teams can invent something completely new or improve an already existing product.
2. Teams must work through each step of the design & engineering process to design, prototype, and refine their design. Teams will demonstrate and present their designs to the class when they are finished.
3. The design must be powered by the Maker ROK-Bot.
4. The product or design should feature a gear train that enables it to function correctly. Teams must determine the gear ratio, input speed, and output speed of the gear train that is included.
5. Teams must determine the overall dimensions (length, depth, and height) of the product or design.
6. With each building component costing $2, determine the total cost of the design.

Example Idea:

Product Innovation/Invention: Directional Fan

Purpose: Provides cool airflow to a desired area

Design Notes: The directional fan includes a gear train that is used to increase the output speed of the fan. This is accomplished by providing power directly to a larger driver gear that is driving a smaller gear. A second motor, located at the base of the fan, is used to rotate the fan in different directions as desired. A user can control the fan using the ROK-Star Controller and Maker ROK-Bot.

Dimensions: 38 cm x 14 cm x 52 cm (L x D x H)

Gear Ratio: 0.57:1
Calculation: 16 ÷ 28 = 0.57

Input Speed: 23 rpm
Calculation: Timed rotations/minute

Output Speed: 40.35 rpm
Calculation: 23 ÷ 0.57 = 40.35

Material Cost: 115 components x $2 = $230
Challenge Evaluation
When teams have completed the design & engineering challenge, it should be presented to the teacher and classmates for evaluation. Teams will be graded on the following criteria:

- **Design and Engineering Process**: Did the team complete each step of the design and engineering process?
- **Design Specification**: Did the team complete the design specification?
- **Team Collaboration**: How well did the team work together? Can each student describe how they contributed?
- **Design Quality/Aesthetics**: Is the design of high quality? Is it structurally strong, attractive, and well proportioned?
- **Presentation**: How well did the team communicate/explain all aspects of the design to others?

### Grading Rubric

<table>
<thead>
<tr>
<th></th>
<th>Advanced 5 Points</th>
<th>Proficient 4 Points</th>
<th>Partially Proficient 3 Points</th>
<th>Not Proficient 0 Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design &amp; Engineering Process</strong></td>
<td>Completed all 5 steps of the process</td>
<td>Completed 4 steps of the process</td>
<td>Completed 3 steps of the process</td>
<td>Completed 2 or fewer steps of the process</td>
</tr>
<tr>
<td><strong>Design Specification</strong></td>
<td>Complete/well-detailed and of high quality</td>
<td>Complete/opportunities for improvement</td>
<td>Incomplete/opportunities for improvement</td>
<td>Incomplete</td>
</tr>
<tr>
<td><strong>Team Collaboration</strong></td>
<td>Every member of the team contributed</td>
<td>Most members of the team contributed</td>
<td>Few members of the team contributed</td>
<td>Team did not work together</td>
</tr>
<tr>
<td><strong>Design Quality/Aesthetics</strong></td>
<td>Great design/great aesthetics</td>
<td>Good design/good aesthetics</td>
<td>Average design/average aesthetics</td>
<td>Poor design/poor aesthetics</td>
</tr>
<tr>
<td><strong>Presentation</strong></td>
<td>Great presentation/very well explained</td>
<td>Good presentation/well explained</td>
<td>Poor presentation/poor explanation</td>
<td>No presentation/no explanation</td>
</tr>
</tbody>
</table>

| Points | .................. | .................. | .................. | .................. |
| Total Points | .................. | .................. | .................. | .................. | /25
Building Basics
The following tips will be helpful when using Kid Spark engineering materials.

Connecting/Separating ROK Blocks:
ROK Blocks use a friction-fit, pyramid and opening system to connect. Simply press pyramids into openings to connect. To separate blocks, pull apart.

Connecting/Disconnect Smaller Engineering Materials:
Smaller engineering materials use a tab and opening system to connect. Angle one tab into the opening, and then snap into place. To disconnect, insert key into the engineered slot and twist.

Snapping Across Openings:
Materials can be snapped directly into openings or across openings to provide structural support to a design. This will also allow certain designs to function correctly.

Attaching String:
In some instances, string may be needed in a design. Lay string across the opening and snap any component with tabs or pyramids into that opening. Be sure that the tabs are perpendicular to the string to create a tight fit.

Measuring:
The outside dimensions of a basic connector block are 2 cm on each edge. This means the length, depth, and height are each 2 cm. To determine the size of a project or build in centimeters, simply count the number of openings and multiply by two. Repeat this process for length, depth, and height.
Maker ROK-Bot Basics
The following information and tips will be helpful when using the Maker ROK-Bot.

The Maker ROK-Bot:
The Maker ROK-Bot is a remote-controlled, robotic vehicle that can be used in a variety of ways when designing robotic systems. It is powered by (3) AA batteries that can be replaced by removing the cover on the bottom of the vehicle. A small Phillips screwdriver is required to open the bottom cover. To power on/off the Maker ROK-Bot, simply press the “R” power button until you hear a chime.

The ROK-Star Controller:
The wireless ROK-Star Controller is used to control the Maker ROK-Bot. The ROK-Star Controller is powered by (3) AA batteries that can be replaced by removing the cover on the bottom of the controller. A small Phillips screwdriver is required to open the bottom cover.

Syncing the ROK-Star Controller to the Maker ROK-Bot

**Step 1:** Power on the Maker ROK-Bot.
**Step 2:** Aim the ROK-Star Controller at the Maker ROK-Bot.
**Step 3:** Press and hold the “R Select” button on the ROK-Star Controller. The Maker ROK-Bot will produce a chime when it is successfully synced with the ROK-Star Controller.
**Step 4:** Press the buttons on the ROK-Star Controller to control the Maker ROK-Bot.

Motors & Cables:
Motor Modules can easily be connected to the Maker ROK-Bot to provide additional functionality to a robotic design.

Connecting Motor Modules to the Maker ROK-Bot

**Step 1:** Connect one end of the cable to the port on the Motor Module.
**Step 2:** Connect the other end of the cable to the A/B or X/Y port on the Maker ROK-Bot.
**Step 3:** Press the A/B or X/Y buttons on the ROK-Star Controller to rotate the Motor Module clockwise or counter-clockwise.

Note: make sure cables are firmly pressed into connecting ports to ensure a good connection.