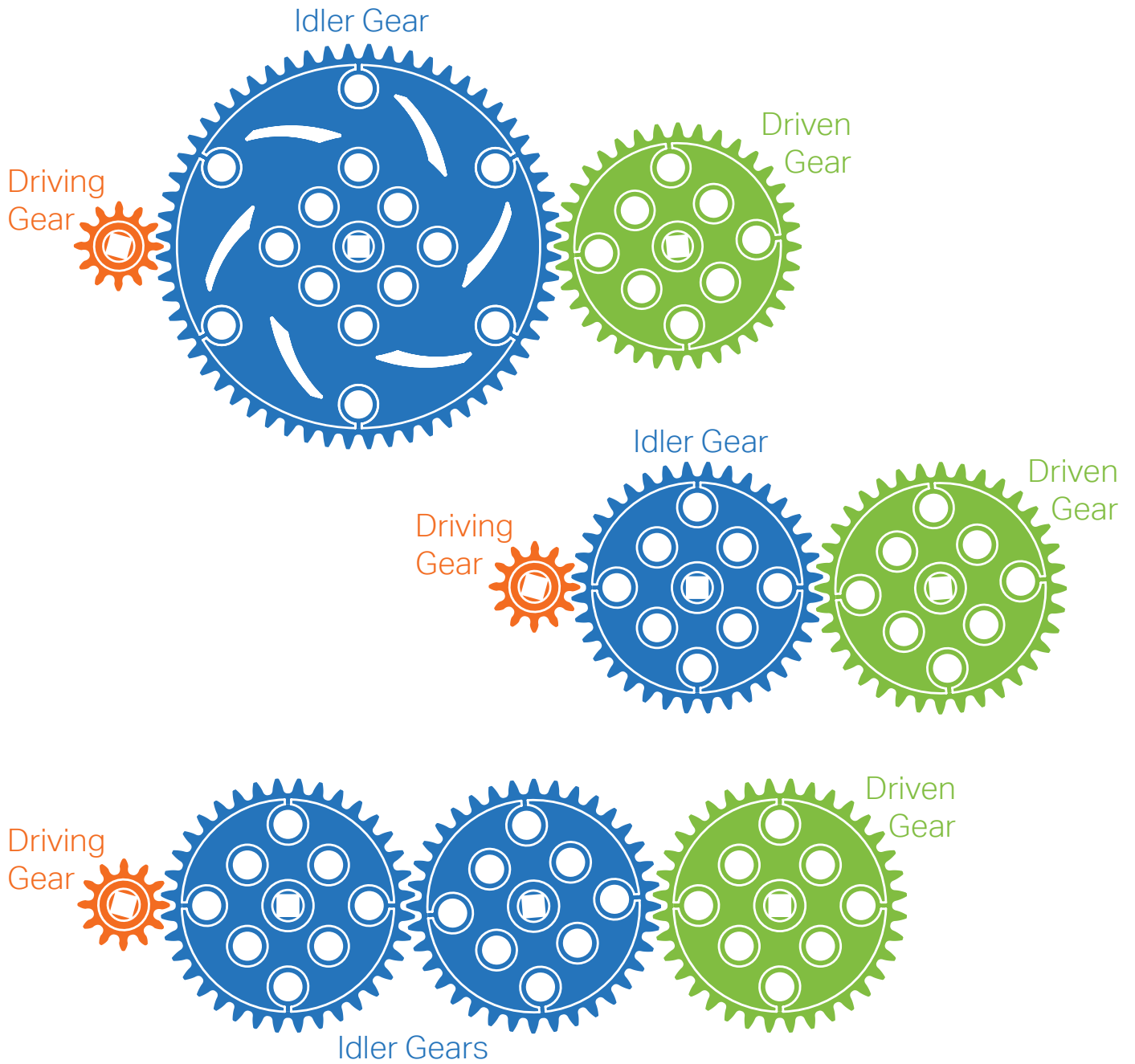
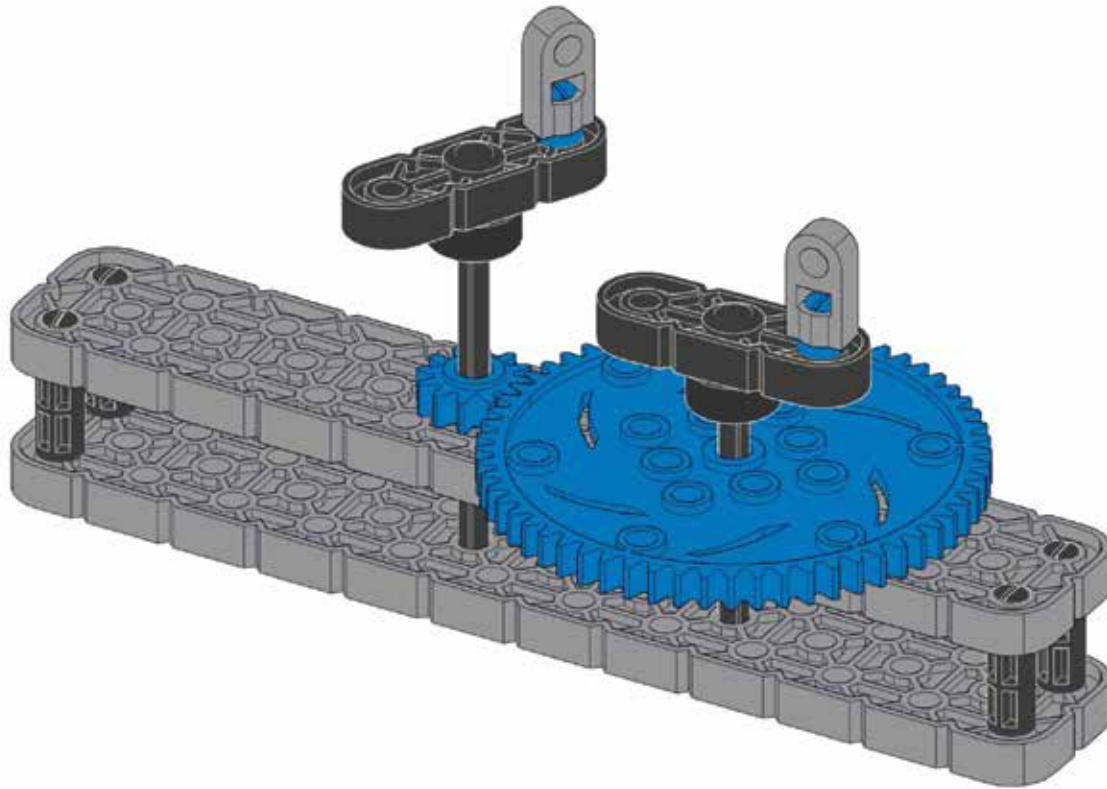




Gears and Gear Ratio





D.c1

Overview of Activity:

Campers will build a gear ratio simulator and complete a small series of short challenges to increase speed or torque by trying out different combinations of driven, driving and idler gears. Each group will select one challenge randomly and cannot receive the next challenge until they have completed the first.

Learning Objectives:

- Campers will become familiar with the basic building components of the VEX IQ Super Kit.
- Campers will use appropriate terminology to describe basic VEX IQ building components.
- Campers will learn about and apply basic knowledge of Gear Ratio (Gear Train, Driving Gear, Driven Gear, Idler Gear, and Gear Ratio).
- Campers will be able to identify different kinds of simple machines visually.
- Campers will document their machine and its use.

Suggested Timing:

Up to 1 hour

VEX IQ Materials:

- VEX IQ Super Kit
- Extra VEX IQ Pulleys (30 mm or 20mm) to launch with the catapult
- 📖 Gear Ratio Challenge Cards
- 📖 "Speed, Torque and Power" Background Information
- 📖 "Mechanisms: Gear Ratio" Background Information
- ⚙️ VEX IQ Build Instructions - Gear Ratio Simulator Assembly

Online Resources:

- VEX IQ Videos – Curriculum & Misc. – Gear Ratios - optional
www.vexiq.com/documents-downloads/
- VEX IQ – YouTube Playlist – VEX IQ Mechanisms – Gear Ratio - optional
www.vexiq.com/videos
- VEX IQ – YouTube Playlist – VEX IQ Key Concepts – Speed, Torque, and Mechanical Advantage - optional
www.vexiq.com/videos

Optional Materials:

Envelopes in which to place the challenge cards. If using these, each team should receive 4 envelopes, each with a different challenge. This adds to the excitement of the activity as they race to get their envelopes and open them quickly.

Pre-learning Suggestions:

- If possible, provide campers with some time to inventory and sort their VEX IQ Super Kits.
- This activity will help campers become more familiar with some of the basic construction elements of the kit.
- It is important to reinforce the habit of an organized workspace and kit.

Based on VEX IQ Robotics Education Guide:

- Speed, Torque, and Power (F.4)
- Mechanisms: Gear Ratio (G.3)
- VEX IQ Gear Ratio Simulator Assembly Instructions – Basic Gear Assembly, Assembly with Idler Gear, Assembly with Compound Gear Reduction (G.8)

D.cl2

Detailed Directions

1. Provide each pair of campers with the VEX IQ Super Kit and the VEX IQ Super Kit Contents and Build Tips poster. Have them use the poster to identify and locate a selection of gears of different sizes.
2. Have campers experiment with and make observations about the gears and share their observations with a partner.

Questions to ask campers:

- How do these gears compare with each other in size? (60 Tooth, 36 Tooth, 12 Tooth)
- Where have you seen gears used in everyday life?
- How can gears help us in robotics?

Examples of Gears in everyday life

- Old-fashioned clocks
- Bicycles
- Food mixers in the kitchen
- Cars

How gears help us in robotics:

- Change direction of movement or rotation
- Lift heavier objects
- Turn more precisely
- Move further or faster without increasing effort

If needed, provide campers with the handouts, "Speed, Torque and Power" Background Information, and "Mechanisms: Gear Ratio" Background Information.

Alternatively, if resources and time allow, have campers watch the following VEX IQ Videos. These are also available for download in the Documents and Downloads section of the VEX IQ Curriculum website.

- VEX IQ Videos – Curriculum & Misc. – Gear Ratios - optional
www.vexiq.com/documents-downloads/
- VEX IQ – YouTube Playlist – VEX IQ Key Concepts – Speed, Torque, and Mechanical Advantage - optional
www.vexiq.com/videos
- VEX IQ – YouTube Playlist – VEX IQ Mechanisms – Gear Ratio - optional
www.vexiq.com/videos

3. Encourage campers to use the gears they have pulled from the VEX IQ Super Kit to create different combinations of Driving Gears (on the left) and Driven Gears (on the right) and consider how this would affect speed and torque.

D.cl2 cont.

4. Provide campers with the handout, Build Instructions - Gear Ratio Simulator Assembly and give them time to construct it. Tell campers that they will use this simulator to complete a series of challenges to learn more about the work that gears help us do.

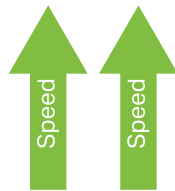
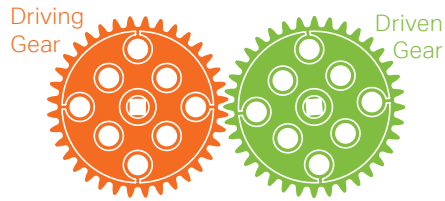
For each challenge, they will need to:

- Read the challenge card carefully.
 - Make modifications to their simulator to accomplish the task on the challenge card.
 - Think of and explain a scenario in robotics where this would be helpful. (e.g., making a drivetrain turn quickly and precisely, on an arm that moves a heavy object, slowing down or speeding up the robot's travel time without putting extra stress on the motor, or moving all the wheels on a drive train at once).
 - Show their camp leader their modifications and provide an example of a useful scenario. When the task has been confirmed as completed, campers will receive their next challenge. If time allows, campers can draw a quick sketch and describe their ideas or take a photo or movie using a smart device. This can be shared with parents or each other.
5. Provide each pair of campers with their first challenge card (see D.cs1) face down or in an envelope and have them wait for your signal to reveal them. Begin the challenge, handing out new challenge cards as the previous challenge is completed.

D.cl2 cont.

These sample answers provide some of the possible solutions to the Challenge Cards. The sample answers can also be used with campers who are "stuck" to show them one possible answer for the challenge, then ask them to come up with another solution that is also correct.

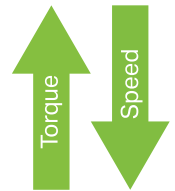
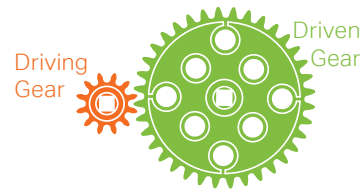
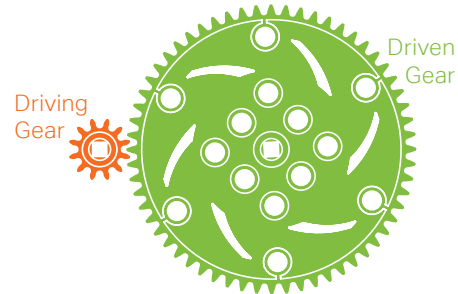
Challenge Card A Solution



How is this useful?

Driving and Driven Gears of equal size are helpful when you want both gears to rotate at the same speed and torque, but in opposite directions.

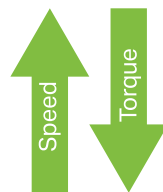
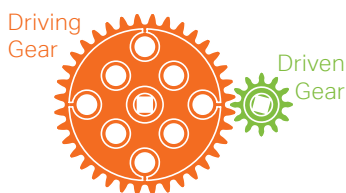
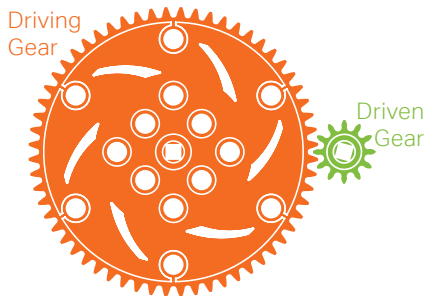
Challenge Card B Solution



How is this useful?

A smaller Driving Gear is helpful when you are trying to move slower mechanically, lift heavier objects, and/or have more pushing ability.

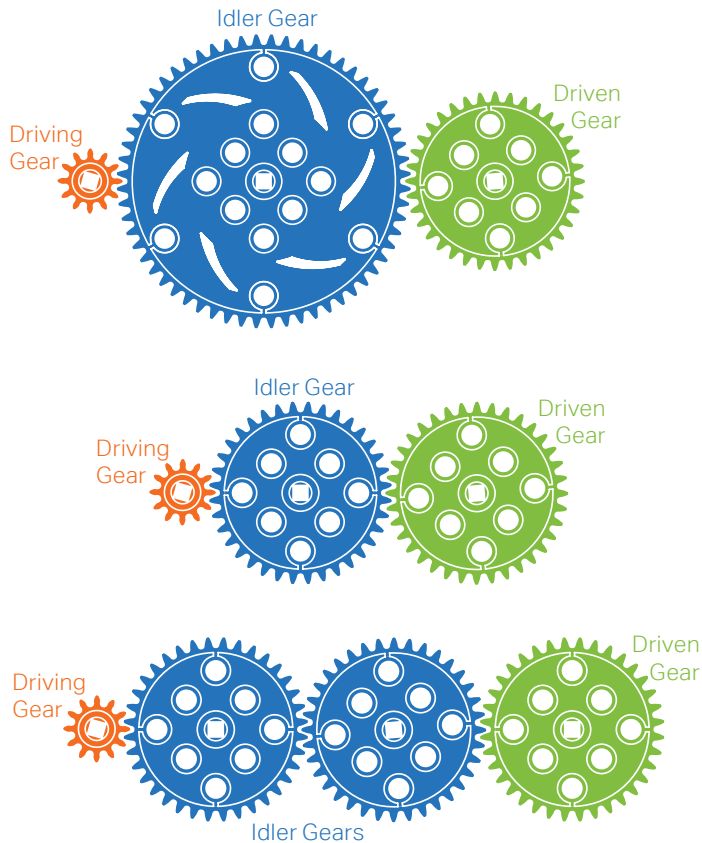
Challenge Card C Solution



How is this useful?

A larger Driving Gear is helpful when you are trying to lift or move faster mechanically, you don't require the ability to lift heavy objects, and/or you favor agility over pushing ability in a drivetrain.

Challenge Card D Solution



An Idler gear does not affect the torque or speed.

Assemblies with two gears spin in opposite directions of each other.

In a gear train with one idler gear, they spin in the same direction.

In a gear train with two idler gears, they will spin in opposite directions again.

How is this useful?

Idler gears can be used to change the direction of rotation from a driven gear, or to reduce the size of the input/output gears without changing the spacing between the axles to which they are attached.

Tips and Best Practices:

- Align the gray standoff connectors before beginning simulation. Note which gear spins faster than the other by counting the number of revolutions until the standoff connectors are re-aligned.
- Different sized gears have different diameters. Campers will need to consider this when positioning the axles for different configurations

Extension:

- Create a gear assembly with three gears that increases speed and decreases torque, or vice versa.
- Modify the gear simulator assembly to function as a hand held lifting mechanism. Experiment with lifting objects manually using gears to demonstrate torque.
- Have students experiment with Compound Gears and Compound Gear Reductions and create challenge cards for each other.

D.cs1

Gear Ratio Challenge Cards

Challenge Card A

1. Create an assembly with two gears where input and output are equal for speed and torque.
2. Think of a situation in robotics where this would be useful.

Challenge Card B

1. Create an assembly with two gears where input and output result in increased torque and decreased speed.
2. Think of a situation in robotics where this would be useful.

Challenge Card C

1. Create an assembly with two gears where input and output result in increased speed and decreased torque.
2. Think of a situation in robotics where this would be useful.

Challenge Card D

1. Create a gear train assembly with more than two gears where there is no increase in speed or torque.
2. Think of a situation in robotics where this would be useful.

D.cs2

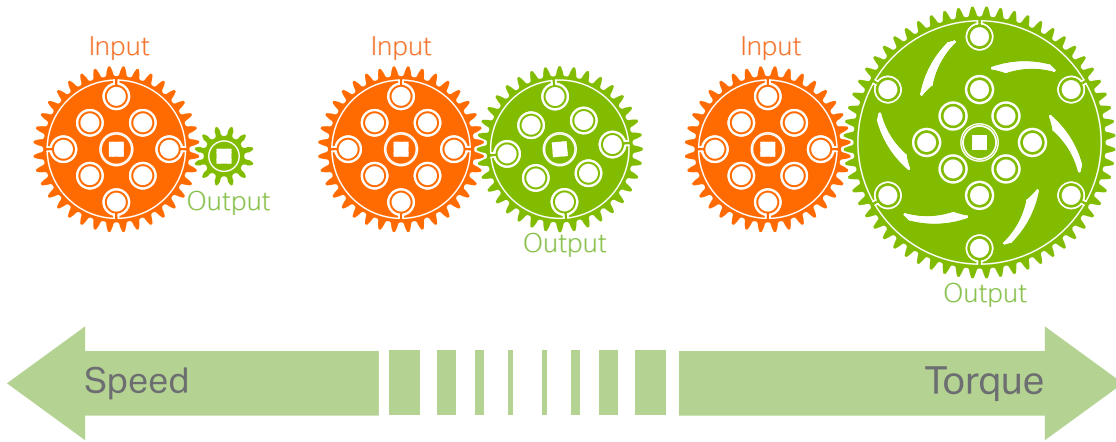
Speed, Torque, and Power

Speed is a way of measuring how fast an object is moving. Speed measures how far an object will travel over a given period of time. This measure is given in units of distance per time such as Miles per Hour or Feet per Second.

Torque is a force directed in a circle, most often rotating an object. Torque is a spinning force. When torque is spinning an object, the object will create a linear (straight line) force at its edge, such as an axle spinning a tire and causing the tire to move in a straight line along the ground. Torque is measured in units of force \times distance, such as Inch-Pounds or Newton-Meters.

Power is the rate at which work is done. With VEX IQ, Smart Motors convert electrical energy into mechanical energy and produce power for a mechanical system. Power is most commonly measured in **Watts**.

The physical principles of **Speed**, **Torque**, and **Power** all fit together in what engineers call **Classical Mechanics**. In Classical Mechanics, **speed and torque have an inverse** (or opposite) **relationship** – as one increases the other decreases. Higher speed means lower torque, and higher torque means lower speed.



Also, the amount of power supplied has an effect on how much speed and/or torque can be produced in a mechanical system.

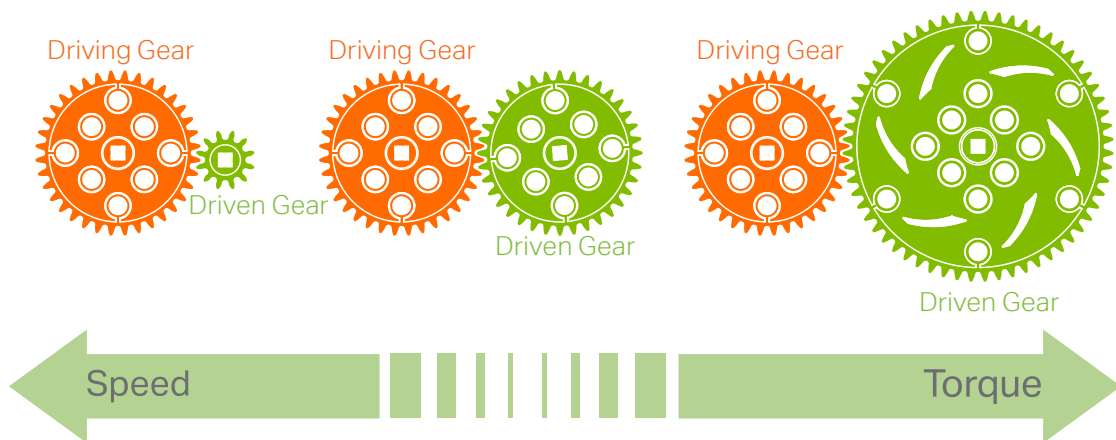
Mechanisms: Gear Ratio

Gear Ratio Basics

As you learned in other lessons, making a **Gear Ratio** change is one of the easiest ways to change Mechanical Advantage in a mechanism or system to achieve desired speed and/or torque. Gear Ratio expresses the relationship between a **Driving Gear** (the gear connected to the input power source, such as a motor) and a **Driven Gear** (the gear connected to the output, such as a wheel or mechanism) in a system.

When you have a system with a **Driving Gear** that is **SMALLER** than the **Driven Gear** you will increase **Torque** and decrease **Speed**:

Making this kind of change to Mechanical Advantage is helpful when you are trying to move slower mechanically, lift heavier objects, and/or have more pushing ability.



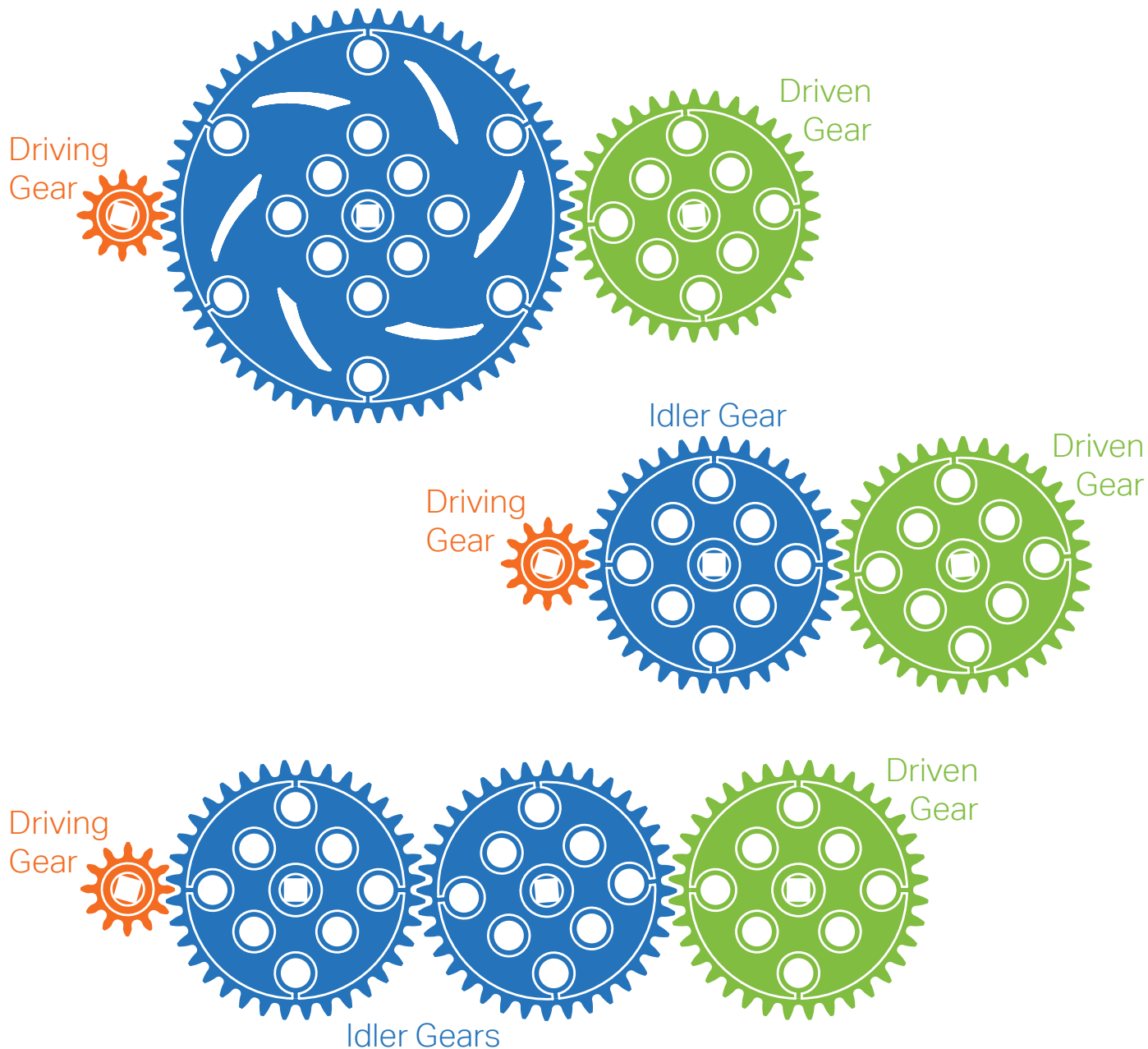
When you have a system with a **Driving Gear** that is **LARGER** than the **Driven Gear** you will increase **Speed** and decrease **Torque**:

Making this kind of change to Mechanical Advantage is helpful when you are trying to lift or move faster mechanically, you don't require the ability to lift heavy objects, and/or you favor agility over pushing ability in a drivetrain.

Gear Trains and Idler Gears

A simple **Gear Train** is a connected set of rotating gears that transmits power from an input (like a **Driving Gear** connected to a motor) to an output (like a **Driven Gear** connected to a wheel or mechanism). Simple Gear Trains can have any number of gears in a single row. All gears in between the **Driving Gear** and the **Driven Gear** that only transmit power are known as **Idler Gears**. **Idler Gears** have **NO EFFECT** on **Gear Ratio** or **Gear Reduction**, regardless of the number of teeth they have.

Example Gear Trains: **Idler Gear**

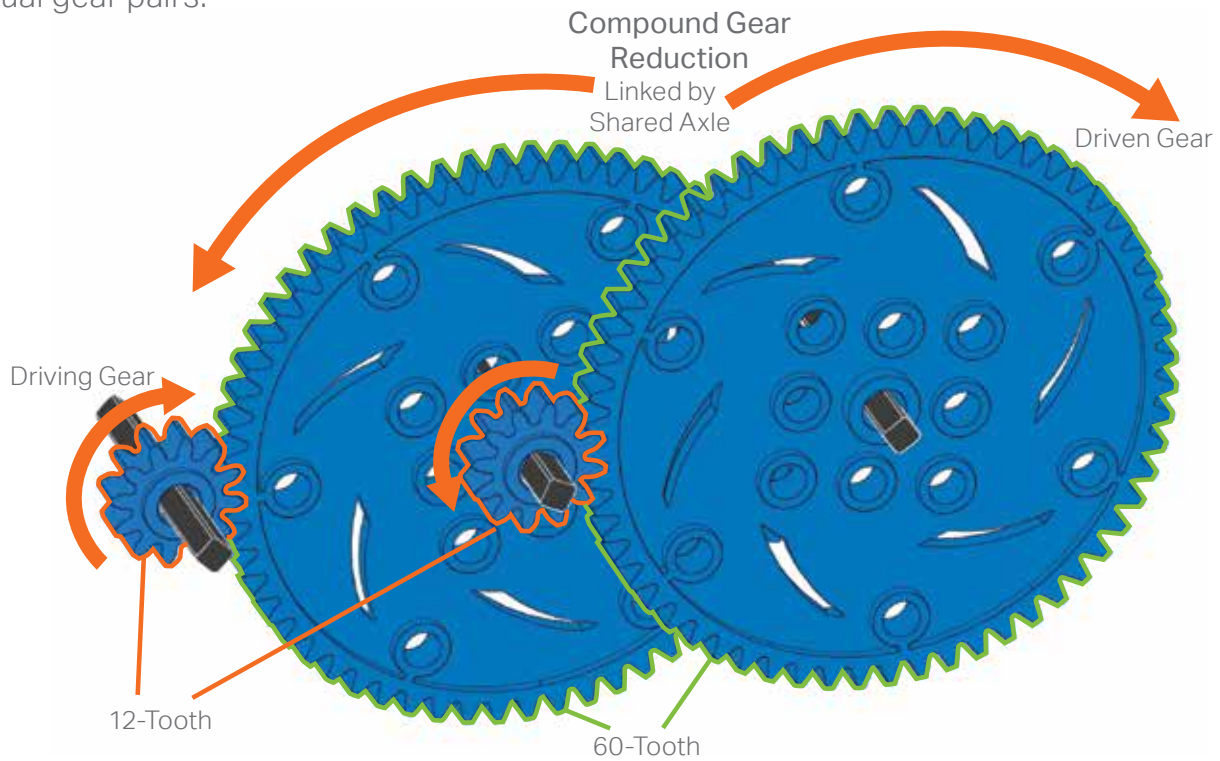


In all three of these example **Gear Trains**, the **Driving Gear** is 12-teeth and the **Driven Gear** is 36-teeth, thus the **Gear Ratio** for all three examples is the exact same - 12:36 . Size and number of **Idler Gears** have no effect on **Gear Ratio** or **Gear Reduction**, they just transmit power!

Compound Gears and Compound Gear Reductions

In certain situations, a design may require more mechanical advantage than a single gear ratio can provide or is otherwise impractical. For example, if a VEX IQ robot design requires a 12:500 gear ratio it is a problem because there is no 500-tooth gear available. In this situation, a designer can use multiple gear reductions in the same mechanism. This is called a Compound Gear Reduction.


In a **Compound Gear** system, there are multiple gear pairs. Each pair has its own **Gear Ratio**, and a shared axle connects the pairs to each other. The resulting Compound Gear system still has a **Driving Gear** and a **Driven Gear**, and still has a **Gear Reduction**. However, it's now called a **Compound Gear Reduction** and is calculated by multiplying the gear reductions of each of the individual gear pairs.



For the above example with 12-tooth and 60-tooth gears, the overall Gear Reduction is calculated this way:

Gear Reduction

$$\begin{matrix} \text{Gear 1} & \text{Gear 2} \\ \text{60 / 12} & \text{60 / 12} \\ \times & \\ \hline \text{5 / 1} & \times & \text{5 / 1} & = & \text{25 / 1} \end{matrix}$$

 Say "25 to 1 Compound Gear Reduction"

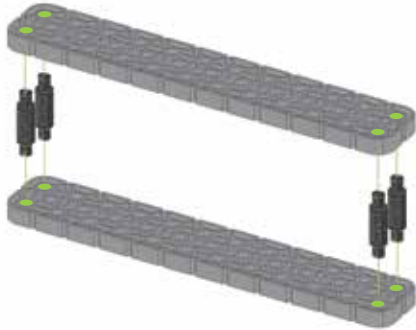
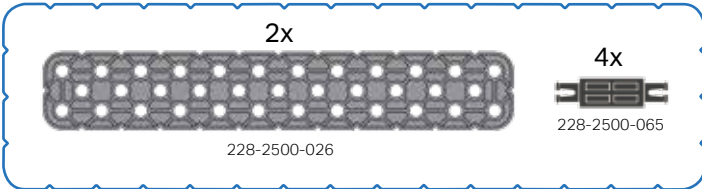
That means the output (**Driven Gear**) shaft is 25 times slower than the input (**Driving Gear**) shaft, and has 25 times as much torque. **Compound Gear Reductions** add up quickly!



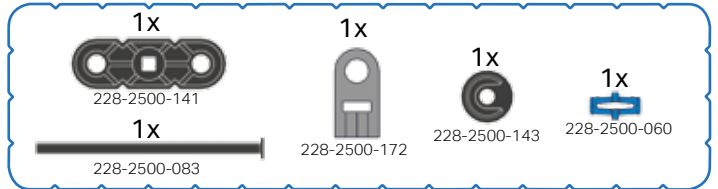
Note: The VEX IQ Gear Ratio Simulator (G.8) and Gear Ratio Exercises (G.9) from the VEX IQ Robotics Education Guide can be used to help understand this section.

VEX IQ Gear Ratio Simulator Assembly Instructions

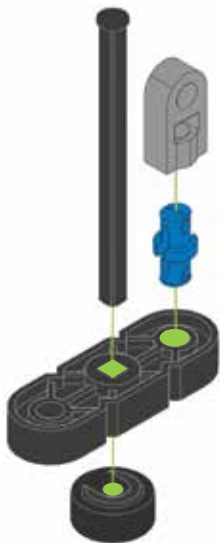
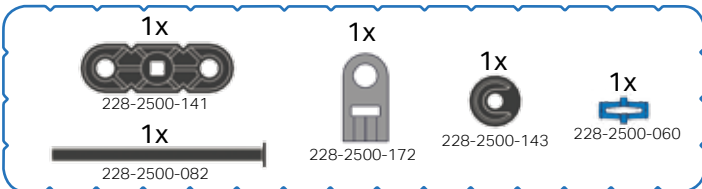
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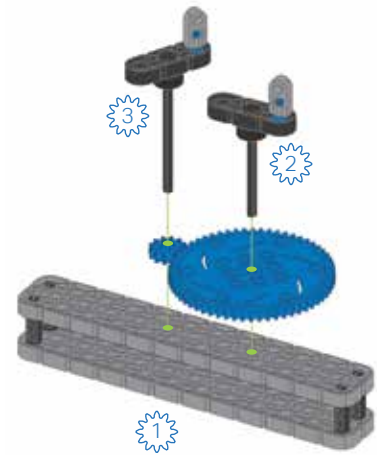
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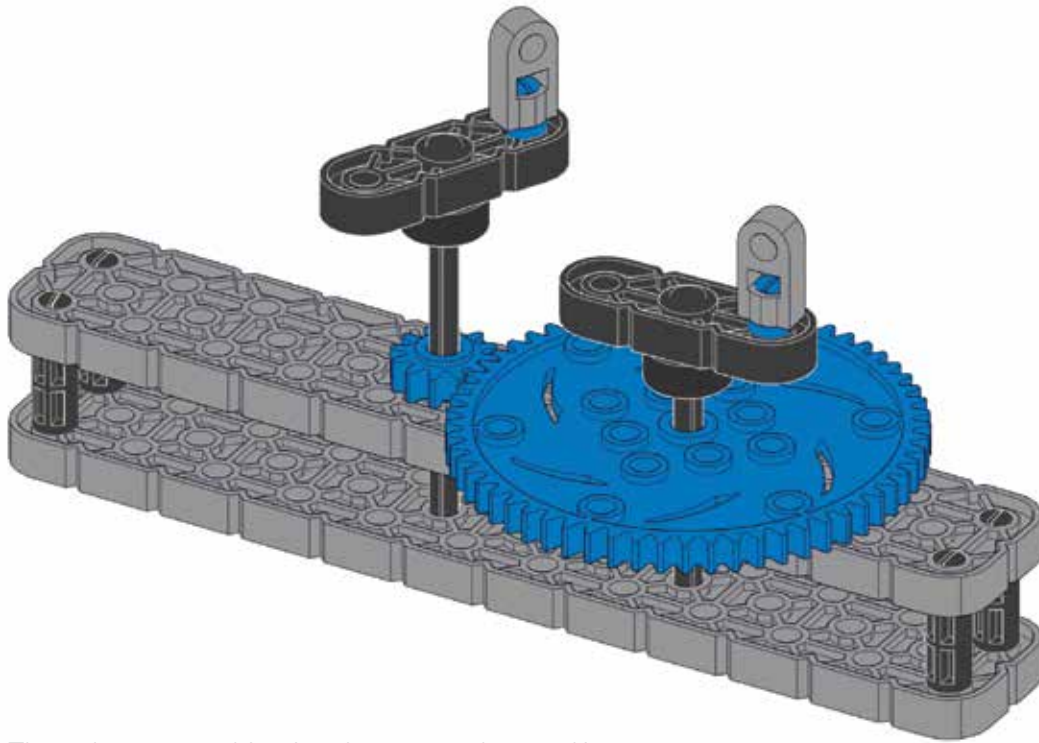
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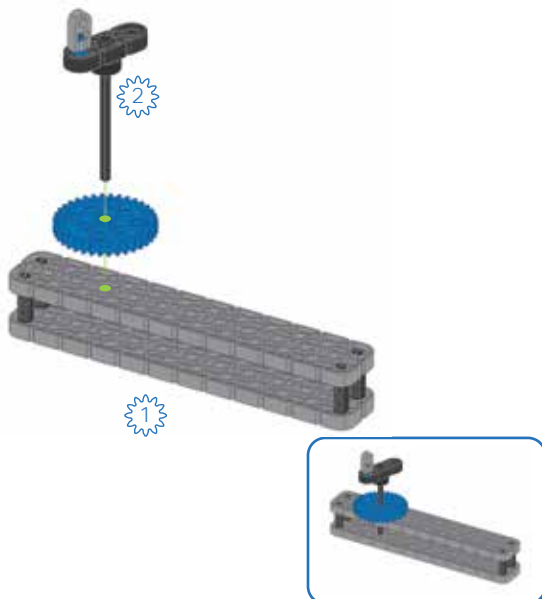


Basic Gear Assembly

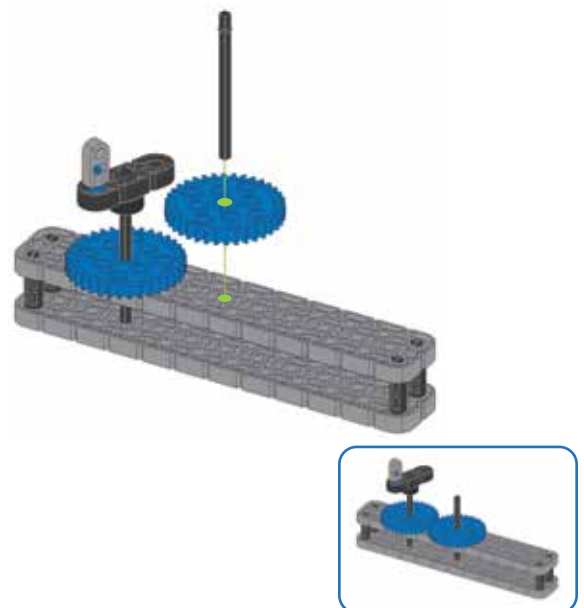
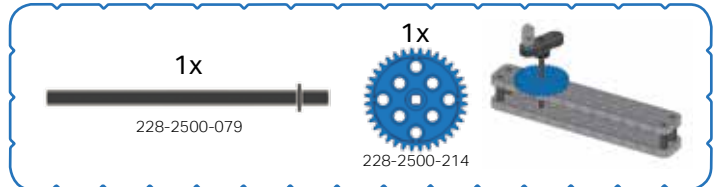


Note: The only gear combination that cannot be used is a 12-tooth gear on both input and output shafts.

5

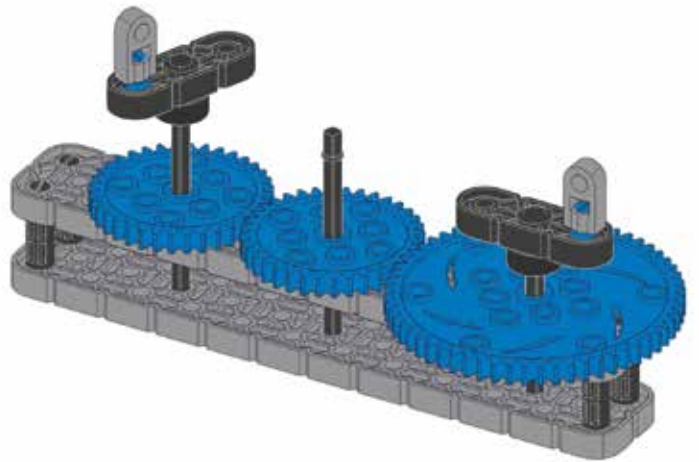


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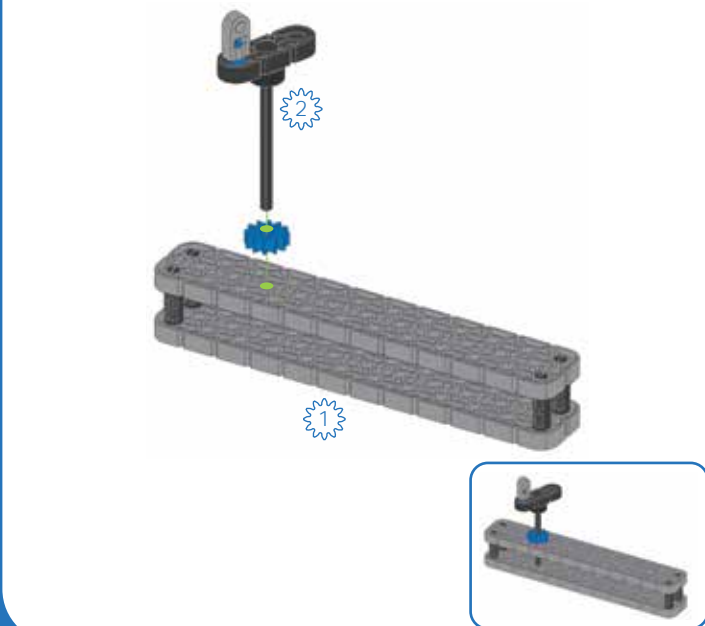


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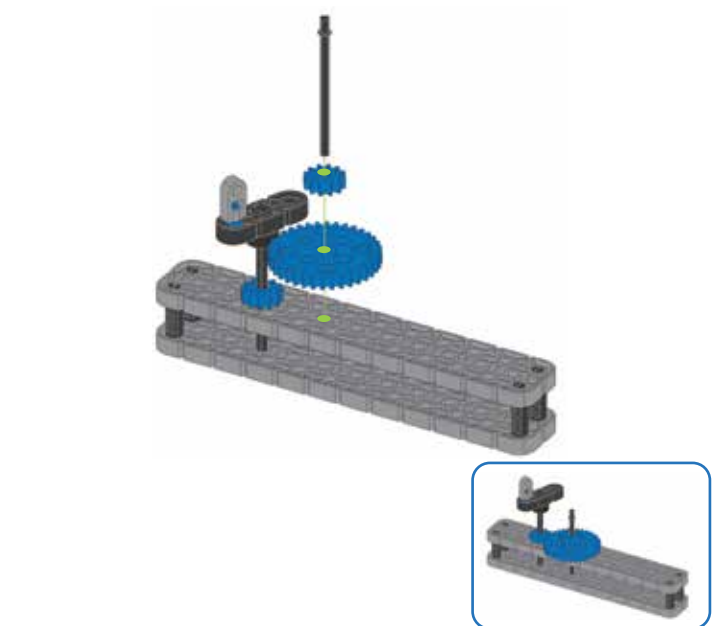
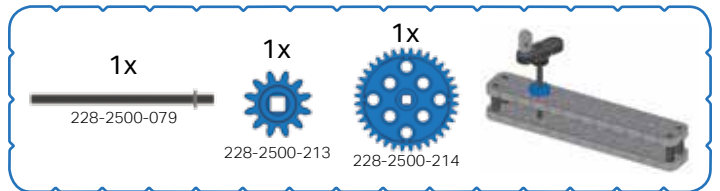
Assembly with Idler Gear



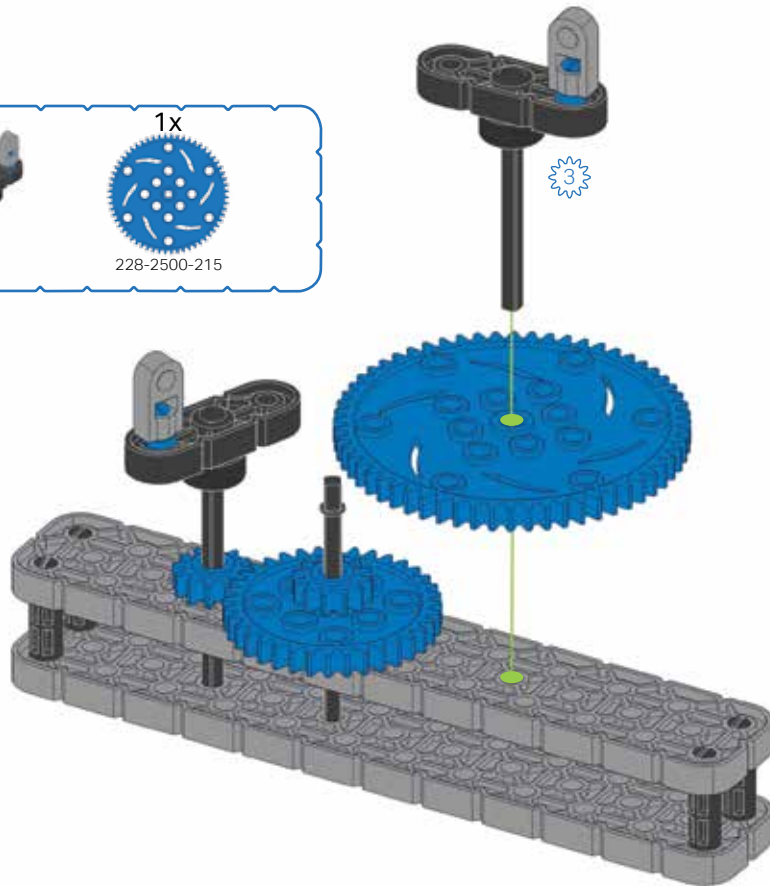
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Assembly with Compound Gear Reduction

