Unit

7

Advanced Gears

In Unit 7: Advanced Gears, you build a steerable, differential tricycle. You learn about differentials, bevel gears, and spur gears, and you document and communicate your learning in a variety of ways.

The concepts regarding advanced gears such as rack and pinion and worm gears have countless real-world applications. In STEM Connections, we present a scenario involving a rack and pinion system for steering an automobile. After completing the Think Phase and Build Phase in Unit 7: Advanced Gears, you will see how concepts regarding advanced gears come into play in the real world.

Unit Objectives

After completing Unit 7: Advanced Gears, you will be able to:

- Identify rack gears, worm gears, worm wheels, and bevel gears and understand applications for differentials.
- Assemble and drive rack and pinion gears in Autodesk® Inventor® Professional.
- Combine gears into a robot drivetrain and build a steerable VEX robot.
- Determine the effect of a differential on a robot drivetrain.

Prerequisites

Related resources for Unit 7: Advanced Gears are:

- Unit 1: Introduction to VEX and Robotics.
- Unit 2: Introduction to Autodesk® Inventor®.
- Unit 4: Microcontroller and Transmitter Overview.
- Unit 5: Speed, Power, Torque, and DC Motors.
- Unit 6: Gears, Chains, and Sprockets.

Key Terms and Definitions

Definitions

Term	Definition
Bevel Gears	Gears that have the axes of the two shafts intersect and the tooth-bearing faces of the gears themselves are conically shaped. Bevel gears are most often mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well.
Differential	A device that splits the supplied torque two ways, allowing each output to spin at a different speed. Used frequently with drive trains that steer to allow for easier/more uniform turning.
Drive Constraint	Drive constraints do not control motion between components, but simulate mechanical motion by driving a constraint through a sequence of steps for a single component.
iProperties	A characteristic of a Microsoft Windows file that can be manipulated from an application or Microsoft Windows Explorer. Properties include author or designer and creation date, and may also be unique properties assigned by applications or users. Specifying properties can be useful when searching for part or assembly files.
Pinion	A gear with a small number of teeth designed to mesh with a rack.
Rack	A bar of rectangular cross section with straight teeth on one side that mesh with teeth on the pinion.
Spur Gears	Spur gears are the simplest and most common type of gear. Their general form is a cylinder or disk.

Required Supplies and Software

The following supplies and software are used in Unit 7: Advanced Gears:

Supplies	Software
VEX Classroom Lab Kit	Autodesk Inventor Professional 2009
One assembled differential tricycle built in the Unit 7: Advanced Gears > Build Phase	
Notebook and pen	
Work surface	
Small storage container for loose parts	
Two "obstacles." Any small object in your class room: books, soda cans, and so on.	
8′x 8′ of open floor space	
One stopwatch	

VEX Parts

The following VEX parts are used in Unit 7: Advanced Gears > Build Phase:

Quantity	Part Number	Abbreviations
2	ANGLE-GUSSET	AG
1	Antenna-Holder	AH
1	Antenna-Tube	AT
2	BATTERY-STRAP	BST
2	BEAM-1000	B1
13	BEARING-FLAT	BF
12	BEARING-RIVET	BR
3	VEX-24-TOOTH-BEVEL-GEAR	BG24
78	CHAIN-LINK	CL
1	Differential-Housing	DG36
4	MEDIUM-WHEEL	W4
1	MICROCONTROLLER	VMC
25	NUT-832-KEPS	NK
1	PLUS-GUSSET	G+
1	RECEIVER	RX75
2	SCREW-632-0250	SS2
2	SCREW-632-0500	SS4
8	SCREW-832-0250	S2
17	SCREW-832-0500	S4
4	SCREW-832-0750	S6
2	SHAFT-2000	SQ2
3	SHAFT-3000	SQ3
2	SHAFT-4000	SQ4
9	SHAFT COLLAR	COL
1	SMALL-WHEEL	W2.8
2	SPACER-THICK	SP2
4	SPACER-THIN	SP1
1	VEX-24-TOOTH-SPROCKET	CS24

Quantity	Part Number	Abbreviations
1	VEX-36-TOOTH-GEAR	G36
2	VEX-48-TOOTH-SPROCKET	CS48
2	VEX-60-TOOTH-GEAR	G60
1	VEX-Motor	MOT
1	VEX-Servo	SER
1	VL-CHAN-121-15-RevA	C15
1	VL-CHAN-151-25-RevA	CW25
2	VL-PLATE-5-25-RevA	P25
7	WASHER-DELRIN	WP

Academic Standards

The following national academic standards are supported in Unit 7: Advanced Gears.

Phase	Academic Standard
Think	**Science (NSES)** *Unifying Concepts and Processes*: Change, Constancy, and Measurement; Form and Function *Physical Science:* Motions and Forces *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design **Mathematics (NCTM)** *Algebra* Analyze change in various contexts. *Measurement* Understand measurable attributes of objects and the units, systems, and processes of measurement. *Communication* Communicate mathematical thinking coherently and clearly to peers, teachers, and others. *Connections* Recognize and apply mathematics in contexts outside of mathematics.

Phase	Academic Standard
Create	**Science (NSES)** *Unifying Concepts and Processes*: Form and Function *Physical Science:* Motions and Forces *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design 5.9: Engineering Design 6.12: Use and Maintain Technological Products and Systems **Mathematics (NCTM)** *Numbers and Operations* Understand numbers, ways of representing numbers, relationships among numbers, and number systems. *Algebra Standard* Understand patterns, relations, and functions. *Geometry Standard* Use visualization, spatial reasoning, and geometric modeling to solve problems. *Measurement Standard* Understand measurable attributes of objects and the units, systems, and processes of measurement.

Phase	Academic Standard
Build	**Science (NSES)** *Unifying Concepts and Processes*: Change, Constancy, and Measurement; Form and Function *Physical Science:* Motions and Forces *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design 5.9: Engineering Design 6.11: Apply the Design Process **Mathematics (NCTM)** *Numbers and Operations* Compute fluently and make reasonable estimate. *Algebra* Analyze change in various contexts. *Geometry* Use visualization, spatial reasoning, and geometric modeling to solve problems. *Measurement* Understand measurable attributes of objects and the units, systems, and processes of measurement. Apply appropriate techniques, tools, and formulas to determine measurements. *Connections* Recognize and apply mathematics in contexts outside of mathematics.

Phase	Academic Standard
Amaze	**Science (NSES)** *Unifying Concepts and Processes*: Change, Constancy, and Measurement; Form and Function *Physical Science:* Motions and Forces *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design **Mathematics (NCTM)** *Number and Operations* Compute fluently and make reasonable estimates. *Algebra* Analyze change in various contexts. *Geometry* Use visualization, spatial reasoning, and geometric modeling to solve problems. *Measurement* Understand measurable attributes of objects and the units, systems, and processes of measurement. Apply appropriate techniques, tools, and formulas to determine measurements. *Communication* Communicate mathematical thinking coherently and clearly to peers, teachers, and others. *Connections* Recognize and apply mathematics in contexts outside of mathematics.

Think Phase

Overview

This phase showcases several gear types and their uses in the VEX Classroom Kit.

Phase Objectives

After completing this phase, you will be able to:

- Identify the following types of gears:
  - Rack gears
  - Worm gears and worm wheels
  - Bevel gears
- Describe applications for differentials.

Prerequisites and Resources

Related phase resources are:

- Unit 5: Speed, Power, Torque, and DC Motors.
- Unit 6: Gears, Chains, and Sprockets.

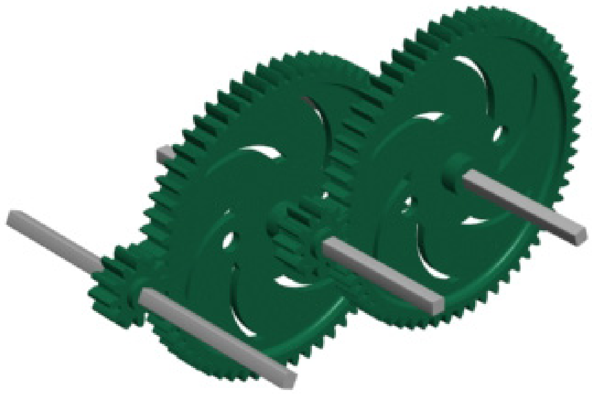
Required Supplies and Software

The following supplies are used in this phase:

Supplies
Notebook and pen
Work surface

Research and Activity

In Unit 6: Gears, Chains, and Sprockets, you learned about gear ratios and how they apply to torque and speed. In this unit, you learn more about several different types of gears and their applications. Gears come in many shapes and sizes and are used in a variety of ways.

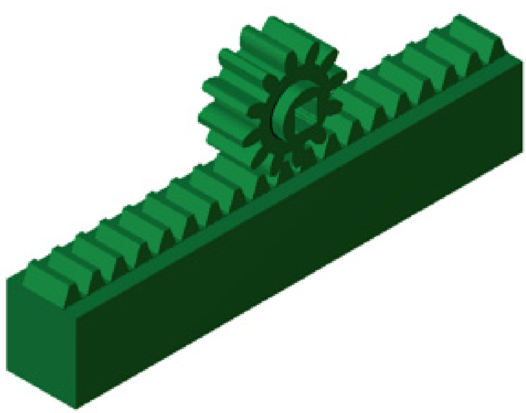


Spur Gears

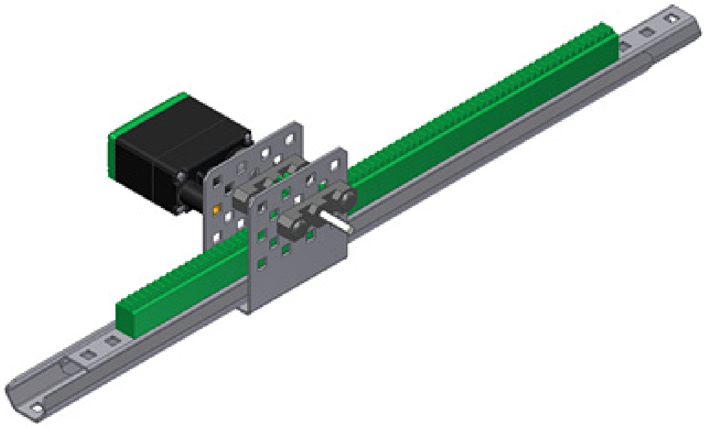
Unit 6 dealt with the most common type or gear, *spur gears*. These gears have teeth parallel to their axis of rotation and a cylinder pitch face. Spur gears are generally used for transmission of rotary motion between parallel shafts. These are the most recognizable form of gear; when most people think of gears, they are usually thinking of spur gears.

Rack Gears

Rack gears are flat bars with straight gear teeth. A rack gear is normally combined with a spur gear, which is commonly referred to as the *pinion*. Rack and pinion setups are designed to convert rotational motion to linear motion. The circular pinion engages the teeth on the rack gear. When rotational motion is applied to the pinion, it moves the rack to the side.



These gears are commonly used as part of the steering mechanism on most cars (you may have heard of rack and pinion steering). In robotic design, rack gears are great for applications where linear motion is required. The VEX System has a 19-tooth rack gear that meshes with all of the VEX spur gears. These short rack gears can be put together to form longer sections.



Worm Gears

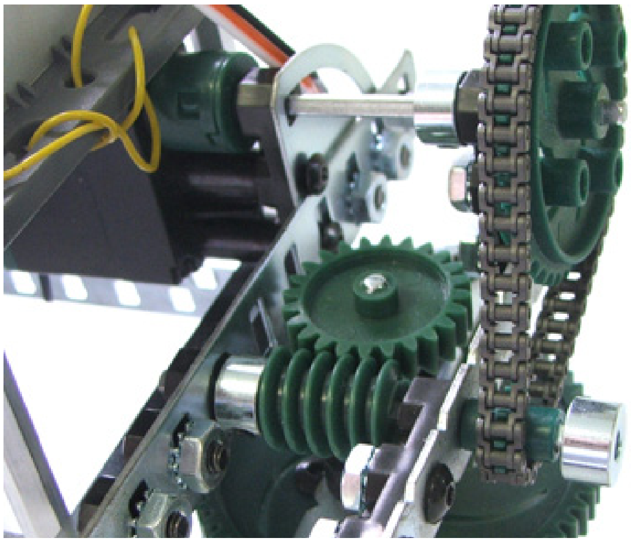
A worm drive is a setup consisting of a worm gear and a worm wheel meshing together. The worm gear resembles a screw, and is the driving gear in this setup. The worm wheel is similar to a spur gear, except that all its teeth are slightly curved so it meshes more effectively with the worm gear.

The primary advantage of a worm drive is the ability to get a large gear ratio in a relatively small package. As the worm spins, it will slowly advance the worm wheel. In a worm drive, the axles are set 90-degrees apart. Another advantage of a worm drive is its resistance to back driving; it is almost impossible to drive the worm with the worm wheel. This property is useful in designs where a braking or locking situation is desired.

To calculate the gearing of a worm drive, you must first see how many independent spirals are on the worm itself. You can typically see the tips of each of these spirals when you look at the end of the worm; it is simple to count how many tips you see. For each time one of these spirals makes a full revolution, it will advance the worm wheel by one tooth. If the worm has two (2) spirals, each revolution of the worm advances the worm wheel two (2) teeth. The gear ratio is calculated based on how many teeth are in the worm wheel. If the worm wheel has twenty-four (24) teeth then for every tooth that is advanced, the worm wheel rotates 1/24th of a revolution.

For example, if a worm has one (1) spiral, and the worm wheel has fourteen (14) teeth, for each revolution of the worm the worm wheel will advance 1/14th of a turn; this means the gear ratio is (14:1). This is a significant reduction in a small package!

The following image shows a worm drive used in a VEX robot.



Bevel Gears

Bevel gears are cone-shaped gears used in applications where a change in the axis of rotation is required. Bevel gears mate together when their axes of rotation intersect. Bevel gears are most often mounted on shafts which are 90-degrees apart, but can be made to work on other angles as well. The teeth are the same basic shape as a spur gear's teeth, but have a slight taper towards the apex of the cone. It is possible for meshing bevel gears to have different numbers of teeth resulting in a gear reduction.

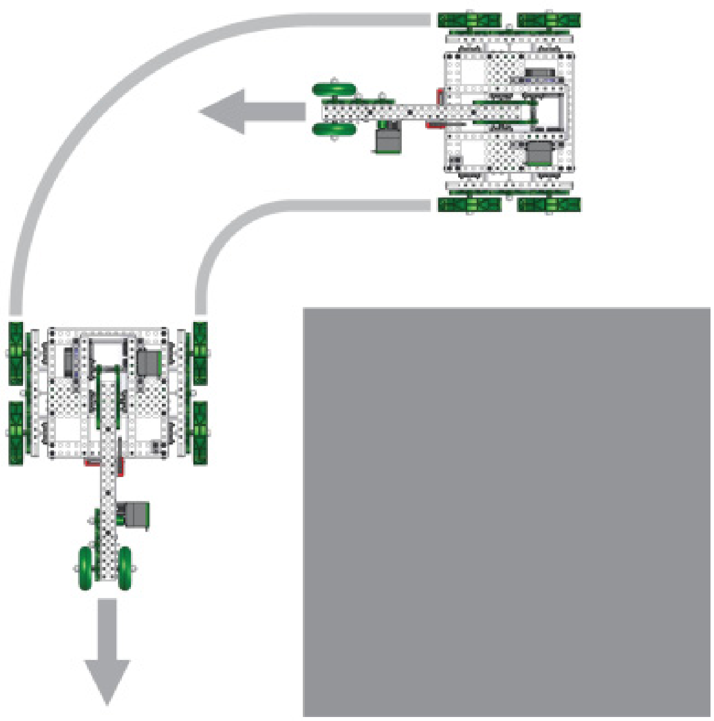
Bevel gears are used commonly in many applications where changing the direction of motion is either required or advantageous to the design. Bevel gears are also used in differentials (see below).

Differentials

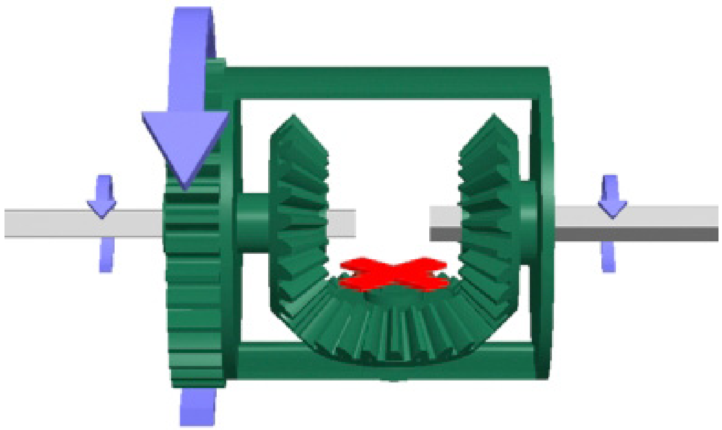
The concept behind *differentials* is difficult to understand at first. The most common type of differential has one input which is divided into two outputs. Less commonly, a differential can have two inputs which combine to form one output. One of the easiest ways to understand differentials is to look at the primary application they are used for; automobile drive trains.

In an automobile, the differential transmits power from the engine to the drive wheels (one input, two outputs). It enables the wheels to rotate at different speeds while supplying equal torque to each of them. This is important because as a wheeled vehicle goes around a turn, the wheel on the outside of the turn must travel further than the wheel on the inside. If these wheels are linked together, some of them will slide on the ground to make up the difference.

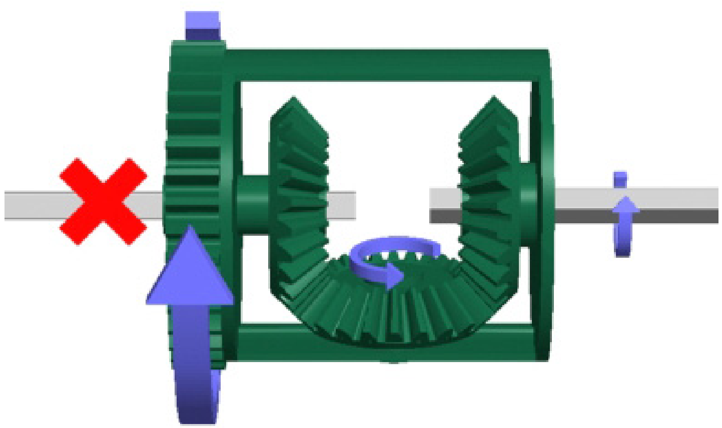
As seen in the following image, the outside wheel needs to move further and spin faster than the inside wheel.



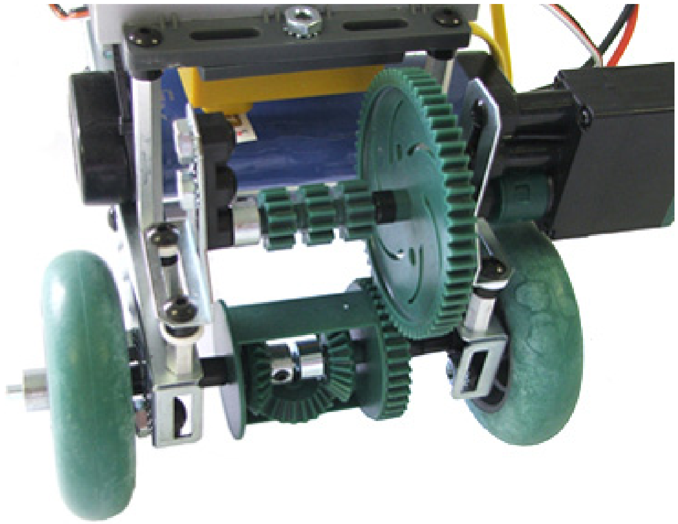
Differentials consist of bevel gears mounted inside a differential housing. When torque is applied to a gear on the outside of the differential housing, the torque is passed to both outputs by spinning the entire housing as one unit. If the load on each output is equal, the center bevel gear does not turn and both outputs turn at the same rate as shown in the following image.



If there is loading on one side, then the center bevel gear will rotate, allowing the outputs to spin at different rates, as shown in the following image. This is why the wheels on a car can spin at different rates.



VEX Robots may also use differentials for the same reasons as cars do. The VEX Differential Housing holds three VEX Bevel Gears and can be driven using a Spur Gear built directly into the Housing. This can be implemented on a robot in a number of ways, one example of which is shown in the following image.



Create Phase

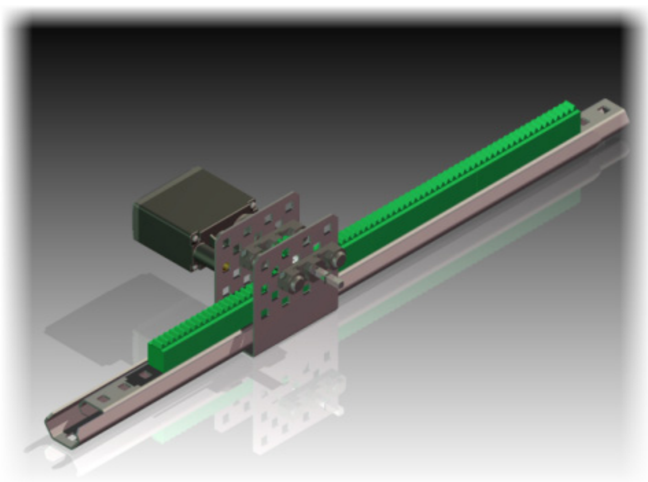
Overview

Objective

After completing this lesson, you will be able to:

- Assemble and drive rack and pinion gears.

In this phase, you learn about creating a rack and pinion assembly. This type of gear assembly is used for linear motion.



The completed exercise

Phase Objective

After completing this phase, you will be able to:

- Assemble and drive rack and pinion gears.

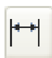
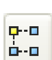
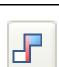
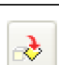
Prerequisites

Before starting this phase, you must have:

- A working knowledge of the Windows operating system.
- Completed Unit 1: Introduction to VEX and Robotics > Getting Started with Autodesk Inventor.
- Completed Unit 2: Introduction to Autodesk Inventor > Quick Start for Autodesk Inventor.

Technical Overview

The following Autodesk Inventor tools are used in this phase.

Icon	Name	Description
	**Line**	Straight curve bounded by two endpoints. The Line tool on the Sketch toolbar chains line segments together and creates arcs tangent or perpendicular to existing curves. Segments and arcs are automatically joined by coincident constraints at their endpoints.
	**General Dimension**	Adds parametric dimensions that control sketch size. When dimensions are changed, the sketch resizes. Dimensional constraints may be expressed as numeric constants, as variables in equations, or in parameter files.
	**2D Sketch**	A sketch consists of the sketch plane, a coordinate system, 2D curves, and the dimensions and constraints applied to the curves. A sketch may also incorporate construction geometry or reference geometry. Sketches are used to define feature profiles and paths.
	**Work Plane**	A construction feature that defines the parametric location of a sketch plane in 3D space. A work plane is useful when no planar face exists to use as a sketch plane; for example, when sketching on curved or toroidal faces. A work plane can be incorporated into dimension and constraint schemes.
	**Look At**	In a part or assembly, zooms and rotates the model to display the selected element planar to the screen or a selected edge or line horizontal to the screen. Not used in drawings.
	**Project Geometry**	Projects geometry (model edges, vertices, work axes, work points, or other sketch geometry) onto the active sketch plane as reference geometry.
	**Rectangular Pattern**	Multiple instances of a placed or sketched feature arrayed in a specified pattern. Patterns are defined by type (rectangular or circular), orientation, number of features, and spacing between features.
	**Place Component**	Specifies one or more files to place as a component in an assembly.
	**Constraint**	Assembly constraints determine how components in the assembly fit together. As you apply constraints, you remove degrees of freedom, restricting the ways components can move.
	**Rotate Component**	Rotate an individual component in an assembly. Constraints are temporarily suppressed.
	**Pattern Component**	Duplicates one or more components and arranges the resulting occurrences in a circular or rectangular pattern. Rectangular and circular patterns can use patterned features on a part to set number and spacing.

Definitions

Term	Definition
Drive Constraint	Drive constraints do not control motion between components, but simulate mechanical motion by driving a constraint through a sequence of steps for a single component.
iProperties	A characteristic of a Microsoft Windows file that can be manipulated from an application or Microsoft Windows Explorer. Properties include author or designer and creation date and may also be unique properties assigned by applications or users. Specifying properties can be useful when searching for part or assembly files.
Rack	A bar of rectangular cross section with straight teeth on one side that mesh with teeth on the pinion.
Pinion	A gear with a small number of teeth designed to mesh with a rack.

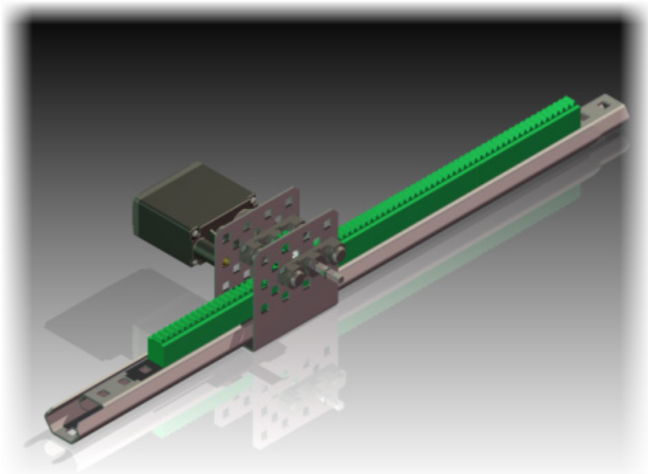
Required Supplies and Software

The following software is used in this phase.

Software
Autodesk Inventor Professional 2009

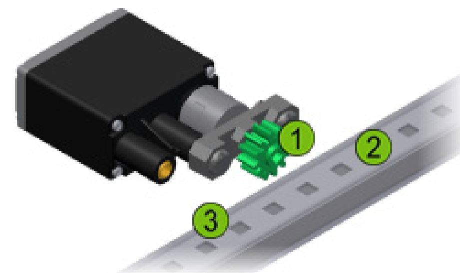
Exercise: Create a Rack Gear

In this exercise, you create a rack gear for a linear motion assembly.



The completed exercise

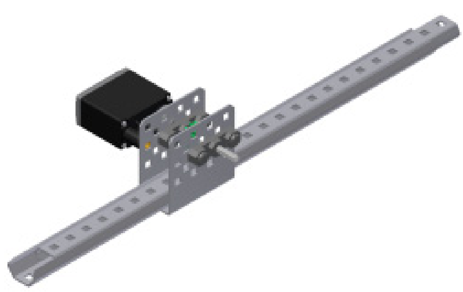
Your task is to design the rack gear for this linear assembly. It has to mesh with the pinion gear (1) and be flush with the slide (2). Each section of the rack will be bolted to the slide through the square holes (3).



Open the File

You have been given the task of creating a rack gear to match the 12 tooth pinion gear. The profile of a rack gear is a straight line.

1. Make *IFI_Unit7.ipj* the active project file.
2. Open *Rack_Pinion.iam*.



Extrude the Rack Gear Base

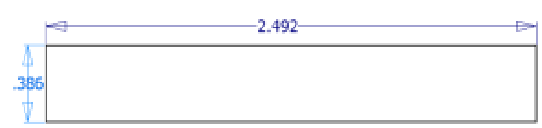
In this section of the exercise, you create the gear outside of the assembly. You can create the part in the assembly or as a new part outside of the assembly.

1. Click New.
2. On the English tab, double-click *Standard (in).ipt*.

   From the design sketches provided by the design team, you model the rack gear.
3. Click Two Point Rectangle.

   
4. Create a rectangle approximately 2.5" x 0.5".
5. Click General Dimension.

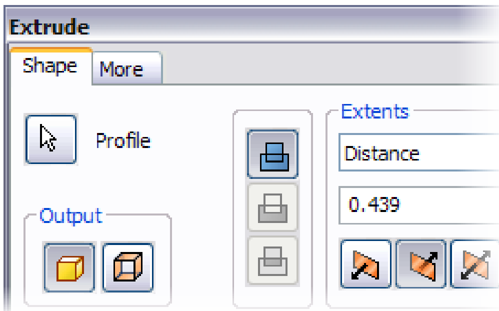
   
6. Add **2.492** and **0.386** dimensions as shown.

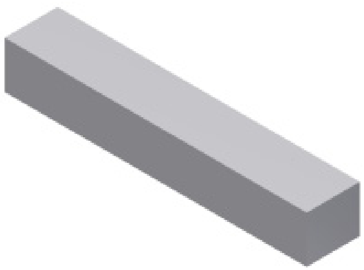


7. On the ViewCube, click Home.

8. Press **E** to start the Extrude tool.

- For Distance, enter **0.439**.
- Click Flip.
- Click OK.



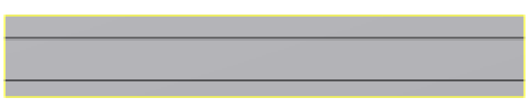


9. On the ViewCube, click Front.

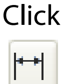
10. Click 2D Sketch. Select the front face of the rack base.

11. Click Line.

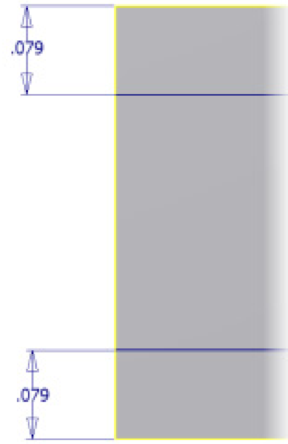
12. Create two horizontal lines as shown. Make sure the endpoints are coincident with the projected sketch.



13. Click General Dimension.



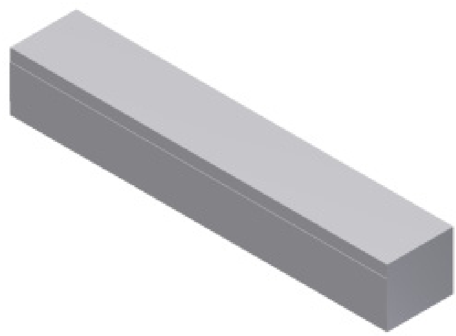
14. Add two **0.079** dimensions as shown.

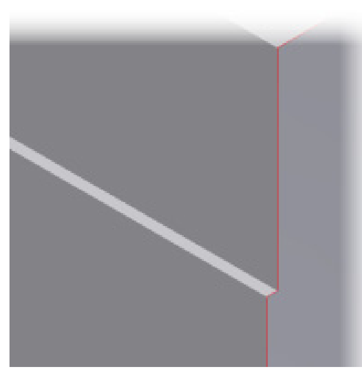


15. On the ViewCube, click Home.

16. Press **E** to start the Extrude tool.

- Select the profile between the two lines.
- For Distance, enter **0.004**.
- Click OK.





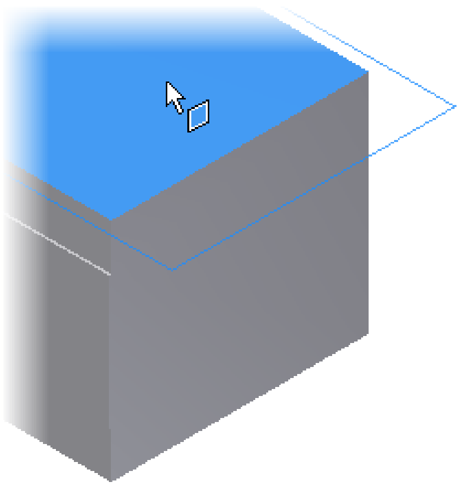
17. Click Save. For File Name, enter **my_rack_gear**.

Create the Gear Tooth

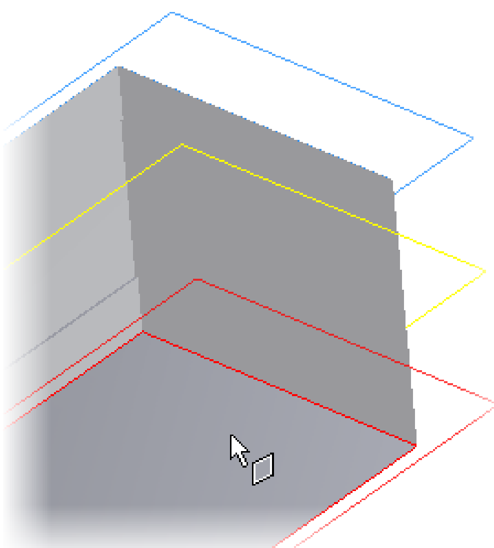
In this section of the exercise, you extrude the sketch of a gear tooth.

1. Click Work Plane.

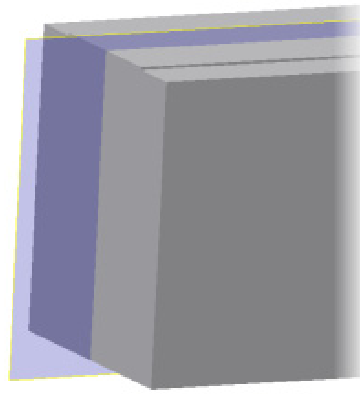
2. Select the top face of the gear base.



3. Rotate the part and select the bottom face of the part. A work plane is created through the middle of the part.



4. Rotate the part to view the front face as shown.



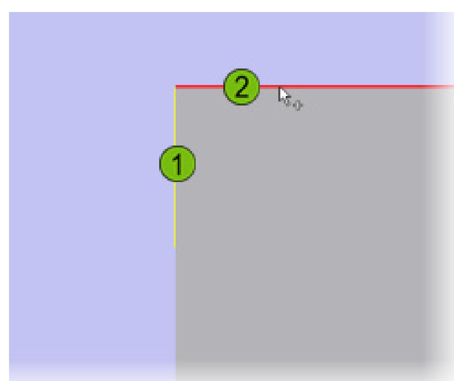
5. Click Look At.

6. Select the left edge of the work plane.

7. Click 2D Sketch. Select the edge of the work plane.

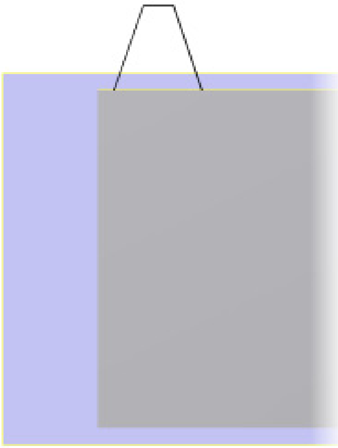
8. Click Project Geometry.

9. Zoom into the top left corner of the sketch. Select the short vertical edge (1) and the top horizontal edge (2) as shown.

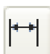


10. Click Line.

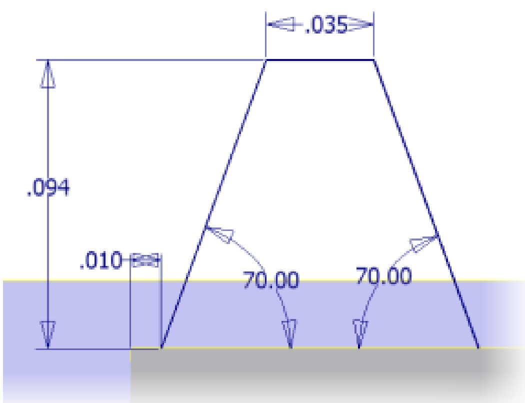
11. Create a sketch of the gear profile as shown.



12. Click General Dimension.

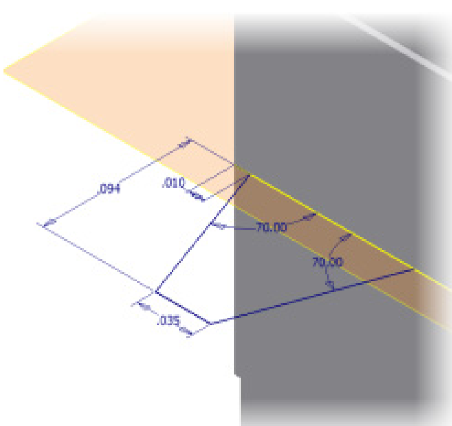


13. Add the dimensions as shown.

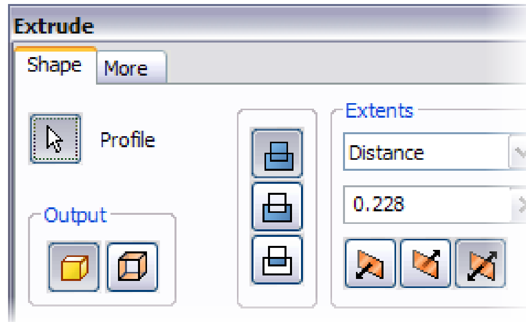


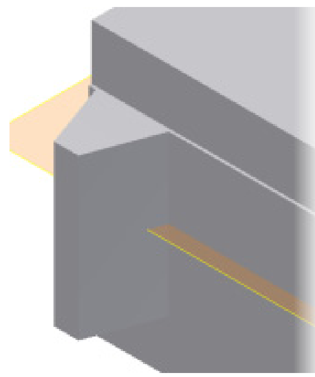
14. On the ViewCube, click Home.

15. Zoom in to the sketch.



16. Press **E** to start the Extrude tool.
    - Select the tooth profile.
    - For Distance, enter **0.228**.
    - Click Midplane.
    - Click OK.



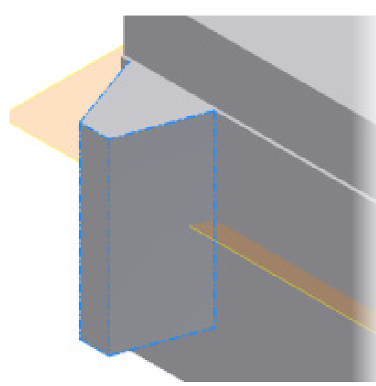


Pattern the Gear Tooth

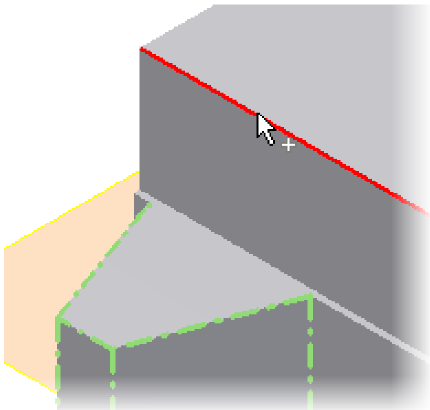
In this section of the exercise, you create the other gear teeth.

1. Click Rectangular Pattern.

2. In the graphics window, select the gear tooth.



3. Click the Path direction button. Select the top edge of the gear base.



4. Click the Flip direction button.

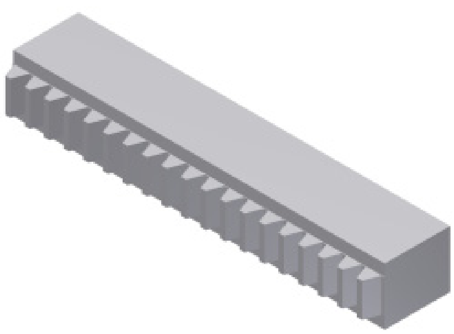
5. For Column Count, enter **19**.

6. For Column Spacing, enter **0.13**.

7. Click OK.

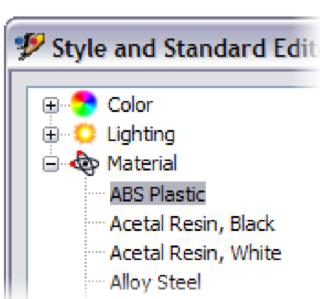
8. On the ViewCube, click Home.

9. Turn off the visibility of the work plane.

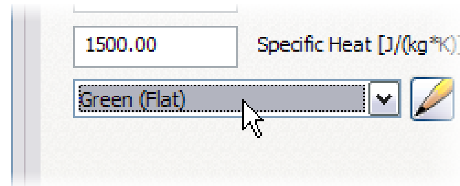


10. Click Format menu > Style and Standard Editor.

11. Expand Material. Select ABS Plastic.



12. For color, select Green (Flat).



13. Click Save.

14. Click Done.

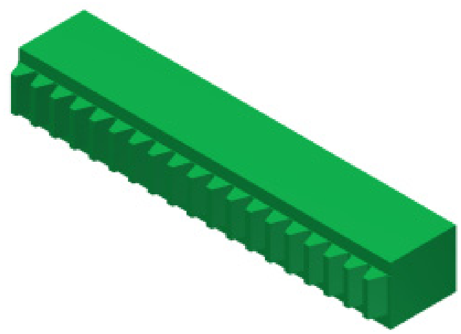
15. In the browser, right-click *my_rack_gear.ipt*. Click iProperties.

16. Click the Physical tab. For Material, select ABS Plastic.

17. Click Apply. Note the properties of the gear, such as Mass, Area, and Volume.

18. Click Close.

19. Click Save.

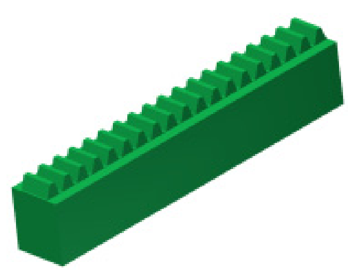


20. Close the file.

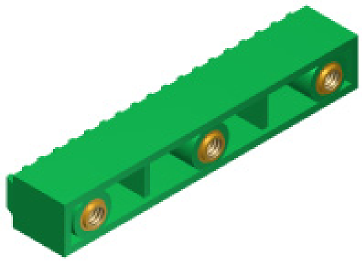
Assemble the Rack and Pinion

In this section of the exercise, you add the rack to the linear motion assembly.

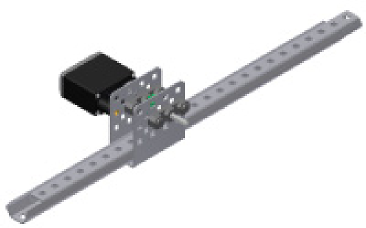
1. Open *Rack_Assembly.iam*.



2. Rotate the assembly and review the updated rack base. Your model from the previous section was updated by another designer. It now has three threaded inserts.



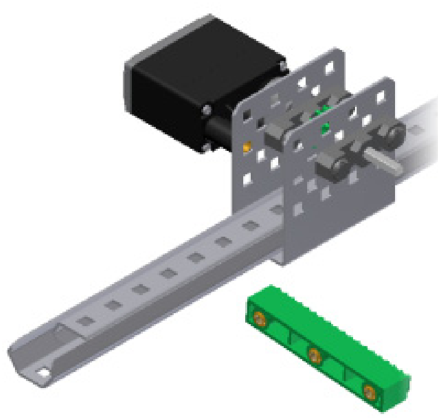
3. Switch to *Rack_Pinion.iam*.



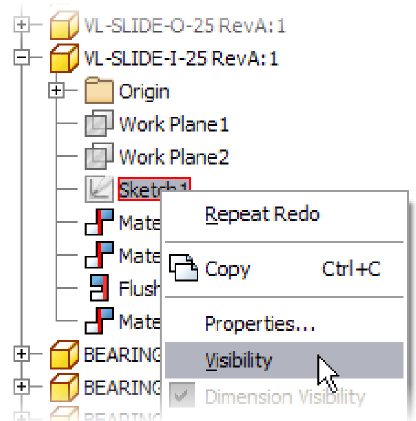
4. Click Place Component.

5. Double-click *Rack_Assembly.iam*.

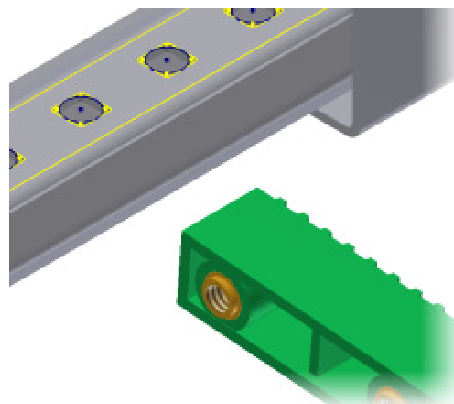
6. Click to place one component. Right-click in the graphics window. Click Done.



7. On the browser, expand VL-SLIDE-I-25 RevA:1. Right-click Sketch1. Click Visibility to turn on the visibility of the sketch.

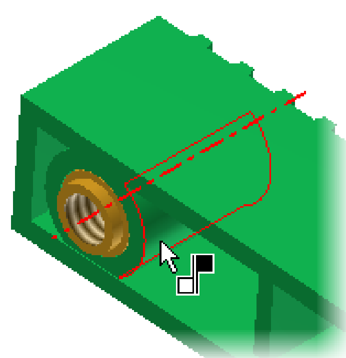


8. Zoom in to the rack assembly.

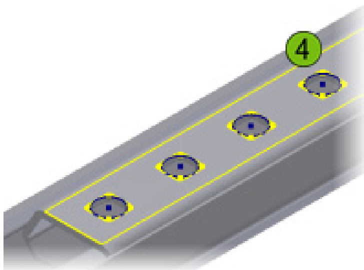


9. Click Constraint.

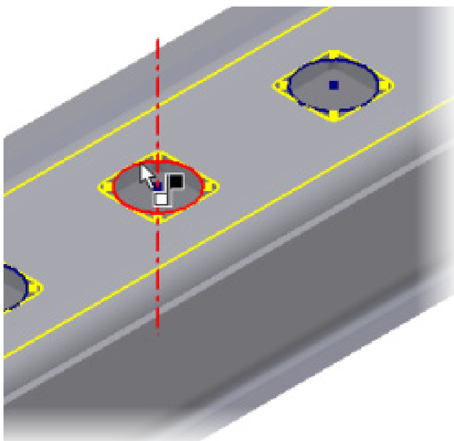
10. Move the cursor over the outside surface of the cylinder. Click when the centerline is displayed.



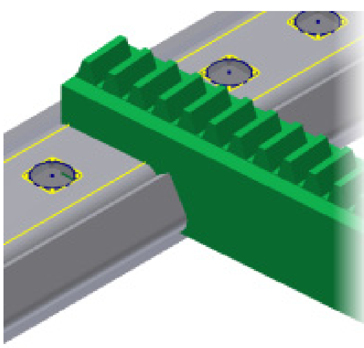
11. Move the cursor over the circle on the fourth hole from the left.



12. Click when the centerline is displayed.



13. Click OK.



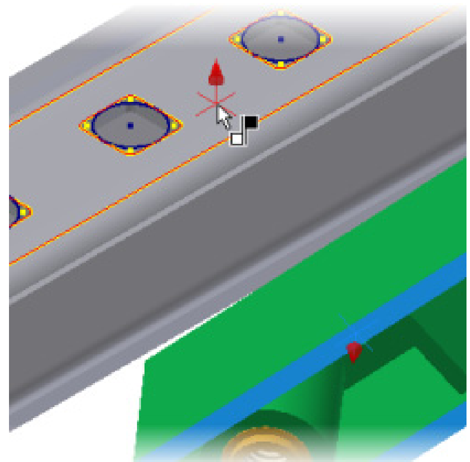
14. Drag the slider assembly to the left so that more of the holes are displayed.

15. Click Rotate Component.

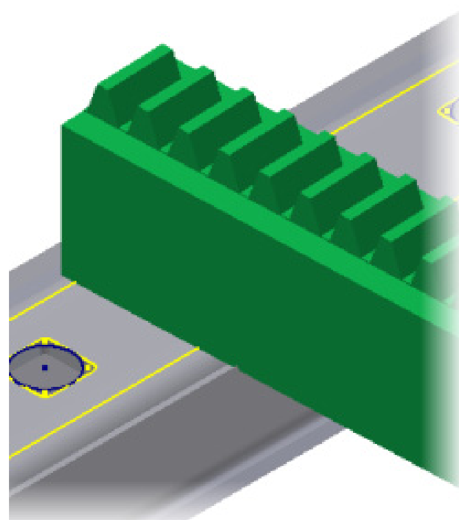
16. Select the rack assembly and rotate it to display the bottom face.

17. Click Constraint.

18. Select the bottom face of the rack assembly and the top of the slider.



19. Click OK.

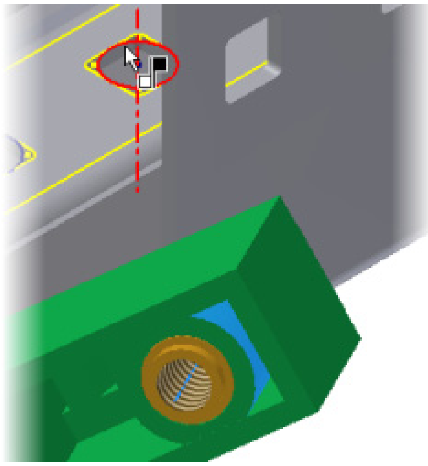


20. Click Rotate Component.

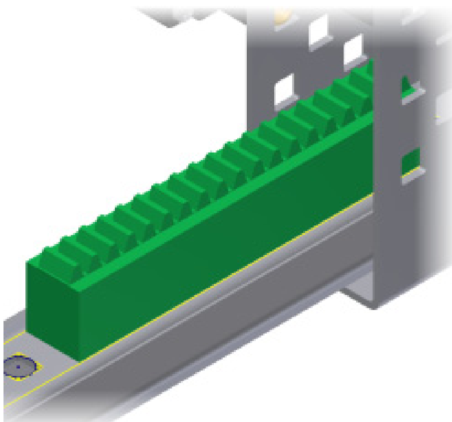
21. Select the rack assembly and rotate it to display the bottom face.

22. Click Constraint.

23. Select the outside surface of the cylinder on the right and the centerline on the eighth hole.



24. Click OK.



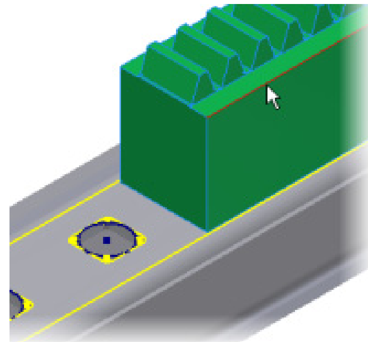
25. Save the file.

Pattern the Rack Assembly

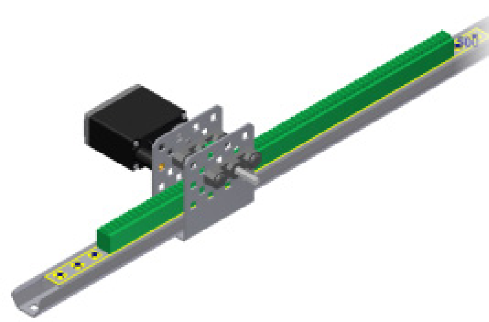
In this section of the exercise, you pattern the rack assembly.

1. Click Pattern Component.

2. In the graphics window, select the rack assembly.
3. In the Pattern Component dialog box, click the Rectangular tab.
4. Under Column, click Column Direction.
5. Select the edge of the rack assembly.



6. For Column Count, enter **4**.
7. For Column Spacing, enter **2.492**.
8. Click OK.



9. On the browser, expand VL-Slide-I-25 RevA:1. Right-click Sketch1. Click Visibility to turn off the visibility of the sketch.

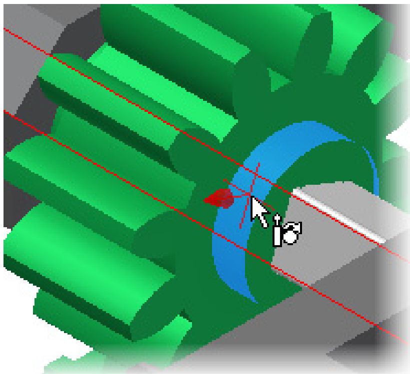
Drive the Rack and Pinion

In this section of the exercise, you add a motion constraint between the rack and the pinion.

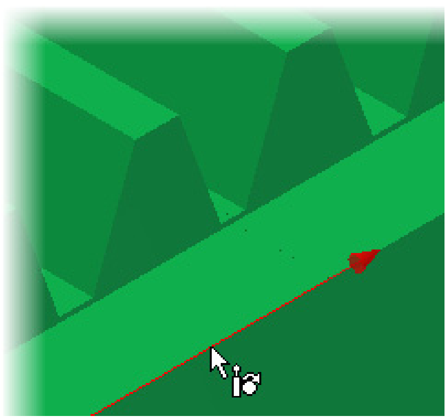
1. Turn off the visibility of VL-RACK-BRK Rev A:1 and Shaft_Collar:1.
2. Zoom in to the pinion gear.
3. Click Constraint.

4. On the Motion tab, under Type, click Rotation-Translation.

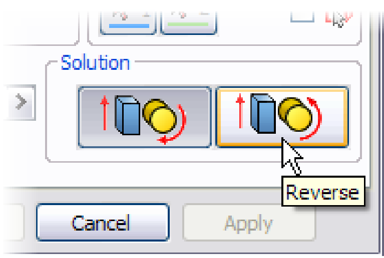
5. Select the circular face of the pinion.



6. Select the edge of the rack.



7. Under Solution, click Reverse.



8. For Distance, enter **1.584**.

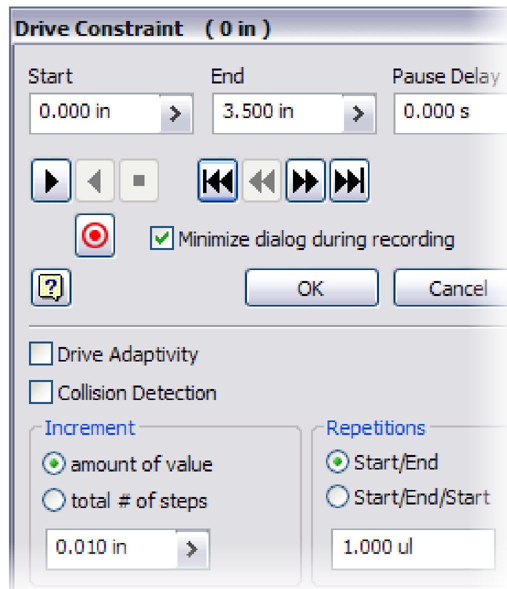
NOTE: The distance is the amount the rack moves for one rotation of the pinion gear. In this model, the pinion has 12 teeth and the pitch of the rack is 0.132 inches. Therefore, the rack moves 12 teeth * 0.132 inches/tooth = 1.584 inches for each turn of the pinion.

9. Click OK.

10. On the browser, expand VL-SLIDE-O-25 RevA:1. Right-click Drive Me (1.000 in). Click Suppress to unsuppress the constraint.

11. Right-click Drive Me (1.000 in). Click Drive Constraint.

- For Start, enter **0**.
- For End, enter **3.5**.
- Click More.
- Under Increment, for Amount of Value, enter **0.010**.
- Click Forward.



12. When the animation is complete, click Cancel.

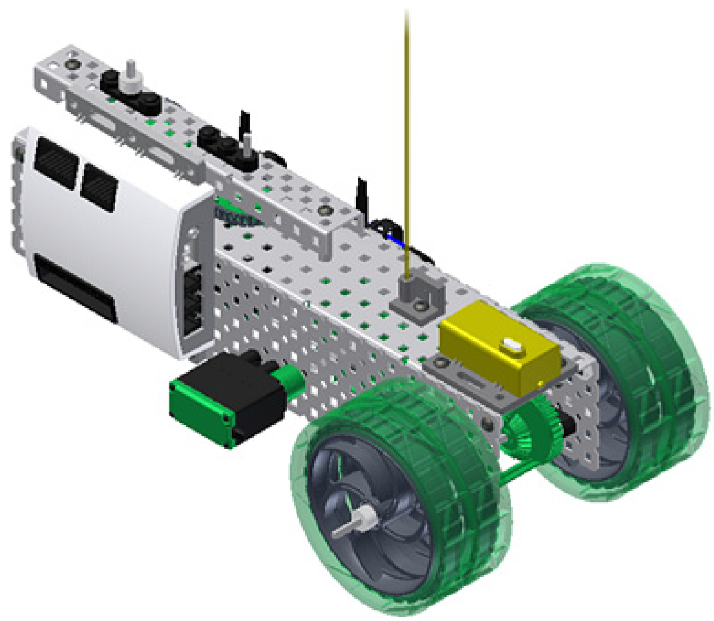
13. Save the file.

14. Close the file.

Build Phase

Overview

In this phase, you build a robotic tricycle using a differential.



Phase Objectives

After completing this phase, you will be able to:

- Apply knowledge gained about differentials in the Unit 7: Advanced Gears > Think Phase.
- Combine spur gears, chain, and sprocket, and bevel gears into a robot drivetrain.
- Build a steerable VEX robot.

Prerequisites

Before starting this phase, you must have:

- Completed Unit 7: Advanced Gears > Think Phase.

Related phase resources are:

- Unit 1: Introduction to VEX and Robotics.
- Unit 4: Microcontroller and Transmitter Overview.
- Unit 5: Speed, Power, Torque, and DC Motors.
- Unit 6: Gears, Chains, and Sprockets.

Required Supplies and Software

The following supplies are used in this phase:

Supplies
Notebook and pen
Work surface
Small storage container for loose parts
Optional: Autodesk Inventor Professional 2009

VEX Parts

The following VEX parts are used in this phase:

Quantity	Part Number	Abbreviations
2	ANGLE-GUSSET	AG
1	Antenna-Holder	AH
1	Antenna-Tube	AT
2	BATTERY-STRAP	BST
2	BEAM-1000	B1
13	BEARING-FLAT	BF
12	BEARING-RIVET	BR
3	VEX-24-TOOTH-BEVEL-GEAR	BG24
78	CHAIN-LINK	CL
1	Differential-Housing	DG36
4	MEDIUM-WHEEL	W4
1	MICROCONTROLLER	VMC
25	NUT-832-KEPS	NK
1	PLUS-GUSSET	G+
1	RECEIVER	RX75
2	SCREW-632-0250	SS2
2	SCREW-632-0500	SS4
8	SCREW-832-0250	S2
17	SCREW-832-0500	S4
4	SCREW-832-0750	S6

Quantity	Part Number	Abbreviations
2	SHAFT-2000	SQ2
3	SHAFT-3000	SQ3
2	SHAFT-4000	SQ4
9	SHAFT COLLAR	COL
1	SMALL-WHEEL	W2.8
2	SPACER-THICK	SP2
4	SPACER-THIN	SP1
1	VEX-24-TOOTH-SPROCKET	CS24
1	VEX-36-TOOTH-GEAR	G36
2	VEX-48-TOOTH-SPROCKET	CS48
2	VEX-60-TOOTH-GEAR	G60
1	VEX-Motor	MOT
1	VEX-Servo	SER
1	VL-CHAN-121-15-RevA	C15
1	VL-CHAN-151-25-RevA	CW25
2	VL-PLATE-5-25-RevA	P25
7	WASHER-DELRIN	WP

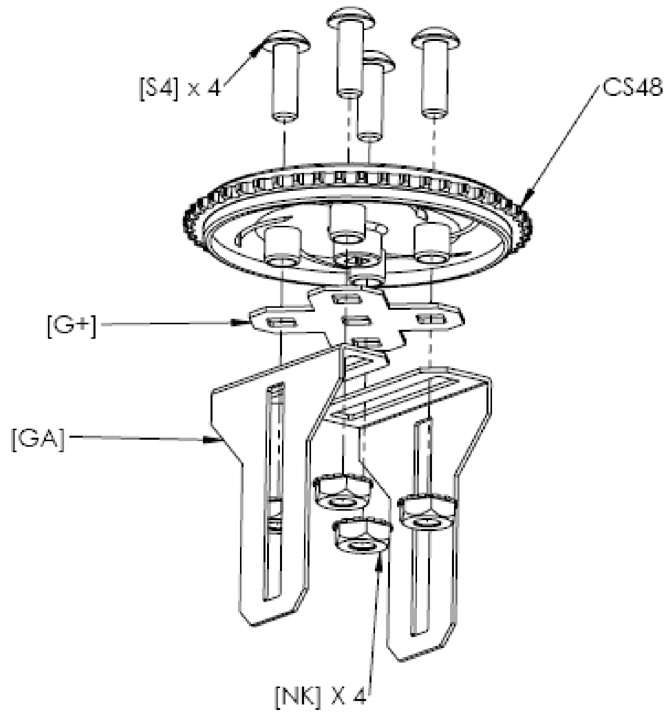
Activity

In this activity, you build a differential tricycle using the concepts learned in previous units and phases, most specifically the Think Phase of Unit 7.

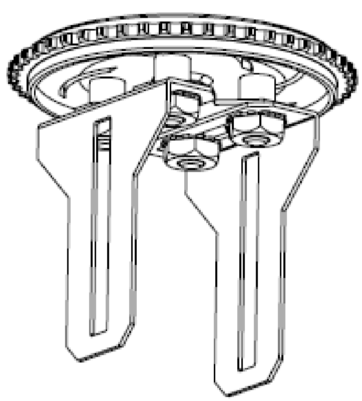
As you work on building this project, have some of your team members focus on expanding their expertise using Autodesk Inventor. Later in the curriculum, you will be challenged to come up with your own creative solutions for robot design. You will save time and maximize your ability to create winning solutions if your team understands how to leverage the power of digital prototypes using Inventor.

NOTE: Team members can download a free version of Autodesk Inventor Professional to use at home, so you can come to class prepared to build and test your best ideas! To do this, simply join the Autodesk Student Engineering and Design Community at *http://www.autodesk.com/edcommunity*.

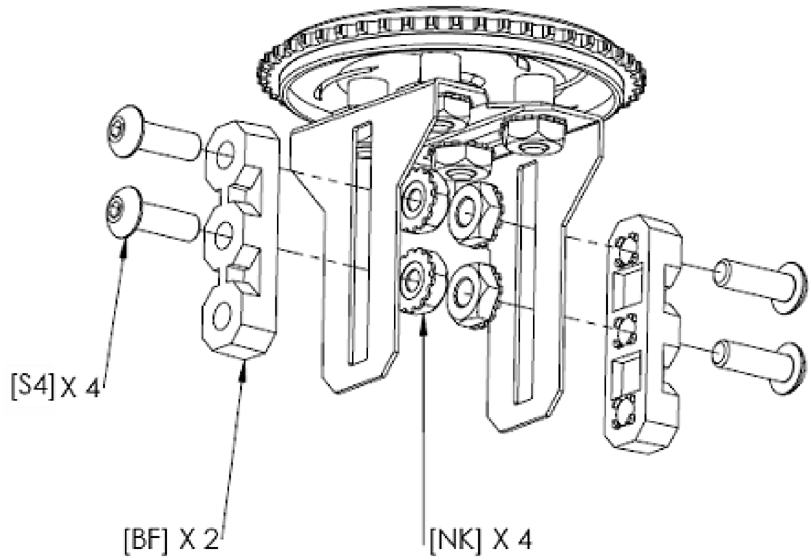
1. Bolt a 48 Tooth Sprocket [CS48], Plus Gusset [G+], and two Angle Gussets [GA] together using #8-32 x 1/2" screws [S4].



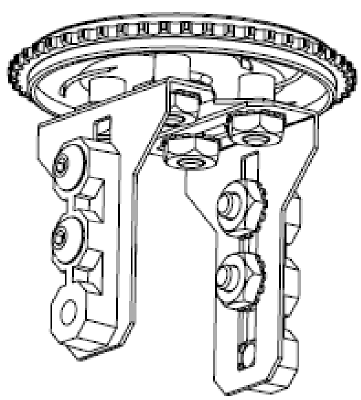
The completed model is as shown:



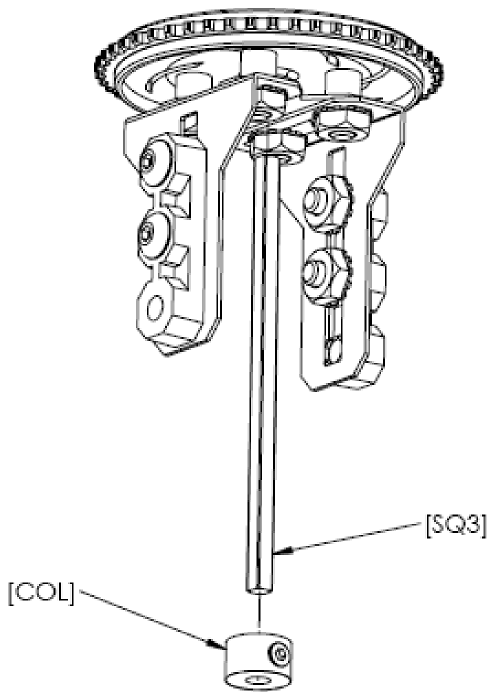
2. Bolt two Bearing Flats [BF] to the Angle Gussets using #8-32 x 1/2″ screws [S4].



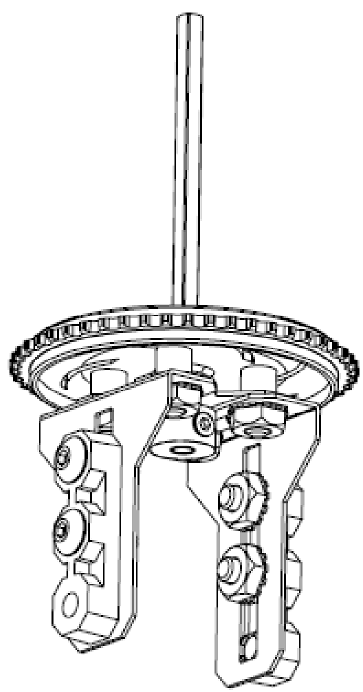
The completed model is as shown:



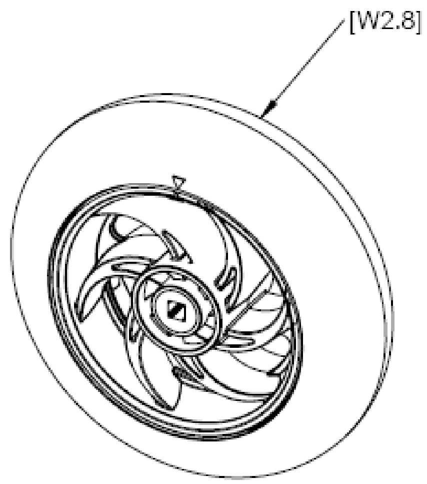
3. Insert a 3″ long shaft [SQ3] and a Collar into the 48 Tooth Sprocket.



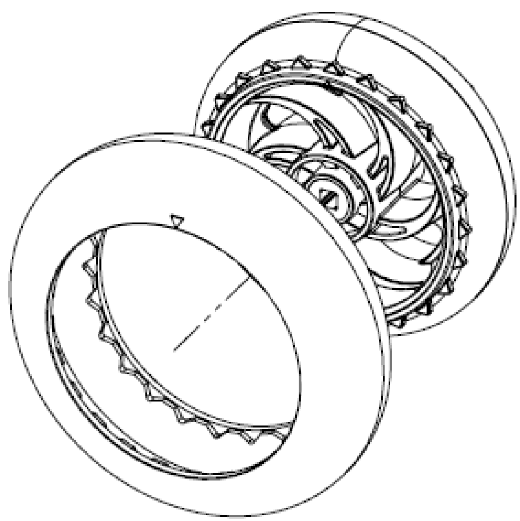
The completed model is as shown:



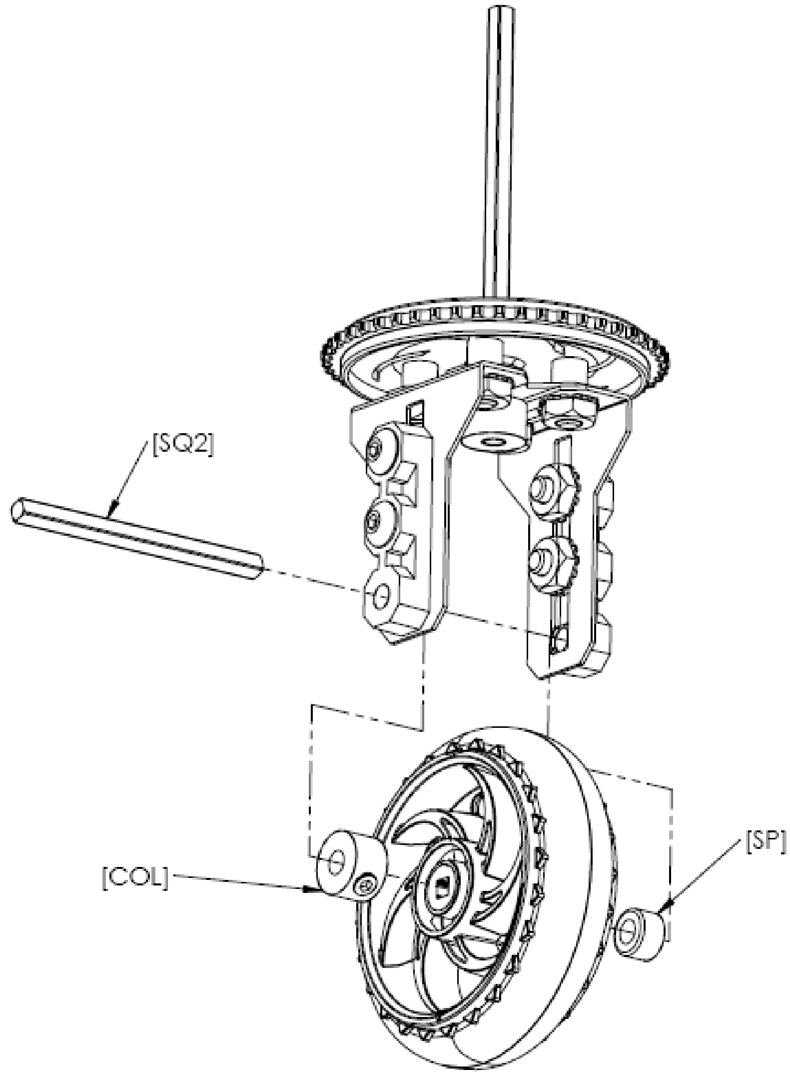
4. Remove the Rubber Tire from a Low Friction Wheel [W2.8].



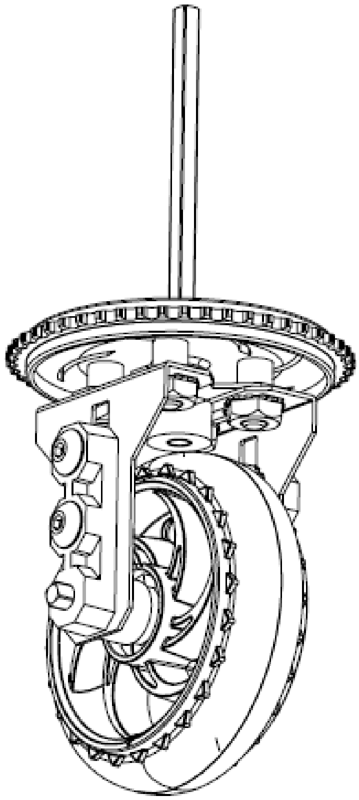
The completed model is as shown:



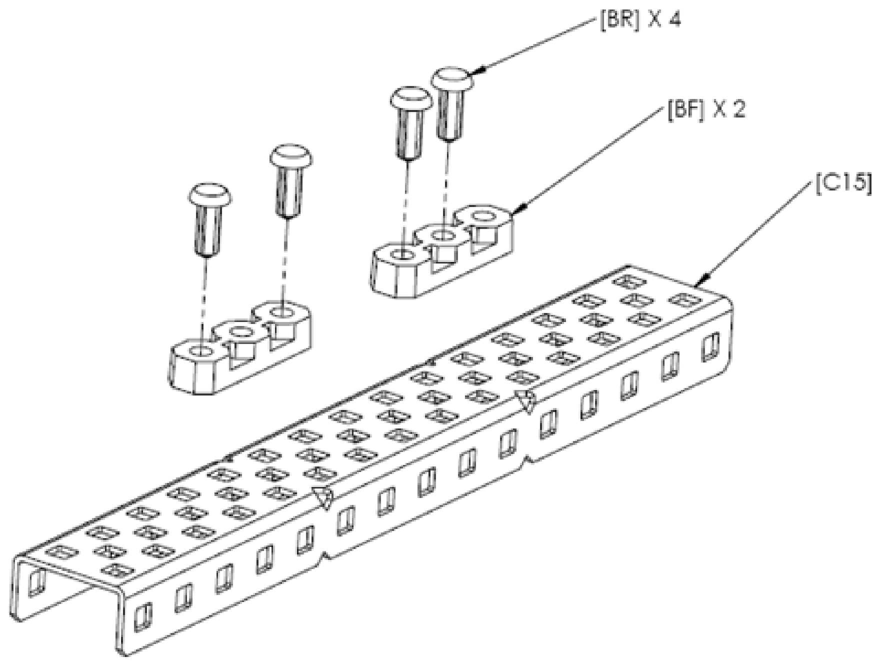
5. Slide a 2″ Shaft [SQ2] into the bearing flats while inserting a Collar, the Small Wheel, and a Thin Spacer [SP1] between the Angle Gussets.



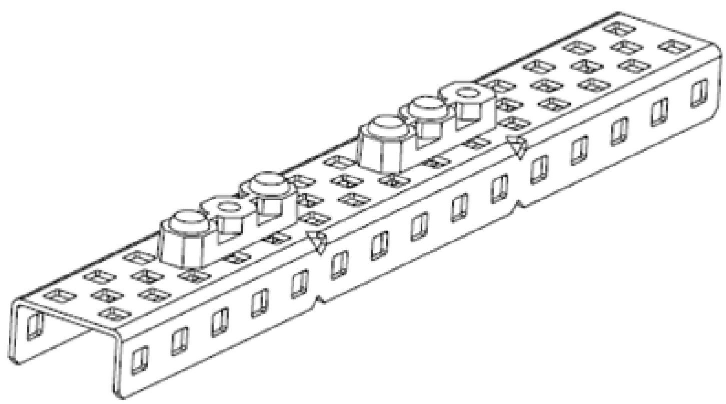
The completed model is as shown:



6. Attach two Bearing Flats to a 1x2x1x15 C-Channel using Bearing Rivets [BR].

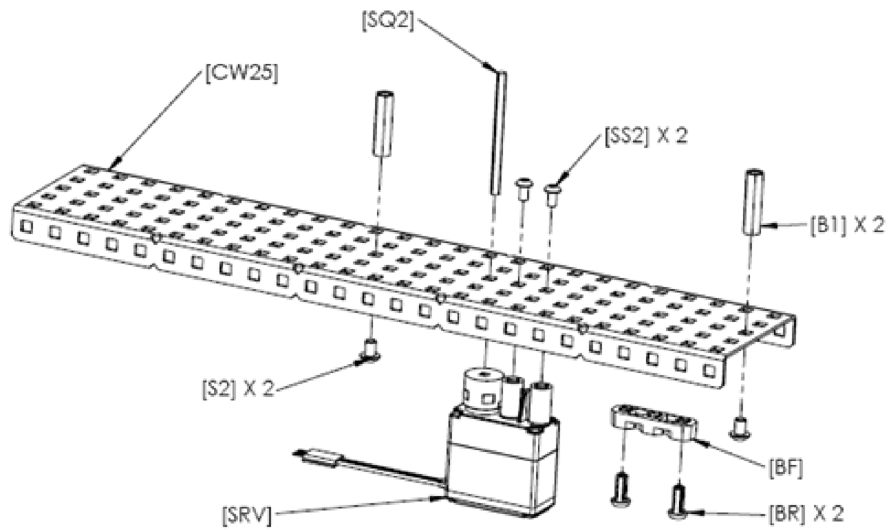


The completed model is as shown:

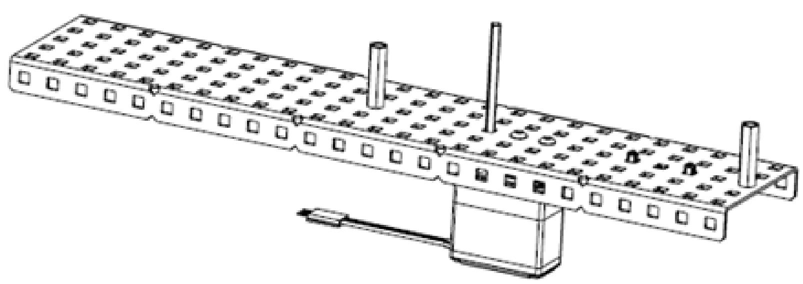


7. To complete the next step:

- Bolt two 1″ Beams [B1] to a 1x5x1x25 C-Channel [CW25].
- Attach a Bearing Flat to the 1x5x1x25 C-Channel using two Bearing Rivets [BR].
- Bolt a Servo [SRV] to the 1x5x1x25 C-Channel.
- Insert a 2″ Shaft fully into the Servo Clutch Post.

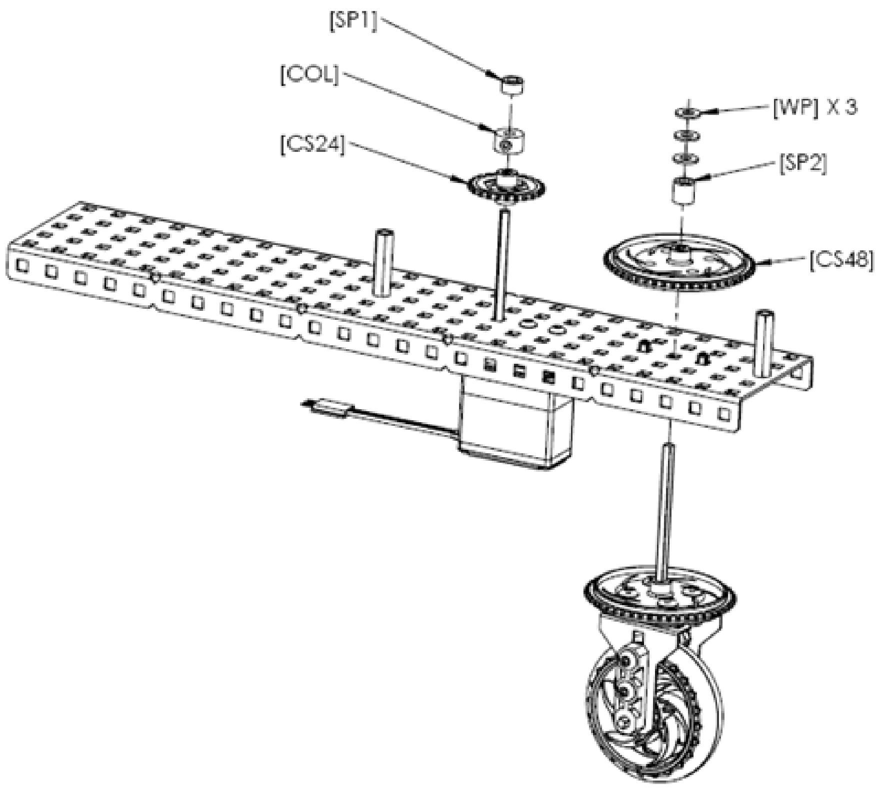


The completed model is as shown:

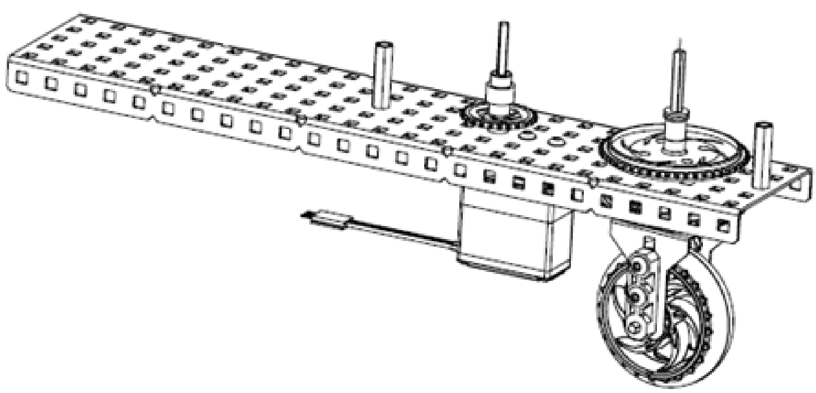


8. To complete the next step:

- Insert the assembly from step 5 into the Bearing Flat.
- Slide a 48 Tooth Sprocket, a Thick Spacer [SP2], and three Delrin (Plastic) Washers [WP] onto the 2" Shaft from the wheel assembly.
- Slide a 24 Tooth Sprocket [CS24], a Collar, and a Thin Spacer onto the Servo Shaft.

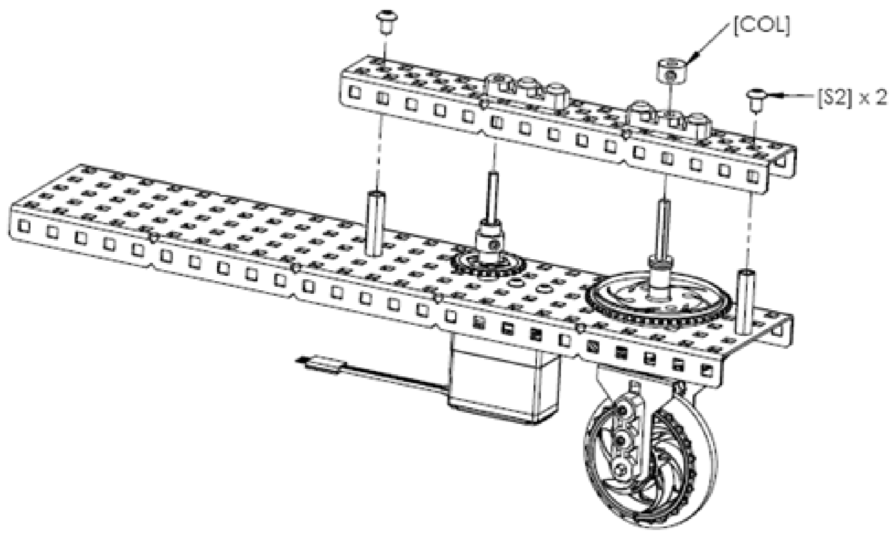


The completed model is as shown:

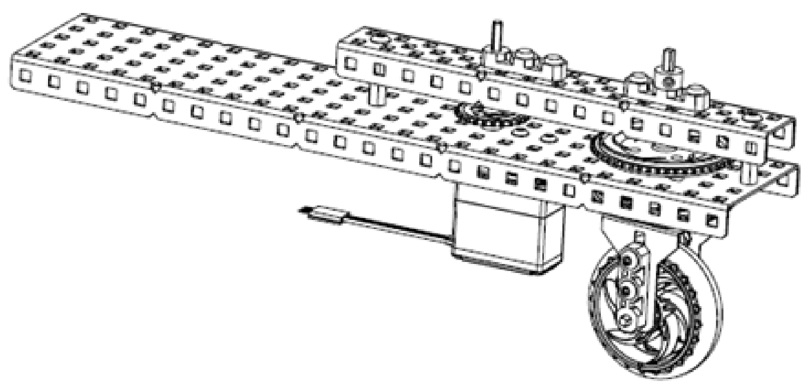


9. To complete the next step:

- Bolt the assembly from step 6 to the 1″ Beams.
- Slide a Collar onto the steering shaft.

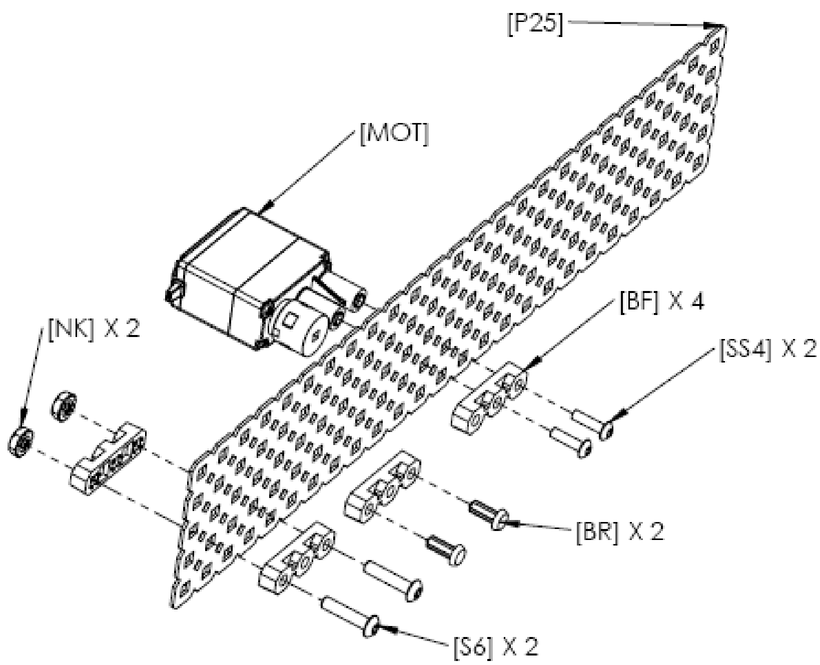


The completed model is as shown:

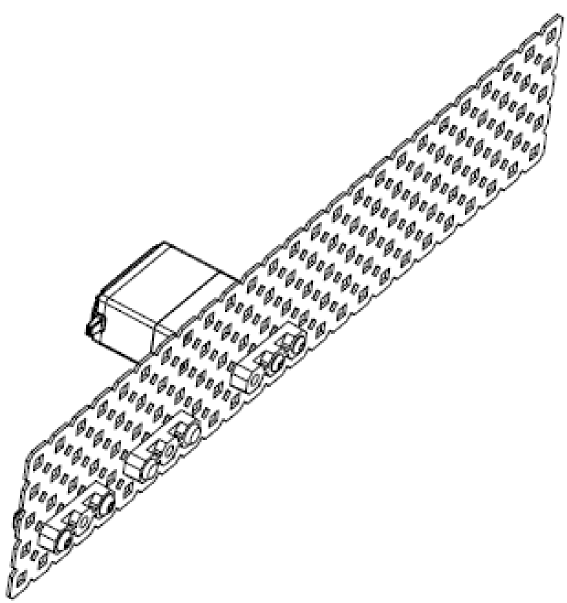


10. To complete the next step:

- Bolt two Bearing Flats to a 5x25 Plate [P25].
- Using Bearing Rivets, attach another Bearing Flat to the 5x25 Plate.
- Bolt a Motor [MOT] to the 5x25 Plate through the Bearing Flat closest to the center of the Plate.

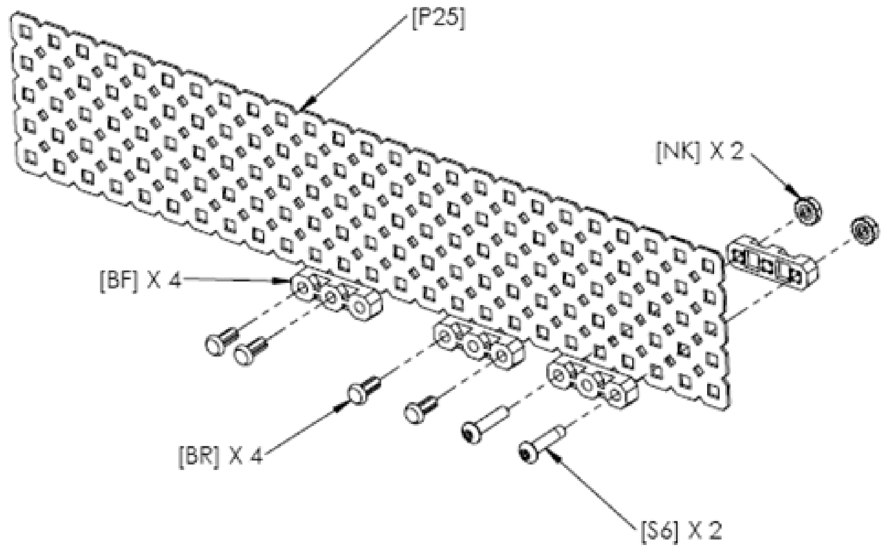


The completed model is as shown:



11. To complete the next step:

- Using Bearing Rivets, Attach two Bearing Flats to a 5x25 Plate.
- Bolt on two more Bearing Flats, one to either side of the 5x25 Plate.



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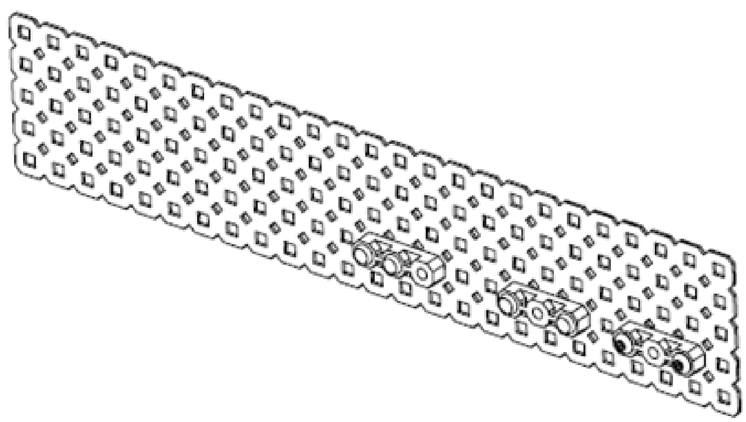
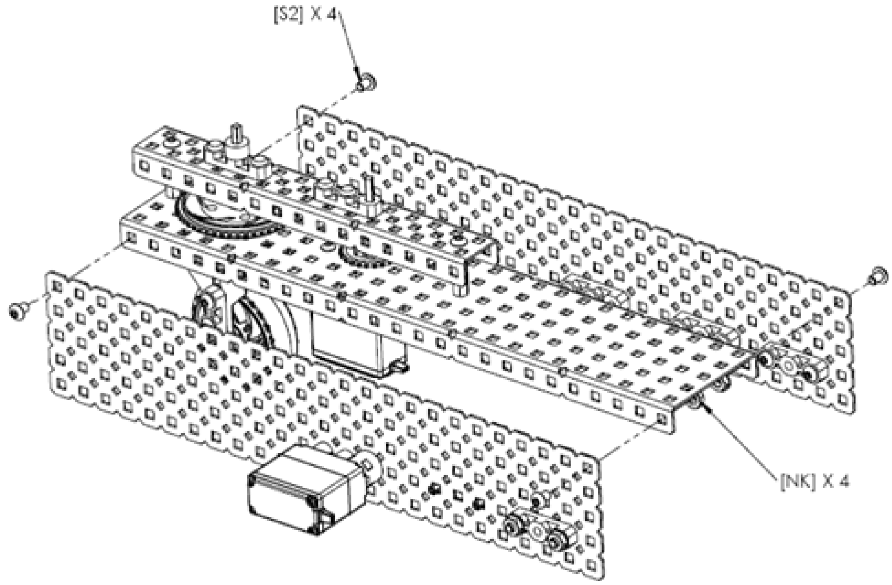


12. Bolt the assemblies from steps 10 & 11 to the assembly from step 9.



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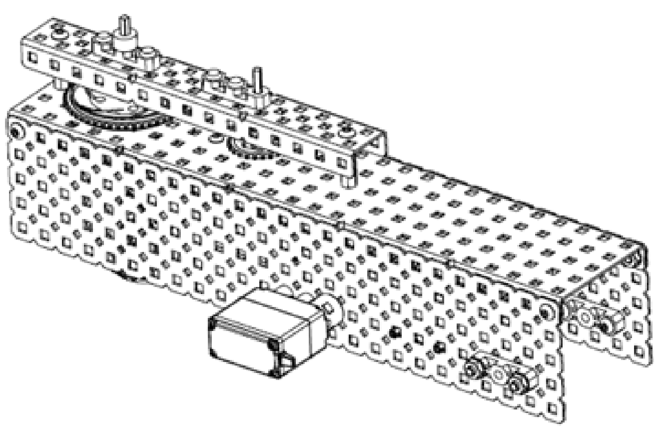
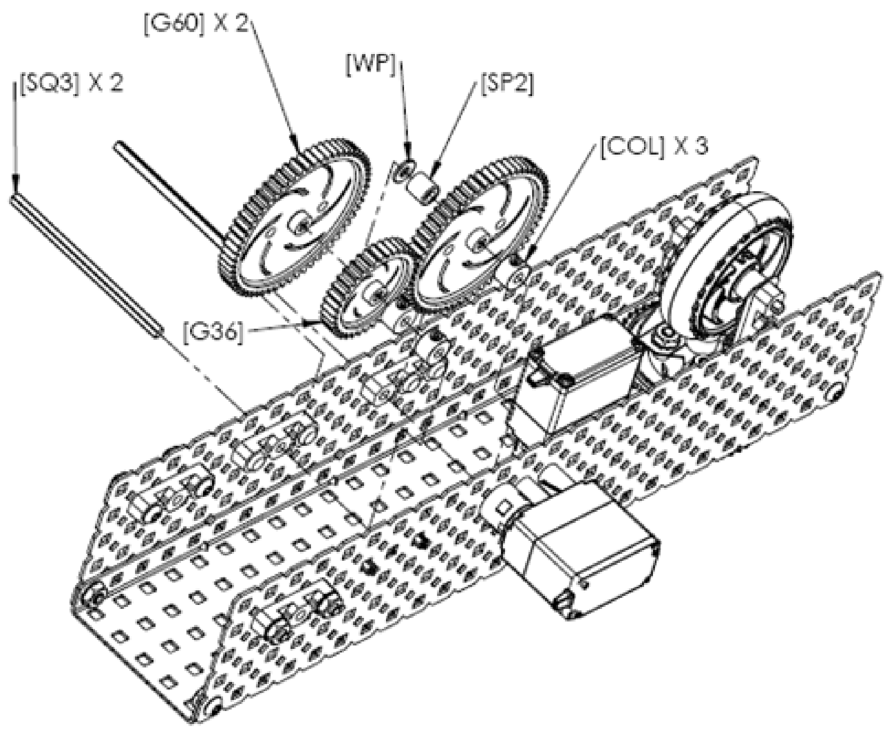


13. To complete the next step:

- Add a Delrin Washer, a Thick Spacer, a 60 Tooth Gear [G60], and a Collar on a 3″ Shaft [SQ3] and insert it fully into the Motor. Slide the Collar up against the gear and tighten.
- Assemble a 60 Tooth Gear, a 36 Tooth Gear [G36], and two Collars on a 3″ Shaft and insert into the middle set of Bearing Flats. Slide one collar against the Bearing Flat, and the other against the 36 Tooth Gear and tighten both.



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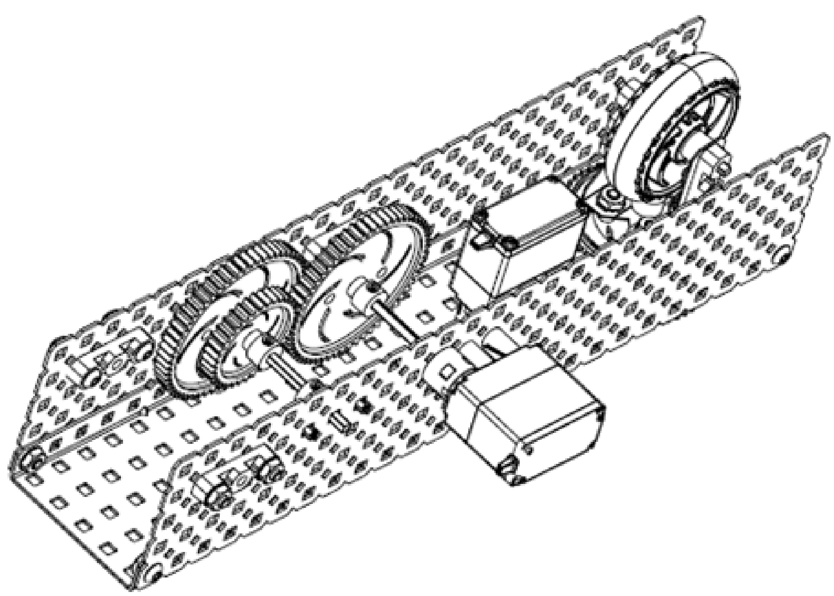
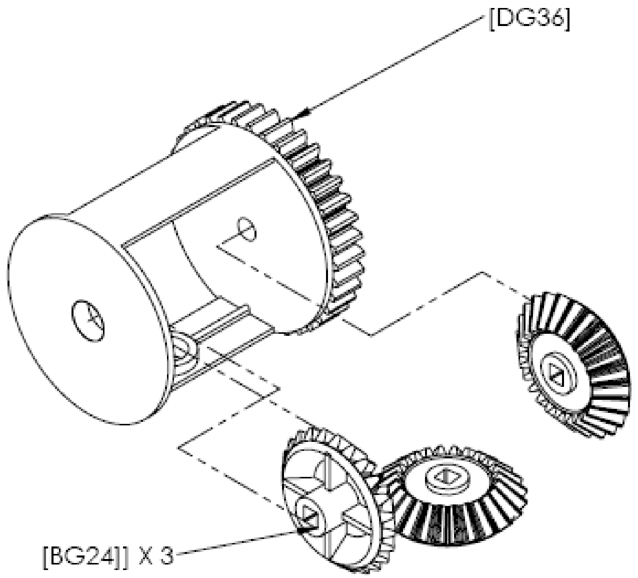


14. Snap three 24 Tooth Bevel Gears [BG24] into the Differential Housing [DG36].



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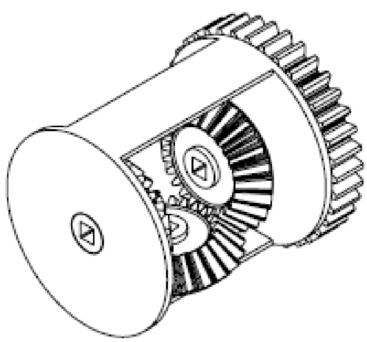
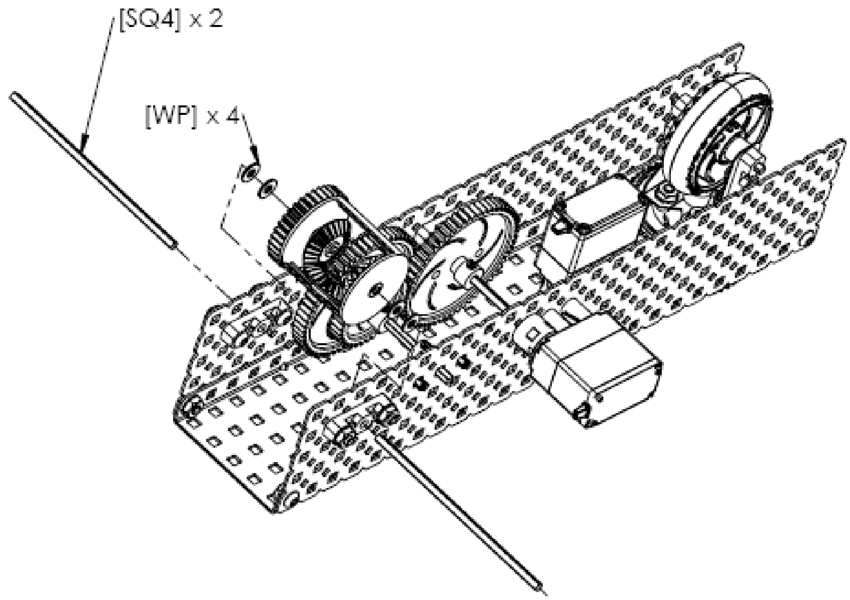


15. Slide two 4″ Shafts [SQ4] into the Differential Housing through both double sets of Bearing Flats with two Delrin Washers on each side of the Housing.



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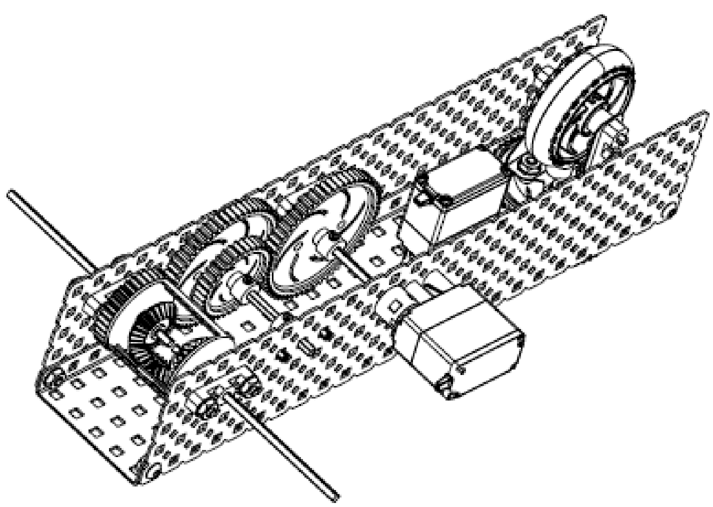
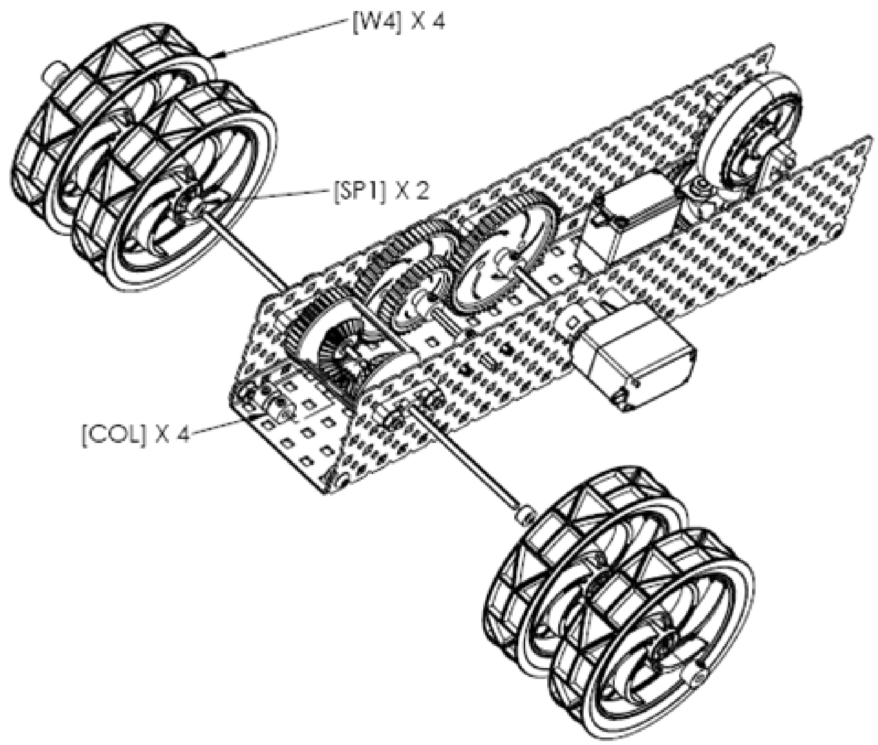


16. To complete the next step:

- Slide two Thin Spacers [SP1] and two 4″ Wheels [W4] onto each side of the two 4″ Shafts.
- Slide two collars onto each shaft; one on the outside of the wheel and one inside the Differential Housing.



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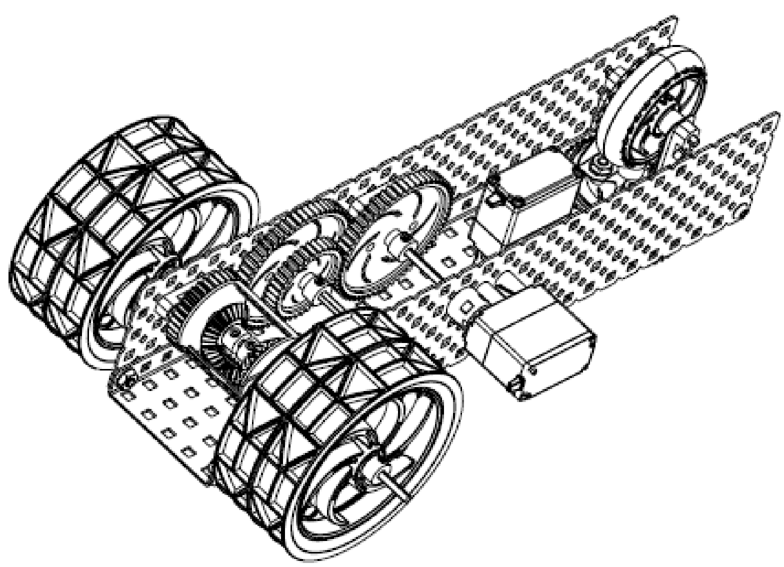
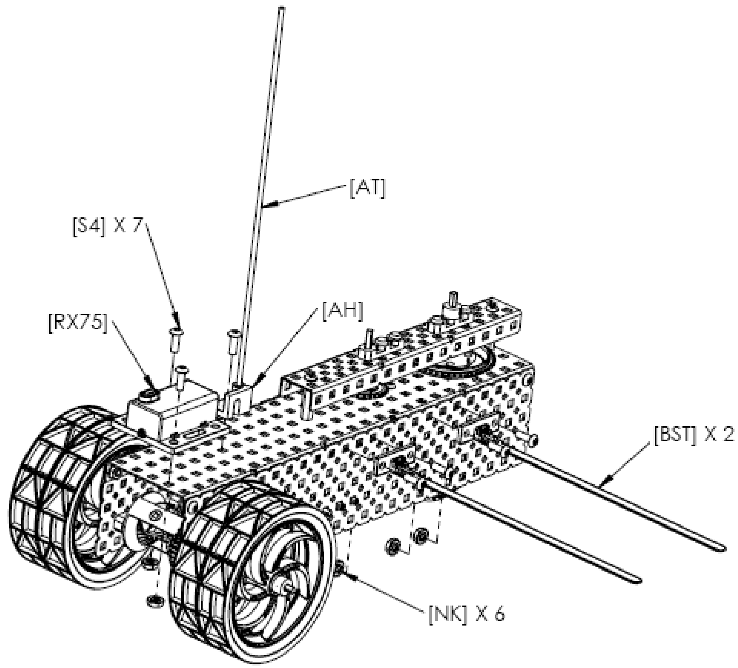


17. To complete the next step:

- Bolt down the Receiver [RX75] and Antenna Holder [AH].
- Slide the Antenna into the Antenna Tube [AT] and insert into the Antenna Holder.
- Bolt (2) Battery Straps to the Chassis [BST].



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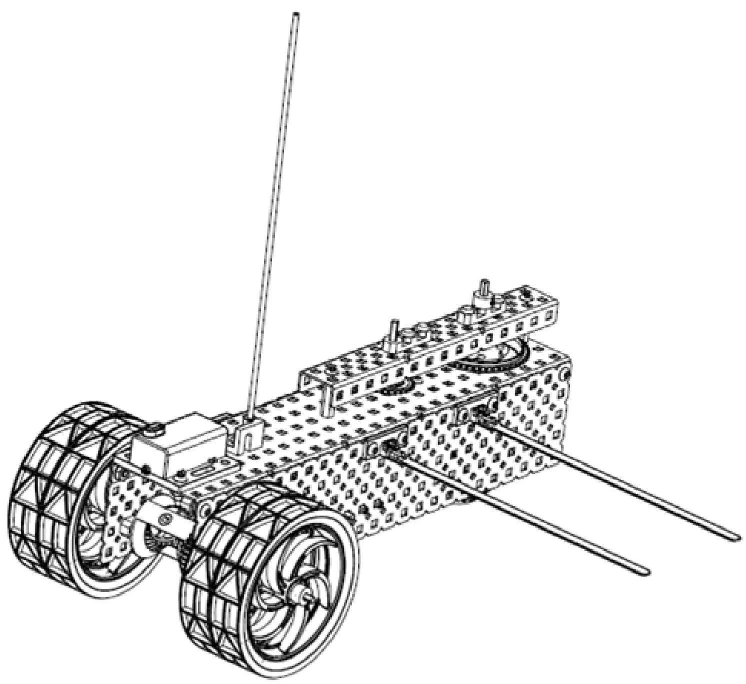
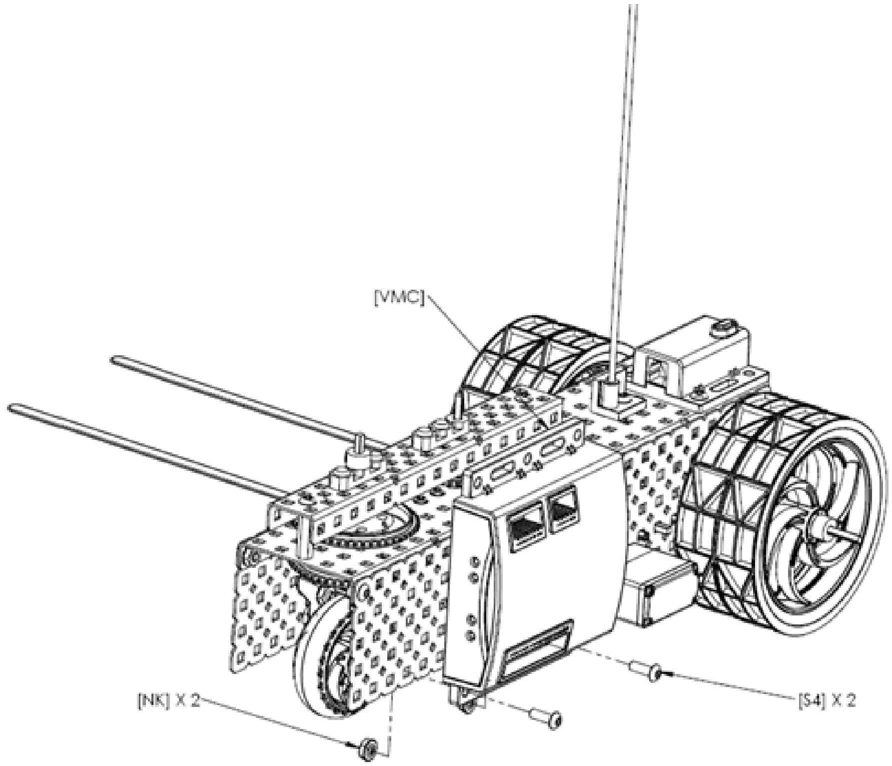


18. Bolt the VEX Microcontroller [VMC] to the Chassis.



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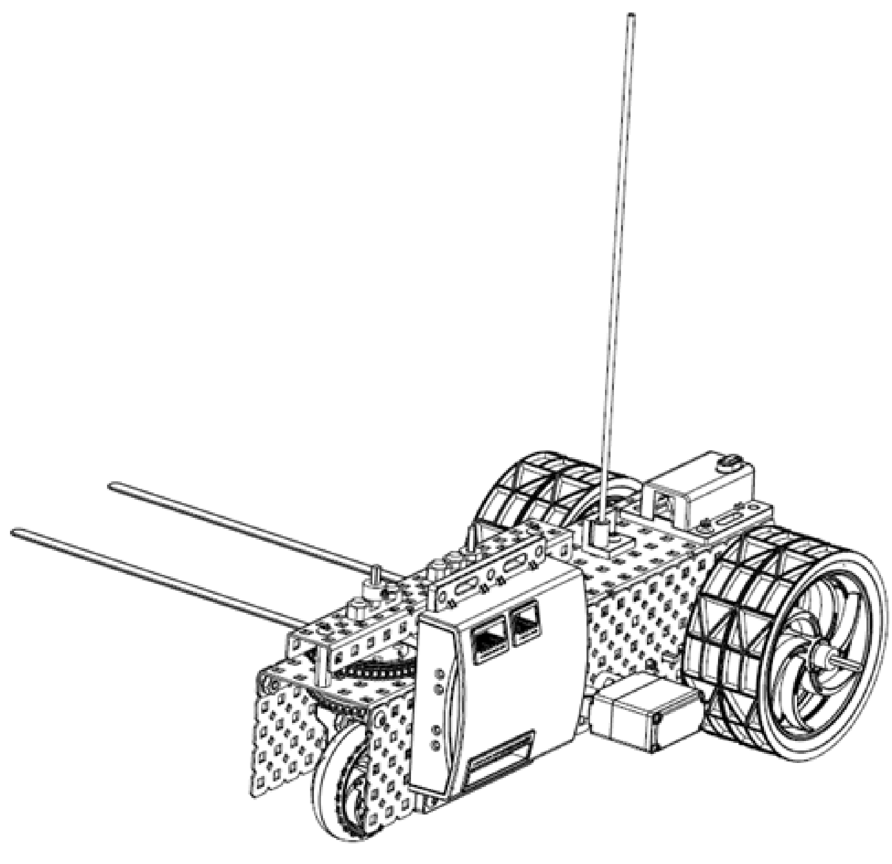
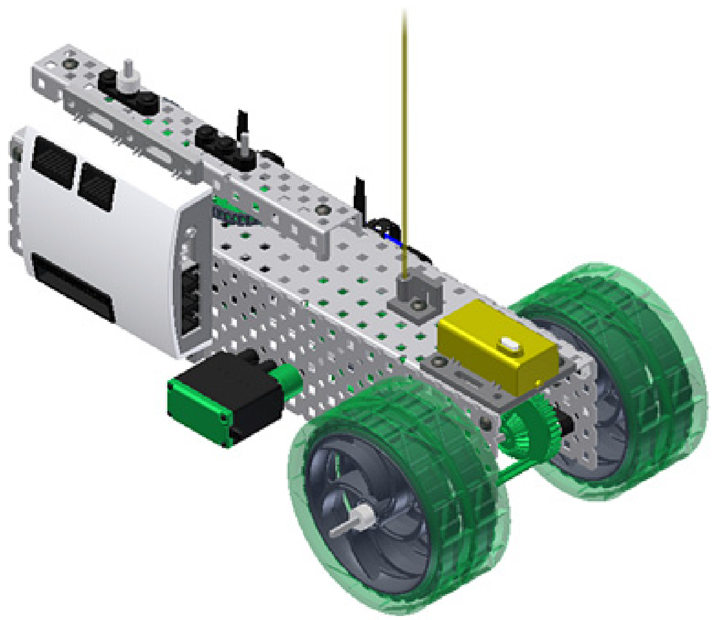


19. To complete the final step:

- Plug the Receiver into RX1 on the Microcontroller.
- Plug the Steering Servo into Motor Port 1.
- Plug the Drive Motor into Motor Port 2.
- Attach a Battery using the Battery Straps and plug into the Battery Port.
- Ensure Transmitter and Robot have matching set of Radio Crystals.
- Turn on the Transmitter and Microcontroller. The Steering Servo should center itself. Turn the front wheel until it is straight, using the right joystick on your transmitter.
- Attach Chain around the Steering Sprocket and the Servo Sprocket.

Your differential tricycle is now complete and ready to go for a test drive!



NOTE: Electrical connections not shown.

Amaze Phase

Overview

In this phase, you test the differential tricycle.

Phase Objectives

After completing this phase, you will be able to:

- Describe the effect of a differential on a robot drivetrain.
- Explain the agility and maneuverability given by a steerable drivetrain.
- Drive a VEX robot through a tight race track.

Prerequisites

Before starting this phase, you must have:

- Completed Unit 7: Advanced Gears > Think Phase.
- Completed Unit 7: Advanced Gears > Build Phase.
- Have an assembled differential tricycle from the Unit 7: Advanced Gears > Build Phase.

Related phase resources are:

- Unit 1: Introduction to VEX and Robotics.
- Unit 4: Microcontroller and Transmitter Overview.
- Unit 5: Speed, Power, Torque, and DC Motors.
- Unit 6: Gears, Chains, and Sprockets.

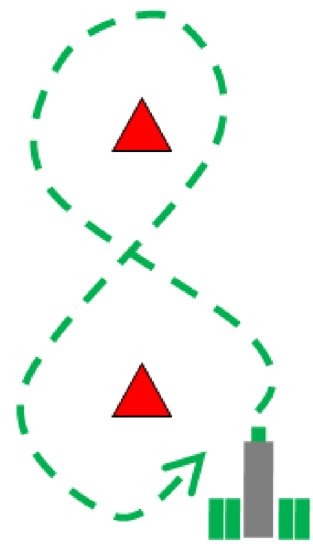
Required Supplies and Software

The following supplies are used in this phase.

Supplies
One assembled differential tricycle built in the Unit 7: Advanced Gears > Build Phase
Notebook and pen
Work surface
Two “obstacles.” Any small objects in your classroom: books, soda cans, and so on
8′ x 8′ of open floor space
One stopwatch

Evaluation

Challenge

<table>
<tr><th>Instructions</th><th>Figure 1</th></tr>
<tr><td>
1. Choose any two "obstacles" available to you in your classroom. These obstacles will act as pylons for the robot to navigate around.
2. Place the two obstacles approximately 4′ apart. See Figure 1.
3. Place the tricycle beside either obstacle furthest from the wall. See Figure 1.
4. Turn the tricycle and its transmitter on.
5. Using the joysticks, have the tricycle drive the path shown in Figure 1.
6. a. The Y axis of the right joystick controls the forward and reverse control of the robot.
b. The X axis of the right joystick controls the steering of the front wheel.
7. Drive five laps of the "figure 8," recording your overall time, and the time of each lap in your notebook.
8. Repeat the five-lap circuit a few more times, until you think you have become as fast as possible. Record your times to track your progress.
9. If time permits, take your robot for a test drive around your classroom or school.
</td><td></td></tr>
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Engineering Notebook

- Calculate your average time per lap for each five-lap session.
- Calculate your average time per lap for all laps driven.
- Calculate your average time for the five-lap sessions.
- Discuss improvements you would like to make to this robot. Does it turn well enough? Does it turn too easily? Does it tip over? If you have encountered problems, discuss how you can fix them.
- Write a brief paragraph comparing the maneuverability of the differential tricycle and Protobot. Which style of drive do you prefer?

Presentation

In the Think Phase for this unit, you learned many concepts about advanced gears. Choose one concept and discuss a real-life application of it. Present an everyday task that can be made faster by using advanced gears.

STEM Connections

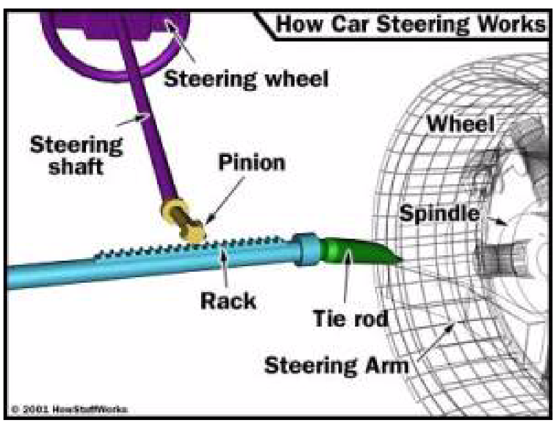

Image courtesy of HowStuffWorks.com

Background

Modern automobiles use a rack and pinion mechanism to steer the car with a steering wheel. When you turn the steering wheel, it turns a spur gear (the pinion), which is meshed with a rack gear that then turns the wheels (*http://static.howstuffworks.com/gif/steering-rack.jpg*).

This design accomplishes two things: it transforms the rotational motion of the steering wheel into linear motion, which is used to turn the wheels; and it creates an advantageous gear differential, which makes steering easier.

Science

The rack and pinion design for steering must be extremely durable considering the long lifetime of many cars.

1. What type of materials do you think are best able to withstand the grinding motion of the rack and pinion system?
2. Do these materials require constant maintenance or lubrication?
3. Design a lab scenario to torture test your materials for durability.

Technology

Power steering is an important part of modern steering systems. In the future, many people believe that steering will be accomplished by a "steer-by-wire" or "drive-by wire" system, eliminating all mechanical connection between the steering wheel and the actual steering mechanism and replacing it with a purely electronic system.

1. What are the potential advantages and disadvantages of this type of steering?

Engineering

1. Is the concept of a steering wheel preferable to other steering methods like a joystick or handlebars?
2. Why do you think cars employ a wheel system as opposed to any other steering method?

Math

In a certain rack and pinion steering mechanism, the teeth of the rack face upwards and are spaced to one tooth per cm. The pinion, which has 30 teeth, sits on top of the rack. The pinion is on the same axle as the steering wheel.

1. In what direction, and by what angle, must the steering wheel be turned in order to move the rack 7 cm to the right?