



Turning



Students will explore robot behaviors and create code to drive the Autopilot robot forward and in reverse.



Discover new hands-on builds and
programming opportunities to further
your understanding of a subject matter.

The Completed Look of the Build



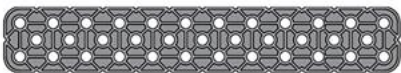
The completed Autopilot robot build.


This robot is designed so that it can be built quickly and drive around either autonomously or with the Controller in a short amount of time.


Build Instructions

1

The section at the top of the step shows important information for the build.


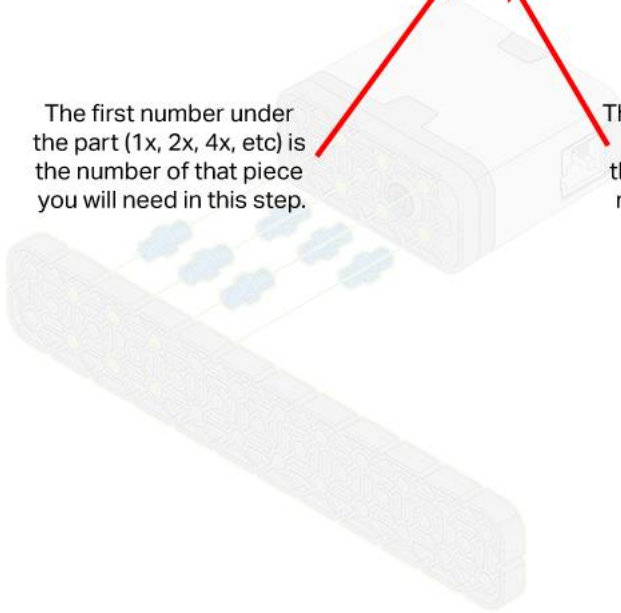
 **1x** - 2x12 Beam

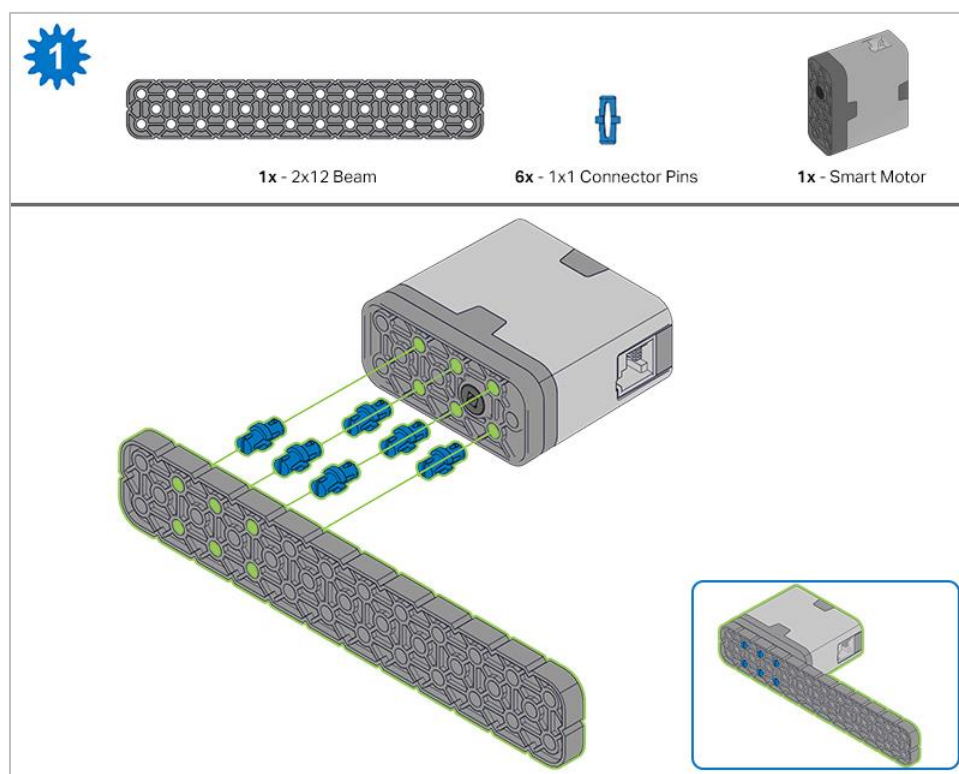
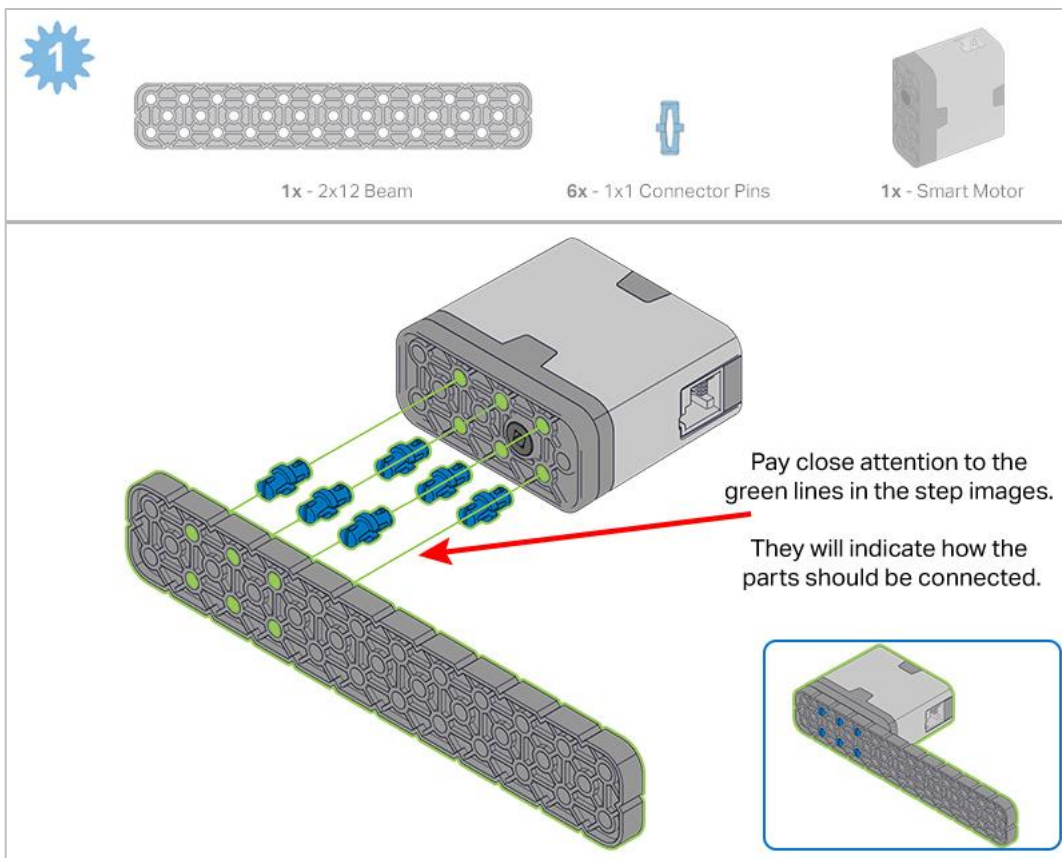
 **6x** - **1x1** Connector Pins

 **1x** - Smart Motor

The first number under the part (1x, 2x, 4x, etc) is the number of that piece you will need in this step.

The next information under the part image is the size (if necessary) and name of the part needed.





Steps 1-6 will be repeated for steps 7-12, so it's possible to make both at once.
Count all pieces before starting your build and have them readily available.

2



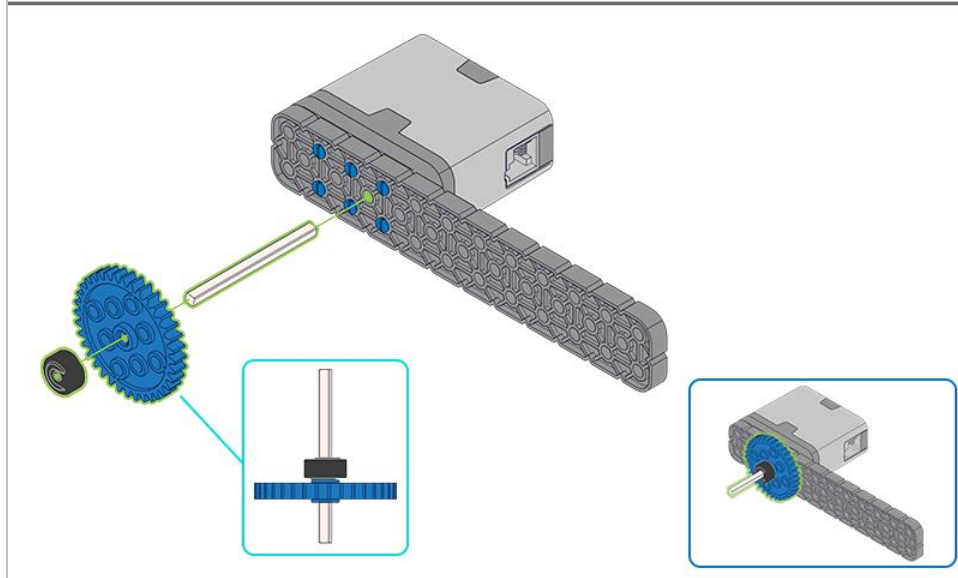
1x - 36 Tooth Gear



1x - Rubber Shaft Collar



1x - 4x Pitch Shaft

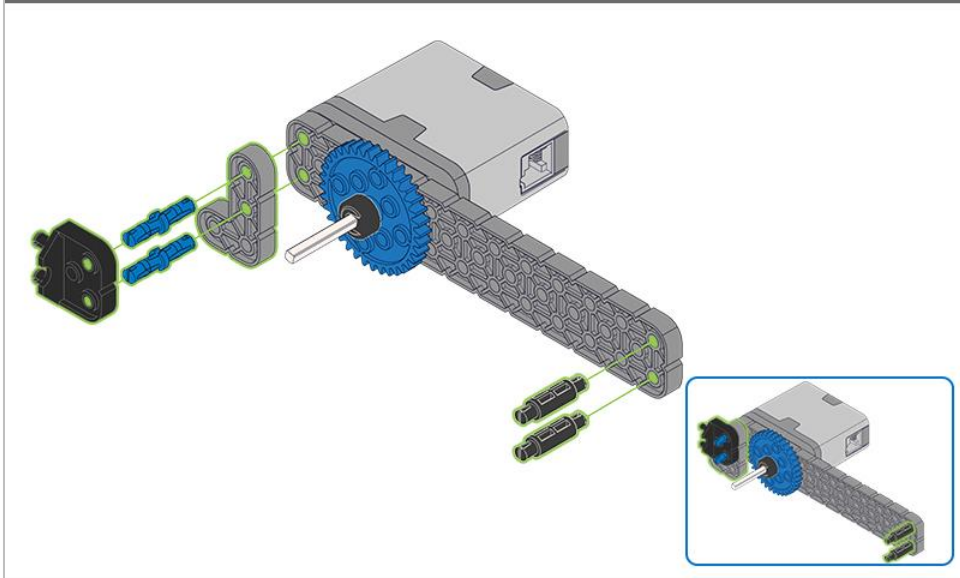


When adding the 4x Pitch Shaft, twist the pitch shaft to check for tension while turning. If it spins freely, it is not properly inserted into the motor.

3



1x - 2x Wide, 1x2 Offset Corner Connector 2x - 2x2 Connector Pins 1x - 2x3 Right Angle Beam 2x - 1x Pitch Standoffs



4



2x - 36 Tooth Gears

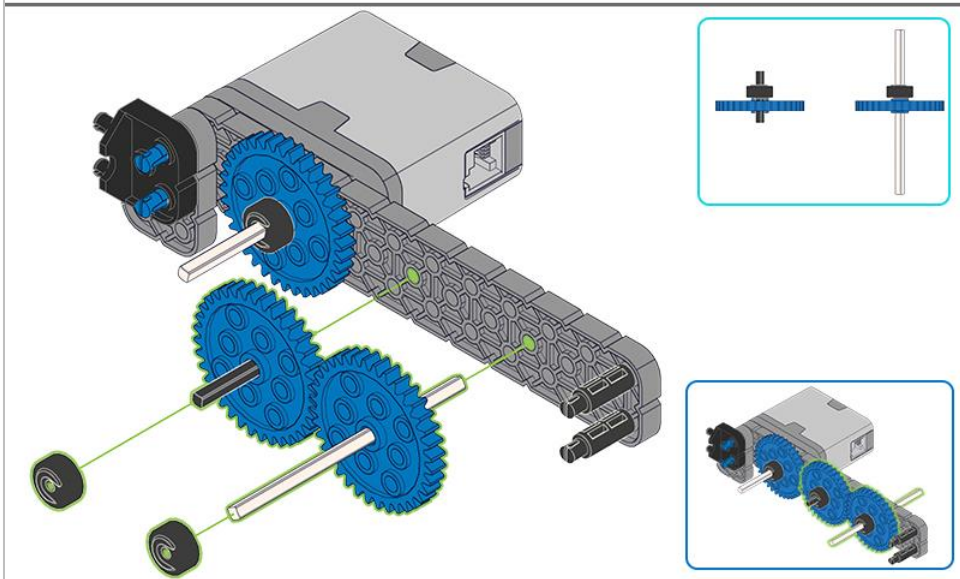


2x - Rubber Shaft Collars

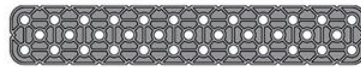
1x - 6x Pitch Shaft



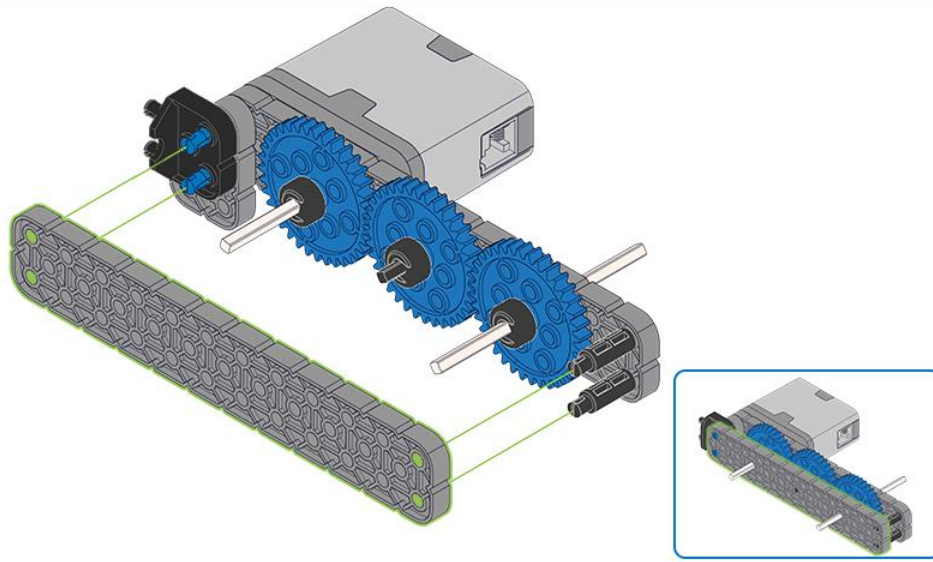
1x - 2x Plastic Pitch Shaft



5



1x - 2x12 Beam



Make sure the gears fit together properly before locking the Beam in place.

6



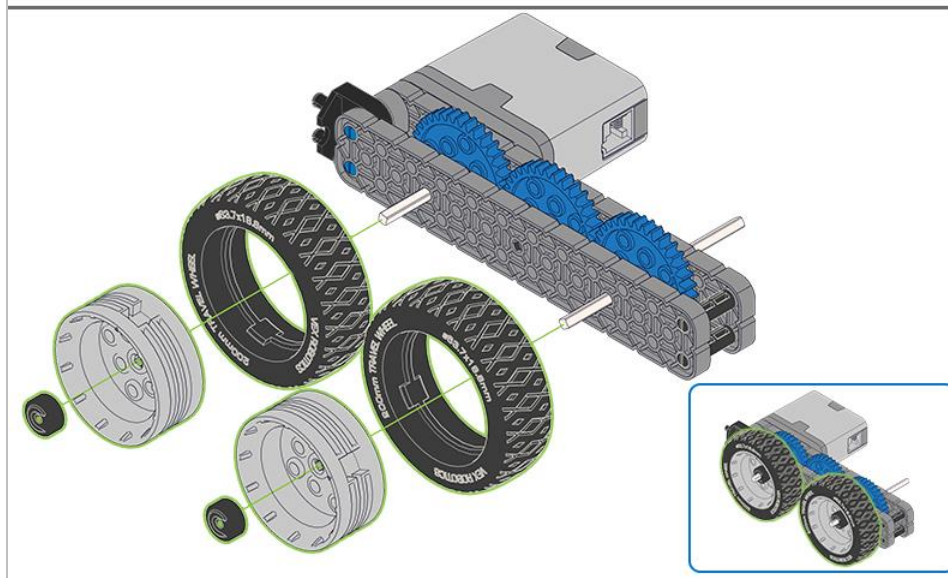
2x - Rubber Shaft Collars



2x - Wheel Hubs

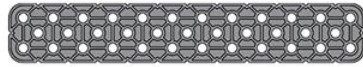


2x - Tires (200mm)



After attaching the wheels, twist the wheel that has the shaft going into the motor. If the wheel spins freely and without tension, the 4x Pitch Shaft has slipped out of place.

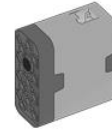
7



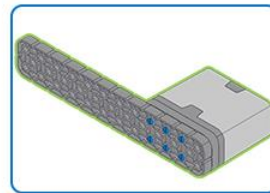
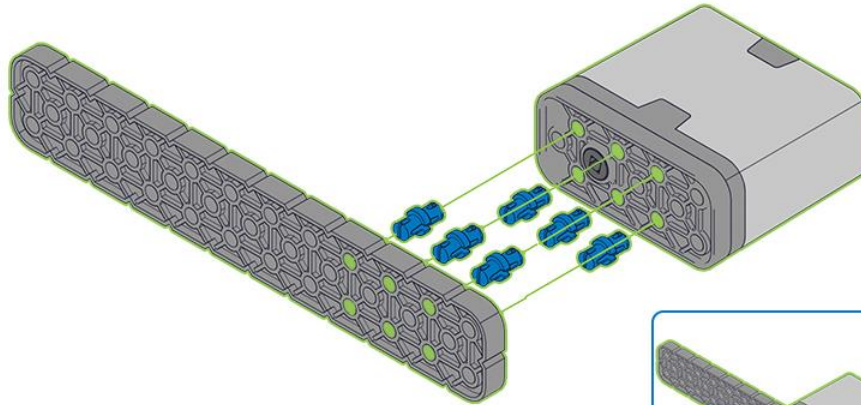
1x - 2x12 Beam



6x - 1x1 Connector Pins



1x - Smart Motor



8



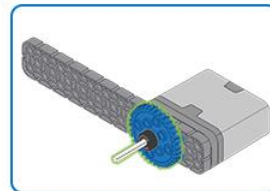
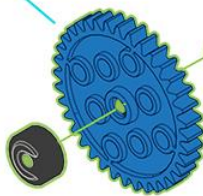
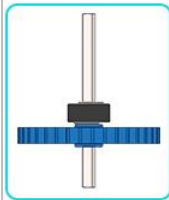
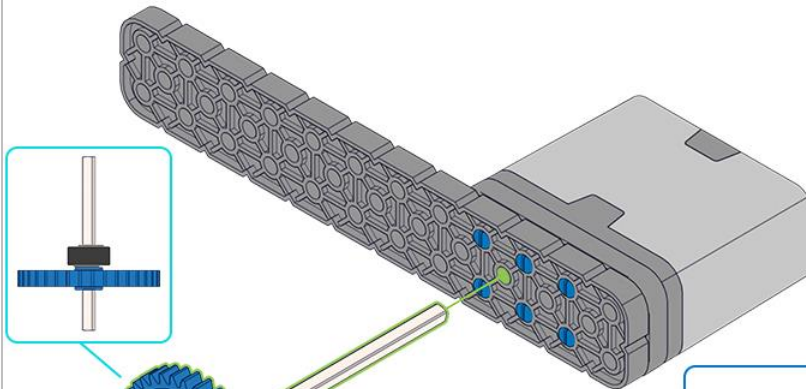
1x - 36 Tooth Gear



1x - Rubber Shaft Collar



1x - 4x Pitch Shaft

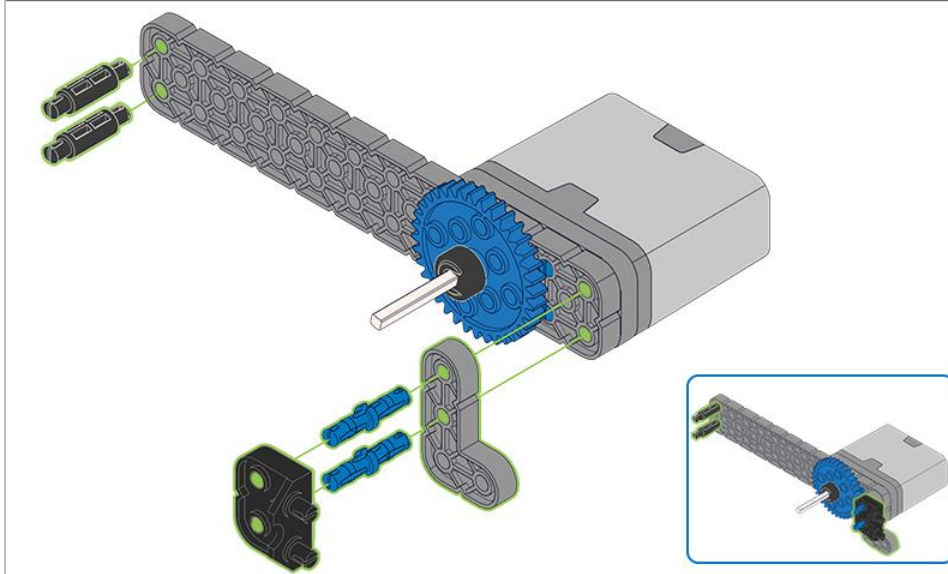


When adding the 4x Pitch Shaft, twist the pitch shaft to check for tension while turning. If it spins freely, it is not properly inserted into the motor.

9



1x - 2x Wide, 1x2 Offset Corner Connector 2x - 2x2 Connector Pins 1x - 2x3 Right Angle Beam 2x - 1x Pitch Standoffs



10



2x - 36 Tooth Gears

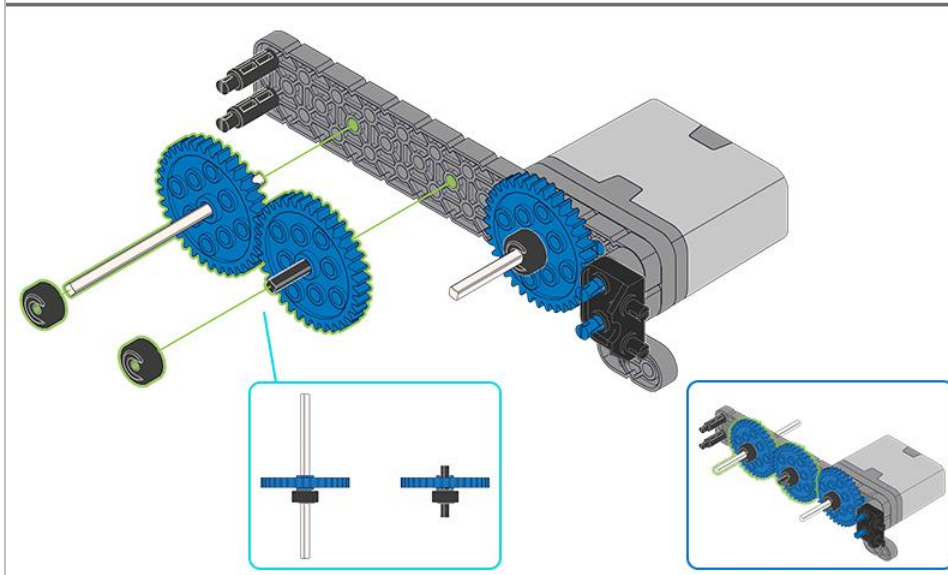


2x - Rubber Shaft Collars

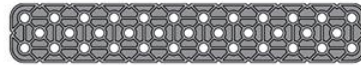
1x - 6x Pitch Shaft



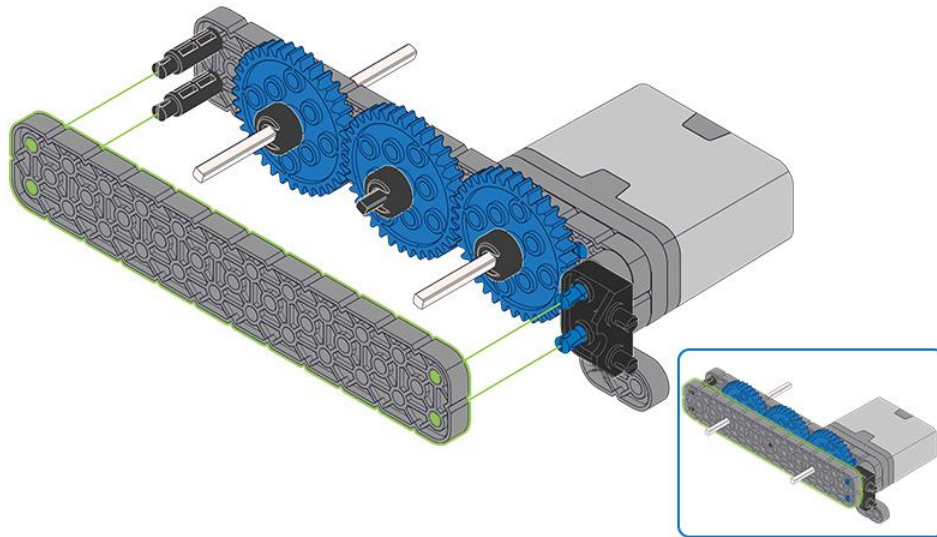
1x - 2x Plastic Pitch Shaft



11



1x - 2x12 Beam



Make sure the gears fit together properly before locking the Beam in place.

12



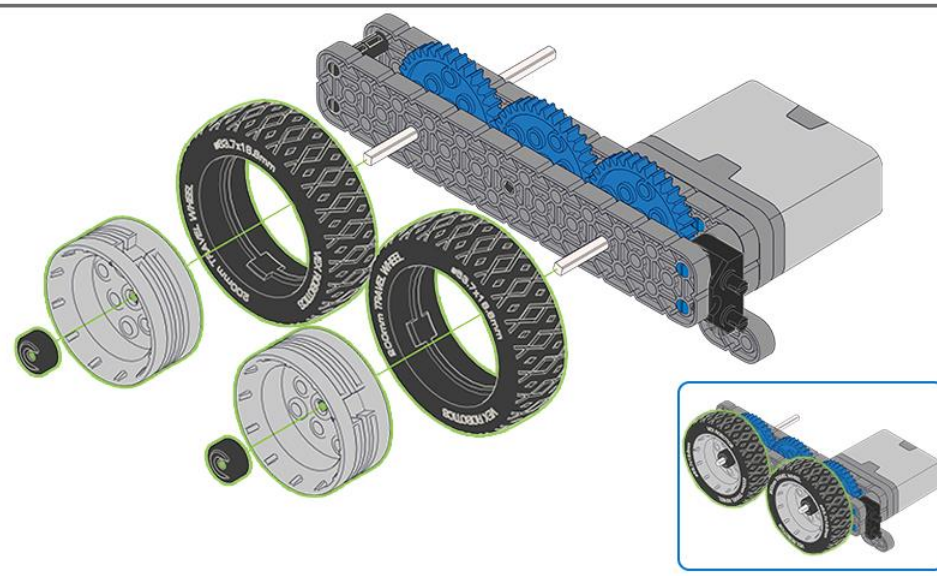
2x - Rubber Shaft Collars



2x - Wheel Hubs



2x - Tires (200mm)



After attaching the wheels, twist the wheel that has the shaft going into the motor. If the wheel spins freely and without tension, the 4x Pitch Shaft has slipped out of place.

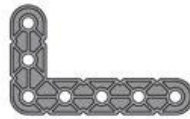
13



1x - 2x8 Beam



2x - 2x Wide, 1x2 Corner Connectors



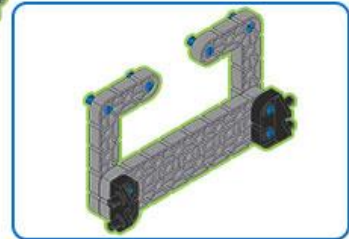
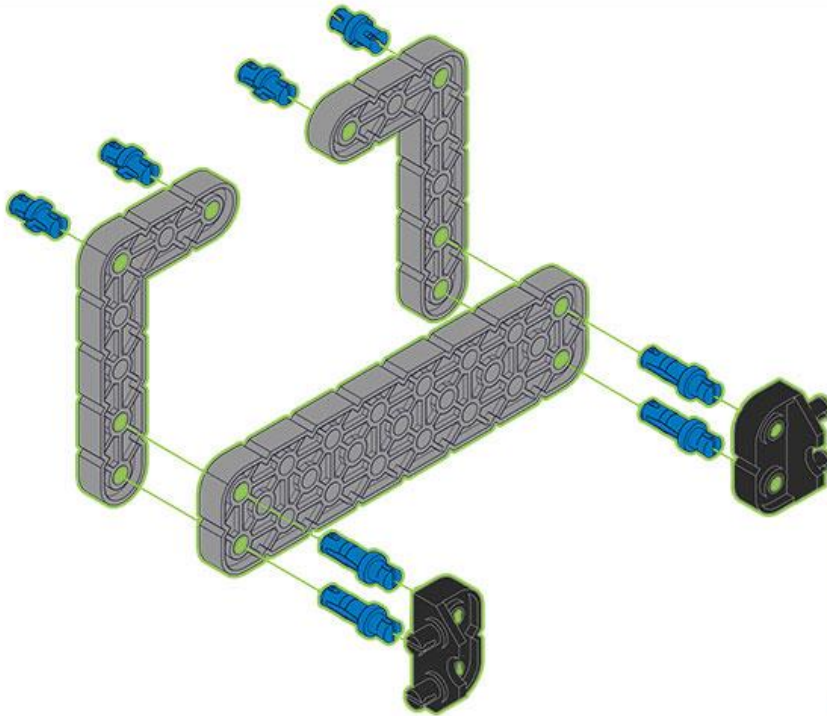
2x - 3x5 Right Angle Beams



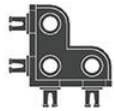
4x - 1x1 Connector Pins



4x - 1x2 Connector Pins



14

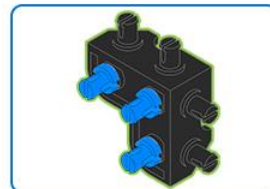
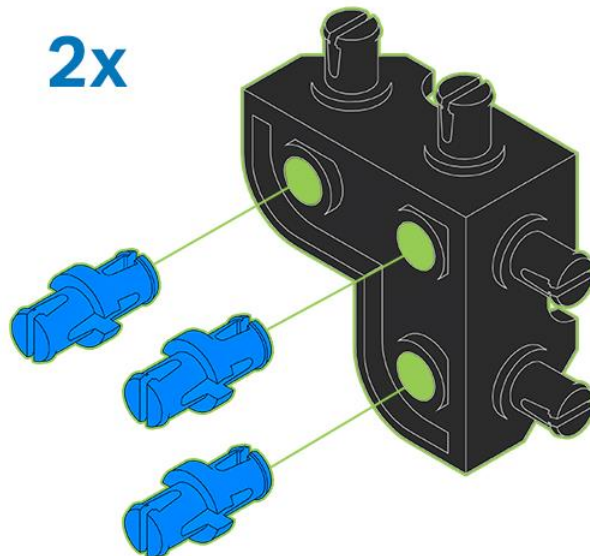


2x - Large Chassis Corner Connectors



6x - 1x1 Connector Pins

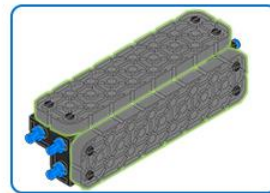
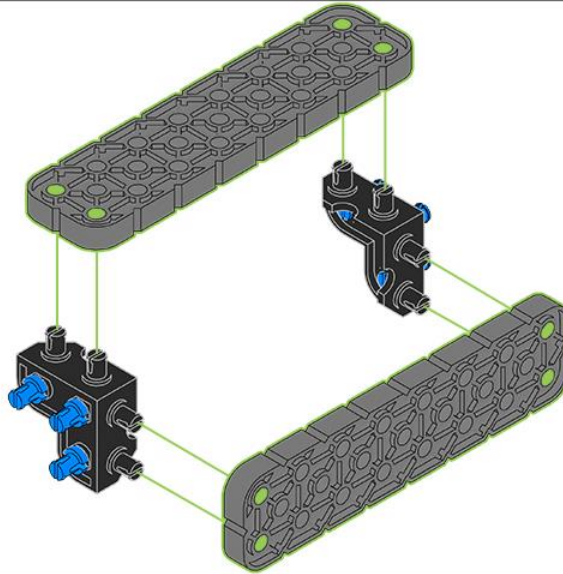
2x



15



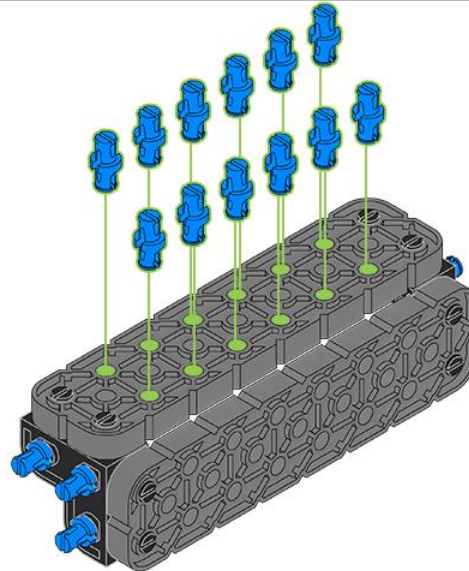
2x - 2x8 Beams



16



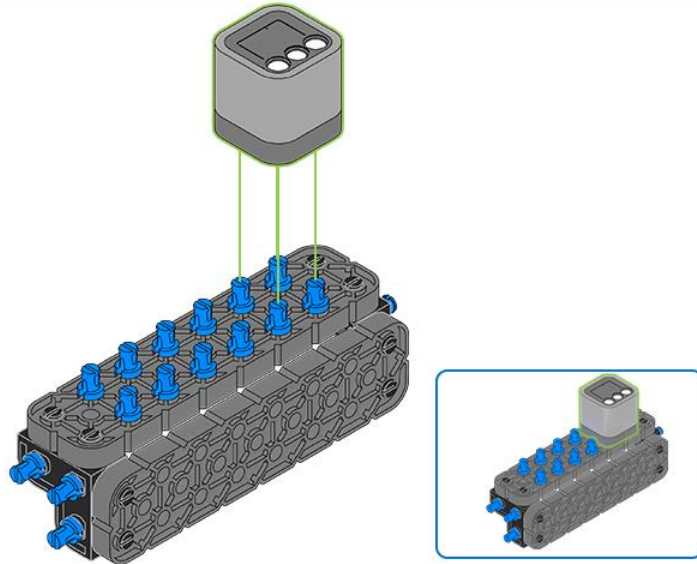
12x - 1x1 Connector Pins



17



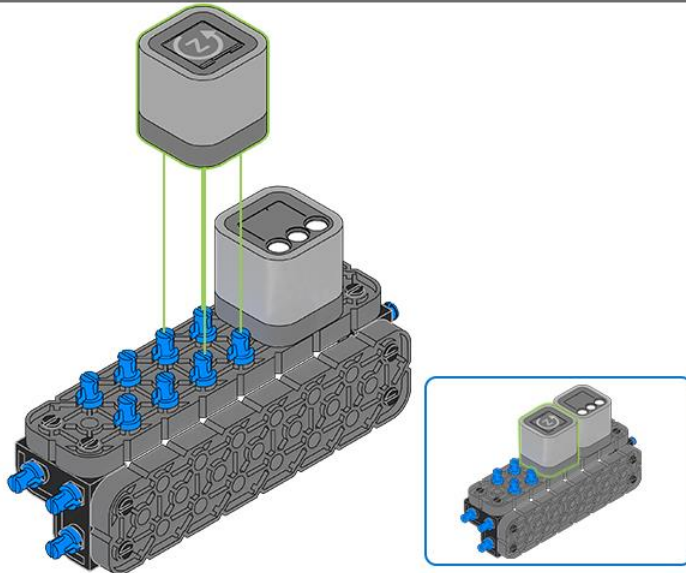
1x - Color Sensor



18



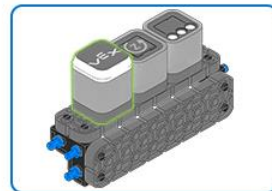
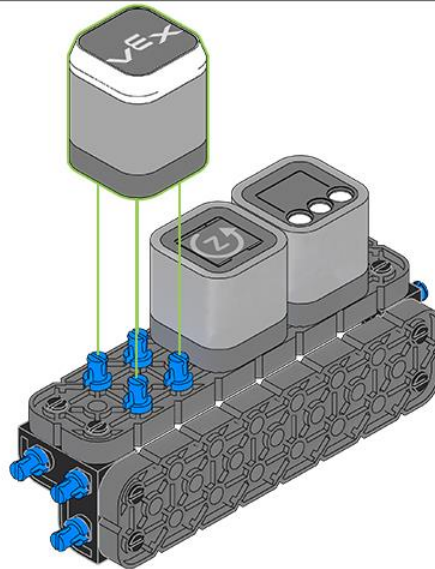
1x - Gyro Sensor



19



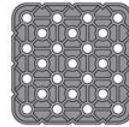
1x - Touch LED



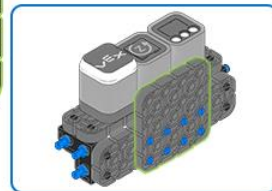
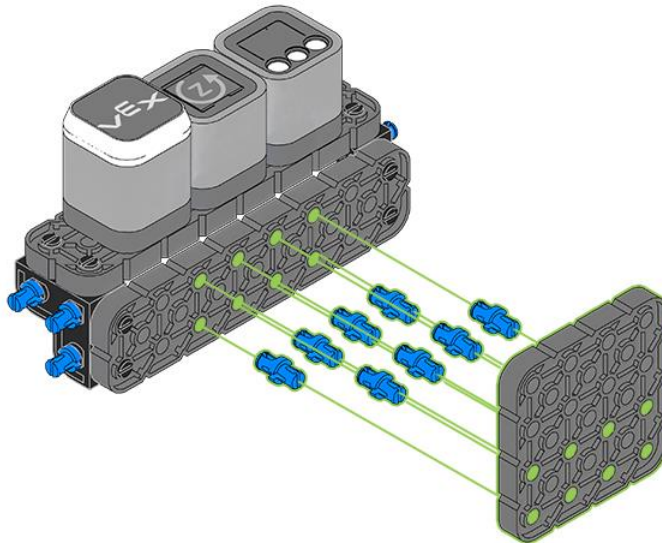
20



8x - 1x1 Connector Pins



1x - 4x4 Plate



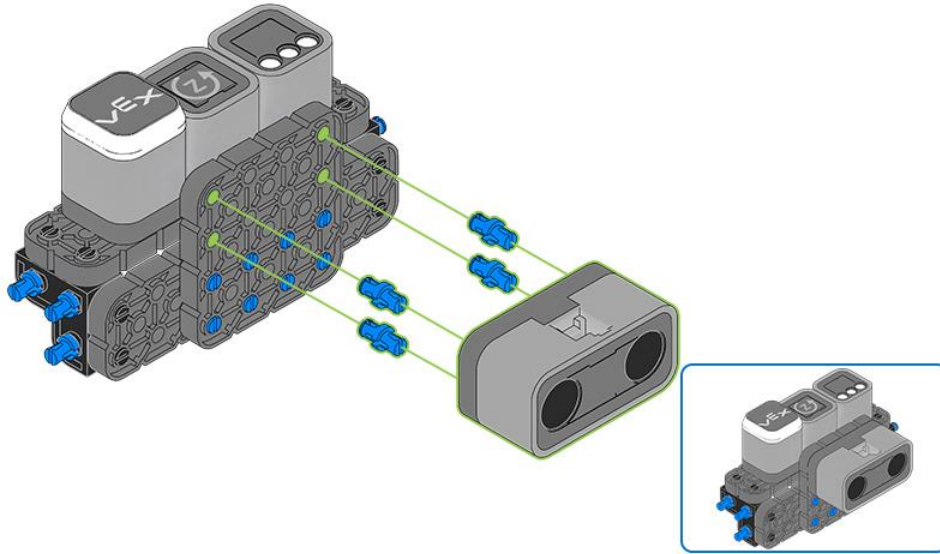
21



1x - Distance Sensor



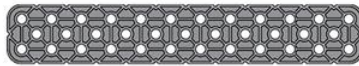
4x - 1x1 Connector Pins



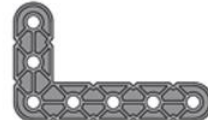
22



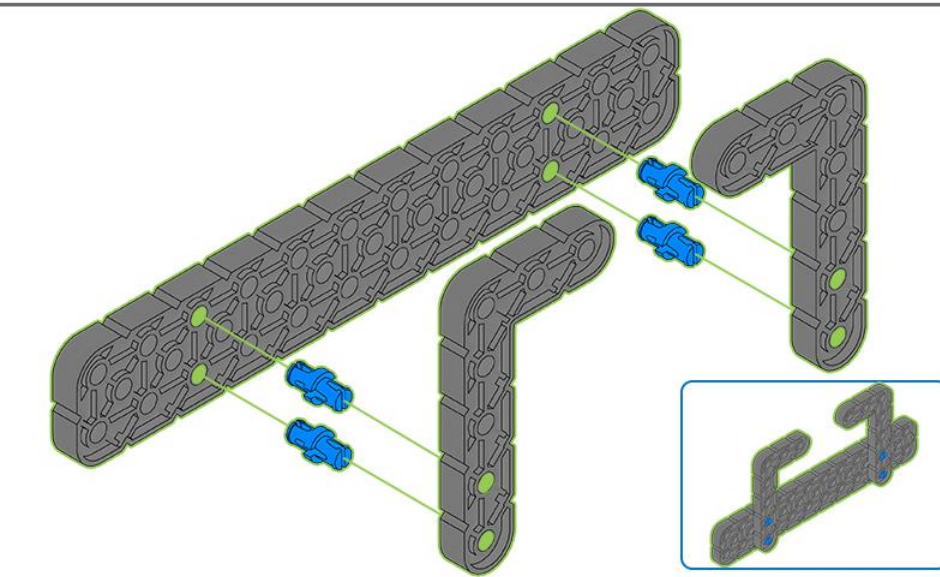
4x - 1x1 Connector Pins



1x - 2x12 Beam



2x - 3x5 Right Angle Beams



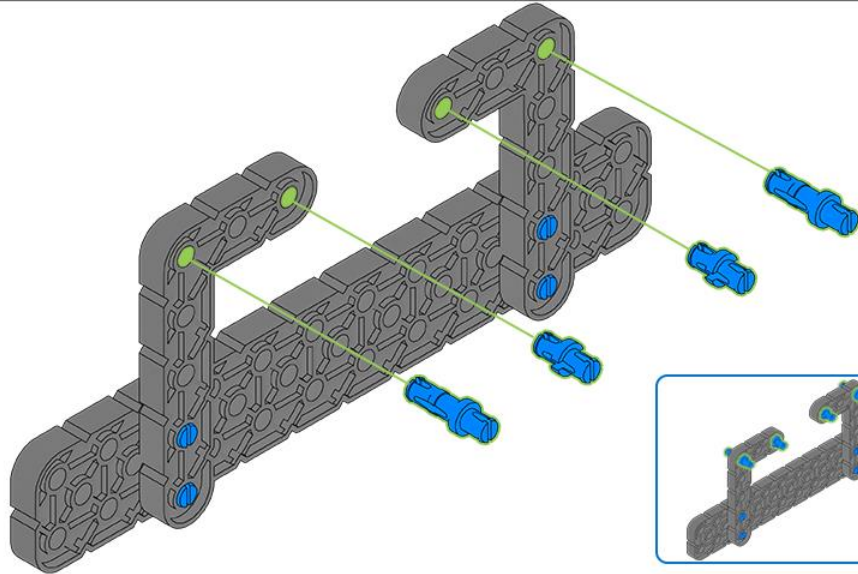
23



2x - 1x2 Connector Pins



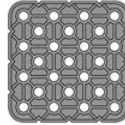
2x - 1x1 Connector Pins



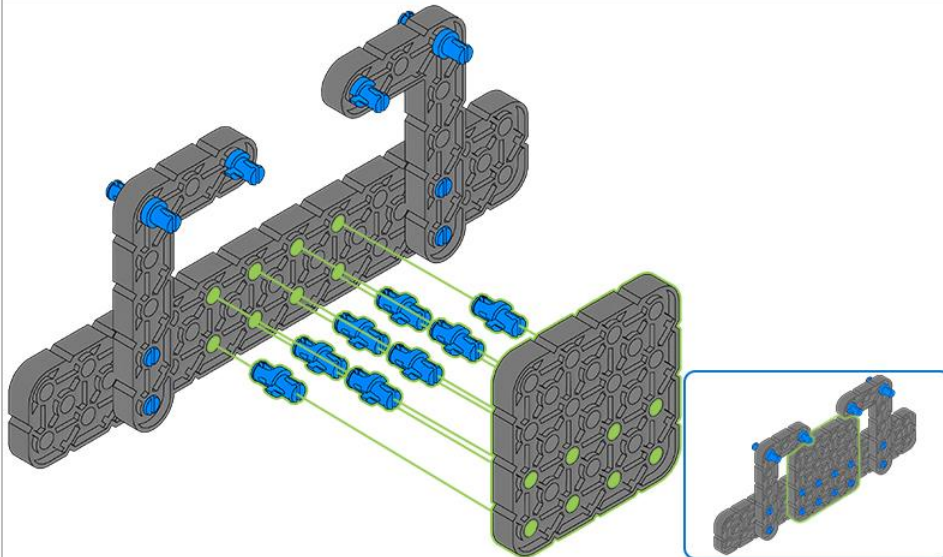
24



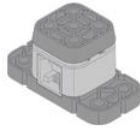
8x - 1x1 Connector Pins



1x - 4x4 Plate



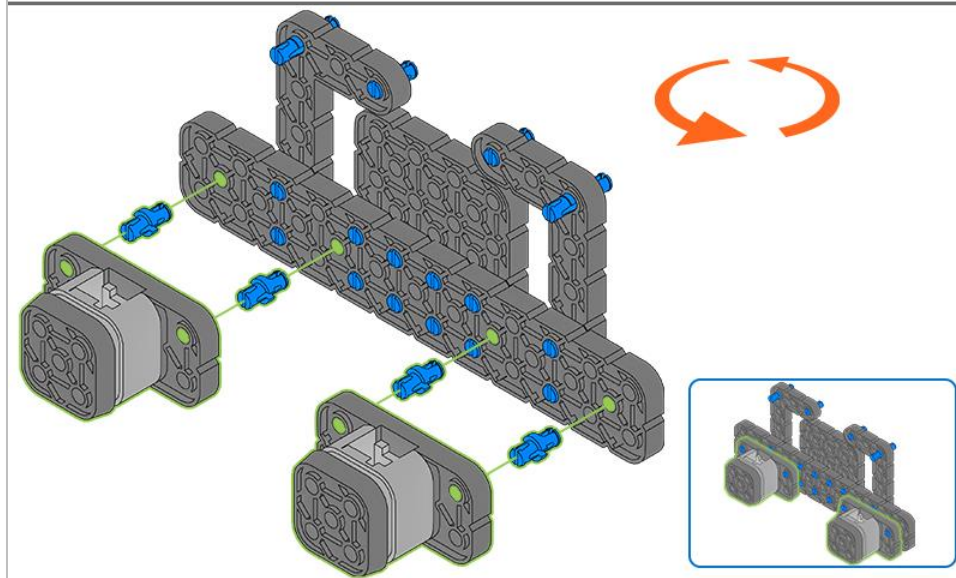
25



2x - Bumper Switch



4x - 1x1 Connector Pins



The orange arrows indicate to turn the assembly around.

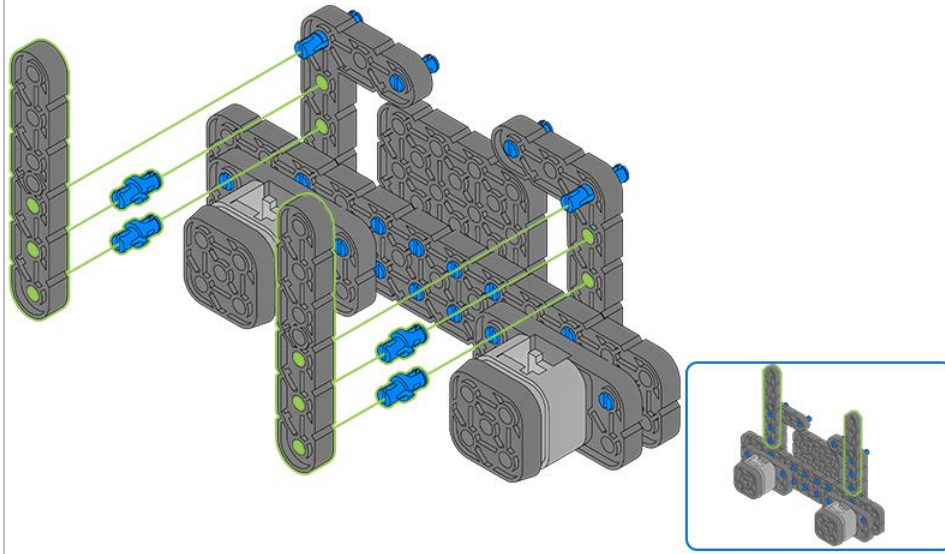
26



2x - 1x6 Beams



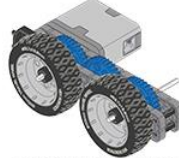
4x - 1x1 Connector Pins



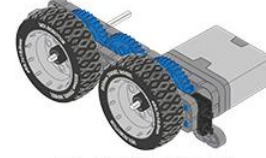
27



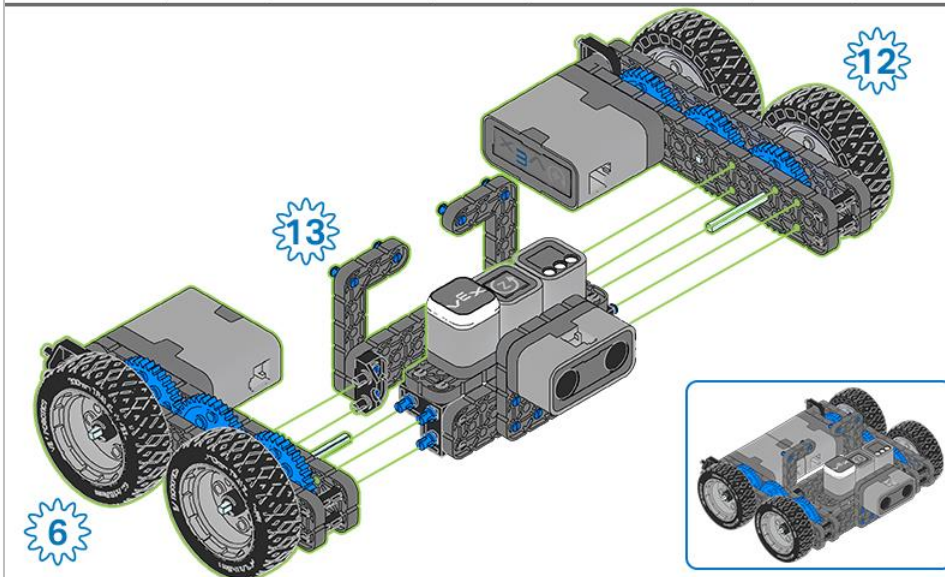
1x - Step 13 Assembly



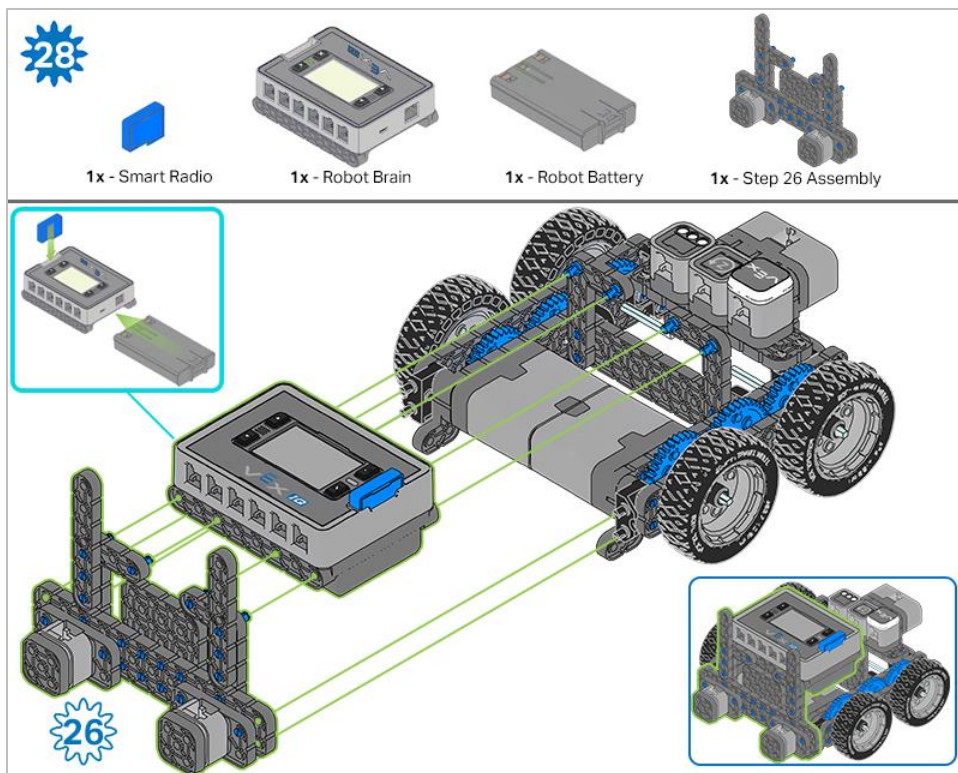
1x - Step 6 Assembly



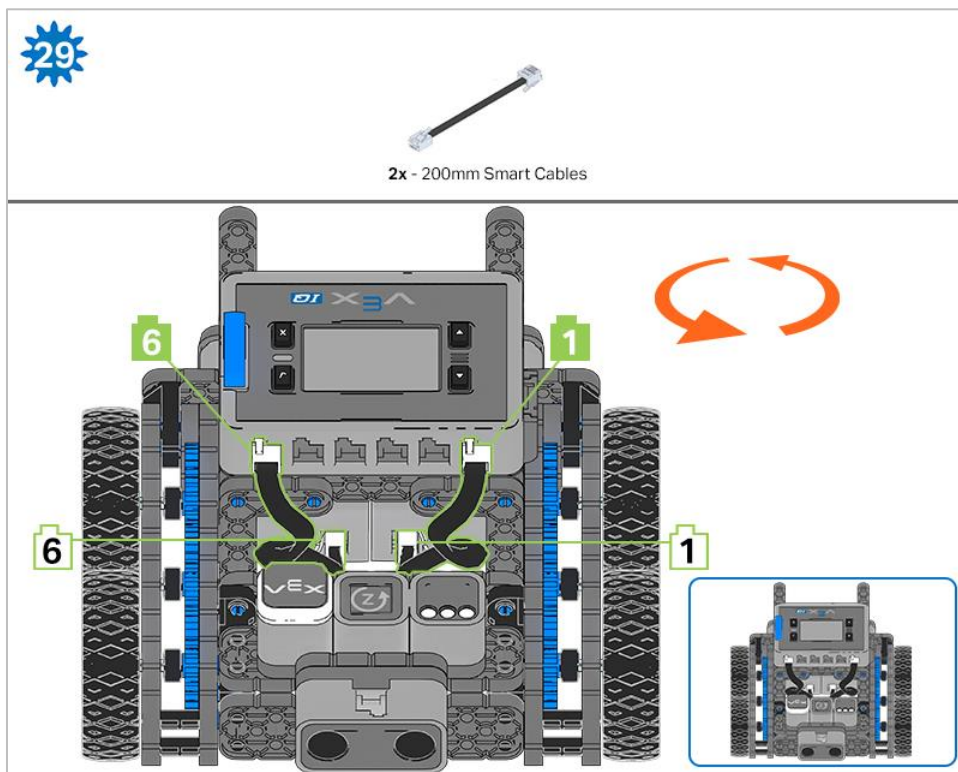
1x - Step 12 Assembly



The highlighted blue numbers placed in gear shapes represent the assemblies completed from those specific steps.



Ensure the Smart Radio and Robot Battery are inserted before attaching the Brain to the rest of the assembly.



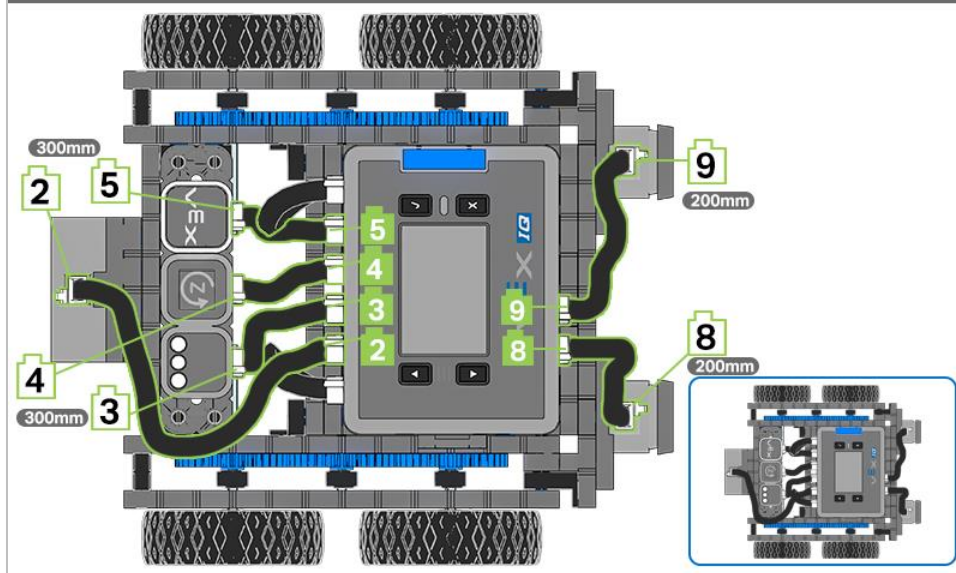
Steps 29-30, when you attach the Smart Cables, make sure they are tucked away so as to not block the Smart Sensors. The orange arrows indicate to turn the robot around.



4x - 300mm Smart Cables



2x - 200mm Smart Cables



Exploration

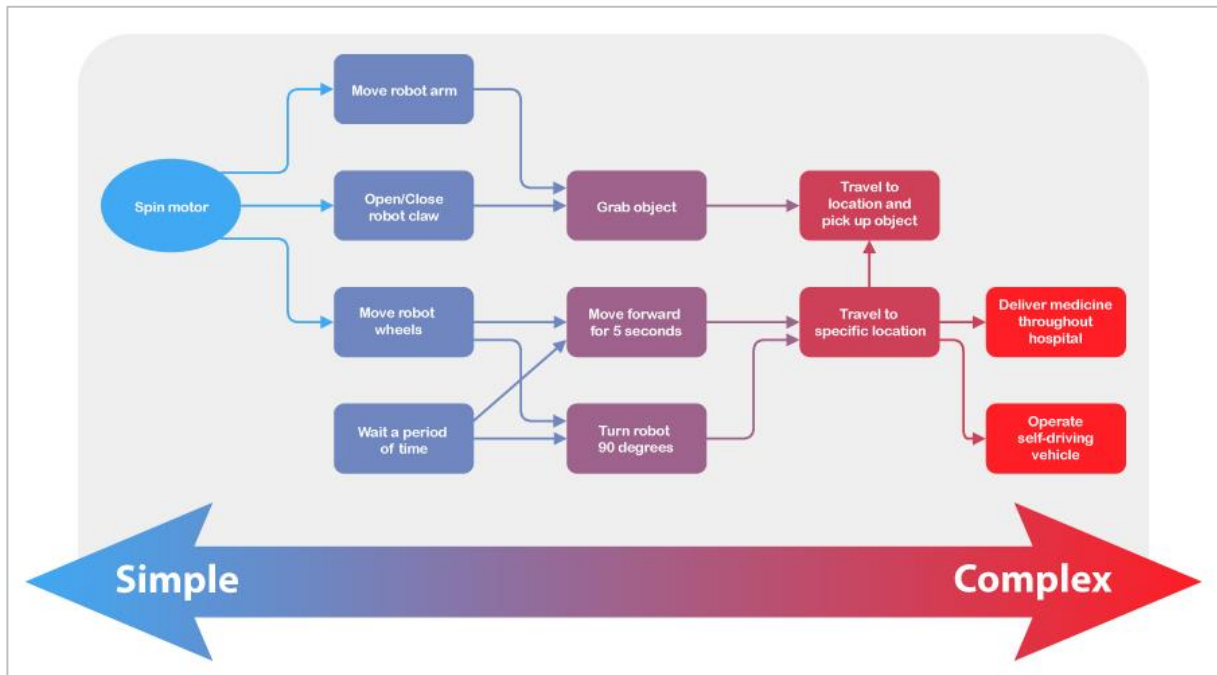
Now that the build is finished, explore and see what it can do. Then answer these questions in your engineering notebook.

- If you wanted the Autopilot to turn clockwise, would it move to the right or left? If you wanted it to turn counterclockwise?
- When building the Autopilot, what items from the kit helped in choosing the correct pieces?
- How could you use the leftover VEX IQ parts to help measure how far the robot moves?



Test your build, observe how it functions,
and fuel your logic and reasoning skills
through imaginative, creative play.

Turning Left and Right



Thinking Like a Robot

Human beings are very complex and can think in very complex ways. Sometimes we think about things consciously, and sometimes unconsciously. Do you ever have to think about breathing in order to make yourself breathe? What about doing a math problem? Now consider how you got from the door of the classroom to your seat. Did you think about every step and turn, or were you thinking of something else?

Robots do not think about many things, and they do not have a subconscious to help them out the way humans do. Robots can only do what they are programmed to do. All robot tasks can be broken down into simpler ones, and these simpler tasks are known as behaviors—the building blocks of robotics programming.

A behavior is a way that a robot acts, and can range from basic to complex, depending on how the robot is built or programmed. A simple mobile robot like the Autopilot only has two motors, so its behaviors will involve turning those motors to accomplish its goals. Autopilot will use simple behaviors such as moving forward, reverse, and turning to accomplish larger tasks.

So how do you think like a robot? Imagine a task you want the robot to do. Now imagine

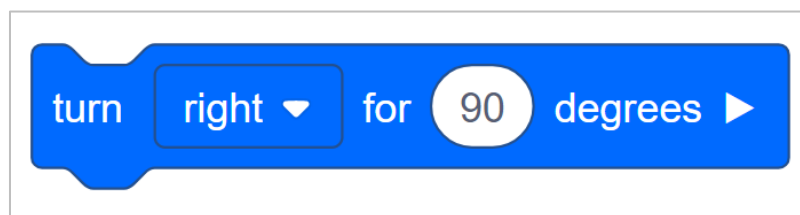
each and every step that the robot would need to do in order to perform that task. Those are the behaviors you would need to program to achieve the task.

Turning Right and Left Exploration - Part 1

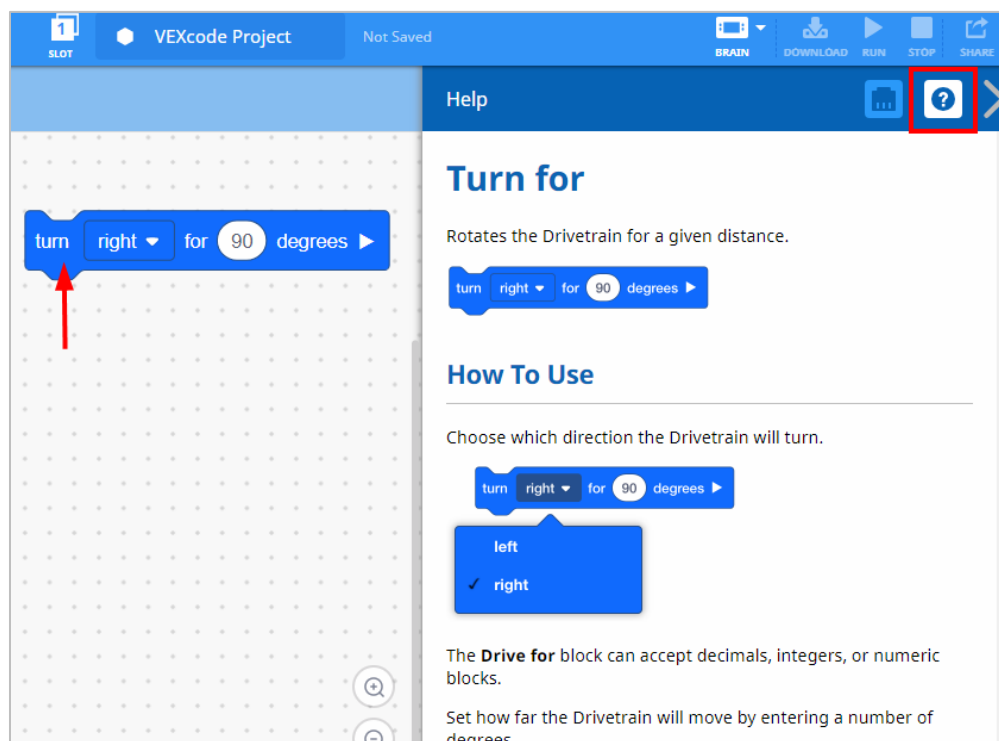
Autopilot is ready to turn!

This exploration will give you the tools to be able to start creating some cool projects for your Autopilot to follow.

- VEXcode IQ Blocks that will be used in this exploration:



- To find out more information about the block, open the Help and then select the turn for block.



- The Builder in each group should get the hardware required. The Recorder should get the group's engineering notebook. The Programmer should open VEXcode IQ Blocks.

Hardware/Software Required:

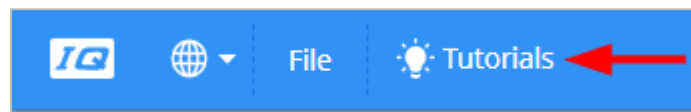
Quantity	Hardware/Other Items
1	Autopilot Robot
1	Charged Robot Battery
1	VEXCode IQ Blocks
1	Engineering Notebook
1	USB Cable (if using a computer)

1. Preparing for the Exploration

Before you begin the activity, do you have each of these items ready? The Builder should check each of the following:

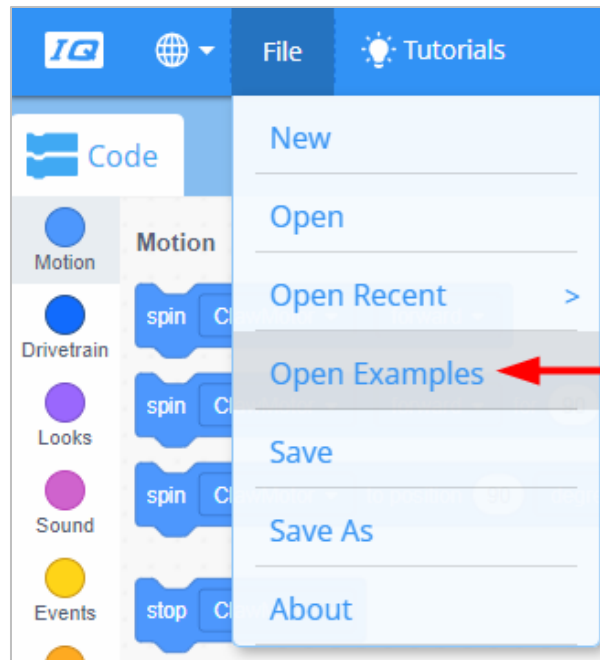
- Are all the motors and sensors plugged into the correct port?
- Are the smart cables fully inserted into all of the motors and sensors?
- Is the Brain turned on?
- Is the battery charged?

Check out the troubleshooting tutorial if Autopilot does not pass any of these steps.



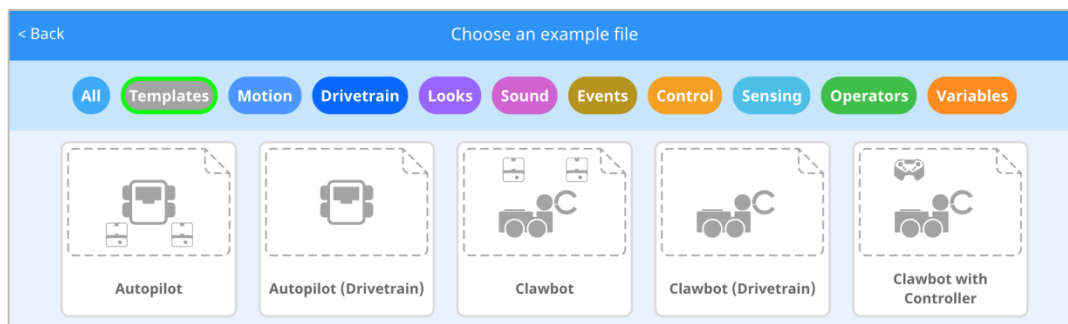
2. Start a New Project

Before you begin your project, the Programmer needs to select the correct template project. The Autopilot (Drivetrain) template contains the Autopilot motors and sensors configuration. If the template is not used, your robot will not run the project correctly.

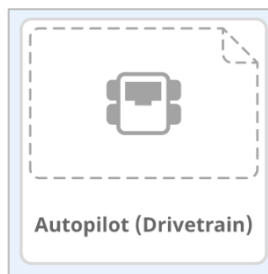


The Programmer should complete the following steps:

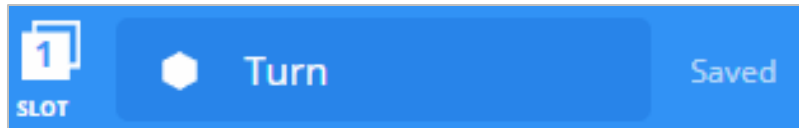
- Open the File menu.
- Select **Open Examples**.
- Use the filter bar at the top of the application and select "Templates."



- Select and open the **Autopilot (Drivetrain) Template**.



- Since we will be using the turn for block, rename your project Turn.
- **Save** your project.

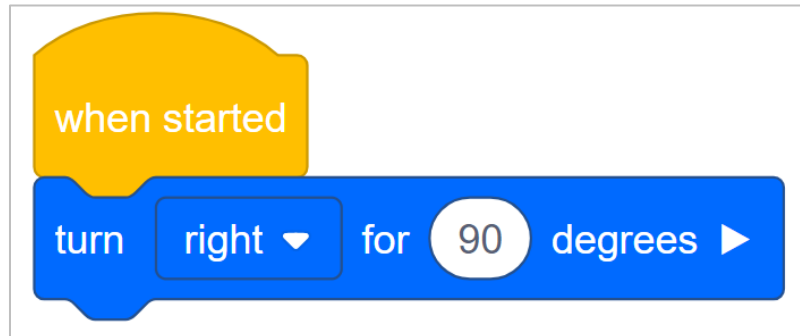


- Check to make sure the project name **Turn** is now in the window in the center of the toolbar.

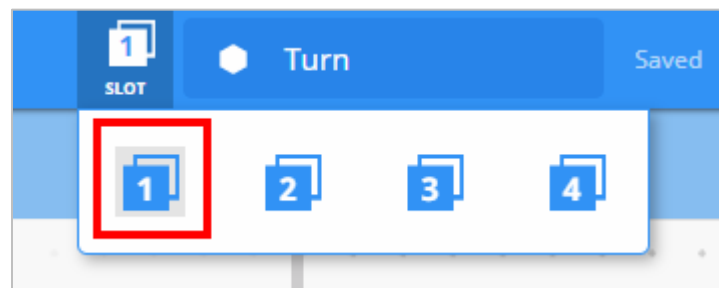
Turning Right and Left

Exploration - Part 2

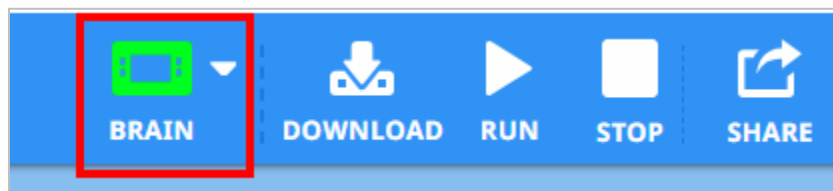
1. Turn Right



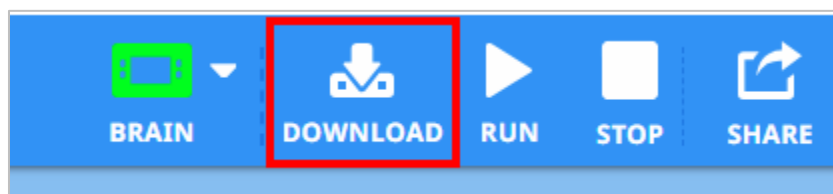
- Add the turn for block to the when started block in the programming area.



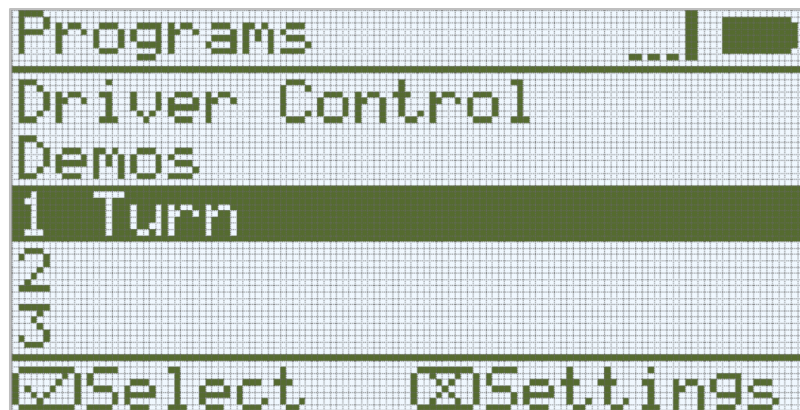
- Click on the **Slot** icon. You can download your project to one of the four available slots in the Robot Brain. Click on the number 1.



- The Programmer should connect the robot to your computer or tablet. The Brain icon in the toolbar turns green once a successful connection has been made.



- Click the Download button on the toolbar to download the Turn project to the Robot Brain.



- The Operator should check to make sure your project has downloaded to the Autopilot's Brain by looking at the Robot Brain's screen. The project name should be listed in slot 1.
- The Operator should now run the project on the Autopilot robot by making sure the project is highlighted and then press the Check button. Congratulations on creating your first project!

2. Turn Left



- Go back to VEXcode IQ Blocks programming area. The Programmer should change the `turn for` to display **left** instead of **right**.
- The Programmer should download the project.
- The Operator should now run the project on the Autopilot robot by making sure the project is highlighted and then press the Check button.



Become a 21st century problem solver
by applying the core skills and concepts
you learned to other problems.

Robots are Amazing

Robots are A-mazing!



*An urban search and rescue robot moves across a rubble pile.
Photo: NIST [Public domain in the United States]*

Many of today's robots have to have the ability to maneuver through maze-like hallways, corridors, and even unknown passages. These robots are quicker, more efficient, and can travel in places that humans cannot.

Here are some robots that use maneuvering skills:

- Medical robots can deliver medicine quickly to patients throughout a hospital. As pharmacists enter prescriptions into their computers, the delivery robots collect the correct type and dosage by scanning the correct bar-codes. These delivery robots travel through the many hallways to take the labeled medications to nursing stations or even individual patient's rooms.
- Search and rescue robots are sent into hazardous areas to help locate people and bring them to safety. Finding people faster can save their lives, especially if they have serious injuries, by bringing much needed assistance to them.

- Exploratory robots are essential when scientists are investigating uncharted areas, such as oceans and caves. These robots are designed to be durable in water and deep, dark areas. Robots can map these areas, take soil and air samples, and detect other hazards that would put people at risk if they were performing the same actions. Some of these robots are even used in space. The Mars rovers use many camera sensors to take pictures that are instantaneously converted into 3D maps that the rover will use to avoid obstacles in its path.

Let's Start a Team!

Let's Start a Team!



Teamwork!

Each fall, students gather in their robotics classes and clubs to start working on the annual VEX competition challenge. Students form teams and work together to design and build a robot to play against other teams in a game-based engineering challenge presented by the Robotic Education and Competition (REC) Foundation. In order for a team to be productive, it is important to assign everyone on the team a job.

Some of the various roles that students can hold are:

- Driver
- Builder
- Programmer
- Recorder
- Pit Team Manager
- Team Treasurer

Many teams attend competitions wearing team shirts and bring giveaway items to share with their fellow competitors. Pit spaces at competitions are places where teams can hang banners and posters to represent their team or club. Creating a VEX Robotic team is a great way to have fun with your friends and meet new ones!



Is there a more efficient way to come to the same conclusion? Take what you've learned and try to improve it.

Improve and Remix Your Project



Exploring Other Blocks

You got your Autopilot to turn! Let's explore how to use the `turn for` block with other blocks to complete more complex tasks.

The Builder in each group should get the hardware required. The Recorder should get the group's engineering notebook. The Programmer should open VEXcode IQ Blocks.

Hardware/Software Required:

Quantity	Hardware/Other Items
1	Autopilot Robot

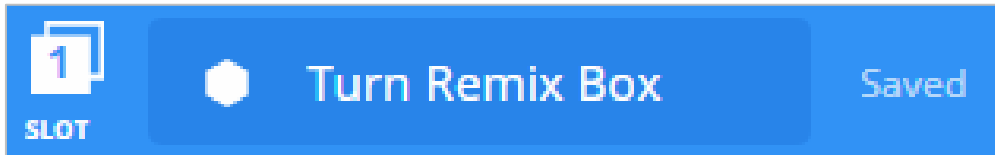
1	Charged Robot Battery
1	VEXCode IQ Blocks
1	Engineering Notebook
1	USB Cable (if using a computer)
1	Ruler
1	Box (or rectangular object)

Before you begin the activity...

Do you have each of these items ready? The Builder should check each of the following:

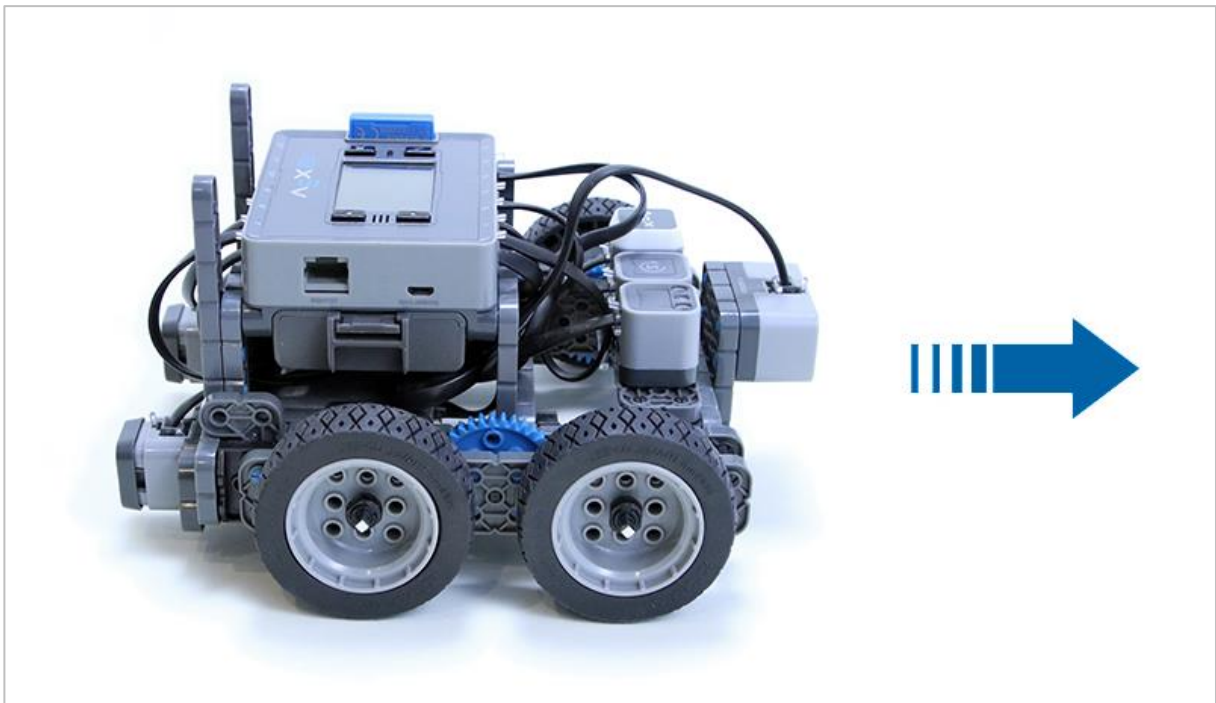
- Are all the motors and sensors plugged into the correct port?
- Are the smart cables fully inserted into all of the motors and sensors?
- Is the Brain turned on?
- Is the battery fully charged?

Remix Challenges - Part 1



The Programmer should complete the following steps:

- Open the **File** menu.
- Select **Open Examples**.
- Select and open the **Autopilot (Drivetrain) Template**.
- Name your project **Turn Remix Box**.
- **Save** your project.



Let's get moving!

Activity A: Drive around a box!

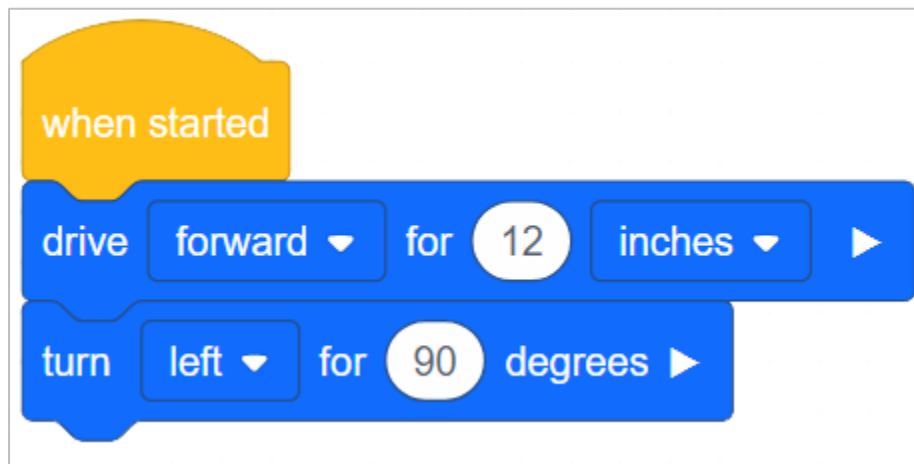
The goal of this activity is to program the Autopilot to drive around a box. This task will require multiple steps, so remember to think like a robot!

You will need to use two blocks to create this project: the `turn for` and `drive for` blocks.



Here are some steps to guide your team:

- **Builder**, place the box and Autopilot next to each other on the floor, making sure to give the Autopilot space to move. Use the ruler to measure the distance the Autopilot will need to move, in inches.
 - **Tip:** Make sure to measure further than the exact side of the box to give Autopilot room to turn!
- **Recorder**, draw a diagram of the box and list the measurements the Builder gives on each side of the box. Confirm with your team that the measurements are correct.
- **Driver**, list the steps the Autopilot will need to drive in order to get around the box. Include the drive and turn steps!
- **Recorder**, write the steps the Driver lists in the engineering notebook.
- **Programmer**, use the diagram and steps from the engineering notebook to program the new project. Add the `turn for` and `drive for` blocks in the correct order. Then change the distances included in the `drive for` blocks to those recorded in the engineering notebook.
 - **Tip:** Make sure `turn for` block is set to turn the correct direction!
 - Your project may begin to look something like this:

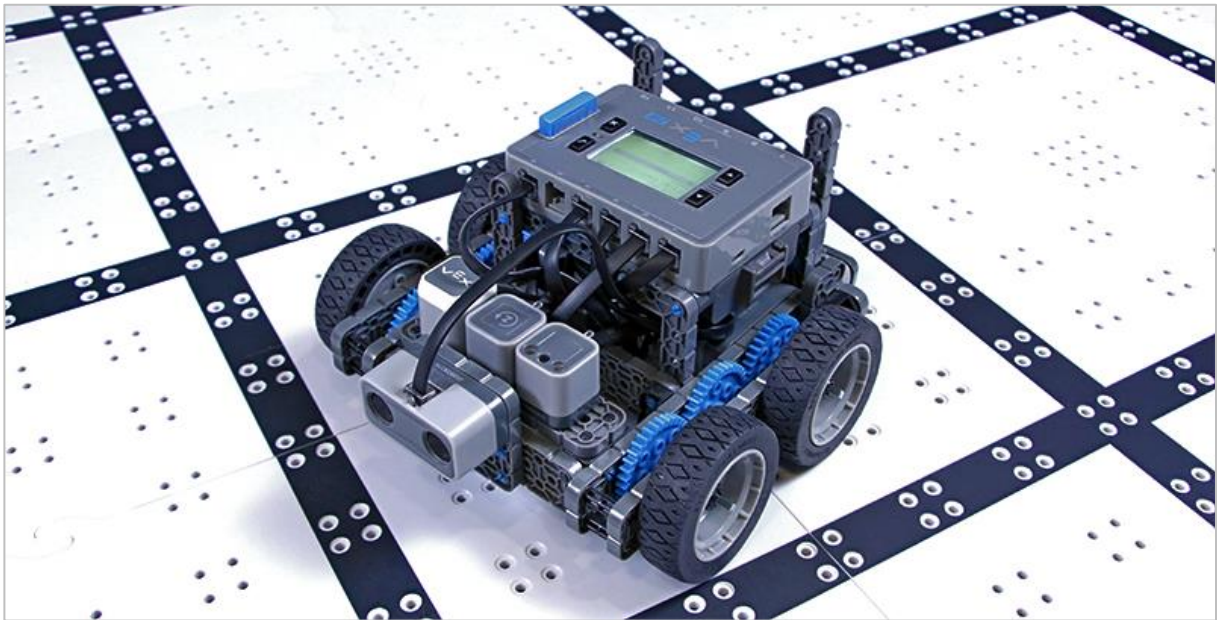


- **Programmer**, download the project when finished.
- **Driver**, run the project on the Autopilot.

Congratulations! You programmed a more complex task using simple behaviors.

Now, did the Autopilot move around the box as you expected? If not, why do you think that is? What changes do you think you could make?

Remix Challenges - Part 2



Activity B: Think like a robot: getting to your seat!

When you walk into the classroom and go to your seat, likely you don't have to count your steps or plan your route every time. However, for Autopilot to go from the door to your seat, it would need to know exactly how to move. For this challenge, create a project which will instruct Autopilot to move from the door to your seat.

First, create a new project in VEXcode IQ Blocks.

The Programmer should complete the following steps:

- Open the **File** menu.
- Select **Open Examples**.
- Select and open the **Autopilot (Drivetrain) Template**.
- Name your program **Turn Remix Box**.
- **Save** your project.

Second, plan and program the new project.

- **Builder:** Place the Autopilot at the door.
- **Driver:** List the steps the Autopilot will need to drive from the door to your seat.

- **Tip:** Make sure to include the drive and turn steps!
- **Builder:** Measure each distance the Driver lists on the route.
- **Recorder:** Write the drive steps the Driver gives and distances the builder measures in the engineering notebook.
- **Programmer:** Use the steps and distances from the engineering notebook to program the new project. Add the `turn for` and `drive for` blocks in order, then change the distances included in the `drive for` blocks to those recorded in the engineering notebook.
 - **Tip:** Make sure turn for blocks are set to turn the correct direction!
- **Programmer:** When finished, download the project.
- **Driver:** Run the project on Autopilot.

Congratulations on completing another task with the Autopilot!

Did the Autopilot successfully navigate from the door to your seat? Why or why not?

Remix Questions

Answer the following questions in your engineering notebook after completing Activity A and B.

- Do you think it is easy or difficult to think like a robot? Why?
- Why is it important to make precise measurements?
- Do robots always make 100% accurate turns?



Understand the core concepts and how
to apply them to different situations.
This review process will fuel motivation
to learn.

Review

You have accomplished a lot in this STEM Lab! The following questions will help you think back over everything you have learned. You can only answer once, so think carefully before you submit!

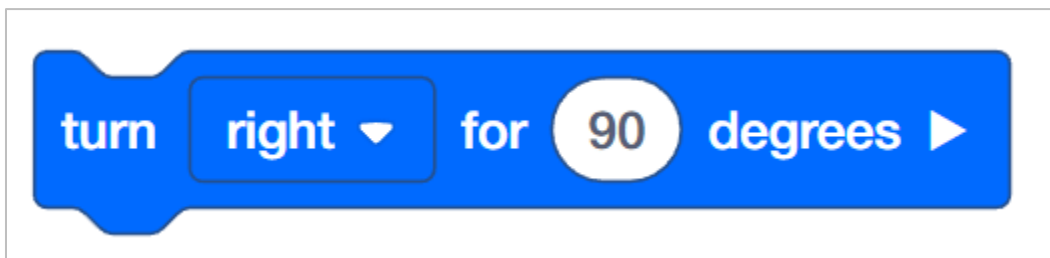
1. True or False: Thinking like a robot means the robot needs to be told exactly what to do, step-by-step.

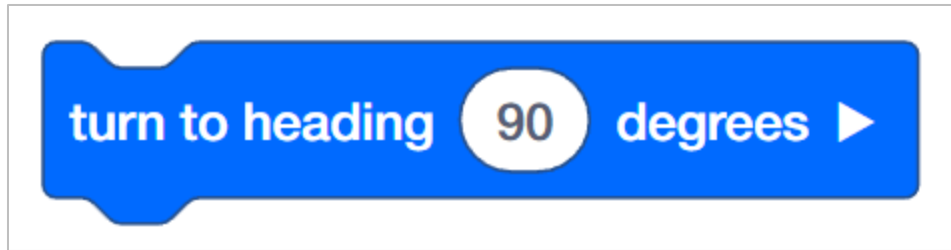
- ☐ True
- ☐ False

2. To start a project in VEXcode IQ Blocks, which is the correct order of steps?

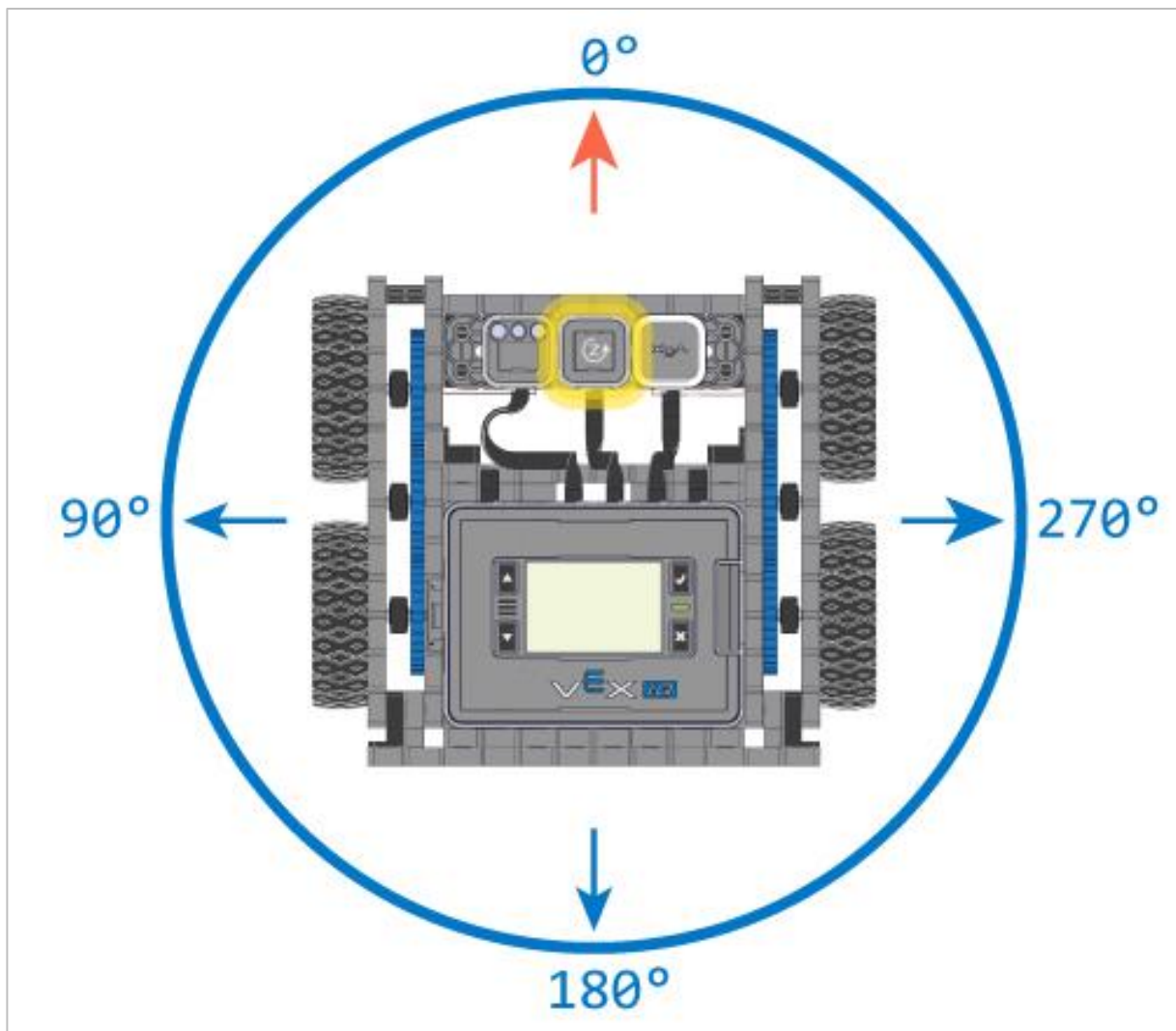
- ☐ Save the project, open the file menu, name the project, select examples, choose a template.
- ☐ Open the file menu, choose a template, name the project, select examples, save the project.
- ☐ Open the file menu, select examples, choose a template, name the project, save the project.

3. Which block would be best to turn Autopilot 90 degrees?





4. **True or False: The Autopilot may not make 100% accurate turns due to turning scrub.**
- ☐ True
 - ☐ False
5. **Autopilot needs to drive around a table. The table is 30 inches wide, by 60 inches long. What is the perimeter of the table?**
- ☐ 90 inches
 - ☐ 120 inches
 - ☐ 180 inches
 - ☐ 240 inches
6. **The turn for block is set to turn the Autopilot 90 degrees to the left. If you wanted the Autopilot to turn 90 degrees to the right, but don't change the direction, which degree could you enter to have the Autopilot face to the right?**



- 90 degrees
- 180 degrees
- 270 degrees
- 360 degrees

APPENDIX

Additional information, resources, and materials.

Knowledge Base Articles

Links to the VEX Robotics Knowledge Base Articles for this STEM Lab:

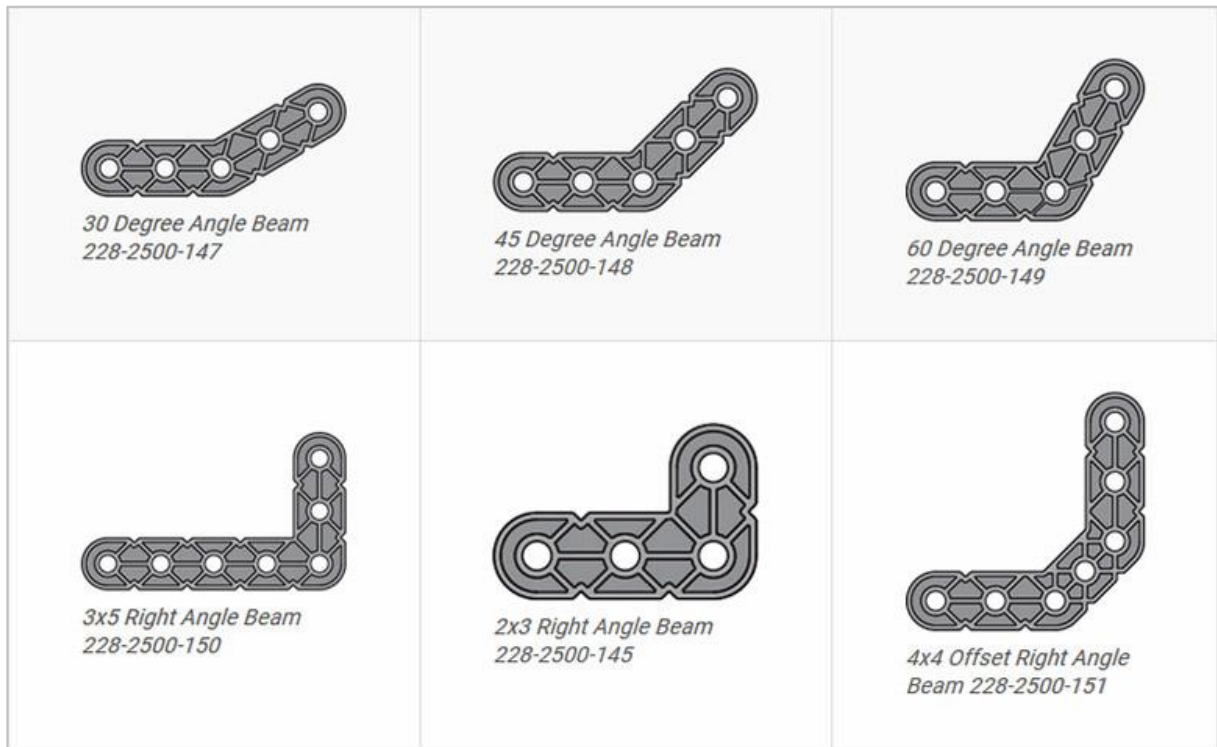
- How to Turn On/Off a VEX IQ Robot Brain
<https://kb.vex.com/hc/en-us/articles/360035952571-How-to-Turn-On-Off-a-VEX-IQ-Robot-Brain>
- How to Read Indicator Lights on the VEX IQ Robot Brain
<https://kb.vex.com/hc/en-us/articles/360035590672-How-to-Read-Indicator-Lights-on-the-VEX-IQ-Robot-Brain>
- How to Navigate the VEX IQ Robot Brain
<https://kb.vex.com/hc/en-us/articles/360035952331-How-to-Navigate-the-VEX-IQ-Robot-Brain>
- How to Connect VEX IQ Devices to Smart Ports
<https://kb.vex.com/hc/en-us/articles/360035952151-How-to-Connect-VEX-IQ-Devices-to-Smart-Ports>
- How to Install or Remove the VEX IQ Robot Battery
<https://kb.vex.com/hc/en-us/articles/360035951991-How-to-Install-or-Remove-the-VEX-IQ-Robot-Battery>
- How to Charge the VEX IQ Robot Battery
<https://kb.vex.com/hc/en-us/articles/360035955011-How-to-Charge-the-VEX-IQ-Robot-Battery>
- How to Use the Autopilot Program in the Demos Folder
<https://kb.vex.com/hc/en-us/articles/360035952031-How-to-Use-the-Autopilot-Program-in-the-Demos-Folder>
- Best Practices for Preserving the VEX IQ Robot Battery's Life
<https://kb.vex.com/hc/en-us/articles/360035953671-Best-Practices-for-Preserving-the-VEX-IQ-Robot-Battery-s-Life>
- Ideas for Organizing the VEX IQ Super Kit
<https://kb.vex.com/hc/en-us/articles/360035590332-Ideas-for-Organizing-the-VEX-IQ-Super-Kit>
- VEX IQ Brain Status (USB Cable)
<https://kb.vex.com/hc/en-us/articles/360035955411-How-to-Understand-the-VEX-IQ-Brain-Status-Icon-USB-VEXcode-IQ-Blocks>

Links to VEXcode IQ Blocks Knowledge Base Articles for this STEM Lab:

- How to Begin a New Project in VEXcode IQ Blocks
<https://kb.vex.com/hc/en-us/articles/360035954551-How-to-Begin-a-New-Project-VEXcode-IQ-Blocks>

- How to Download and Run a Project
<https://kb.vex.com/hc/en-us/articles/360035591232-How-to-Download-and-Run-a-Project-VEXcode-IQ-Blocks>
- How to Save a Project on Windows
<https://kb.vex.com/hc/en-us/articles/360035954531-How-to-Save-a-Project-on-Windows-VEXcode-IQ-Blocks>
- How to Save a Project on macOS
<https://kb.vex.com/hc/en-us/articles/360035954511-How-to-Save-a-Project-on-macOS-VEXcode-IQ-Blocks>
- How to Save a Project on Chromebook
<https://kb.vex.com/hc/en-us/articles/360035955351-How-to-Save-on-a-Chromebook-VEXcode-IQ-Blocks>
- How to Download to a Selected Slot on the Brain
<https://kb.vex.com/hc/en-us/articles/360035591292-How-to-Download-to-a-Selected-Slot-on-the-Brain-VEXcode-IQ-Blocks>

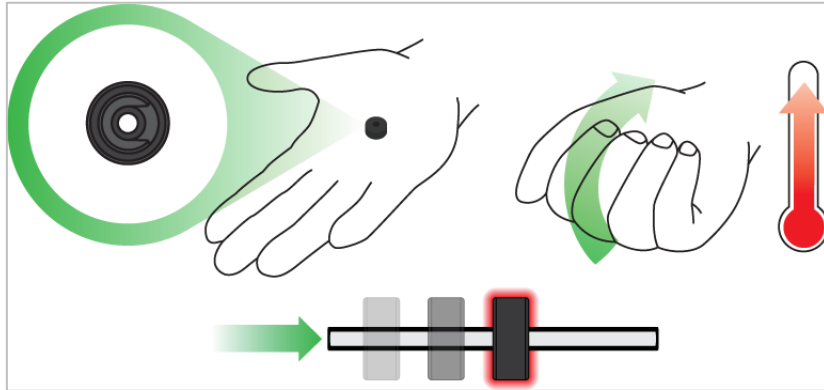
Identifying Angle Beams



How to Identify the Different Angles of the Angled Beams

There are four different types of beams that have a bend at an angle: 30° Angle Beams, 45° Angle Beams, 60° Angle Beams, and Right Angle (90°) Beams. There are also three types of Right Angle Beams: 3x5, 2x3, and Offset. The best way to tell which angles are which is to stack the beams on top of each other. Then you can compare how they look. You can also use a protractor to measure the angle of the beam.

Installing Rubber Shaft Collars

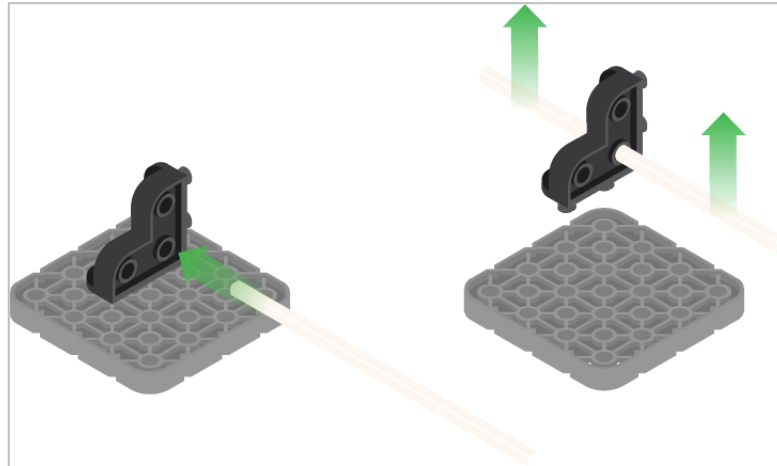


Using your hand to warm a Rubber Shaft Collar

Rubber Softens as it gets Warm

Hold the Rubber Shaft Collars in your hand for 15-30 seconds before you slide them onto a shaft. Holding the Rubber Shaft Collar in your hand will warm and soften the rubber to make it easier to slide onto a shaft.

Removing Connectors from Beams and Plates

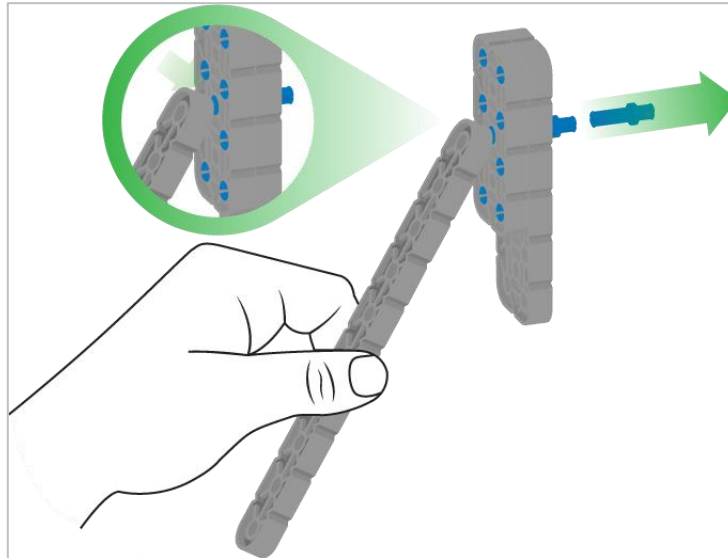


Using a pitch shaft to remove a corner connector

How to Easily Remove Connectors

You can easily remove corner connectors from beams or plates by placing a metal shaft through one of the holes of the corner connector and pulling outward while holding down the beam or plate.

Removing Pins from VEX IQ Beams and Plates



Removing a pin from a plate assembly using a beam

How to Easily Remove Pins from Beams and Plates

You can quickly remove connector pins from beams or plates by pressing a beam against the back of the pin, which partially pushes the pin out, so you can remove it with your fingers. You can use this technique to more easily remove pins from individual plates and beams, or from built structures.

Removing Standoffs from Mini Standoff Connectors

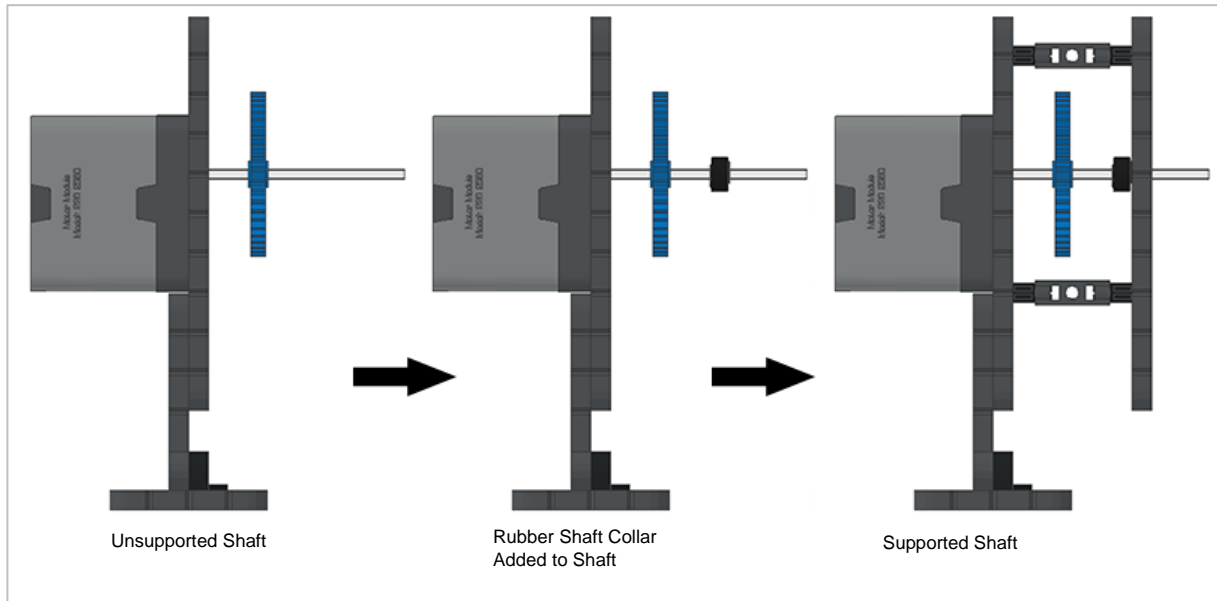


Removal of a standoff from a Mini Standoff Connector

How to Easily Remove Parts from Mini Standoff Connectors

Standoffs and Mini Standoff Connectors can be separated by pushing a shaft through the Mini Standoff Connector. The same technique can be used for parts with similar ends in Mini Standoff Connectors, such as pins.

Supporting Shafts using Rubber Shaft Collars

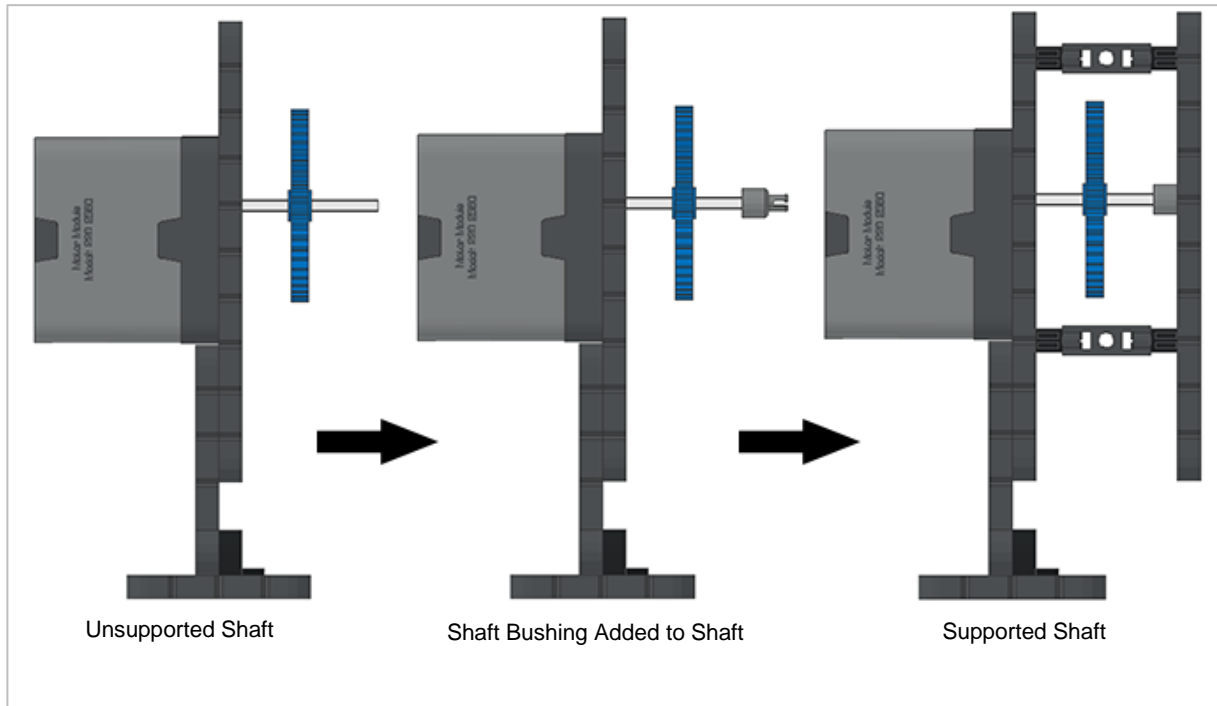


Supporting a shaft with a Rubber Shaft Collar

How to Support Shafts with Rubber Shaft Collars

Shafts can fall out of place or alignment very easily if they aren't supported properly. You can make a shaft more secure and prevent it from falling out of place by putting a Rubber Shaft Collar before the end of it. You can then connect the shaft to a support structure with the shaft collar positioned against it. That will allow the shaft to turn but will prevent it from wobbling or falling out.

Supporting Shafts using Shaft Bushings



Supporting a shaft with a Shaft Bushing

How to Support Shafts Using Shaft Bushings

Shafts can fall out of place or alignment very easily if they aren't supported properly. You can make a shaft more secure and prevent it from falling out of place by putting a bushing at the end of it. You can then connect that bushing into another beam or additional part. That will allow the shaft to turn but will prevent it from wobbling or falling out.

Popups within this STEM Lab

Turning Right and Left

Exploration Outline

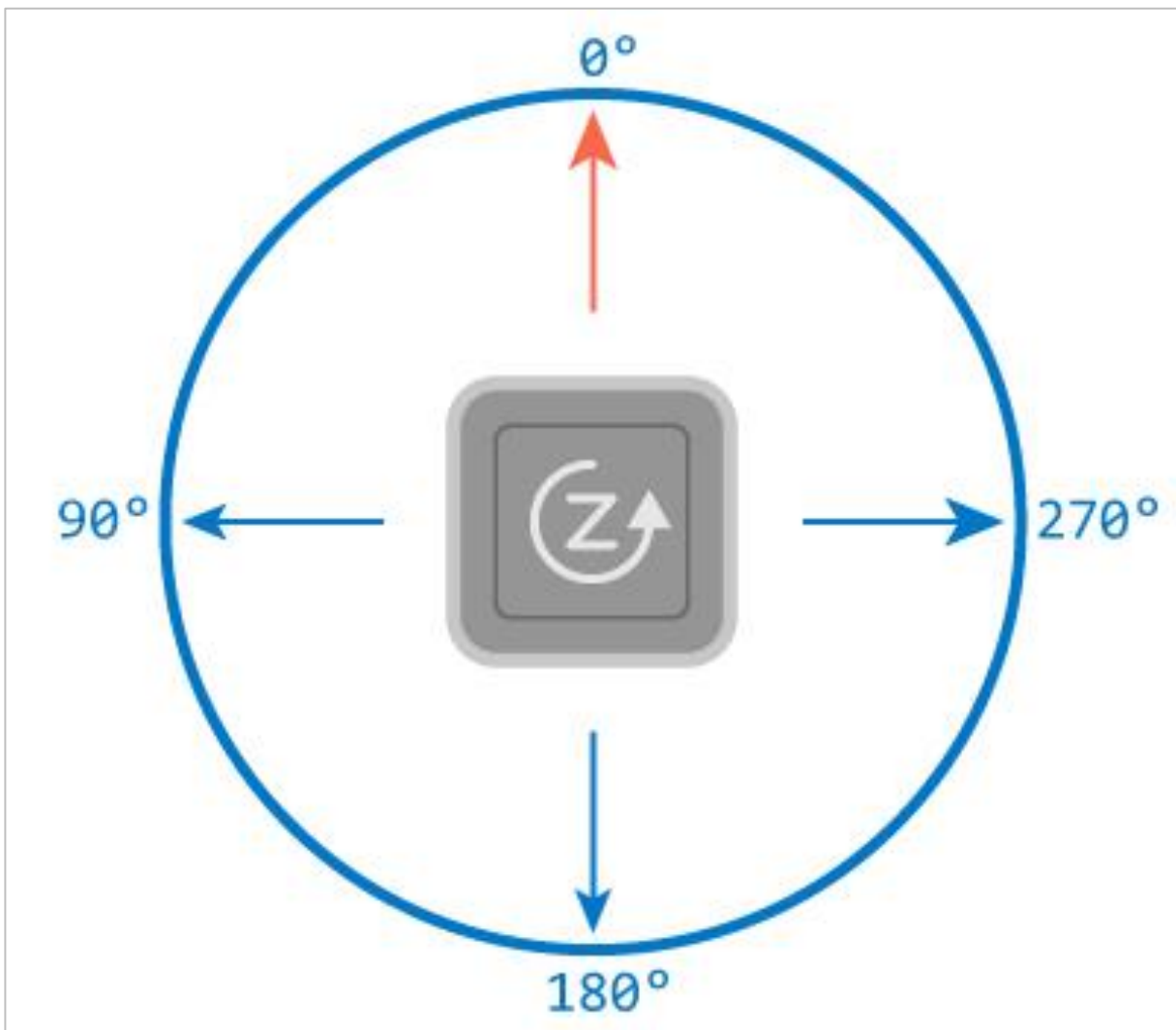
The outline for the Turning Right and Left Exploration is as follows:

- Introduce the `turn` and `turn_for` block
- The students check that the Autopilot is ready with a charged battery and that its Robot Brain is properly wired.
- Start a new project in VEXcode IQ Blocks
- Rename and save the project (Windows, macOS, Chromebook)
- Create the Drive project that turns Autopilot right
- Download and run the project
- Change the Drive project to move Autopilot left
- Download and run the project
- Wrap up the activity with a discussion

turn to heading Block

The `turn to heading` block turns a robot based on relative position. It does this by using the Gyro Sensor. The `turn for` block also uses the Gyro sensor.

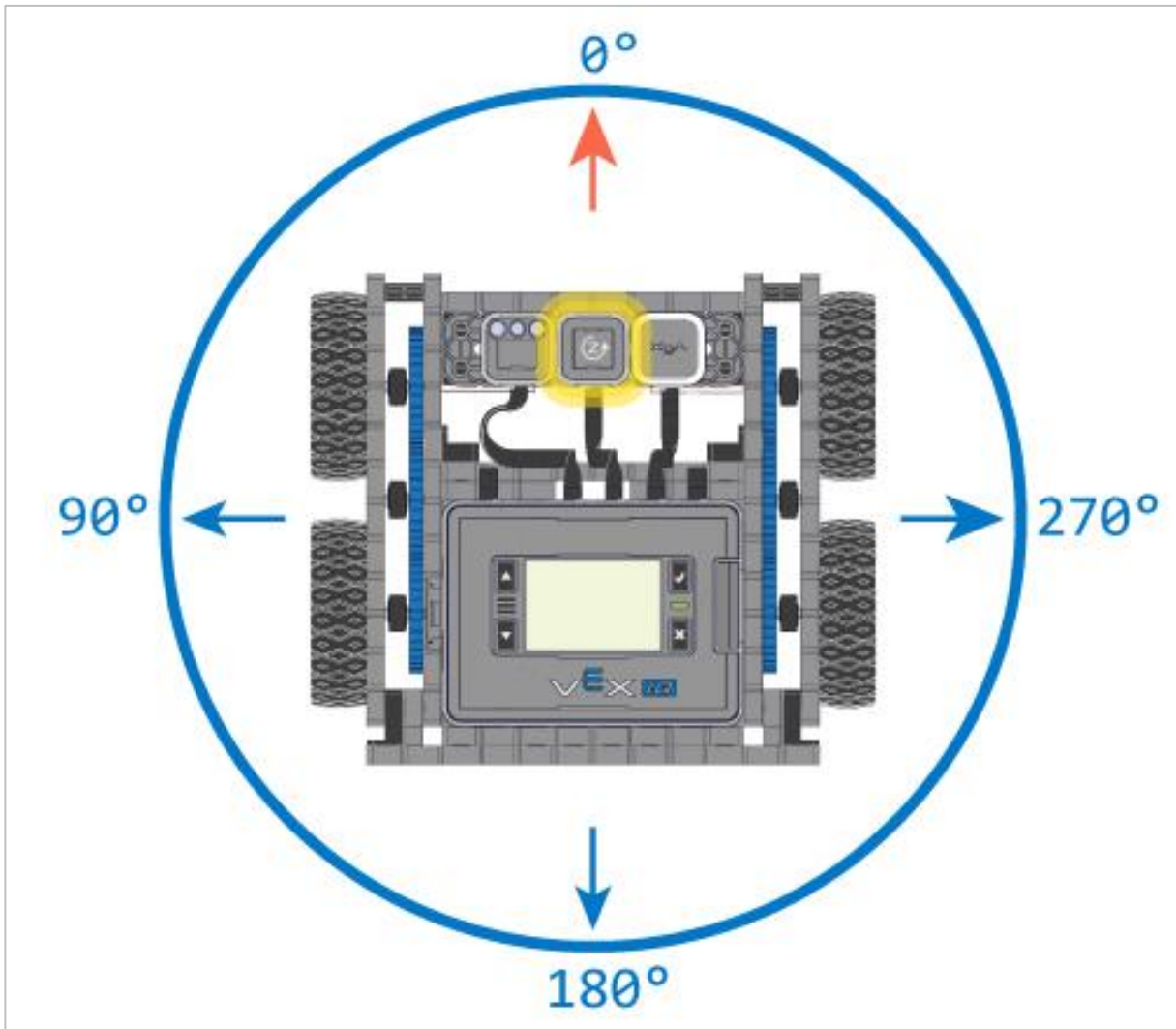
The Gyro Sensor measures rotational angle of the robot. The sensor measures rotation along the axis indicated by the curved arrow. The Gyro Sensor returns values in degree. Counter-clockwise movement increases the value, clockwise movement decreases.



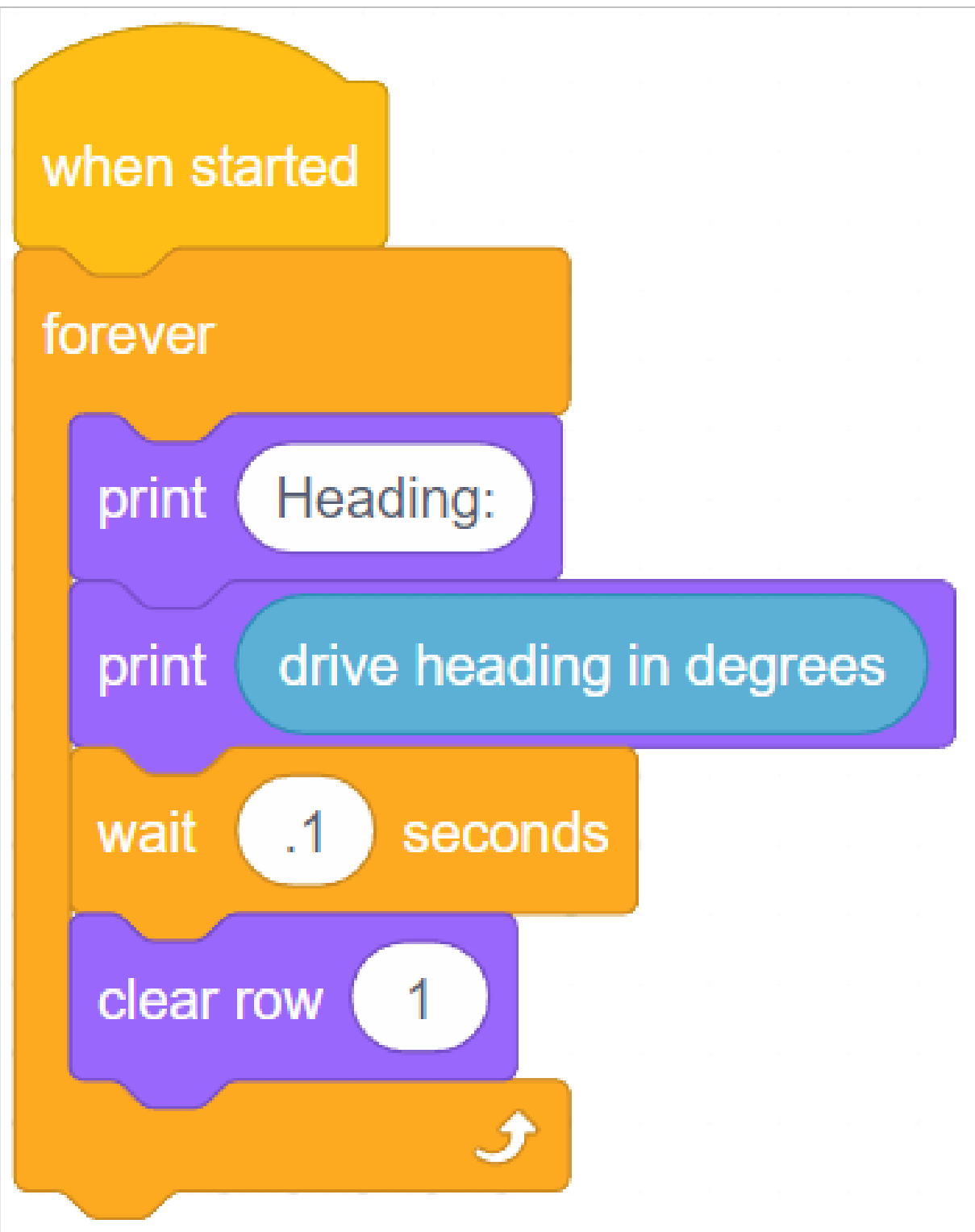
A Gyro Sensor measures angular rotation based off of a “zero” point. Whatever the heading of Autopilot when it begins, that will be the zero point. Therefore, using the `turn for` block, Autopilot will also turn 90 degrees from its original position. However, if using the `turn to heading` block, the robot will just turn to that specific heading. If this block is used:

turn to heading 90 degrees ►

The robot will turn until it reaches the 90 degree heading. It doesn't matter how many degrees it takes to get there.



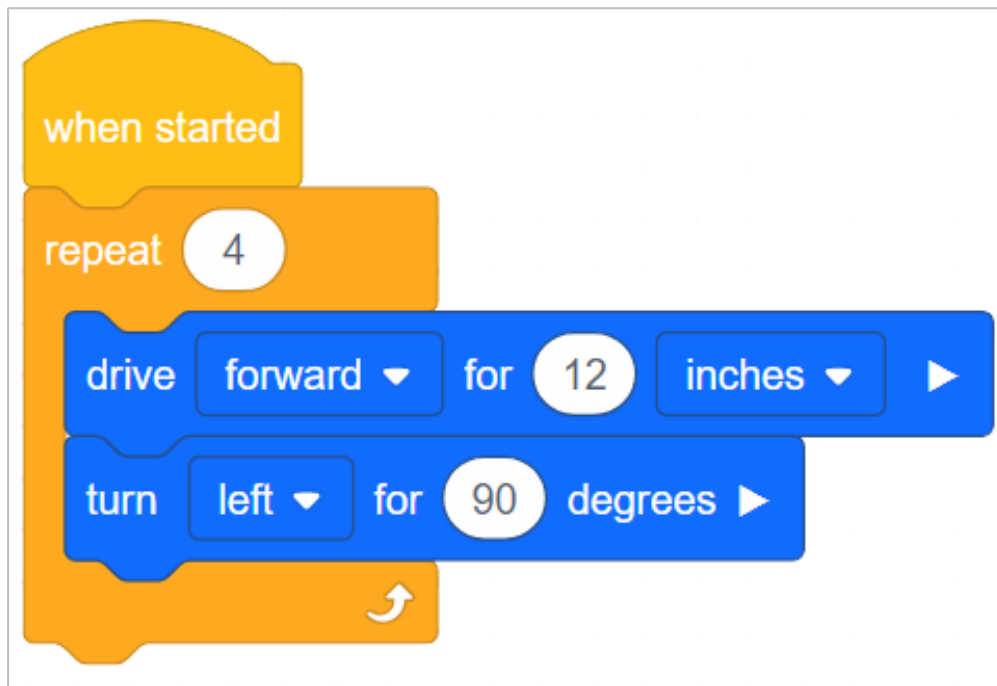
Here is a program that can also be used with the students to demonstrate the how the output of the Gyro sensor changes as the Autopilot moves:



This program prints "Heading:" on the first line, followed by the drive heading in degrees of the Gyro sensor. Run this program (make sure to use the Autopilot robot configuration) and turn the robot to the left. The Gyro sensor value should increase. Turn it to the right, the Gyro sensor value decreases.

repeat Block

The `repeat` block can be found in the control section of VEXcode IQ Blocks. Once you drag this block to the sequence, everything inside it will repeat. You can change the number of times it repeats by changing the parameter in the repeat block.



If some students finish earlier than others, introduce them to the repeat block and ask them to create a project to move around the box using as few blocks as possible. Their program could look like the above, with the Autopilot moving in a square around the box.

Remix Challenges - Activity A

Example

While the distances and turn direction will vary depending on the size of the box students are using, the final project should look something like this:



In this example, each individual behavior is listed with an individual block. The pattern of drive forward and turn are repeated until the Autopilot moved around the box. However, there are other ways besides placing each block individually.

Program Autopilot to Turn

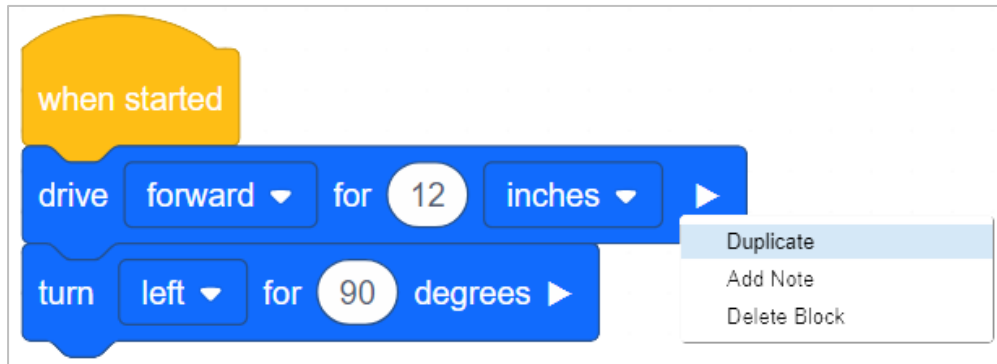
Using the drivetrain robot configuration enables the students to program Autopilot to make precise left and right turns. There are three different turn blocks available in VEXcode IQ Blocks, which can be used to turn either left or right. In order to turn the Autopilot, the student will just need to change the `turn_for` block to right or left using the dropdown arrow next to the direction. Anything editable inside of the blocks is called a parameter. The number of degrees is considered a parameter as well.

The three blocks are as follows:

- The `turn` block—this block simply tells Autopilot to turn. It will turn continuously in the direction specified until otherwise instructed by the project.
 -
 - If time allows, you could show students how this works by creating the following program and running it on Autopilot as a demonstration.
 -
- The `turn_for` block—this block instructs Autopilot to turn for a specific number of degrees in a direction. This is the block students will be using in this investigation.
 -
- The turn to heading block—this block tells Autopilot to turn a specific number of degrees based on its relative location. This block is not used in the lesson, but students may ask about it. For more information on how this block works, [click here](#).
 -

Duplicating Blocks

Any group of blocks can be duplicated by right clicking or long pressing on the block.



Once the block(s) is duplicated, you can drop the block(s) onto the end of the block series.



Note that the block you right click (or long press) will impact how many are duplicated. If you select the last block in the sequence, that will be the only block duplicated. The further up the sequence you go, the more blocks will be duplicated.

Demonstrating how the Drivetrain to turn for Blocks are Related

Have an Autopilot robot to demonstrate for the students. Introduce to students the `turn for` block. Read the description of the turn for block in the Help. Either have VEXcode IQ Blocks displayed in front of the classroom, or have each student group follow along at their workstation. When discussing the descriptor and purpose of the block, ask the students if they can identify what a Drivetrain is. Discuss with the students that a Drivetrain consists of:

- A rectangular Chassis (the structure of a mobile robot that holds wheels, motors, and/or any other hardware used to make up a Drivetrain)
- Two Motors
- Four Wheels
- Gears transmitting Power from the Motors to all Wheels

Use Autopilot robot to show the students the parts of the Drivetrain during the discussion. Next, gently turn one of the wheels that is connected to a motor. Show the students that because of the gears, even though the force is being applied to one wheel, both wheels are moving. Tell the students that instead of moving the wheels by hand, we'll use the `turn for` block to program the motors to run and the wheels to turn.

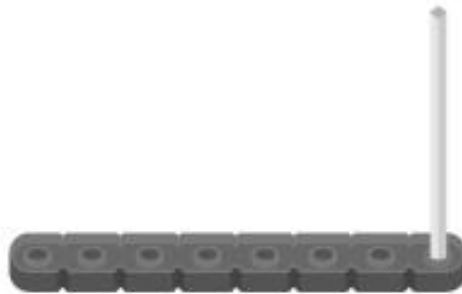
Angle Reference

To create the angle reference, they will need:

- 1- 1x8 beam
- 2- 1 x 12 beams
- 1 -8x pitch shaft
- 1-1x1 connector pin
- a pencil
- a piece of paper

Steps

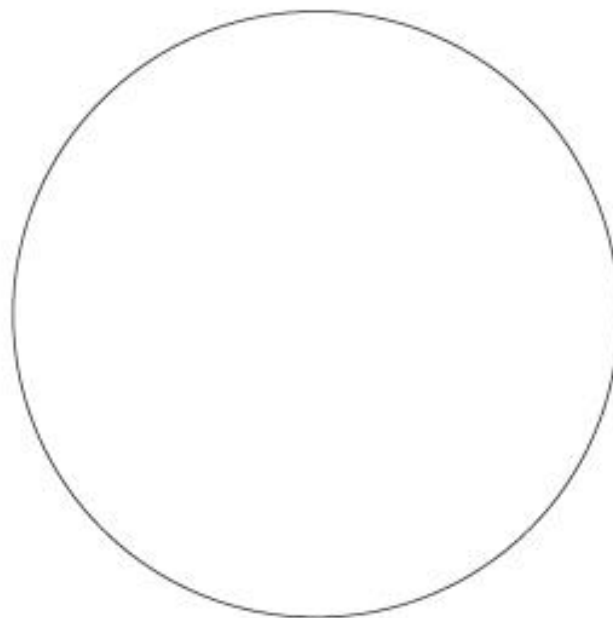
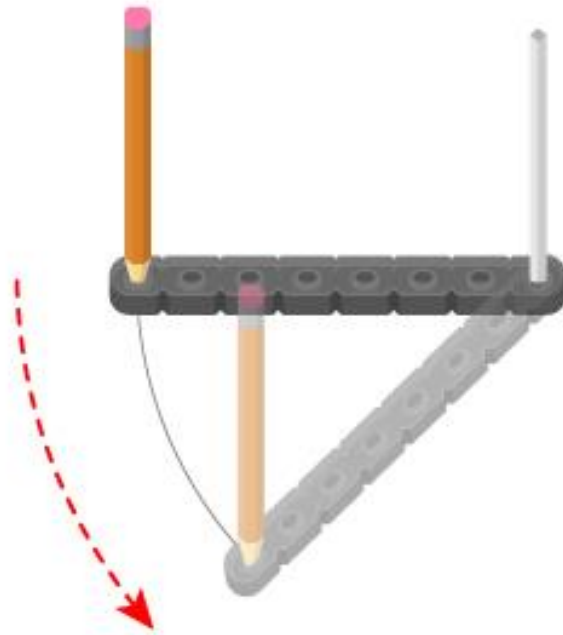
- Put the 8x pitch shaft in the 1 x 8 beam as shown. The 8x pitch shaft should be in the center of your paper.



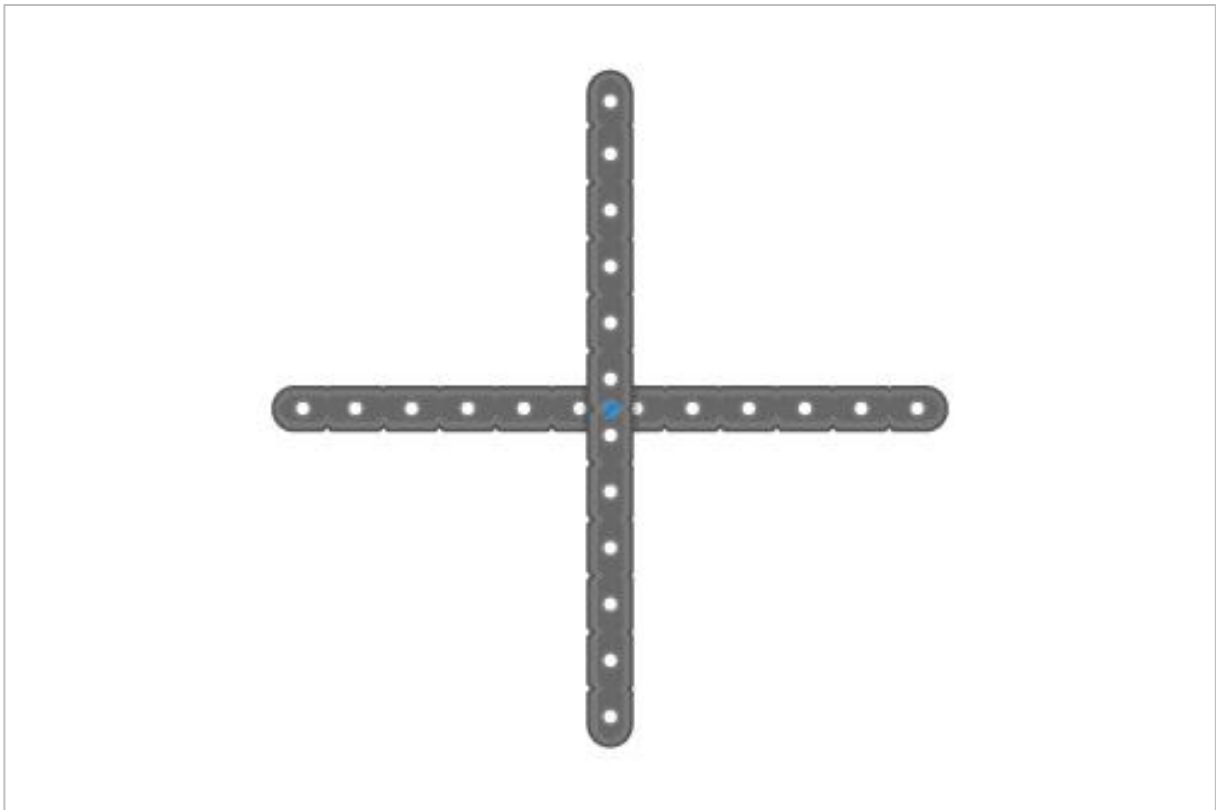
- Place your pencil in the farthest opposite hole.



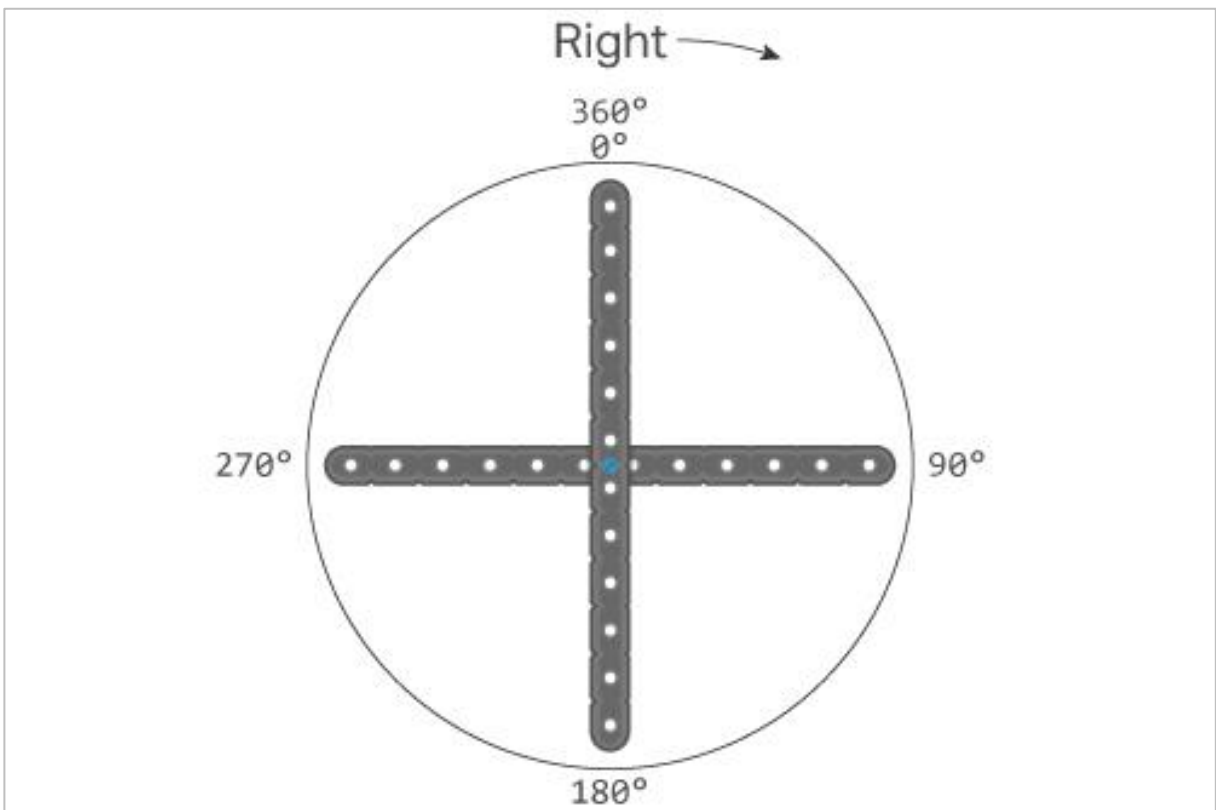
- While holding the 8x pitch shaft with one hand, spin the beam around drawing a circle on a piece of paper.



- Connect the 1 x 12 beams together in the center with the 1x1 connector pin.



- Place the beams in the center of the circle and label the diagram as shown.



You can repeat the steps on the other side of the paper and create the same design, but reverse the numbers and turn direction for turning left.

Tips for creating and Angle Reference:

- Step 2 - A mechanical pencil works best.
- Step 3 - Explain the students that we can have the Autopilot turn in a complete circle. A full rotation is 360 degrees. Why 360 degrees? Most likely because ancient mathematicians watched the stars revolve around the North Star 1 degree each night throughout the year. The Persian Calendar used 360 days in a year.
- Step 4 - Explain that many times we need to turn the Autopilot at a smaller angle. We can divide the circle into parts using the VEX pieces. The blue connector pin represents the Autopilot.
- Step 5 - Explain that if a full circle is 360 degrees, three quarters of a circle is 270 degrees, half of a circle is 180 degrees, and a quarter of a circle is 90 degrees. We can use these measurements to help us determine how many degrees we will need to program the Autopilot when we are programming it turn.

Activity A Troubleshooting

Students may not have programmed the Autopilot to go around the box perfectly. It could have run into the box on a turn, turned the wrong direction, not driven far enough, etc. This is a good opportunity to check in with groups and share results. If the project did not work as expected, work through some troubleshooting with students. Ask students:

- What happened that you did not expect?
- What do you think caused this behavior?
- Should you adjust your measurements?
- Should you change the blocks in the project?

If there is time, allow students to make adjustments and try again. Fixing bugs is an important part of programming that even the most experienced programmers do!