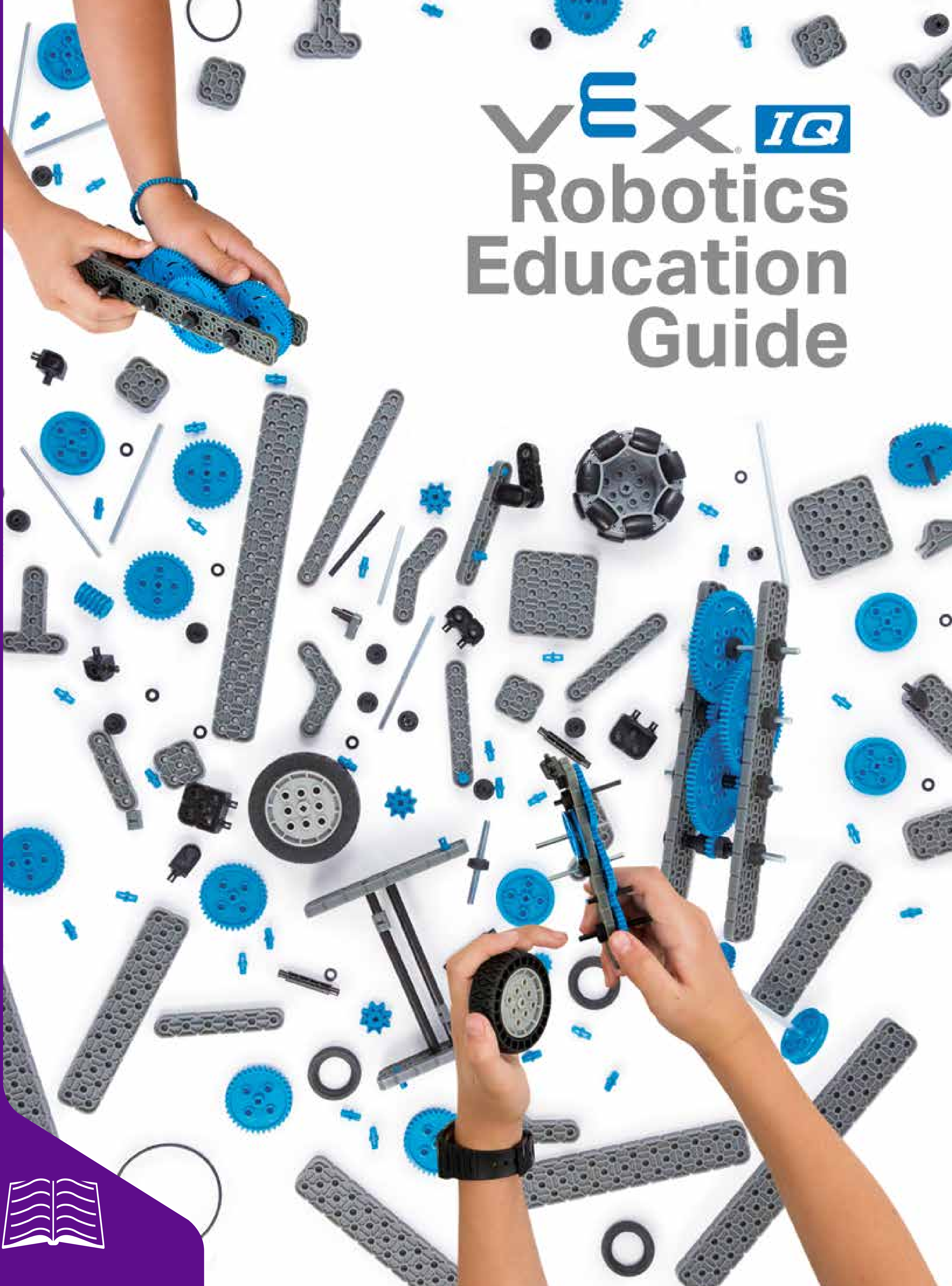
VEX IQ Robotics Education Guide



VEX IQ Robotics Education Guide
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- Rubrics
- Build Instructions
- Application exercises
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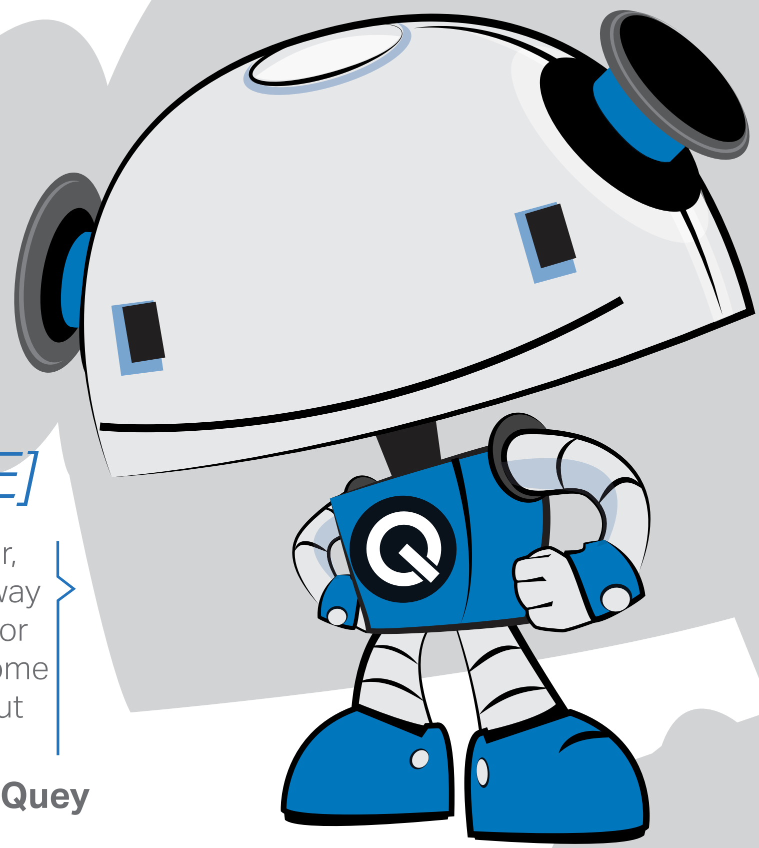
When you see these icons, refer to your Kit Documentation for more information.

Build Instructions | Control System User Guide



Quey *[Q-E]*

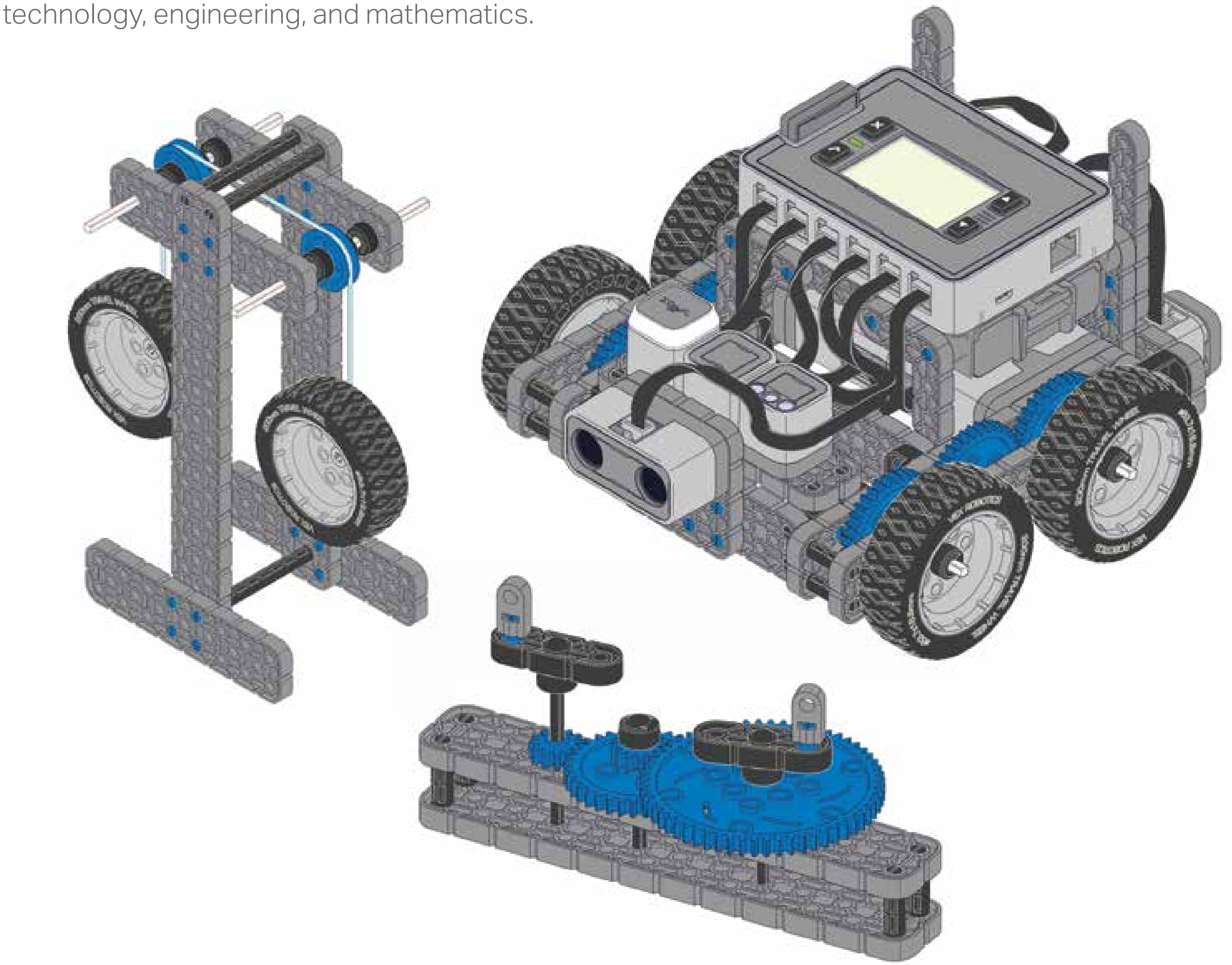
I'm Quey, your personal VEX IQ helper, and I'll be with you every step of the way as you learn how use VEX IQ! Watch for me on the sidelines - I'll try to offer some tips and tricks that should help you out when things get tough.

vexiq.com/askquey **@AskQuey**

VEX IQ Robotics Education Guide Overview

We have developed this Robotics Education Guide, the companion Teacher Supplement, and the online VEX IQ Curriculum (available at www.vexiq.com/curriculum) as learning companions to the VEX IQ platform for elementary and middle school students. This guide details 12 flexible units of instruction that can be used in sequence, in chunks, or as individual stand-alone lessons.

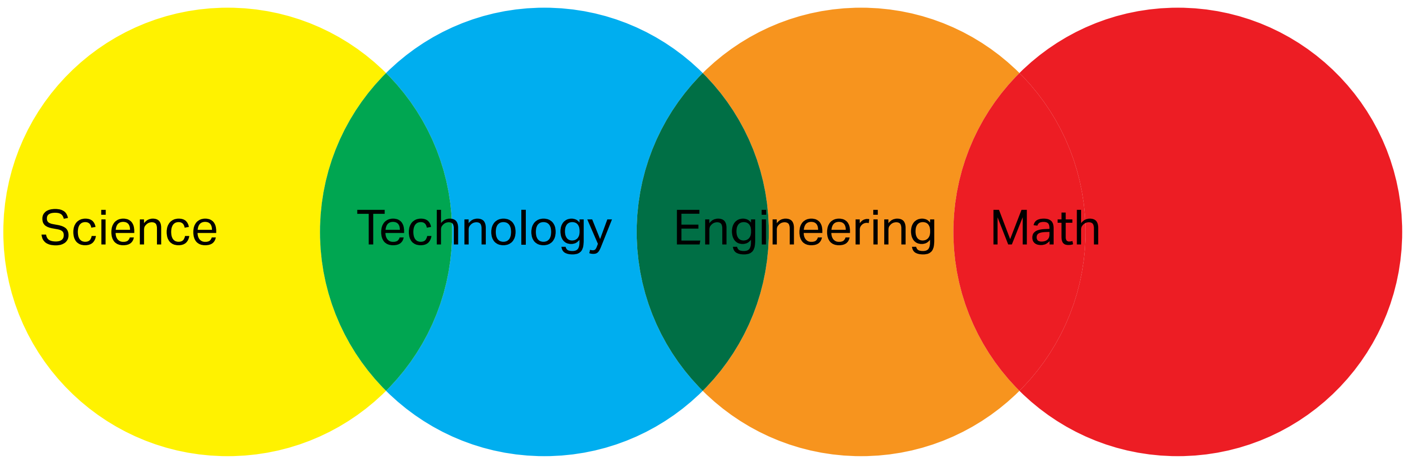
With these resources, students and teachers will use VEX IQ to explore the worlds of science, technology, engineering, and mathematics.



The twelve units of instruction include:

Unit A: **It's Your Future -** Learn about STEM, engineering, and robotics
Unit B: **Let's Get Started -** Learn about the VEX IQ kit, the Controller, & the Robot Brain
Unit C: **Your First Robot -** Build and test the Clawbot IQ
Unit D: **Simple Machines & Motion -** Explore the world of levers, pulleys, pendulums, and more
Unit E: **Chain Reaction Challenge -** Design and control fun devices using simple machines
Unit F: **Key Concepts -** Explore and apply the science and math that engineers use
Unit G: **Mechanisms -** Dig deeper into mechanical design
Unit H: **Highrise Challenge -** Design and build a challenge-ready teleoperated robot
Unit I: **Smart Machines -** Learn how sensors work and the basics of programming
Unit J: **Chain Reaction Programming Challenge -** Apply knowledge to automate fun devices
Unit K: **Smarter Machines -** Expand your knowledge of sensors and programming
Unit L: **Highrise Programming Challenge -** Design and build a challenge-ready autonomous robot

It's Your Future



A.1

It's Your Future

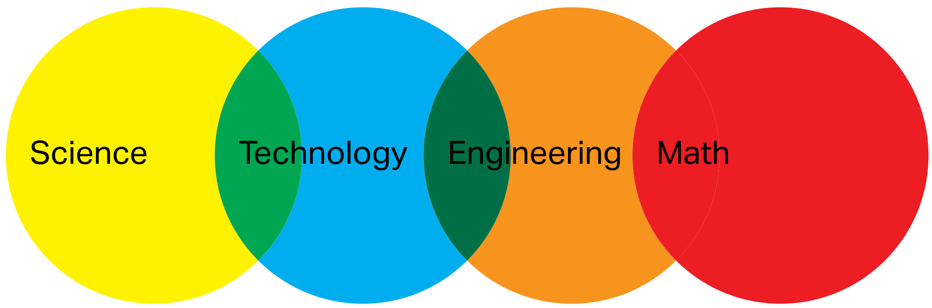
Unit Overview:

The world needs the students of today to become the scientists, engineers, and problem solving leaders of tomorrow. Science constantly presents us with new breakthroughs and challenges, creating greater opportunities for problem solving through technology.

The solutions to such problems could help change the world, and technology-based problem solvers will be the people to make it all possible. The VEX IQ platform and curriculum provide a fun and engaging vehicle to begin the journey toward becoming the type of problem solver our world needs the most. No matter what you see in your future, the VEX IQ platform and curriculum can help you build the kinds of skills expected of a 21st century innovator.

Unit Content:

- What is STEM?
- What is Engineering?
- What is Robotics?



Unit Activities:

- Matching Exercise
- Idea Book Exercise

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

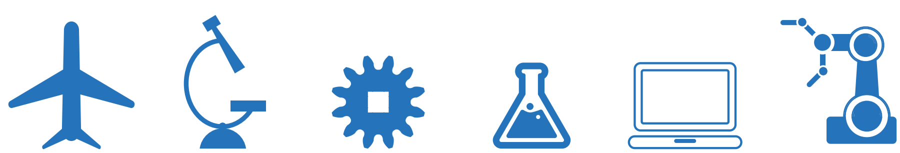
A.2

What is STEM?

STEM combines **science**, **technology**, **engineering**, and **mathematics** education to form an engaging field of study. The VEX IQ platform is a great way for students to explore STEM hands-on while learning.

A.3

What Is Engineering?



Engineering is all about using practical & scientific knowledge to create solutions for identified problems. Engineers use math and science to create most of the products, buildings and structures we see every day. Engineers often use an engineering notebook to help them think about and solve problems. You will have the chance to use "Idea Book" pages alongside activities that help you to think like an engineer!

There are Five Basic Types of Engineering:

Chemical engineering – Using physical and biological sciences to convert raw materials or chemicals into more useful forms for the purpose of solving a problem.

Civil engineering - Using design, construction, and maintenance of physically and naturally built environments to solve a problem. Environmental and structural engineers are two examples.

Electrical engineering – Using electricity, electronics, and electromagnetism to solve a problem.

A.3 cont.

Mechanical engineering – Using design, construction, and mechanical power to create machines and mechanical systems that solve a problem.

Specialized engineering fields – These engineering fields use two or more types of engineering together to form a brand new kind of engineering. Biomedical and robotics engineers are two examples.

A.4

What is Robotics?

Robotics is the type of specialized engineering that deals with the design, construction, operation, and application of robots.

A **Robot** is any man-made machine that can perform work or other actions normally performed by humans.

Robots can be operated by remote control (known as **teleoperated robots**), automatically by themselves (known as **autonomous robots**), or a combination of teleoperated and autonomous operation (known as **hybrid robots**). Robots have become more popular over time because they are able to perform very repetitive tasks or very dangerous tasks in the place of humans.

Robotic assembly lines can build cars, computers, and other things that you use in everyday life.

Police robots can investigate risky situations while human officers control them from a safe distance.

Service robots can clean your floor, mow the lawn, or assist those with disabilities.

Deep sea robots crawl on the ocean's floor, discovering new life that thrives nearly six miles under water.

A.5

It's Your Future Matching Exercise

Student Name(s): ____

Teacher/Class: ________________________________ Date: ___________

Instructions:

Match terms from the word bank to the correct definition by writing terms on the correct line. Each term is only used once.

Word Bank:

Autonomous Robots	Chemical Engineering	Civil Engineering
Electrical Engineering	Engineering	Hybrid Robots
Mechanical Engineering	Robot	Robotics
Specialized Engineering	STEM	Teleoperated Robots

_________________________combines science, technology, engineering, and mathematics education to form an engaging field of study.

_________________________is using practical & scientific knowledge to create solutions for identified problems.

_________________________uses physical and biological sciences to convert raw materials or chemicals into more useful forms for the purpose of solving a problem.

_________________________uses design, construction, and maintenance of physically and naturally built environments to solve a problem.

_________________________uses electricity, electronics, and electromagnetism to solve a problem.

_________________________uses design, construction, and mechanical power to create machines and mechanical systems that solve a problem.

_________________________fields use two or more types of engineering together to form a brand new kind of engineering.

_________________________is the specialized type of engineering that deals with the design, construction, operation, and application of robots.

A_____________________is any man-made machine that can perform work or other actions normally performed by humans.

Robots operated by remote control are called______________________ .

Robots operated automatically by themselves are called________________ .

Robots that have both teleoperated and autonomous features are called________________ .

A.6

It's Your Future Idea Book Exercise

Student Name(s): ____

Teacher/Class: ____________________________________ Date: ______________

Instructions:

Imagine a robot that could solve a problem that you know about.

Draw a picture of what that robot might look like and give it a name in the box below.

Instructions:

Write about what your robot would be able to do and what problem it would solve. Write about how it would work and what type of control it would have (autonomous, teleoperated, or hybrid).

____

____

____

____

B

Let's Get Started

B.1

Let's Get Started

Unit Overview:

In this unit you will learn about the VEX IQ kit contents, the VEX IQ Controller, the VEX IQ Robot Brain, and all other important parts. You may also learn how pair the Controller with the Robot Brain and how to use a protractor to identify Angle Beam types.

Unit Content:

- Using VEX IQ Hardware
- Using the VEX IQ Controller & Robot Brain

Unit Activities:

- Matching Exercise
- Pairing the Controller with the Robot Brain (see VEX IQ Kit Documentation for procedure)
- Optional: Identifying Angle Beam types with the use of a protractor (see teacher for details)

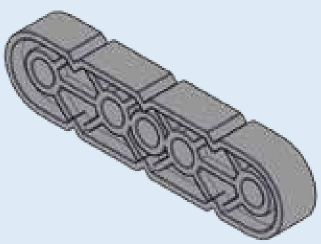
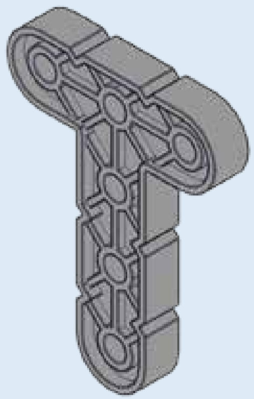
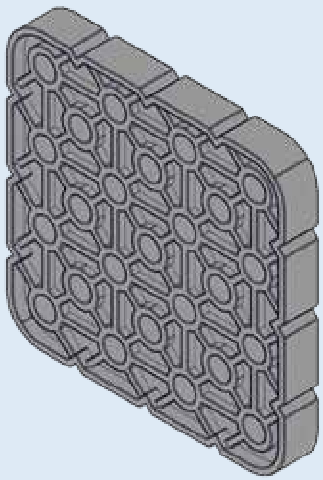
Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

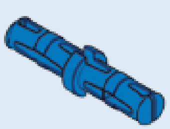
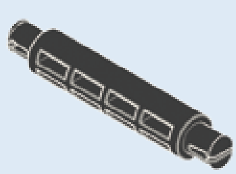
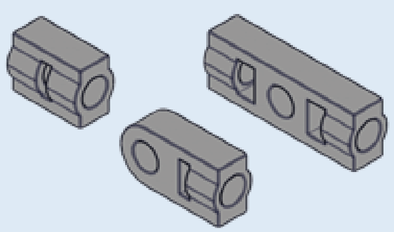
B.2

Using VEX IQ Hardware

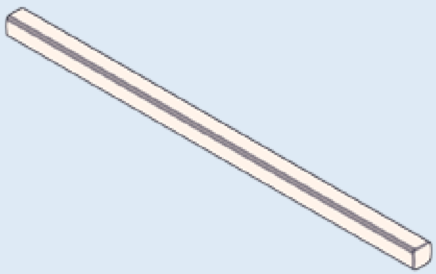
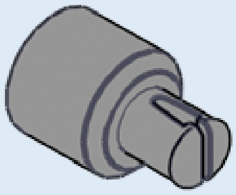
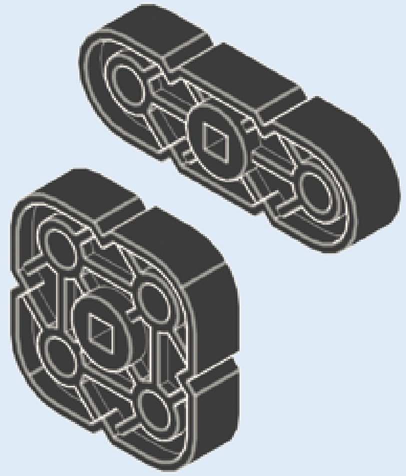
The VEX IQ platform kits provide easy, fun, and accessible tools to teach and learn about all four legs of STEM, no matter what your learning needs and desires may be. This curriculum unit lesson will familiarize you with the kit hardware. If you're looking for information on the VEX IQ Controller or Robot Brain, please see our second lesson **(B.2)** that covers those topics. One of the best overall features of the VEX IQ hardware is its flexibility. If you can imagine it, you can build it with VEX IQ. The system allows for building of non-powered models, powered mechanisms and machines, as well as full-blown teleoperated and autonomous robots, enabling teaching and learning in a wide variety of ways while engaging and challenging every student from beginner to expert.

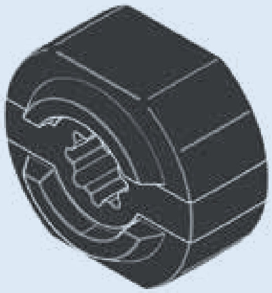
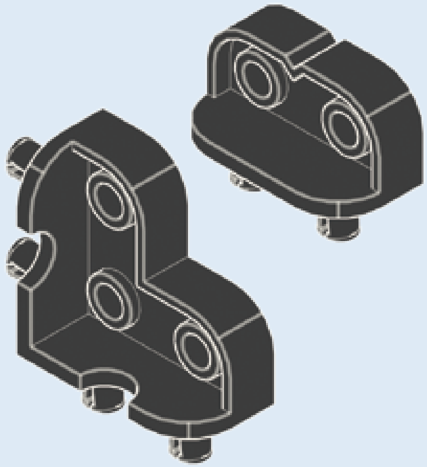
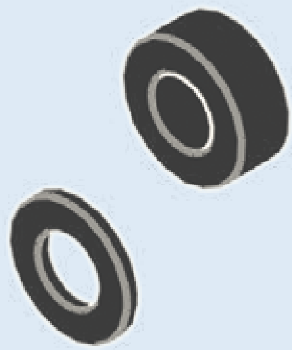
Kit Hardware Overview

Beams various sizes	Specialty Beams angle, tee, right-angle beams	Plates various sizes
		
Structural parts.	Structural parts.	Structural parts.

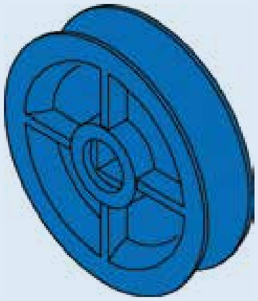
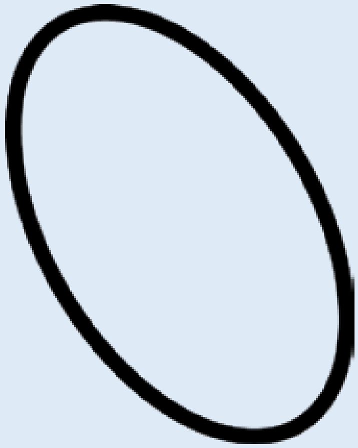
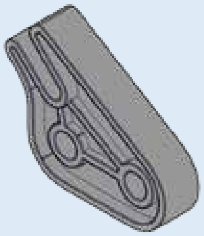
Connector Pins several lengths	Standoffs several lengths	Standoff Connectors several types
		
Use with beams, plates, corner connectors, and more.	Maintain desired spacing between beams and plates.	Connect standoffs and connector pins.

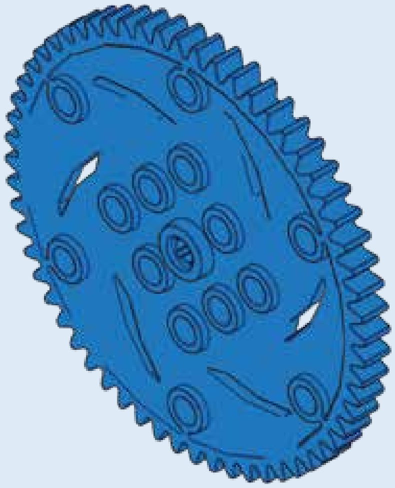
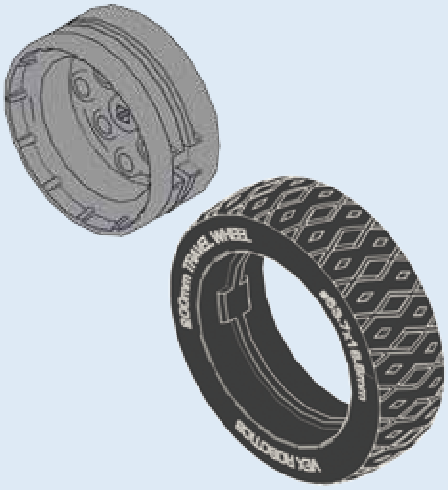
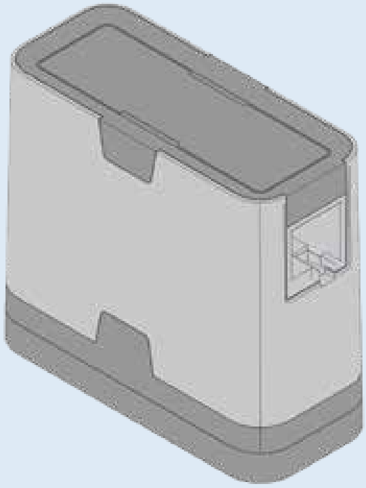
B.2 cont.

Shaft several lengths	Shaft Bushing	Shaft Lock Plates multiple sizes
		
Transmit power to, or allow rotation of, wheels, pulleys, gears, and more.	Interfaces shafts with beams and plates, allowing the shaft to spin and be held in desired location.	Plates that lock onto shafts allowing design components to spin with the shaft.

Rubber Shaft Collars	Corner Connectors several types	Washers & Spacers
		
Holds objects on shafts and/or the shaft itself in place.	Create corner connections between beams, plates, or other VEX IQ parts.	Use with shafts, reduces friction and maintains desired spacing.

B.2 cont.

Pulleys several options	Rubber Belts several size options	Rubber Band Anchor
		
Drive belts or make rollers and small wheels.	Use with pulleys, as a form of stored energy, and/or as a fastener.	Use with rubber belts and bands.

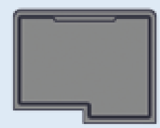
Gears several lengths	Wheel Hubs and Tires several size options	Smart Motor
		
Transmit power to another gear and/or mechanism.	Rolling and powering movement.	Creates rotary motion.

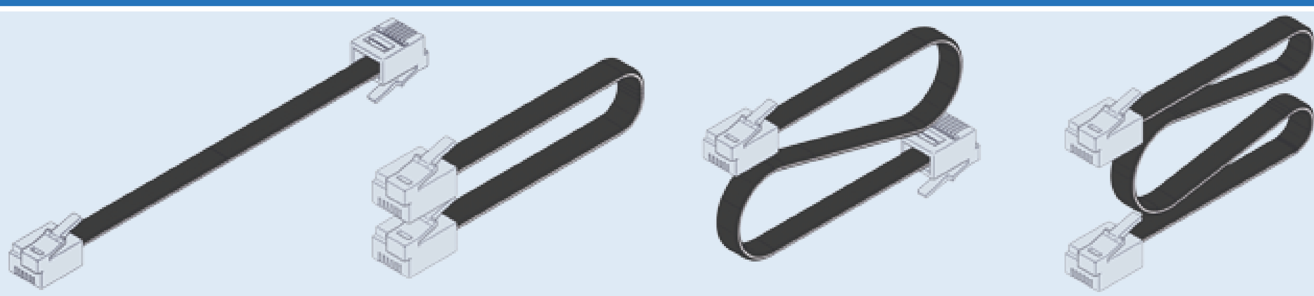
B.3

Using the VEX IQ Controller and Robot Brain

The VEX IQ Controller and Robot Brain are easy to use. This lesson will introduce their key components and get you up and running in no time. Don’t forget to see your kit documentation for more useful information.

Component Overview

Controller	Robot Brain	Radio
		
Pair the Controller with a Robot Brain and gain full control of your robot. Over 50 hours of battery life on a single charge.	Use the twelve identical smart ports to connect any device to any port. Built in programs make robot building fast and fun. Programmable.	Connects the Controller with the Robot Brain. Both 900 MHz and 2.4 GHz options to accommodate worldwide use.

Smart Cables

Cables of different lengths to connect your Smart Motors and sensors to the Robot Brain.

B.4

Optional Activities

Pairing the VEX IQ Controller with the Robot Brain: Your teacher may choose to pair the Controller and Robot Brain for you or have you do it. Please see your teacher and your kit documentation for details.

Identifying Angle Beam Types: Your teacher may choose to teach you different ways to identify Angle Beam types, including using a protractor to measure angles. Please see your teacher for details.

B.5

Let's Get Started Matching Exercise

Student Name(s): ______________________________

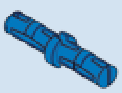
Teacher/Class: ______________________________ Date: ______________

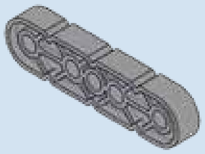
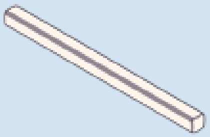
Instructions:

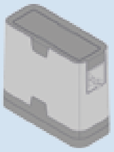
Match terms from the word bank and label correctly below each picture (pictures are NOT to scale).

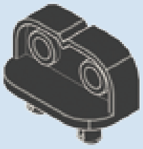
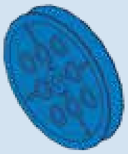
Word Bank:

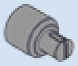
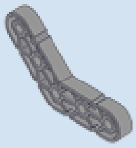
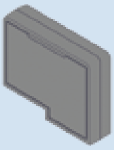
Specialty Beam	Beam	Connector Pin	Controller
Corner Connector	Gear	Plate	Pulley
Radio	Robot Brain	Rubber Band Anchor	Rubber Belt
Rubber Shaft Collar	Shaft	Shaft Bushing	Smart Motor
Standoff	Standoff Connector	Tire	Wheel Hub

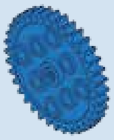
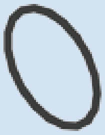


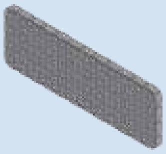



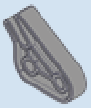
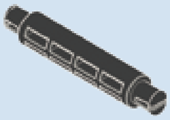


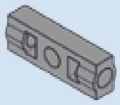



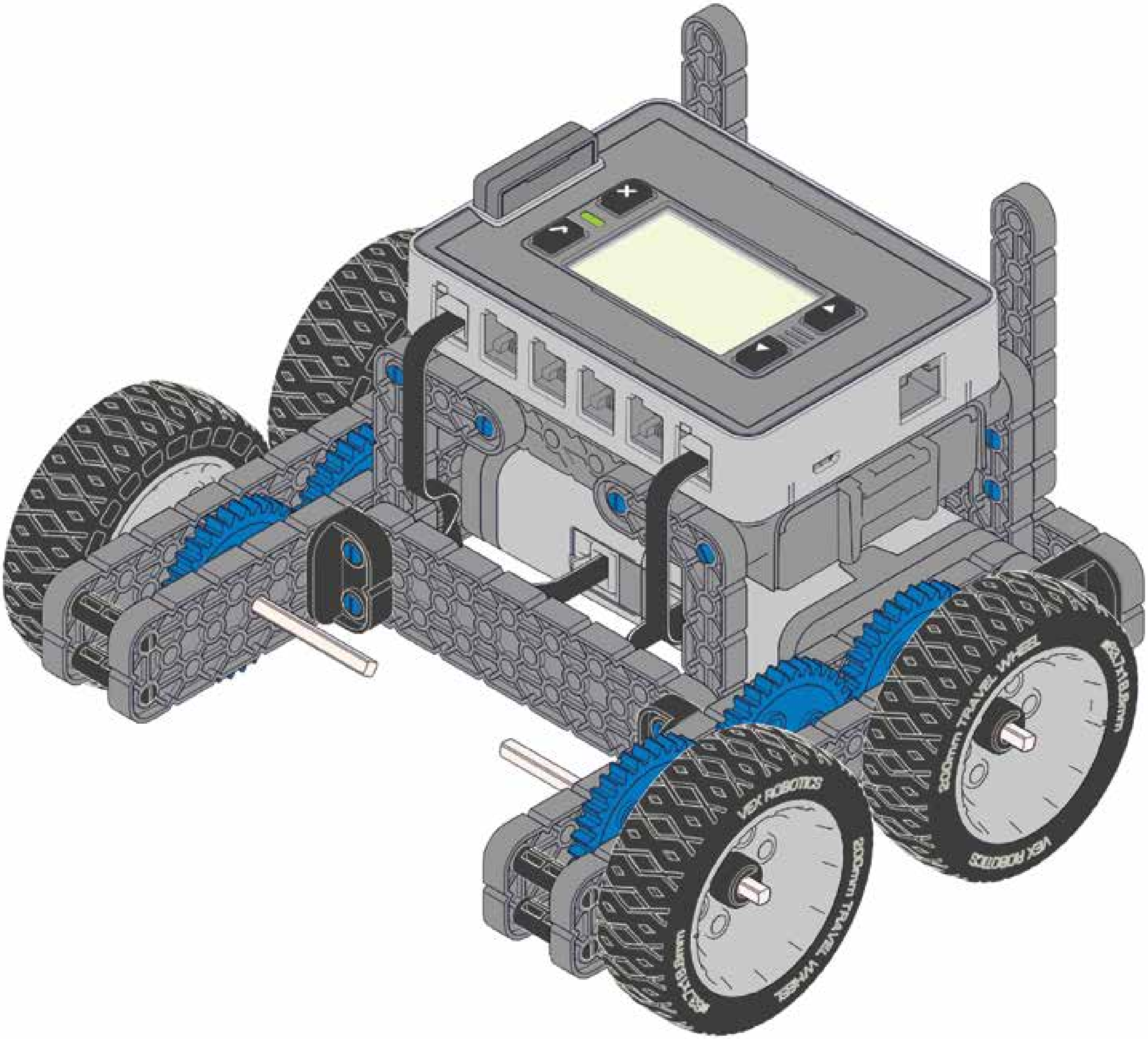


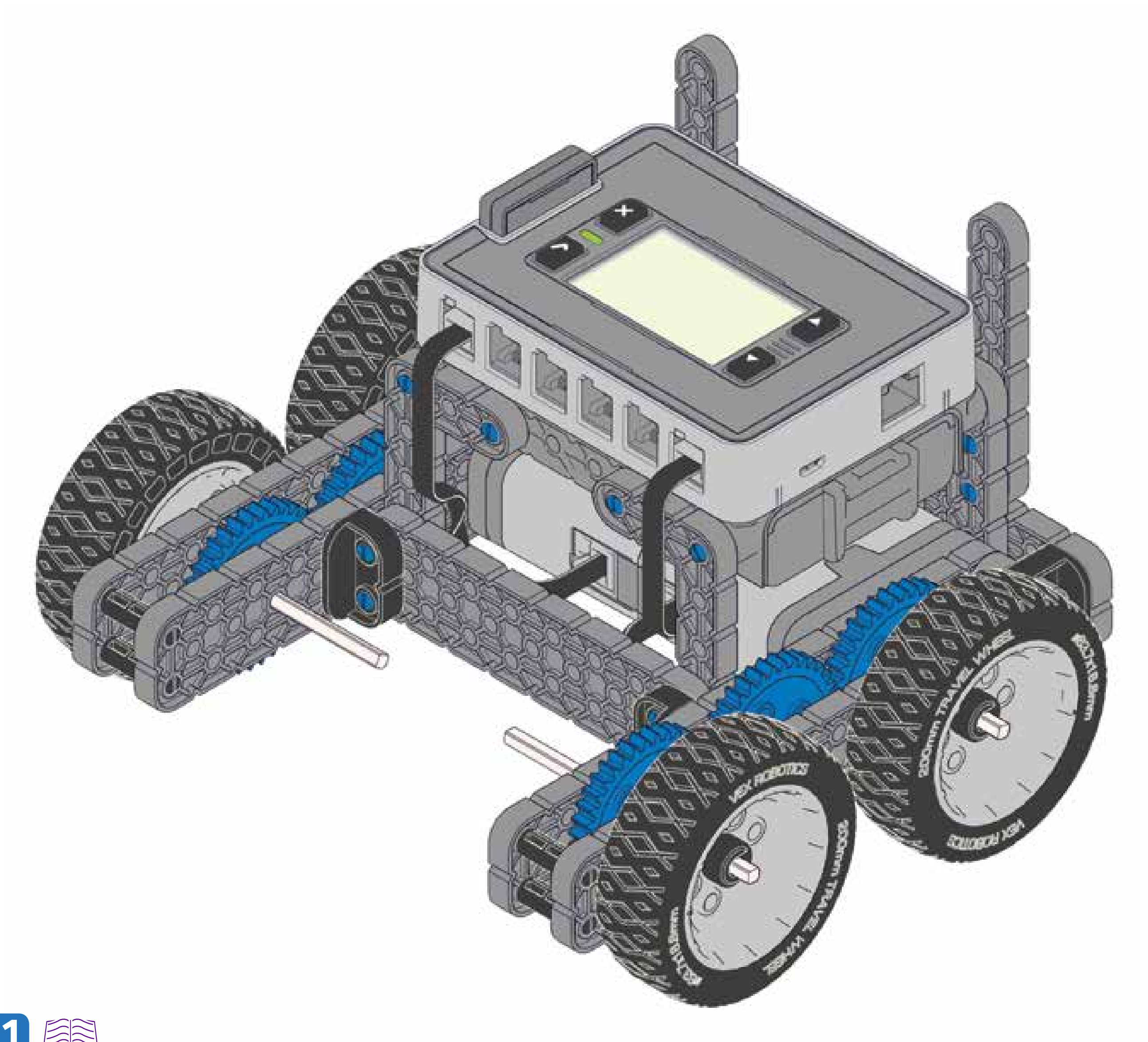





C

Your First Robot





C.1

Your First Robot

Unit Overview:

In this unit you will build and test your first VEX IQ Robot. You will follow assembly instructions provided in your kit, and use the Your First Robot Build Rubric for evaluation. Idea Book Pages for each part of your build will be used to help you document your process and test your finished robot.

Unit Content:

- Your First Robot Build Options
- Learning Design Process

Unit Activities:

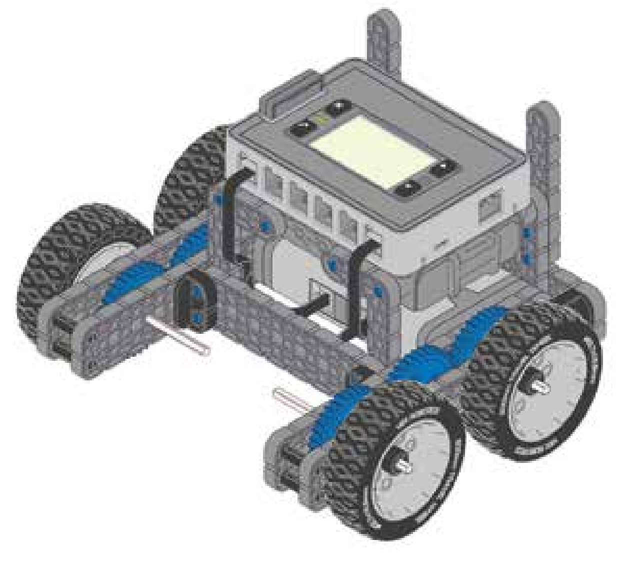
- Robot build with assembly instructions (included with kit) and Your First Robot Build Rubric
- Completion of Idea Book Pages with robot build and testing

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

C.2

Build and Test Clawbot IQ

There's nothing quite like building your first robot. The Clawbot IQ enables even a complete beginner to build and test a fully functional teleoperated robot! Just use the easy to follow VEX IQ Clawbot Assembly Instructions and you'll be on your way.



Build Options

Option 1: Follow the assembly instructions to complete and test the Standard Drive Base only. This gives you a fully functional drivetrain that can be operated and modified with your own creativity. Also note that this robot base will be the basis for other lessons as well, so your work will be used!

Option 2: Follow the assembly instructions to complete and test the Standard Drive Base then continue using the assembly instructions to build and complete the claw, tower, and object holder. Suggested test objects to use for full Clawbot IQ testing are VEX IQ Challenge game objects, tennis balls, cubes, or any similar object.

C.3

Downloadable Build Instructions

The Standard Drive Base and full Clawbot IQ build instructions can be downloaded online. Your teacher may have a copy already made for you; if not, visit www.vexiq.com/clawbot-iq to get started!

C.4

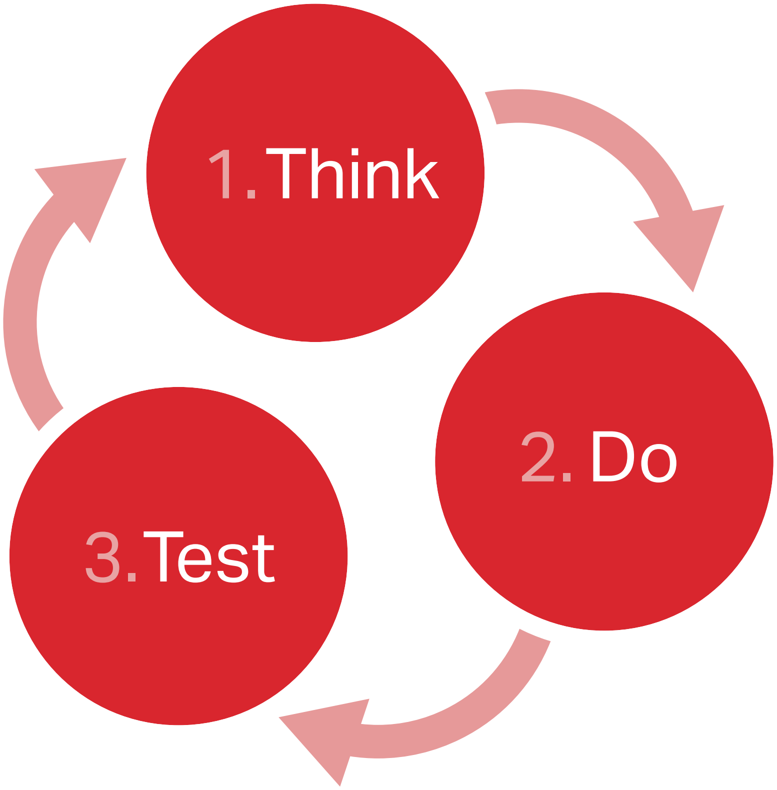
Your First Robot Idea Book Pages: Learning The Design Process

The Your First Robot unit also comes with Idea Book Pages that help guide you through your first robot build and help you to learn about the design process.

Engineering was defined in the It's Your Future unit as **using practical & scientific knowledge to create solutions for identified problems**. In that unit we also learned that engineers often use an engineering notebook to help them think about and solve problems. However, if questions and instructions aren't already on the page, what does an engineer write/draw in that notebook?

Engineers use a **design process that is a series of steps that can be followed to help solve a problem and design a solution for something.** This is similar to the "Scientific Method" that is taught to young scientists. There is no single universally accepted design process. Most engineers have their own twist for how the process works. The process is a cycle that generally starts with a problem and ends with a solution, but steps can vary.

When simplified, the design process can be seen as a three-step loop:



Step 1: Think about a problem or generate an idea. Don't forget to write it down and/or draw it. Sometimes the problem or idea is given to you, but sometimes you come up with the problem or idea on your own.

Step 2: This is where you take action and "do" something to solve the problem or try to prove your idea. In our lessons, this is where you will build your potential solution.

Step 3: Test what you did in Step 2.

Is your problem fully solved? In testing, if you conclude the problem is not fully solved, then you have something more to think about. This means you write down or draw your next problem (that you see in testing) and repeat the cycle until your problem is fully solved. **Always keep in mind that problems ARE NOT failures. They are an expected part of the design process!**

In this unit you will use one Idea Book page for each "Think-Do-Test loop" you need to solve your given problem of following directions to build your first functional robot. The prompts and questions in the Idea Book Pages will lead you through the robot build, preparing you for full engineering notebook use when you make all of the design decisions in the future. **Now, build your first robot!**

C.5

Your First Robot: Build Rubric

Evaluation Criteria	Expert = 4	Proficient = 3	Emerging = 2	Novice = 1	Assessment	Comments
Design & Process Criteria						
Clawbot IQ Systems	Specified system(s) function(s) efficiently	Functioning specified system(s) exist(s)	Specified system(s) exist; partially function	Specified system(s) exist without function		
Design Process (documented in Idea Book as desired by teacher)	Design process utilized and documented creating enhanced efficiency	Design process utilized and fully documented	Design process utilized consistently	Some evidence that design process was utilized		
Utilization of Resources (materials and parts, Information and instructions, people, and time)	Resources used within constraints and efficiency maximized	Resources utilized to maximize efficiency	Evidence that some resources utilized meeting intended purpose	A few resources (e.g., materials and parts) utilized		
Technical Criteria						
Control System – Controller-Motor interaction	Completely functional control system with all expected system behaviors	Consistently functional control system with some expected system behaviors	Functional, but inconsistent control system behaviors	Non-functional or incomplete control system behaviors		
Electrical Systems	Battery charged. Wire routing safe, efficient, & completely functional	Battery charged. Wire routing safe & consistently functional	Functional, but Inconsistent (battery or wiring issues)	Non-functional or Incomplete (battery and wiring issues)		
Mechanical Systems (drivetrain, arm, claw)	Completely functional and consistent mechanical systems	Consistently functional mechanical systems	Functional, but inconsistent mechanical systems	Non-functional or incomplete/ unsafe mechanical systems		
Unifying Themes (This area emphasizes the Interaction of Science, Technology, & Human Endeavor)						
Communication (written, electronic and/or oral as defined by the teacher)	Sophisticated and highly efficient communica-tion for stated audiences	Purposeful, consistent, effective communica-tion	Purposeful, partially consistent communica-tion	Communi-cation very inconsistent and lacks purpose		
Teamwork	Teamwork that maximizes outcomes is evident	Team members define roles, goals, & work together	Team members partially define roles, goals, & work together	Participants function separately within a group		

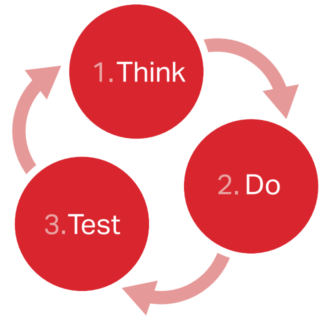
Rubric Adapted from Rubric and Evaluation Criteria for Standards-Based Robotics Competitions & Related Learning Experiences – TSA, 2005

C.6

Your First Robot Idea Book Page: Standard Drive Base

Student Name(s): ____

Teacher/Class: ____________________ Date: _________ Page #: _____



Instructions:

Follow the steps on this page while you use the Clawbot IQ Instructions (build steps 1-19) to build the Standard Drive Base.

1. "THINK" - Here is where your "idea" or "problem" is written/drawn:
Examples: "Idea - I want to build Clawbot's base" or "Problem - right side wheels don't turn."

____

____

Draw your idea or problem here, too, if it helps you to describe it.

2. "DO" – Here is where you list your task or tasks that your "THINK" step created:
Examples: "Use Clawbot IQ Instructions to build the Standard Drive Base" or "Check right side wheels, shaft, shaft collars, Smart Motor, and cable connection to Robot Brain."

____

____

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3. "TEST" – After your "DO" step is done, test your design. Write down your observations:

____

____

Does your Standard Drive Base drive and function like is expected? YES NO

If you answered "YES" - Congratulations! You will score well on the Build Rubric. You may now move on to build the rest of the Clawbot IQ or move on to other lessons.

If you answered "NO" - Use your observations above and the Build Rubric to determine what problem exists, then use another copy of this page to help solve that problem. Keep repeating this "THINK-DO-TEST" process, until your Robot Base functions correctly.

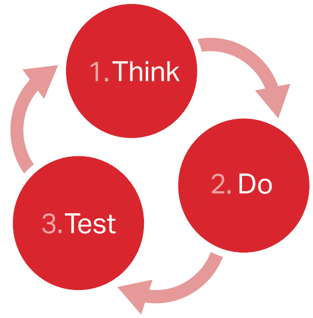
Problems ARE NOT failures. They are an expected part of the design process!

C.6 cont.

Your First Robot Idea Book Page: Clawbot IQ Tower

Student Name(s): ____

Teacher/Class: ____________________ Date: _________ Page #: _____



Instructions:

Follow the steps on this page while you use the Clawbot IQ Instructions (build steps 20-38) to build the Clawbot IQ Tower (after Robot Base is done).

1. "THINK" - Here is where your "idea" or"problem" is written/drawn: Examples: "Idea – I want to build Clawbot IQ's Tower." Or "Problem – Tower doesn't fit on the Standard Drive Base correctly."

Draw your idea or problem here, too, if it helps you to describe it.

2. "DO" – Here is where you list your task or tasks that your "THINK" step created: Examples: "Use Clawbot IQ Instructions to build Clawbot IQ Tower" or "Double check Tower assembly instructions for accuracy of my build."

3. "TEST" – After your "DO" step is done, test your design. Write down your observations:

Does your Clawbot IQ Tower function like is expected? YES NO

If you answered "YES" - Congratulations! You will score well on the Build Rubric. You may now move on to build the rest of Clawbot IQ or move on to other lessons.

If you answered "NO" - Use your observations above and the Build Rubric to determine what problem exists, then use another copy of this page to help solve that problem. Keep repeating this "THINK-DO-TEST" process, until your Tower functions correctly.

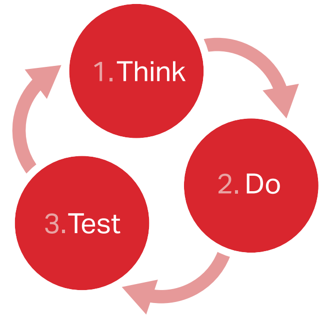
Problems ARE NOT failures. They are an expected part of the design process!

C.6 cont.

Your First Robot Idea Book Page: Clawbot IQ Object Holder

Student Name(s): ____

Teacher/Class: ____________________ Date: __________ Page #: _____



Instructions:

Follow the steps on this page while you use the Clawbot IQ Instructions (build steps 39-48) to build the Clawbot IQ Object Holder (after Base and Tower are done).

1. "THINK" - Here is where your "idea" or "problem" is written/drawn:
Examples: "Idea - I want to build the Clawbot IQ's Object Holder" or "Problem - Object Holder not correctly assembled."

Draw your idea or problem here, too, if it helps you to describe it.

2. "DO" – Here is where you list your task or tasks that your "THINK" step created:
Examples: "Use Clawbot Instructions to build Clawbot IQ Object Holder" or"Check Object Holder parts, compare to instructions, make necessary changes."

3. "TEST" – After your "DO" step is done, test your design. Write down your observations:

Does your Clawbot Object Holder function like is expected? YES NO

If you answered "YES" - Congratulations! You will score well on the Build Rubric. You may now move on to build the rest of Clawbot IQ or move on to other lessons.

If you answered "NO" - Use your observations above and the Build Rubric to determine what problem exists, then use another copy of this page to help solve that problem. Keep repeating this "THINK-DO-TEST" process, until your Object Holder functions correctly.

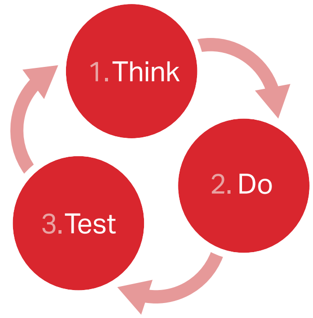
Problems ARE NOT failures. They are an expected part of the design process!

C.6 cont.

Your First Robot Idea Book Page: Clawbot IQ Claw

Student Name(s): ____

Teacher/Class: ____________________ Date: _________ Page #: _____



Instructions:

Follow the steps on this page while you use the Clawbot IQ Instructions (build steps 49-87) to build the Clawbot IQ Claw (after Robot Base, Tower, and Object Holder are done).

1. "THINK" - Here is where your "idea" or "problem" is written/drawn: Examples: "Idea - I want to build the Clawbot IQ's Claw" or "Problem - Claw doesn't open or close."

Draw your idea or problem here, too, if it helps you to describe it.

2. "DO" – Here is where you list your task or tasks that your "THINK" step created: Examples: "Use Clawbot IQ Instructions to build Clawbot IQ Tower" or "Check claw motor, shaft, shaft collars, and cable connection to Robot Brain."

3. "TEST" – After your "DO" step is done, test your design. Write down your observations:

Does your Clawbot IQ Claw function like is expected? YES NO

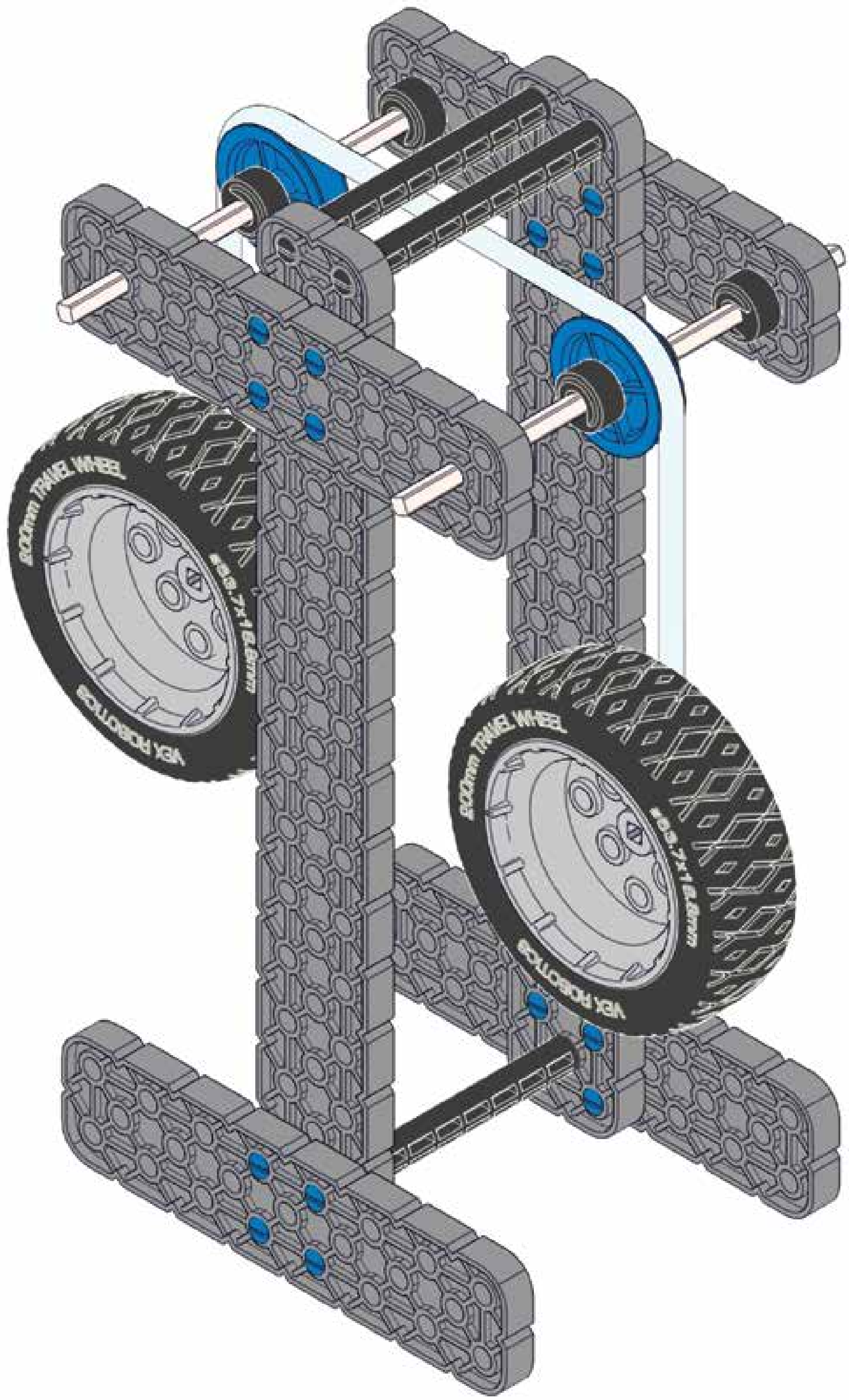
If you answered "YES" - Congratulations! You will score well on the Build Rubric. You may now move on to other lessons.

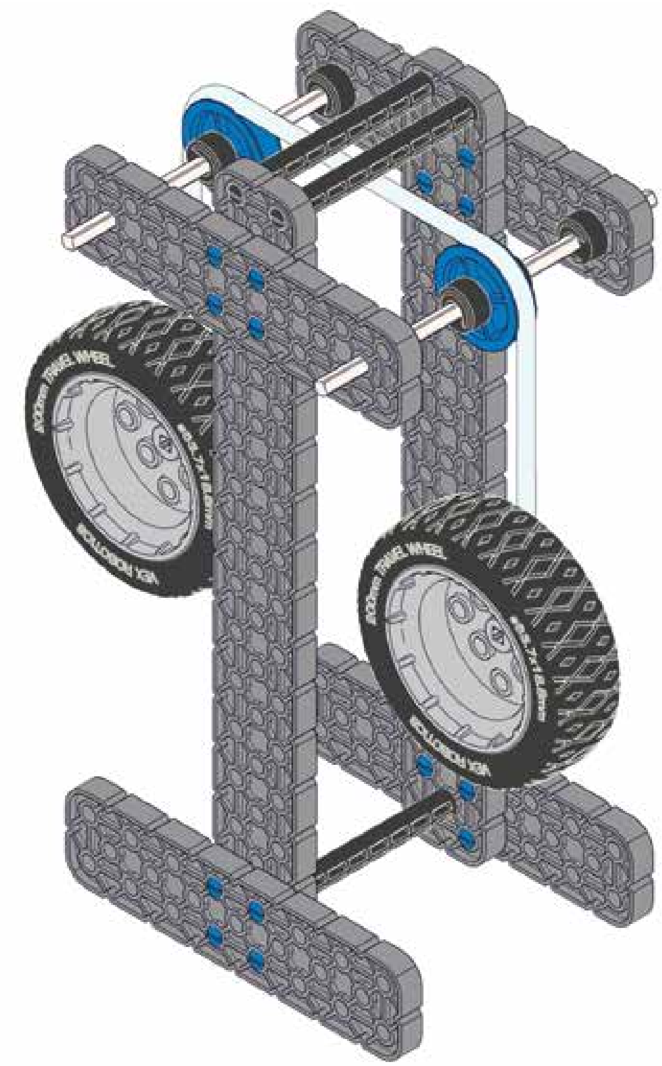
If you answered "NO" - Use your observations above and the Build Rubric to determine what problem exists, then use another copy of this page to help solve that problem. Keep repeating this "THINK-DO-TEST" process, until your Claw functions correctly.

Problems ARE NOT failures. They are an expected part of the design process!

D

Simple Machines & Motion





D.1

Simple Machines & Motion

Unit Overview:

In this unit you will learn about the six types of simple machines, a seventh machine called a pendulum, and all of the scientific concepts and terms that go along with these machines. Simple machines are the basis for all mechanical systems, no matter how complex they may become.

Unit Content:

- Six Types of Simple Machines: Wheel & Axle, Inclined Plane, Wedge, Lever, Pulley, and Screw
- Simple Motion: The Pendulum
- Key Terms: Work, Force, Fulcrum, Simple Harmonic Motion

Unit Activities:

- Matching Exercise
- Sample Simple Machines build with assembly instructions
- Completion of Build and Idea Book Page for Machine Design and/or Robot Design

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

D.2

Simple Machines & Motion

This unit focuses on the most basic building blocks of design, simple machines, and motion. The basic knowledge of simple machines and motion allows students to better understand how things work, provides a foundation for designing mechanisms, and is the first step in learning the principles of mechanical design.

Simple Machines

Simple Machines are tools used to make work easier. In science, **work** is defined as a force acting on an object to move it across a distance. Pushing, pulling, and lifting are common forms of work. A **force** is any push or pull that causes an object to change its position (movement), direction, or shape.

Inclined Plane

Lever

Wedge

Screw

Pulley

Wheel and Axle

D.3

The Six Types of Simple Machines:

Wheel & Axle - Makes work easier by moving objects across distances. The wheel (or round end) turns with the axle (or cylindrical post) causing movement. On a wagon, for example, a container rests on top of the axle.

Inclined Plane - A flat surface (or plane) that is slanted, or inclined, so it can help move objects across distances. A common inclined plane is a ramp.

Wedge - Instead of using the smooth side of the inclined plane to make work easier, you can also use the pointed edges to do other kinds of work. When you use the edge to push things apart, this movable inclined plane is called a wedge. An ax blade is one example of a wedge.

Lever - Any tool that pries something loose is a lever. Levers can also lift objects. A lever is an arm that "pivots" (or turns) against a **fulcrum** (the point or support on which a lever pivots). Think of the claw end of a hammer that you use to pry nails loose; it's a lever. A see-saw is also a lever.

D.3 cont.

Pulley - Instead of an axle, a wheel could also rotate a rope, cord, or belt. This variation of the wheel and axle is the pulley. In a pulley, a cord wraps around a wheel. As the wheel rotates, the cord moves in either direction. Attach a hook to the cord, and now you can use the wheel's rotation to raise and lower objects, making work easier. On a flagpole, for example, a rope is attached to a pulley to raise and lower the flag more easily.

Screw - When you wrap an inclined plane around a cylinder, its sharp edge becomes another simple tool: a screw. If you put a metal screw beside a ramp, it may be hard to see similarities, but a screw is actually just another kind of inclined plane. One example of how a screw helps you do work is that it can be easily turned to move itself through a solid space like a block of wood.

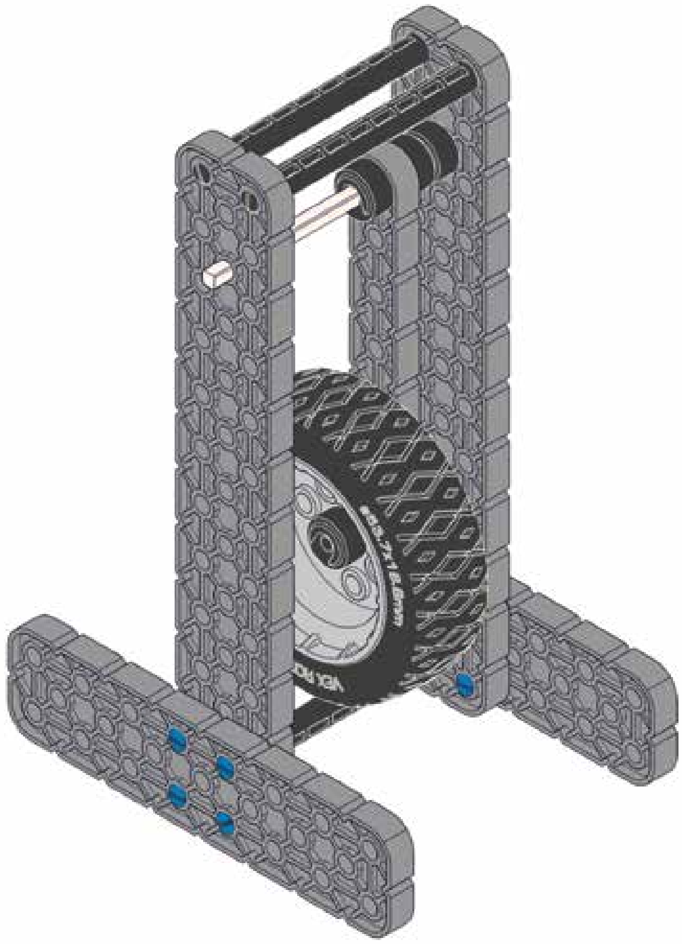
D.4

Simple Motion: The Pendulum

Simple Motion (more fully known as Simple Harmonic Motion) is what happens when an object moves in a non-complex periodic way. This means that:

- The object experiences a force that moves it
- The movement occurs, reaching some maximum value
- The object returns to its "original" conditions
- The process repeats

Let's take the example of a pendulum and consider what happens. A pendulum is defined as a body suspended from a fixed point so that it can swing back and forth under the influence of gravity as a force.



When a pendulum is started, it swings (accelerates) down under the influence of gravity. Gravity is the attraction between two masses, such as the earth and an object on its surface. At the bottom of its arc, the pendulum then swings up on the other side. It continues to move up (and decelerate) until it stops. The pendulum then begins to swing back down, reaching some maximum velocity at the bottom of its arc before swinging back up to where it began. The pendulum has gone through one complete cycle of its motion, and because it is a repetitive cycle, it can be said to be simple harmonic motion. Friction (the force that resists motion through the rubbing of one object against another) will eventually stop the pendulum, but not before several cycles have passed.

D.5

Simple Machines & Motion Matching Exercise

Student Name(s): ____

Teacher/Class: __________________________________ Date: ____________

Part I Instructions:

Match terms from the word bank to the correct definition by writing terms on the correct line. Each term is only used once.

Part I Word Bank:

Force	Friction	Gravity	Pendulum
Simple Harmonic Motion	Simple Machines	Work	

________________ are tools used to make work easier.

________________ is a force acting on an object to move it across a distance.

A ______________ is any push or pull that causes an object to change its position, direction, or shape.

________________ is what happens when an object is in motion in a non-complex periodic way.

A ______________ is a body suspended from a fixed point so that it can swing back and forth under the influence of gravity.

________________ is the attraction between two masses, such as the earth and an object on its surface.

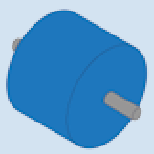
________________ is the force that resists motion through the rubbing of one object against another.

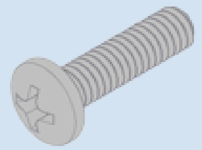
Part II Instructions:

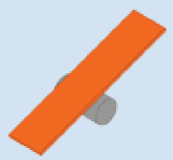
Match terms from the word bank and label correctly below each picture.

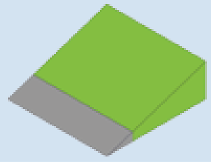
Part II Word Bank:

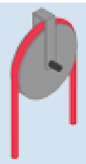
Inclined Plane   Lever   Pulley   Screw   Wedge   Wheel & Axle











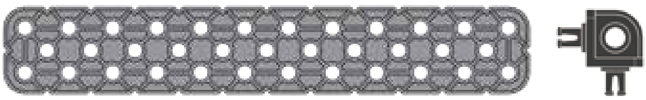
D.6

Simple Machines & Motion Sample Assemblies

Inclined Plane Assembly

1

1x
4x



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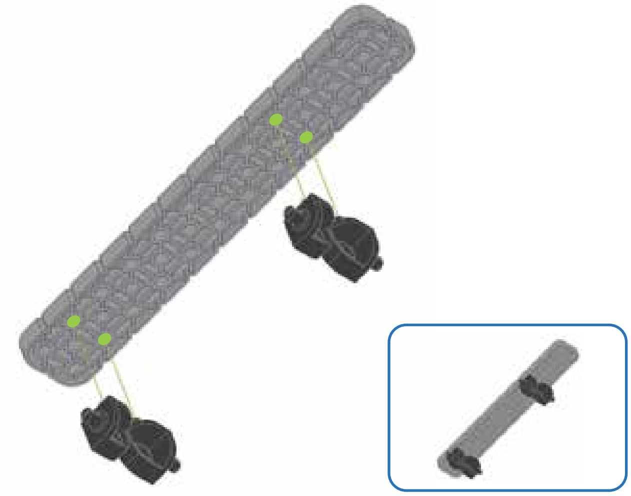
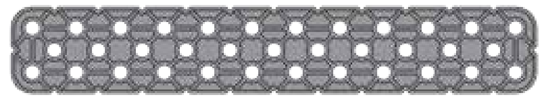
228-2500-127



2

2x



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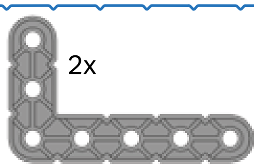
3

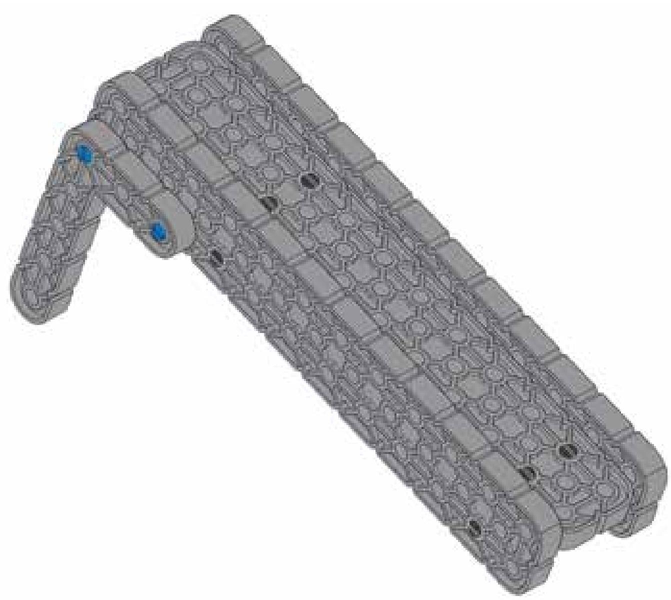
4x

228-2500-060

2x



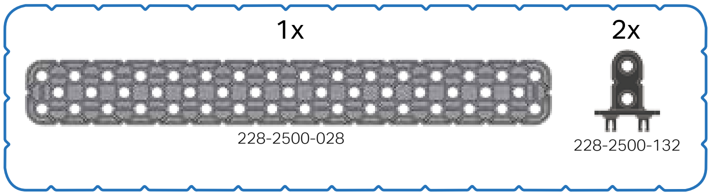
228-2500-150

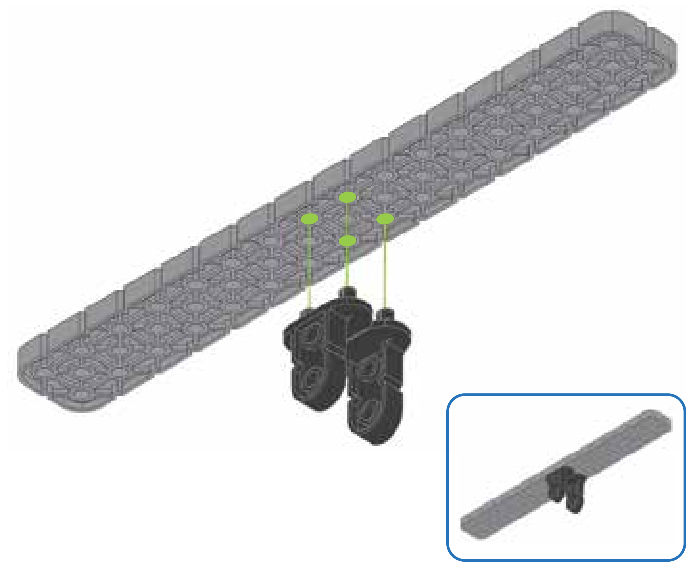


D.6 cont.

Lever Assembly

1





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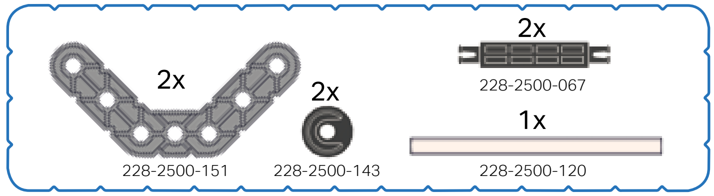

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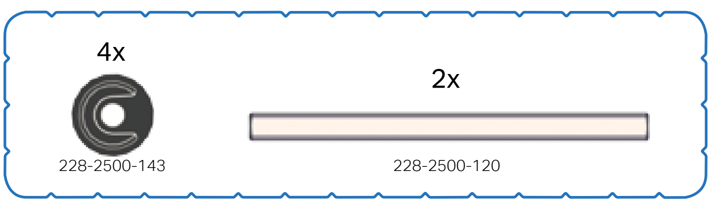

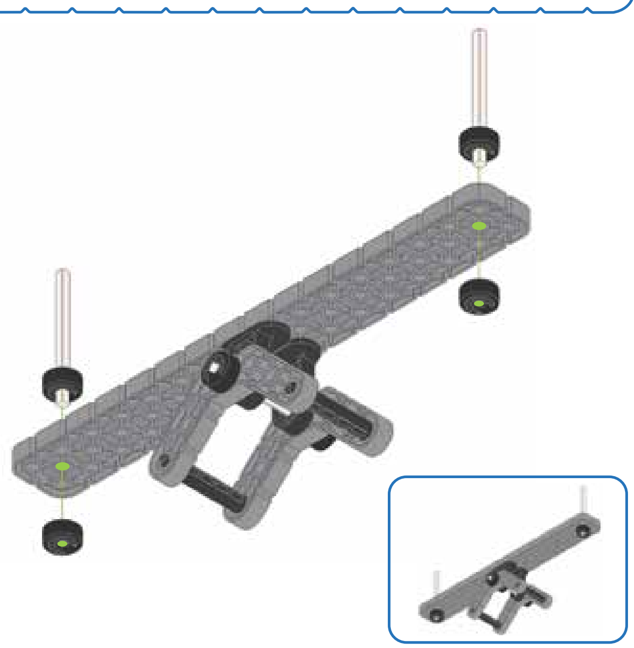

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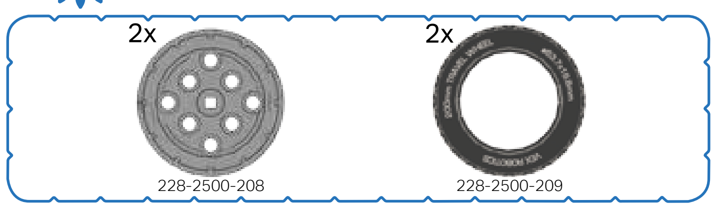
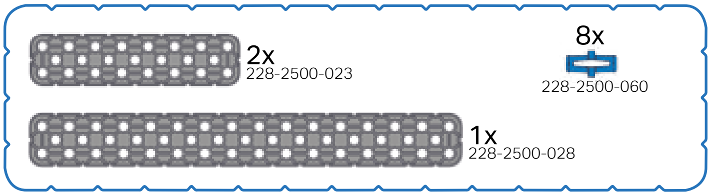
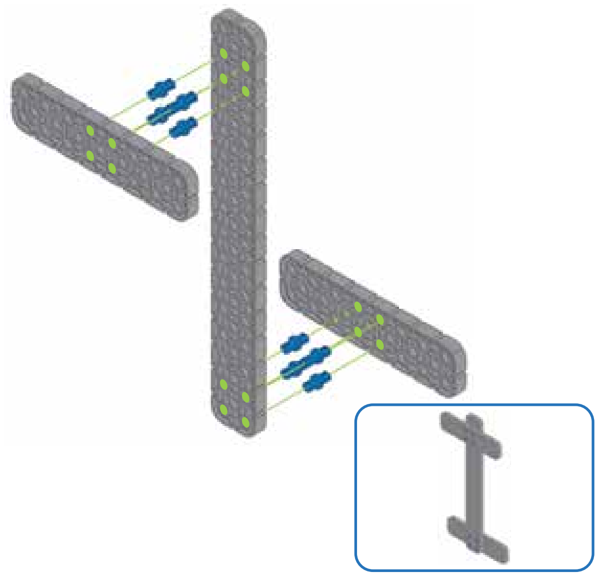


D.6 cont.

Pulley Assembly

1





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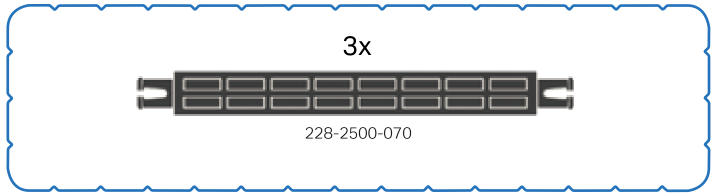

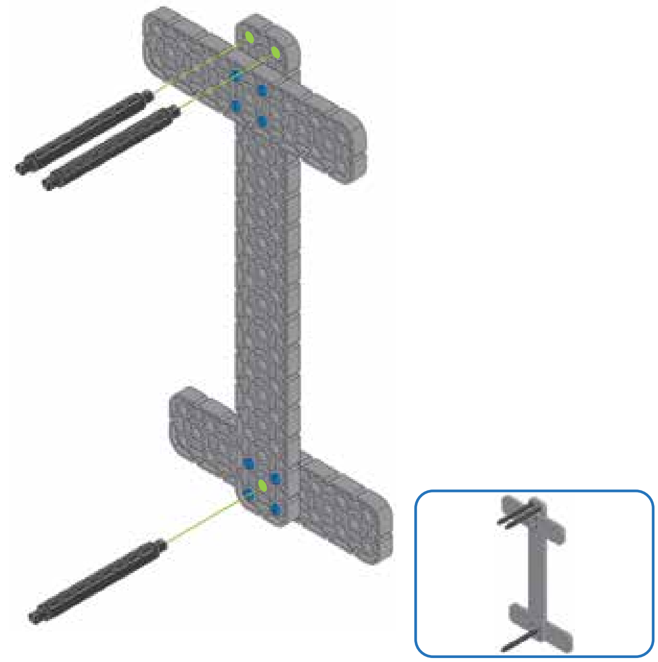

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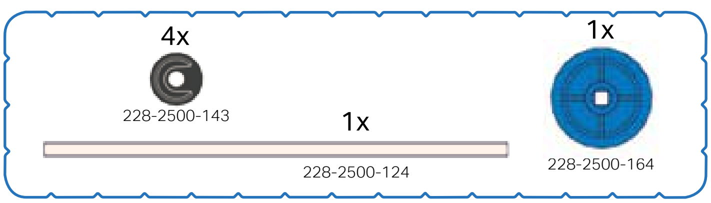

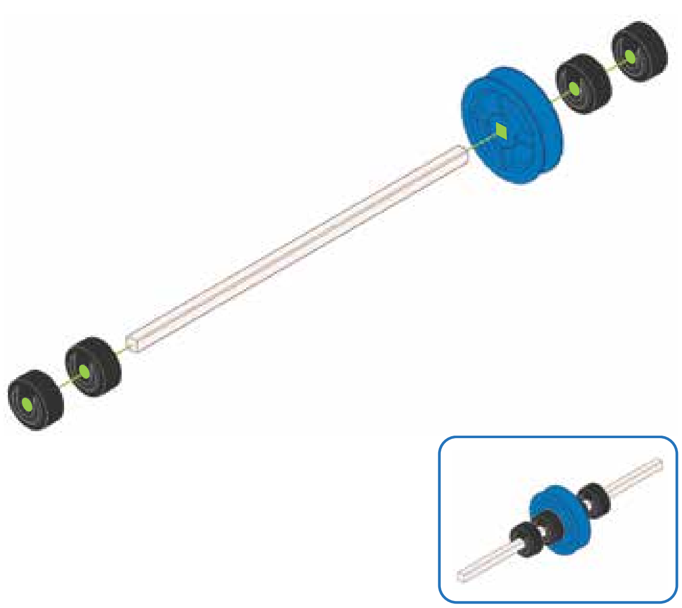

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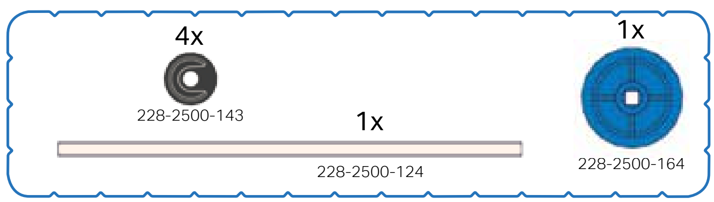

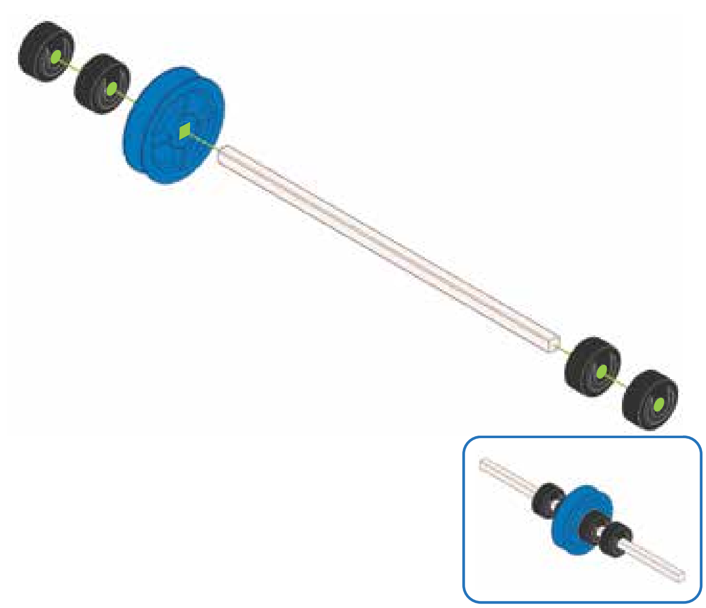

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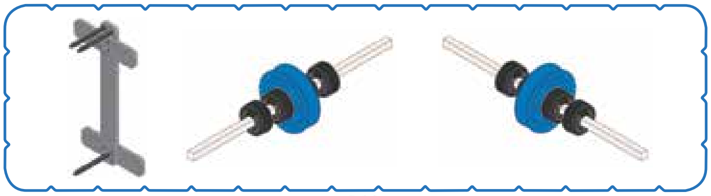

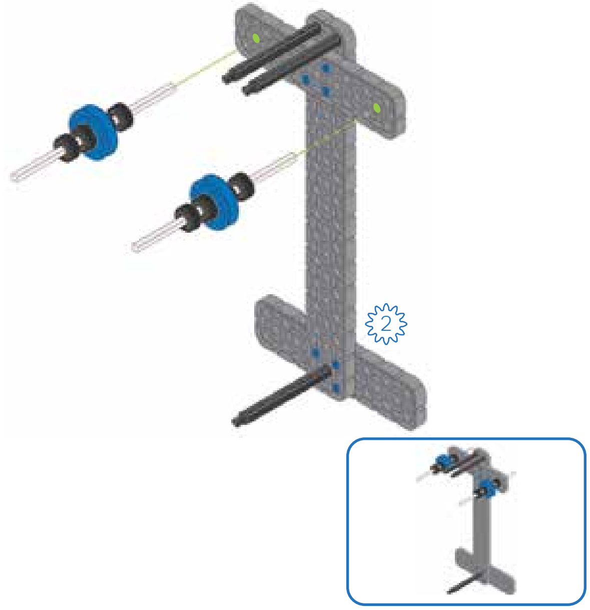
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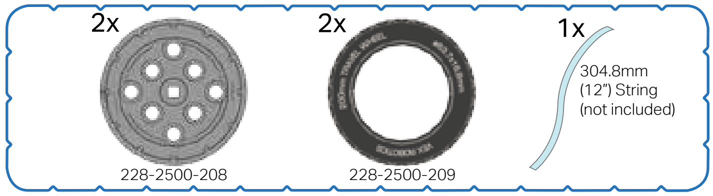
6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228-2500-208
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(12") String
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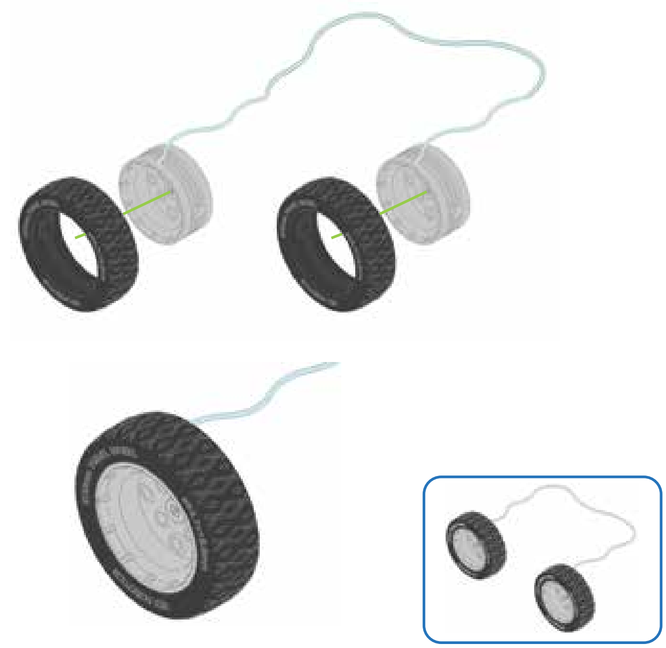

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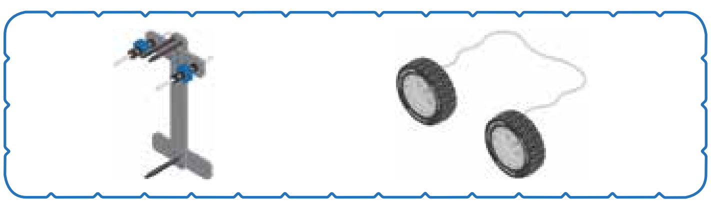

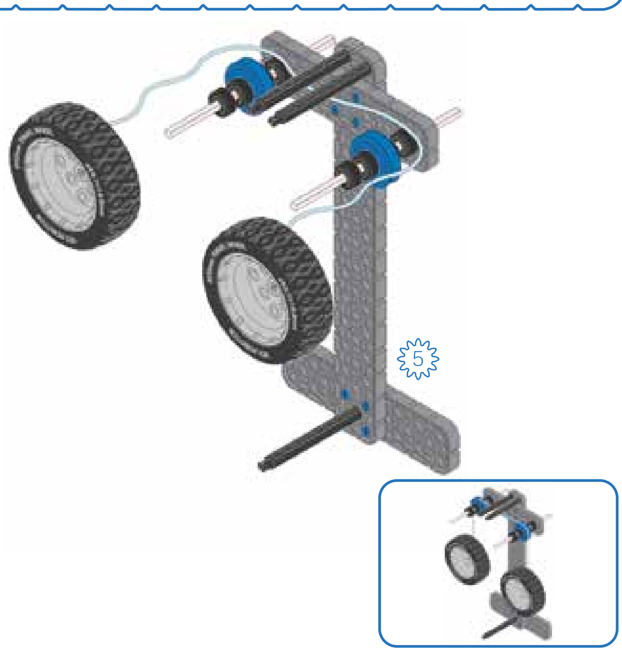
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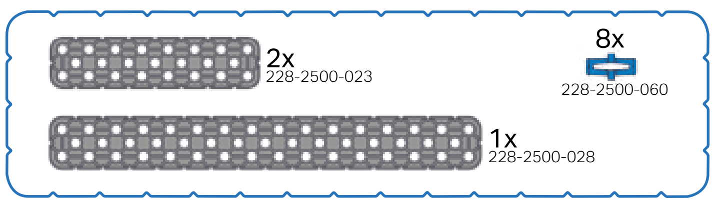
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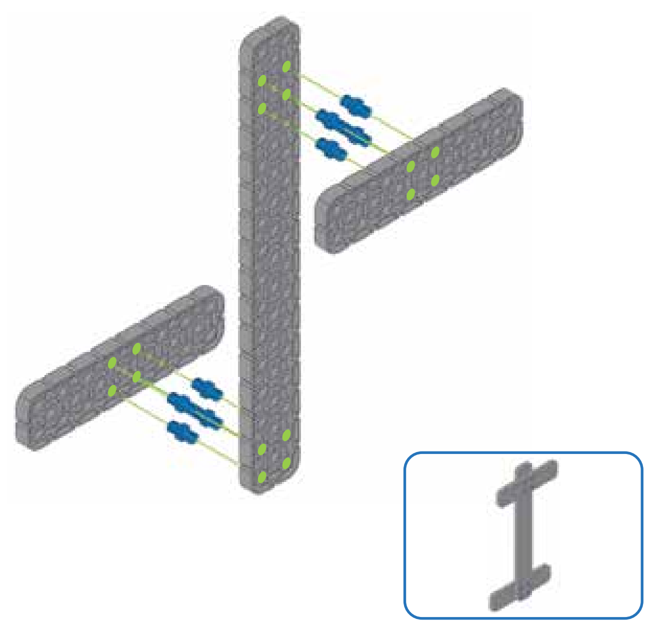

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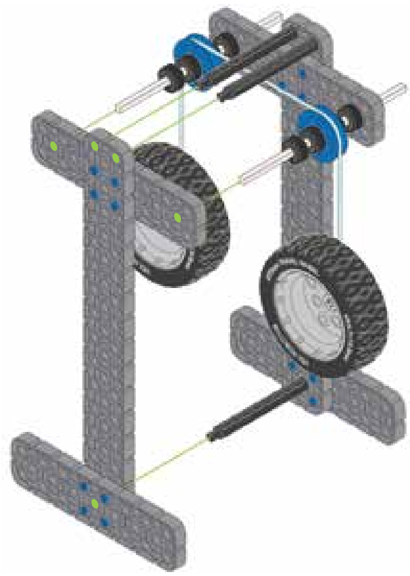

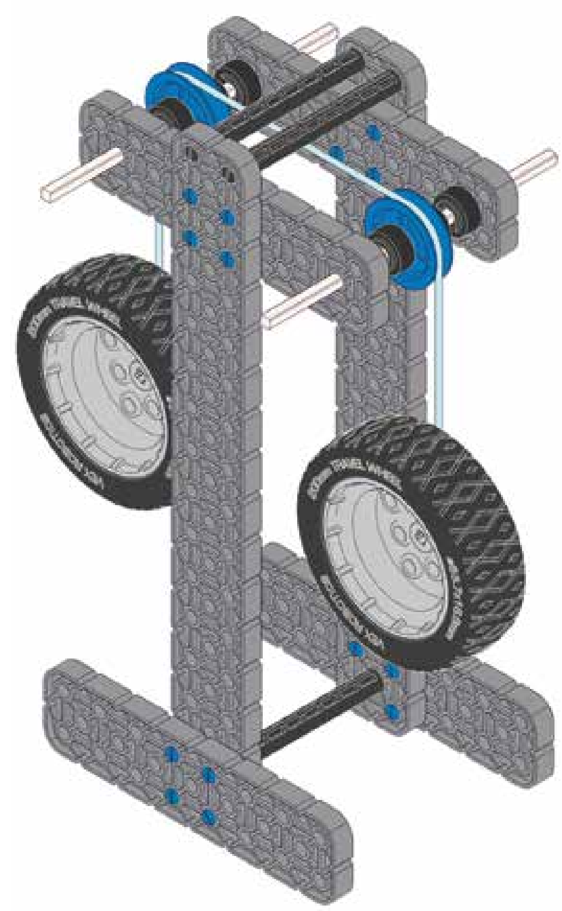

Pendulum Assembly

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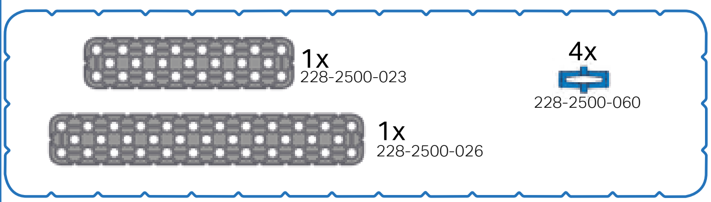

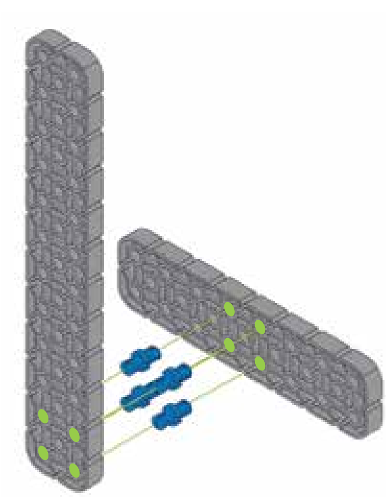

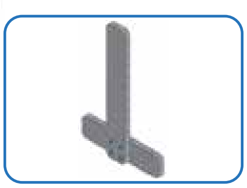

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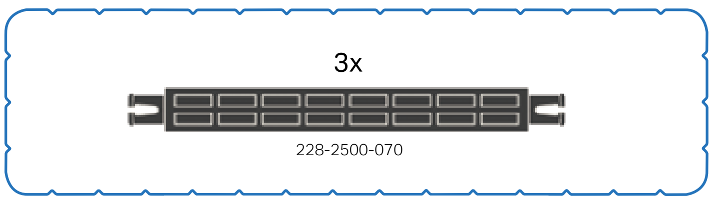

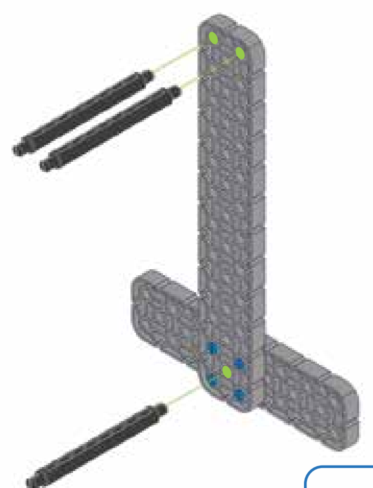

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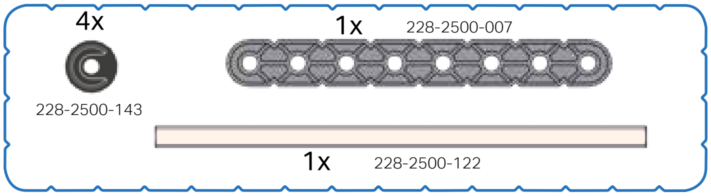
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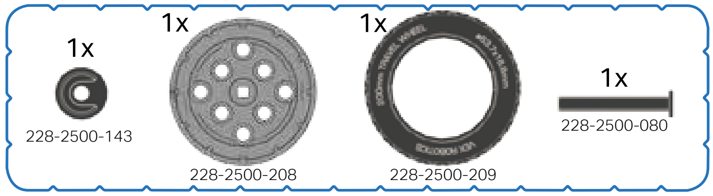
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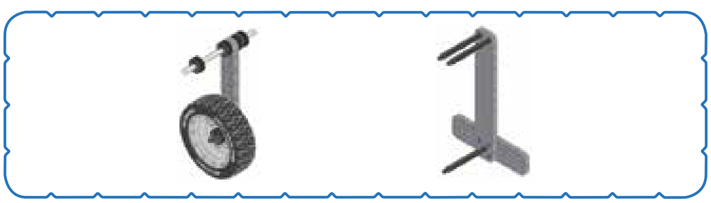


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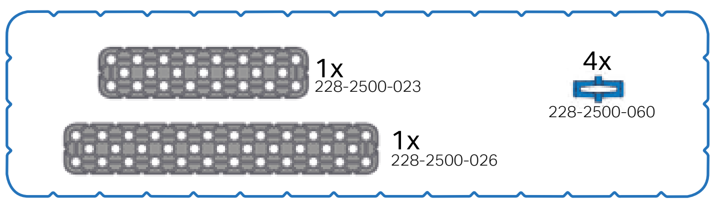
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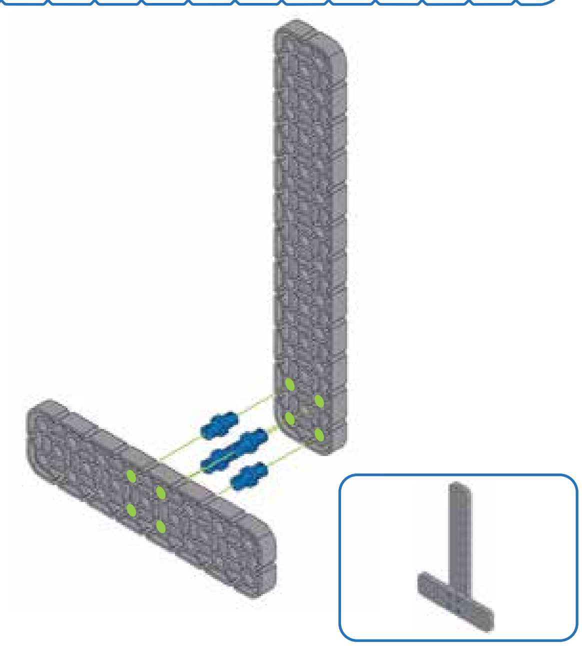

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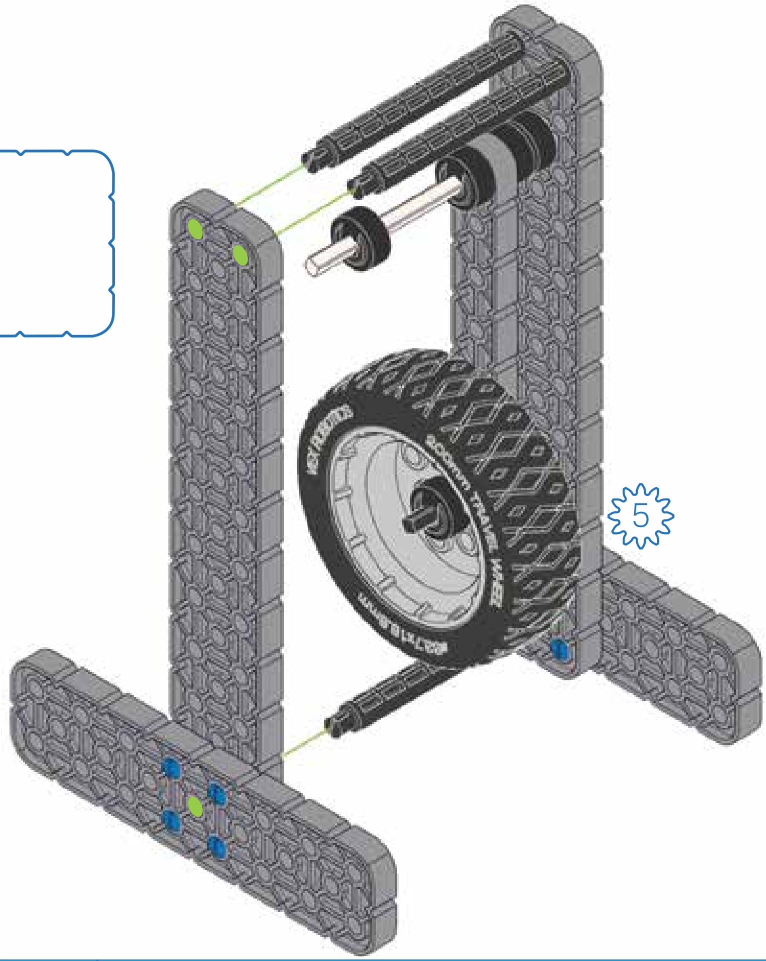
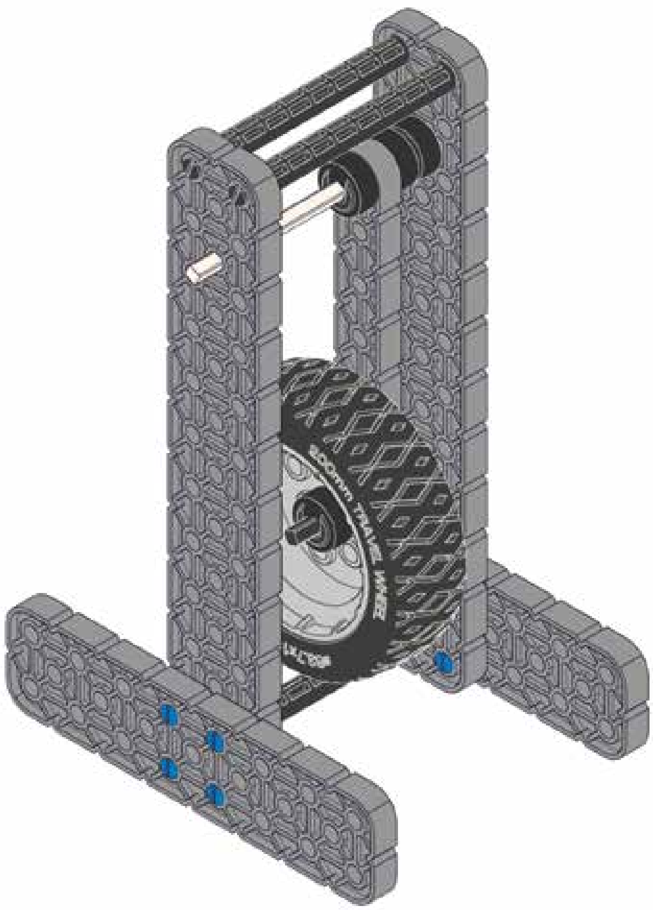


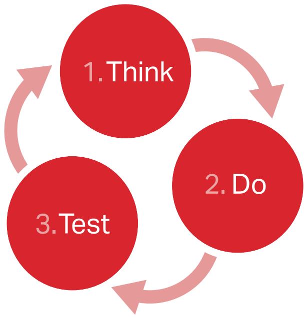


D.7

Simple Machines & Motion Idea Book Page Exercise: Machine Design

Student Name(s): ______________________________

Teacher/Class: ______________ Date: ________ Page #: ____



Instructions:

After you have completed building the Simple Machines & Motion Sample Assemblies your teacher may ask you to design a simple machine or pendulum of your own. Following your teacher's instructions, use this Idea Book Exercise page to document your design.

1. "THINK" - Here is where your "idea" or "problem" is written/drawn:

Draw your idea and/or problem here, too, if it helps you to describe it. What might your solution look like?

2. "DO" – Here is where you list your task or tasks that your "THINK" step created:

3. "TEST" – After your "DO" step is done, test your design. Write down your observations:

Does your simple machine/pendulum function like you expected? YES NO

If you answered "YES" - Congratulations! You may now move on to repeat this task with a new simple machine/pendulum or move on to other lessons.

If you answered "NO" - Use your observations above to determine what problem exists, then use another copy of this page to help solve that problem. Keep repeating this "THINK-DO-TEST" process, until your robot completes the task.

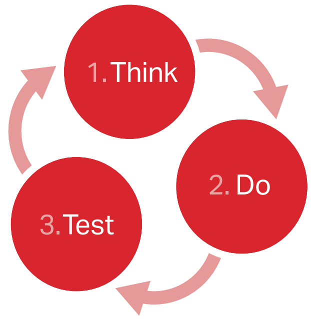
Problems ARE NOT failures. They are an expected part of the design process!

D.7 cont.

Simple Machines & Motion Idea Book Page Exercise: Robot Design

Student Name(s): ____

Teacher/Class: ____________________ Date: _________ Page #: _____



Instructions:

Starting with the Clawbot IQ Robot Base, add one simple machine or pendulum so the result is a teleoperated robot that moves a tennis ball, cube, or similar round object from a floor or table top onto a 1-inch to 2-inch high platform (a book will suffice for this exercise). Your teacher may assign which simple machine/pendulum you are to use or you may get to pick.

1. "THINK" - Here is where your "idea" or "problem" is written/drawn:

____

____

Draw your idea and/or problem here, too, if it helps you to describe it. What might your solution look like?

2. "DO" – Here is where you list your task or tasks that your "THINK" step created:

____

____

____

____

3. "TEST" – After your "DO" step is done, test your design. Write down your observations:

____

____

Does your simple machine/pendulum function like you expected? YES NO

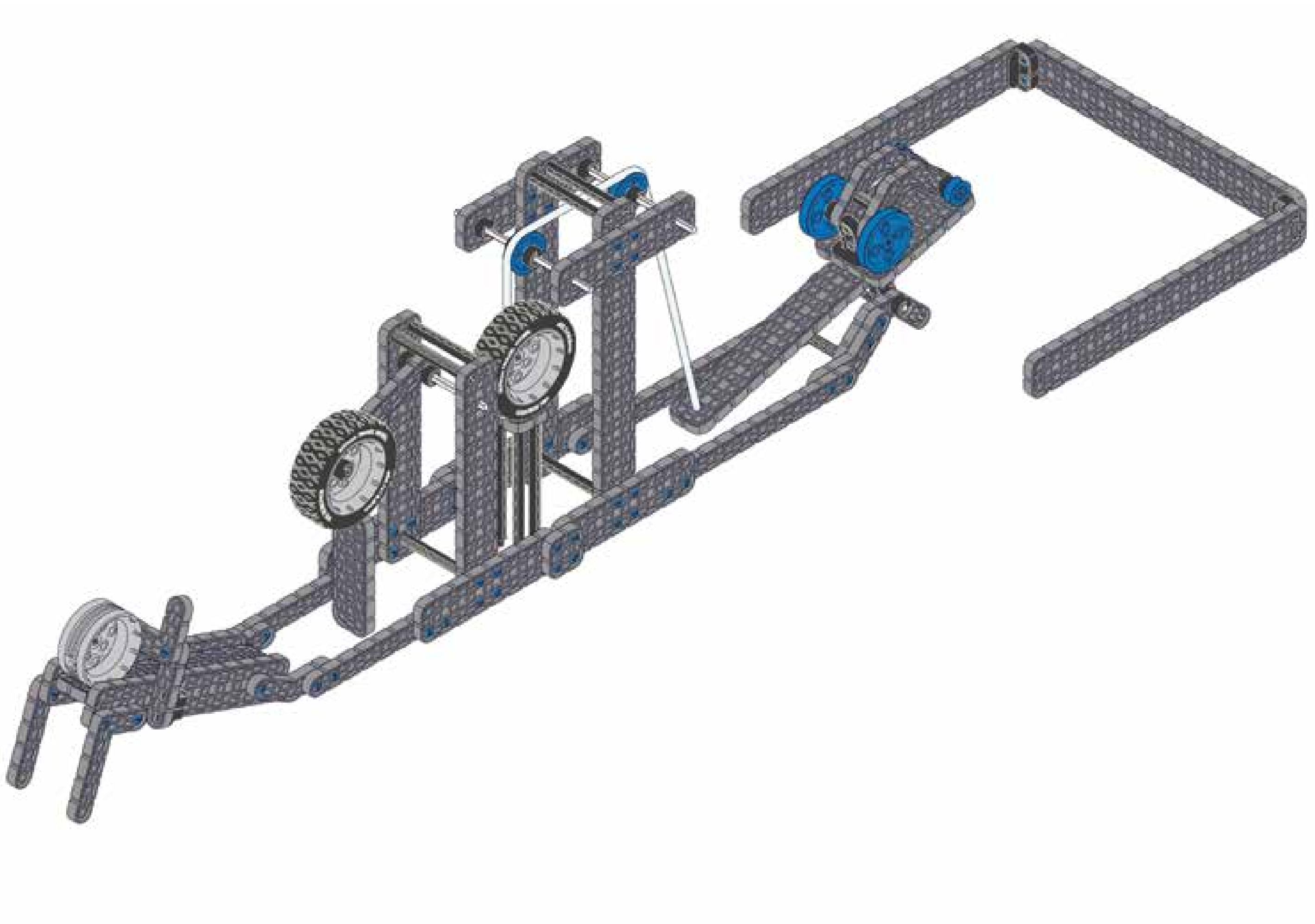
If you answered "YES" - Congratulations! You may now move on to repeat this task with a new simple machine/pendulum or move on to other lessons.

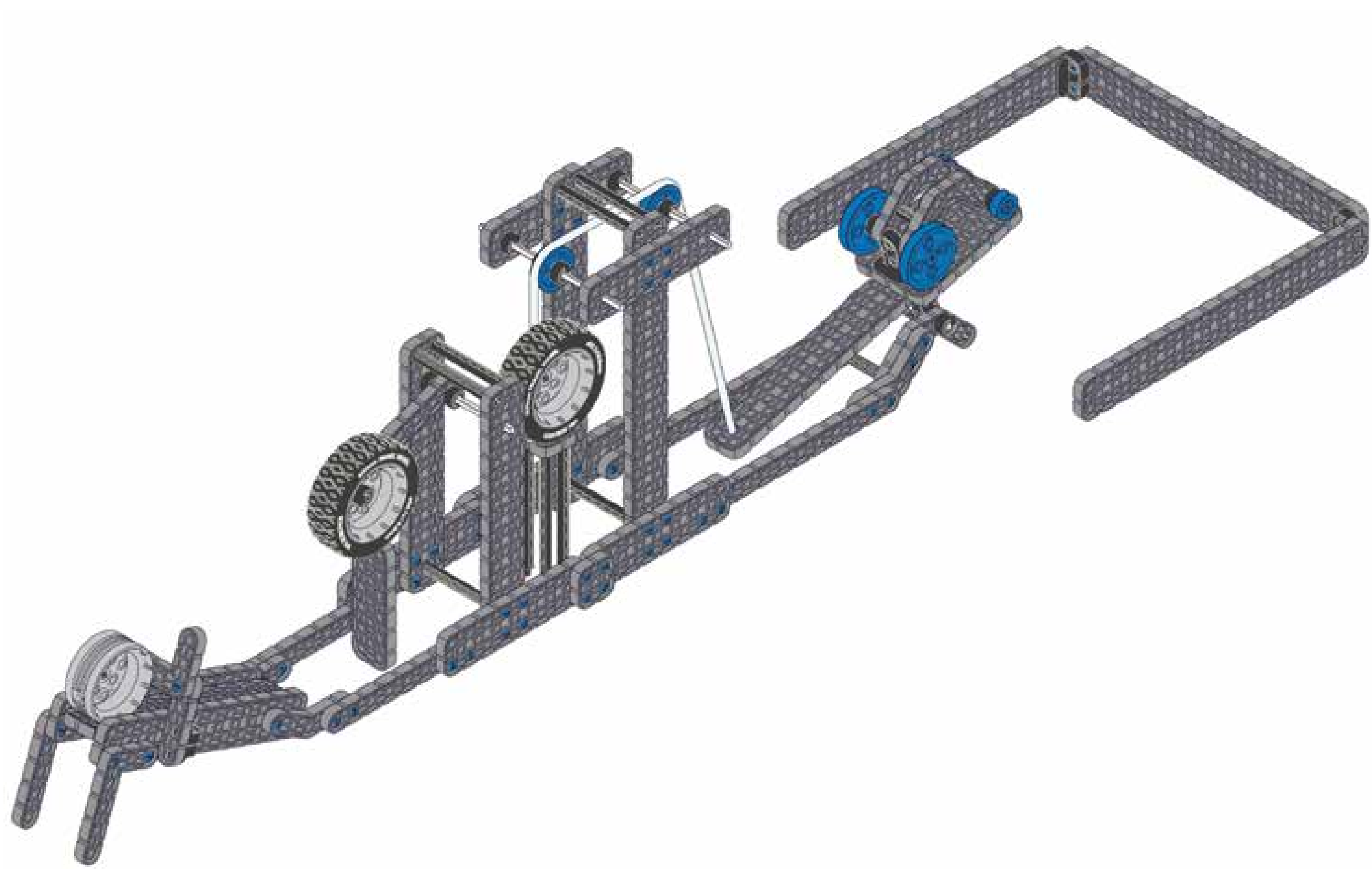
If you answered "NO" - Use your observations above to determine what problem exists, then use another copy of this page to help solve that problem. Keep repeating this "THINK-DO-TEST" process, until your robot completes the task.

Problems ARE NOT failures. They are an expected part of the design process!

E

Chain Reaction Challenge





E.1

Chain Reaction Challenge

Unit Overview:

In this unit you will use your knowledge of simple machines to learn about, build, and test Chain Reaction Devices.

Unit Content:

- What is a Chain Reaction Device?
- Sample Chain Reaction Device Assembly Instructions
- Chain Reaction Challenge Rules

Unit Activities:

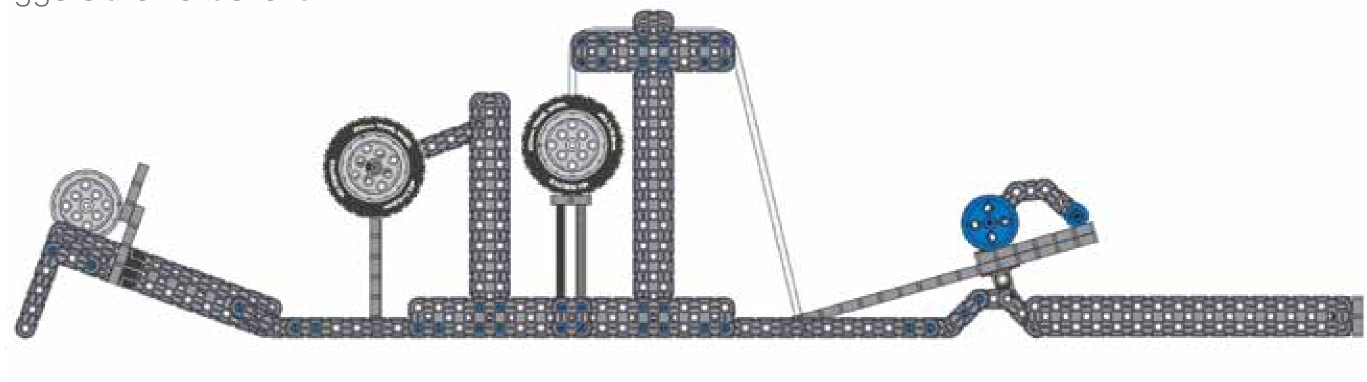
- Optional: Building The Sample Chain Reaction Device (see your teacher for details)
- Chain Reaction Challenge Device Build using Chain Reaction Device Rubric (unpowered, powered, or both – see your teacher for details)
- Completion of Idea Book Pages with device build and testing

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

E.2

What is a Chain Reaction Device?

A Chain Reaction Device is a complex machine that performs a very simple task in a very complicated way. A Chain Reaction is a series of events so related to each other that each event triggers the next event.



In this unit you will use a series of simple machine and/or pendulum assemblies to create Chain Reaction Devices. Each individual simple machine/pendulum assembly is known as a Stage of the overall device. Students will also build and/or design at least one Trigger Mechanism to activate the operation/chain reaction of their device(s) in this unit.

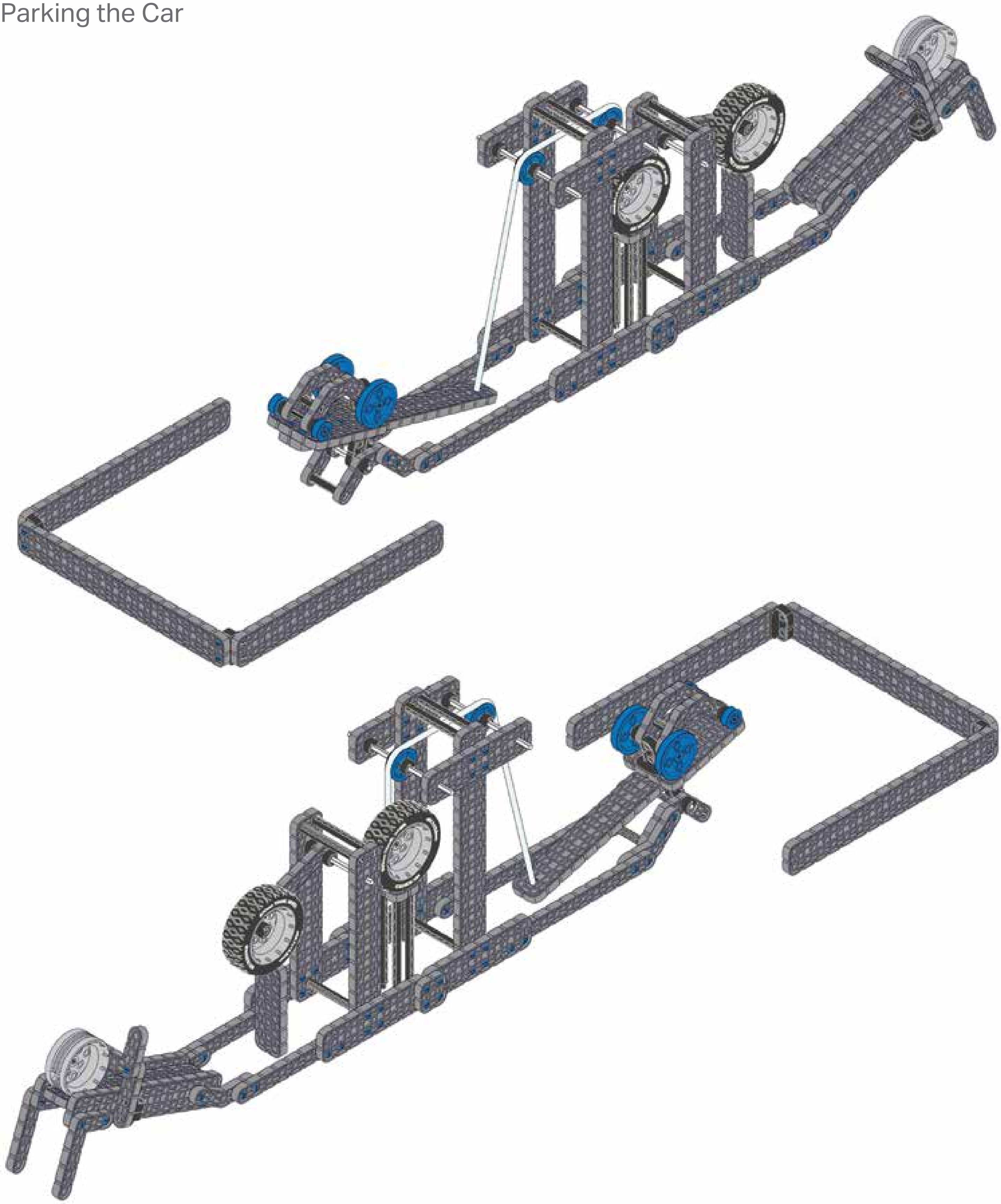
Assembling the Sample Chain Reaction Device

Your teacher may instruct you to assemble and test the sample unpowered Chain Reaction Device next.

E.3

Sample Chain Reaction Device Instructions

Parking the Car

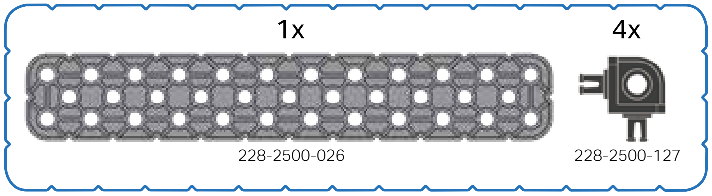


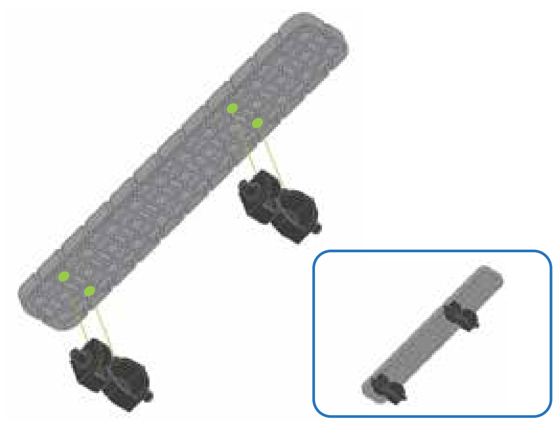
E.3 cont.

Inclined Plane Assembly

Note for Teachers: This sample Chain Reaction Device is built using the Inclined Plane, Pulley, and Pendulum from the Simple Machines & Motion Sample Assemblies. The Lever in this sample Chain Reaction Device has its own assembly instructions, however this lever can also be created by modifying the lever that is part of the Simple Machines & Motion Sample Assemblies.

1





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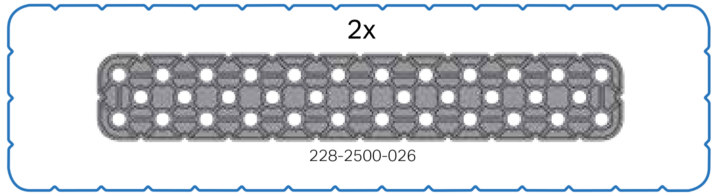

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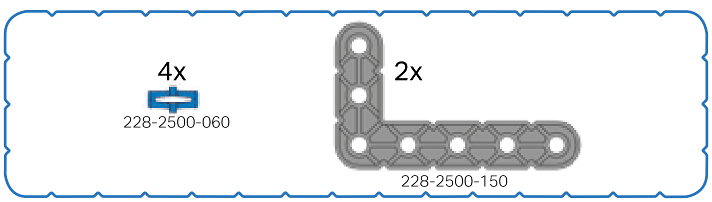

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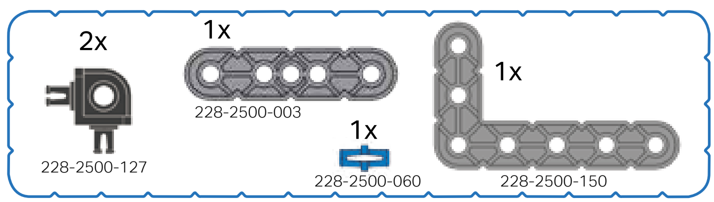

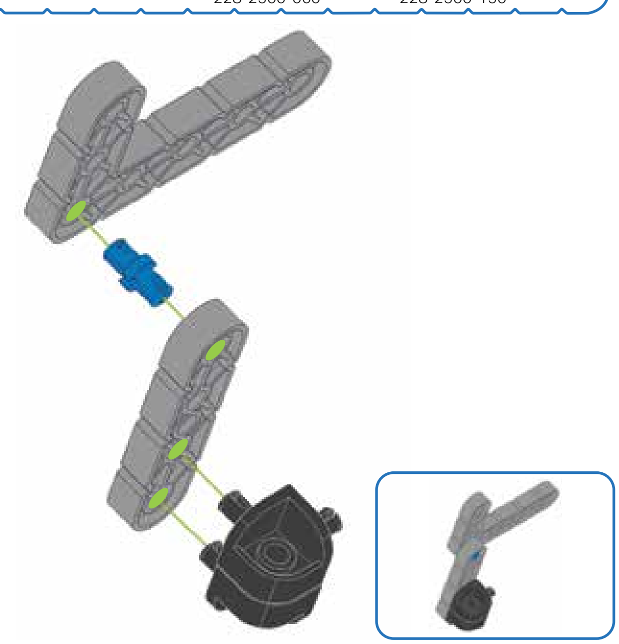

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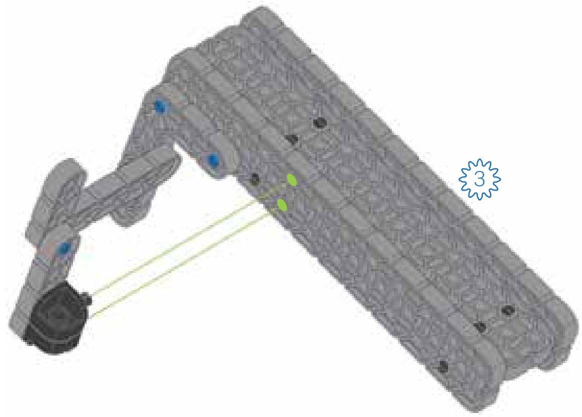

Lever Assembly

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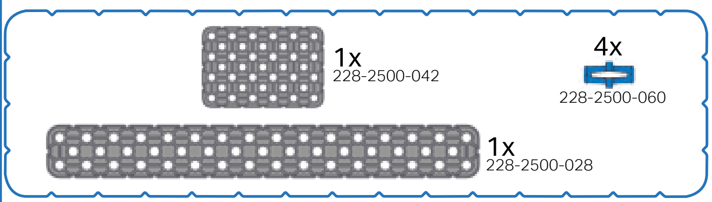

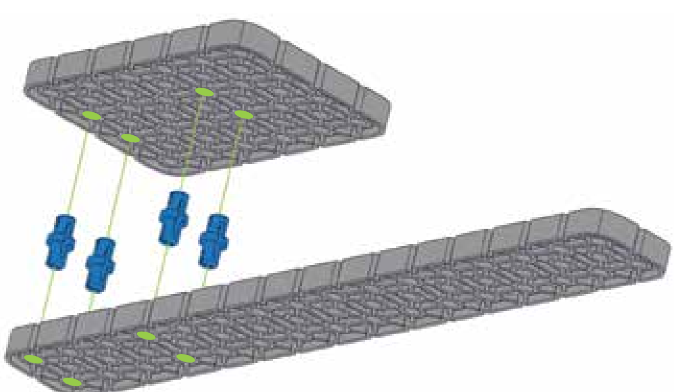

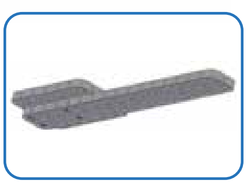

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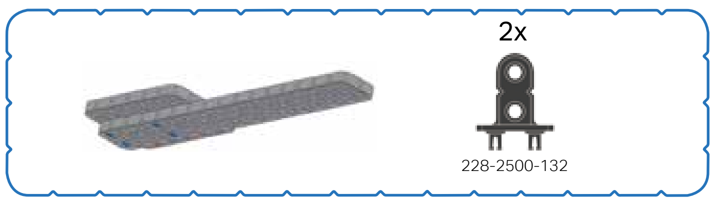

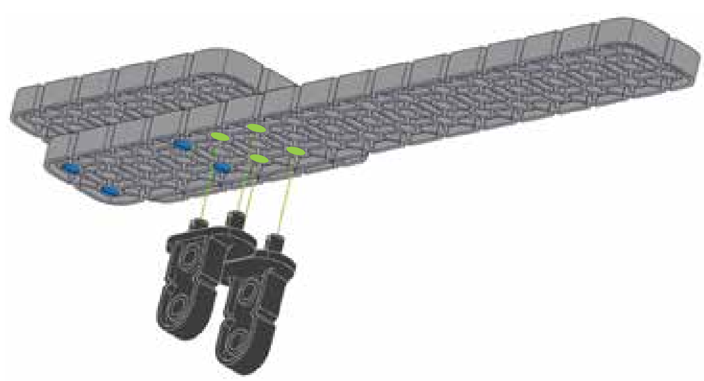

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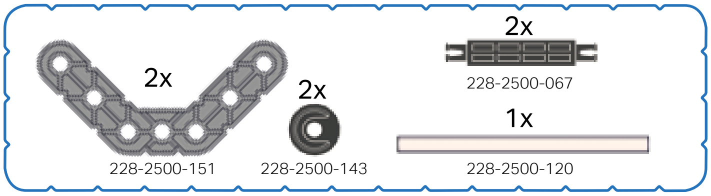

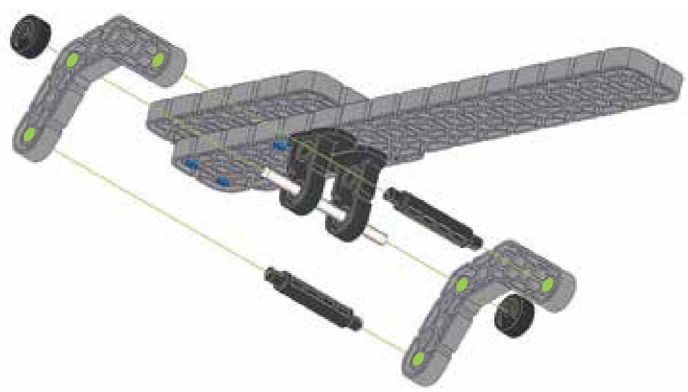

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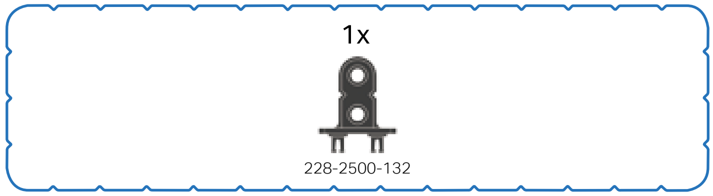
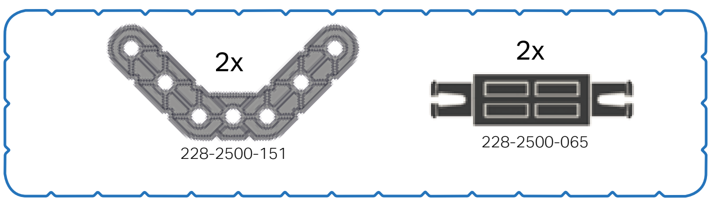
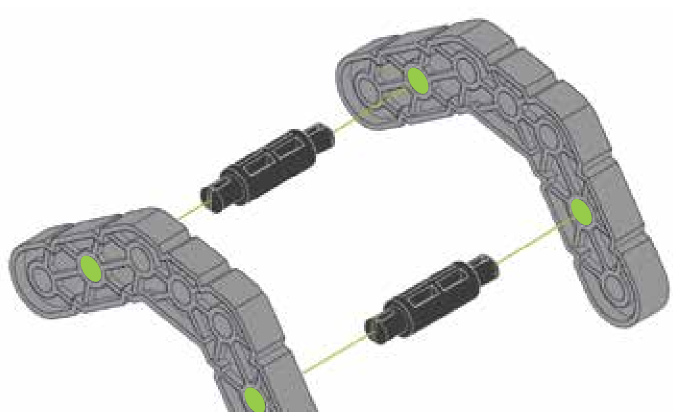


Car Assembly

1





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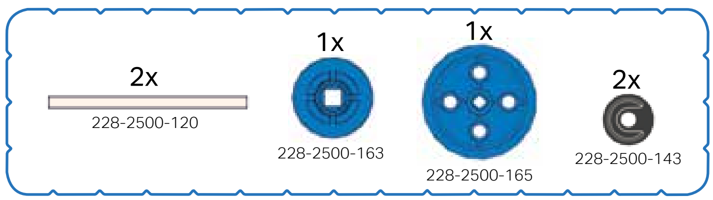

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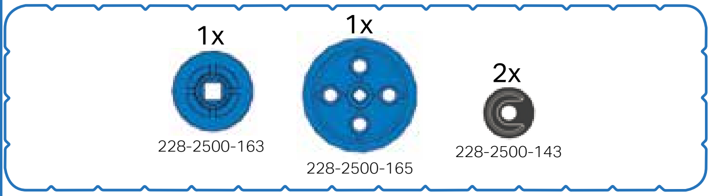

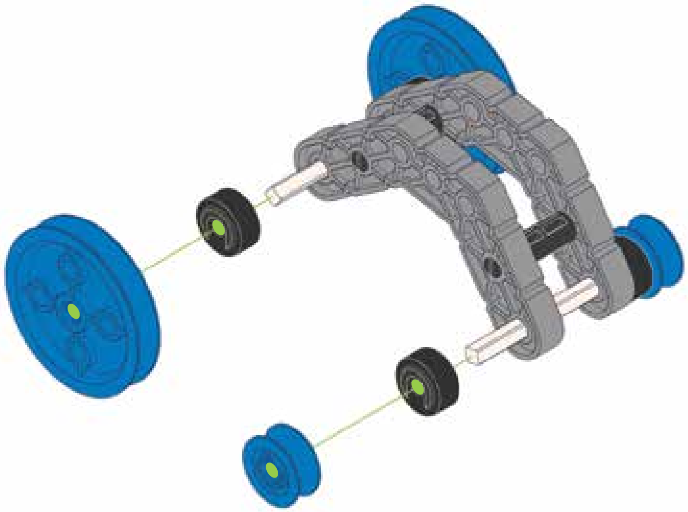

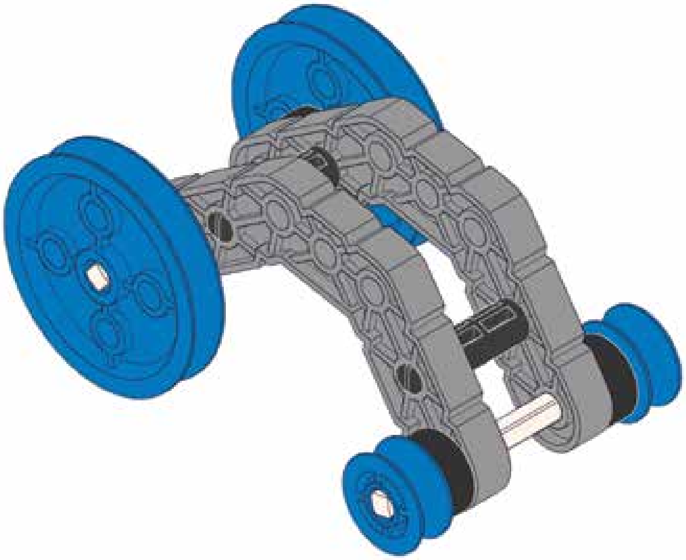

Garage Assembly

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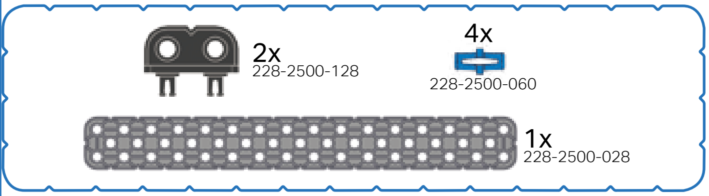

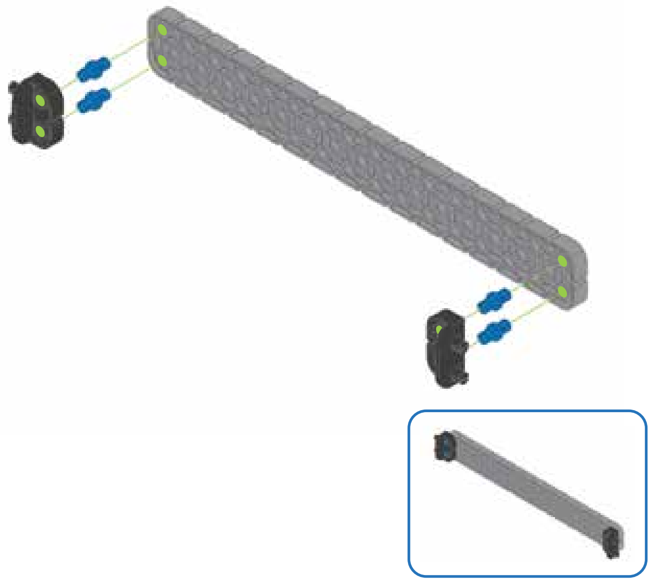

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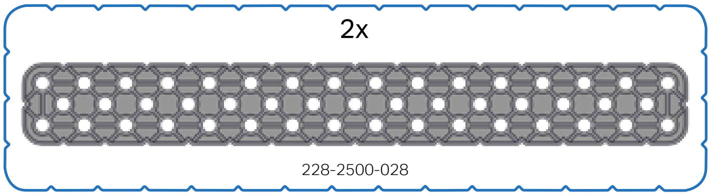
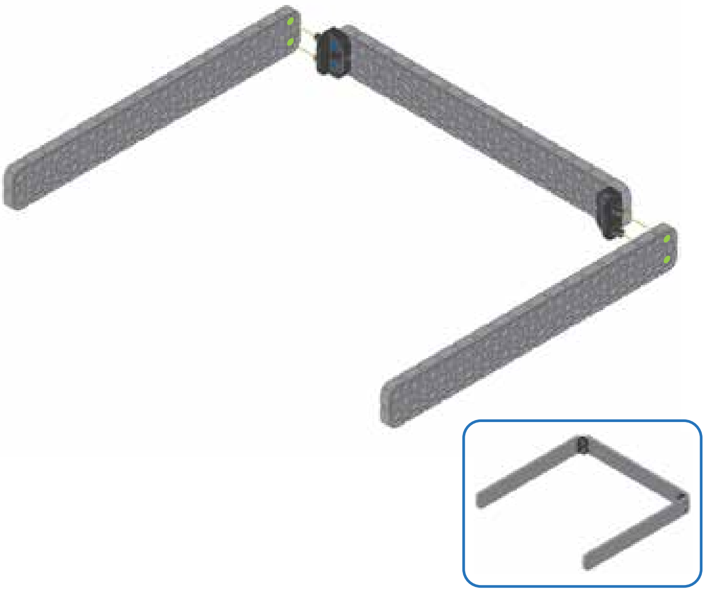
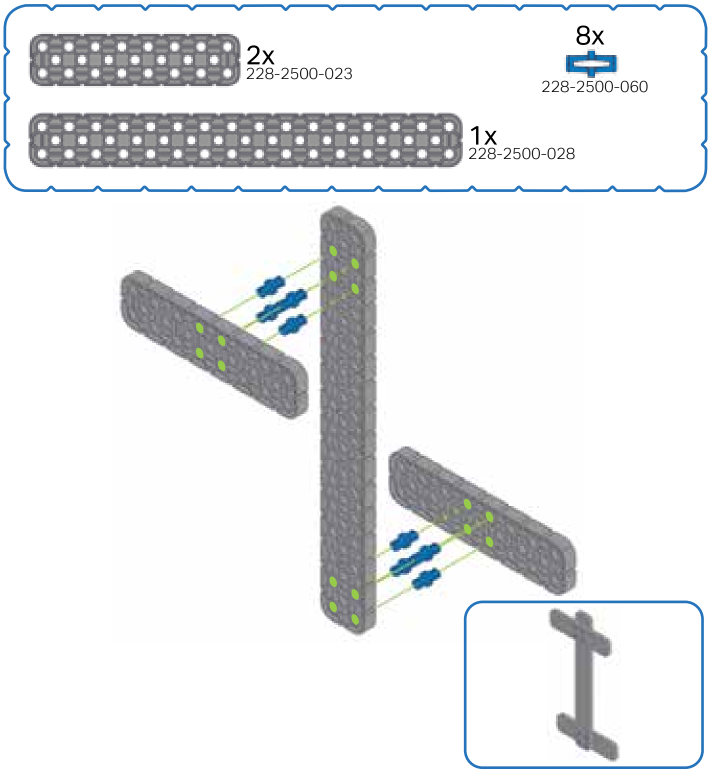




E.3 cont.

Pulley Assembly

1



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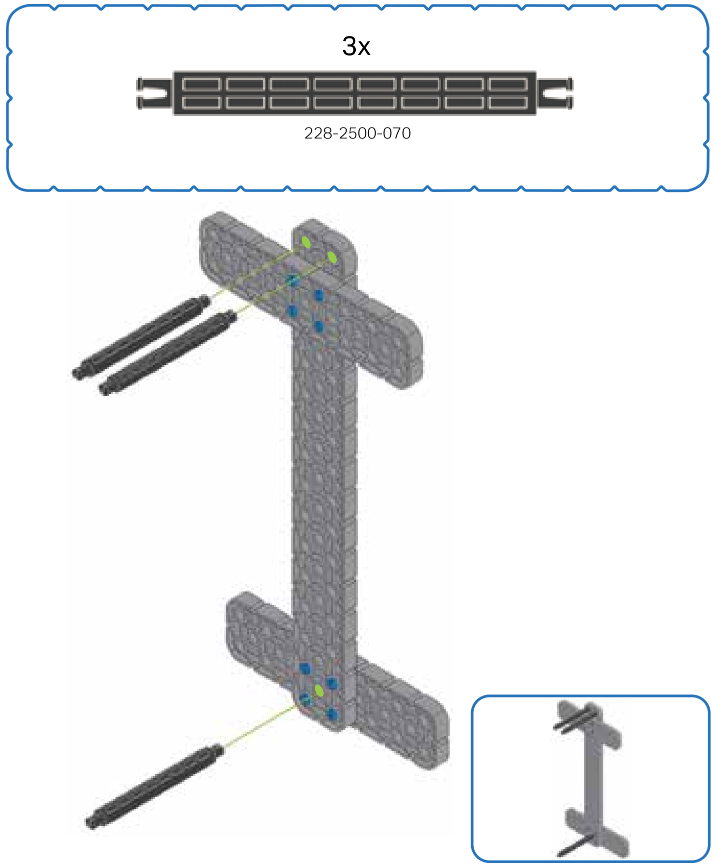

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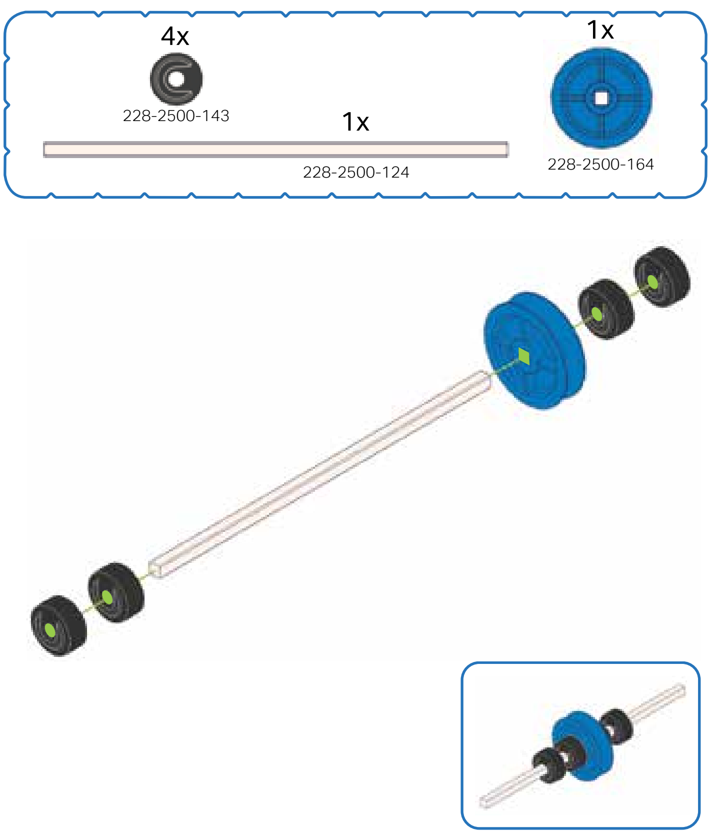

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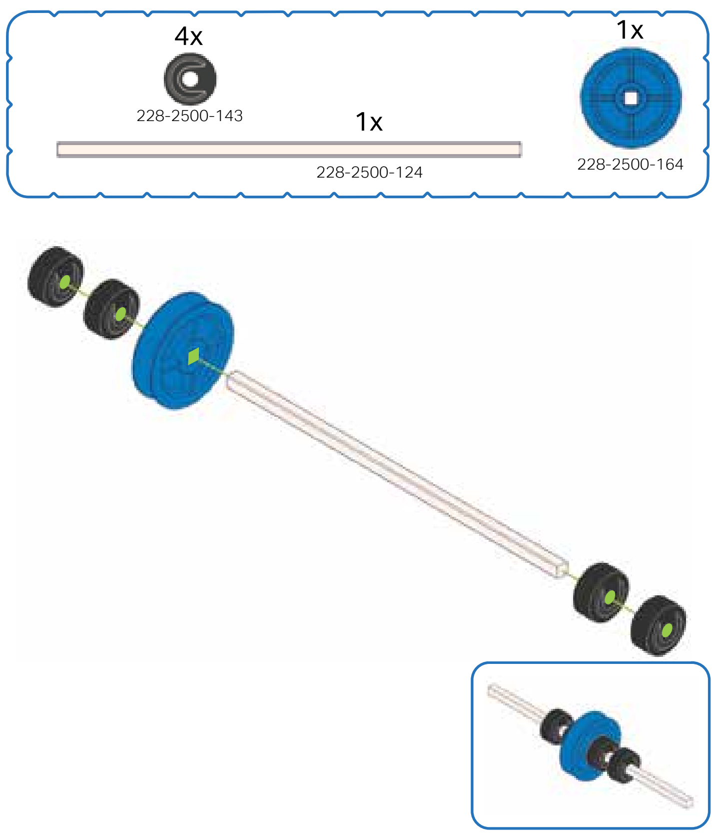

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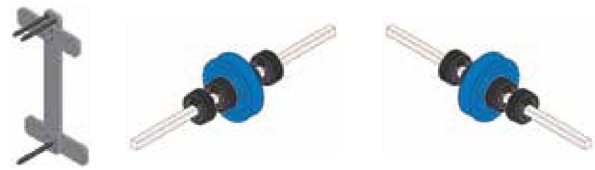

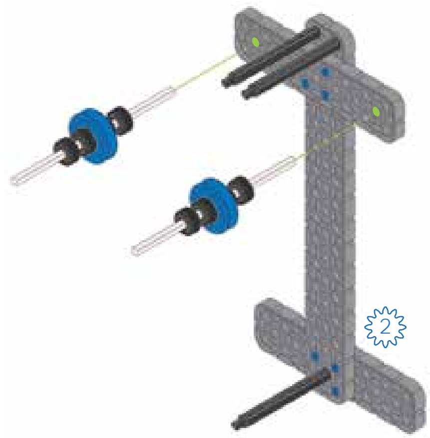

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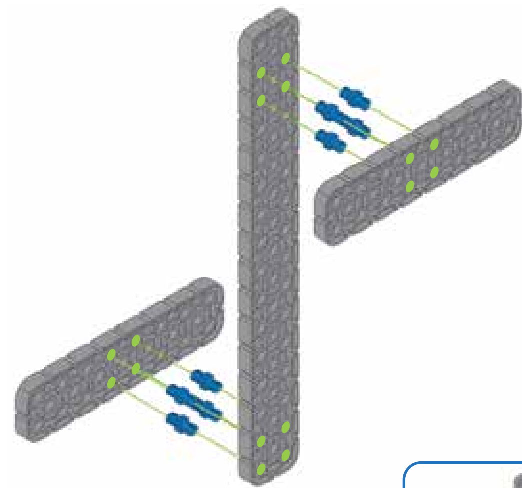

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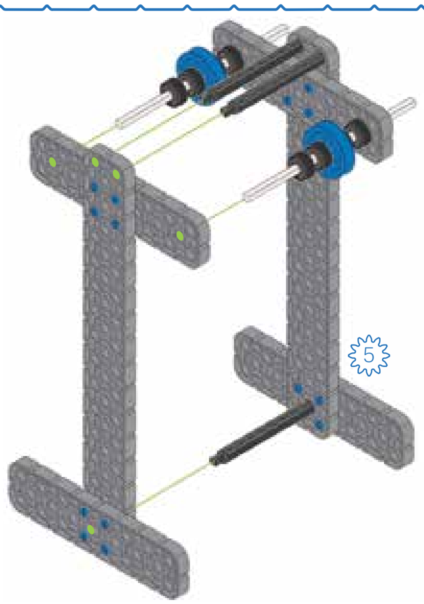

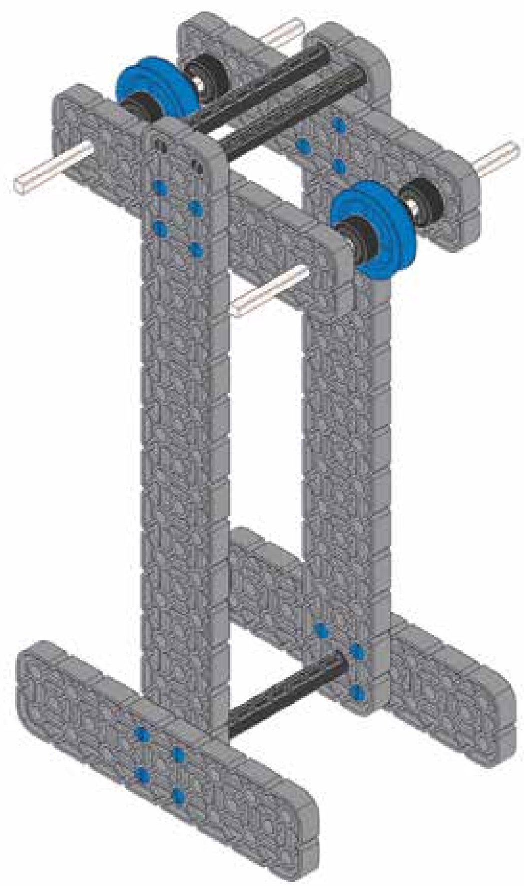

E.3 cont.

Pendulum Assembly

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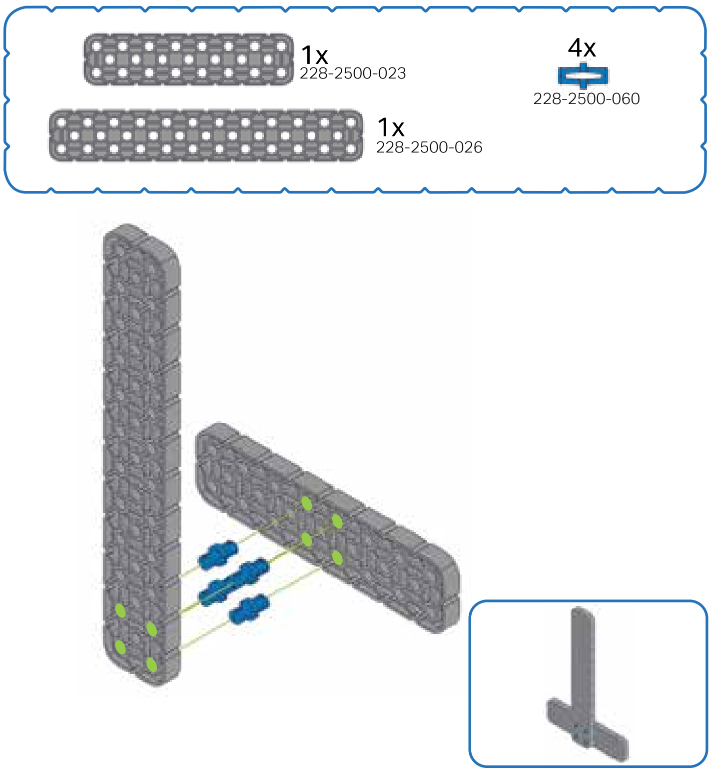

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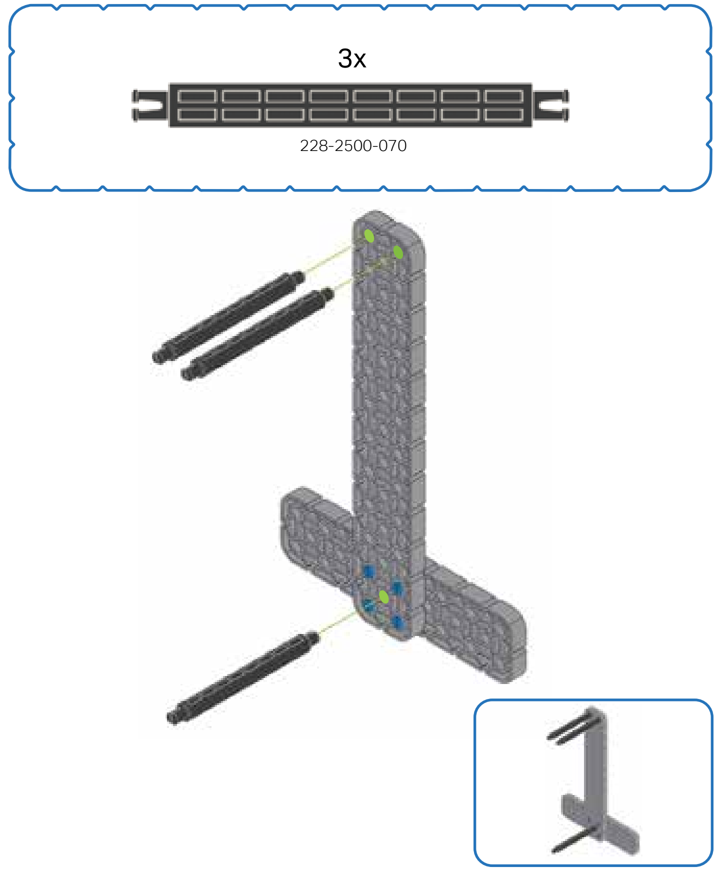

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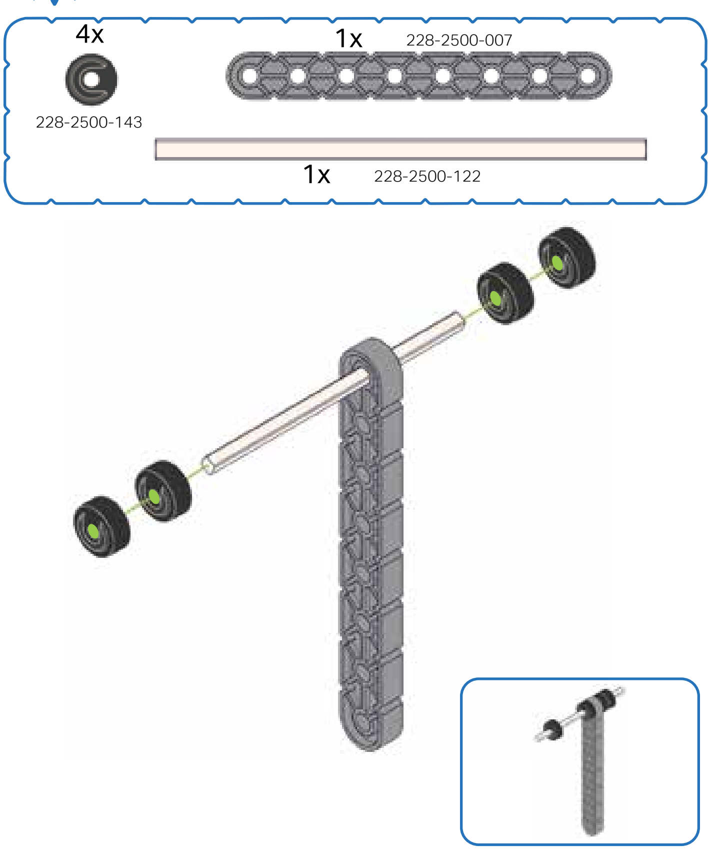

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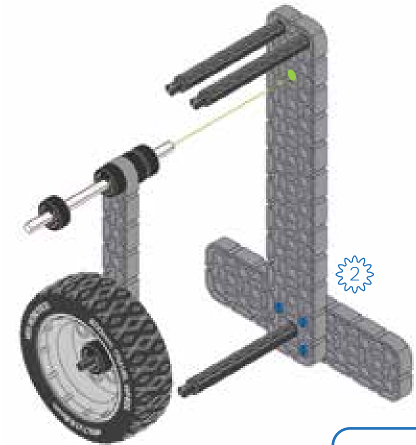

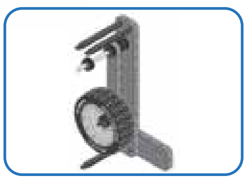

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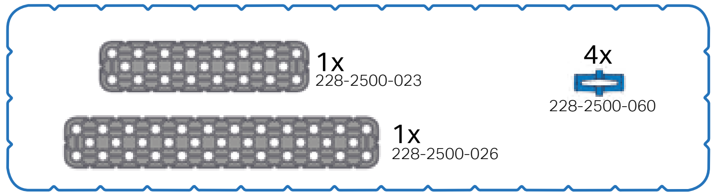

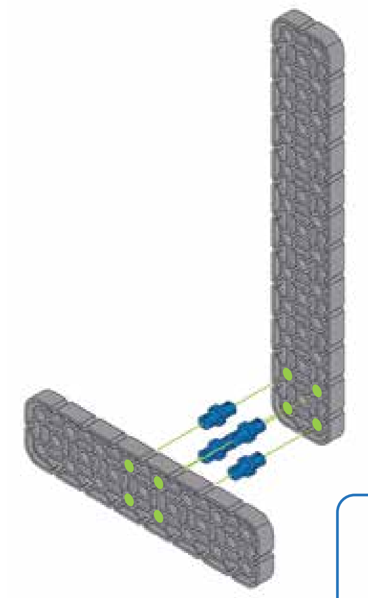

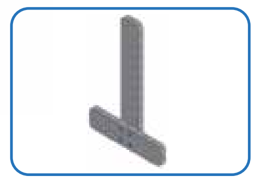

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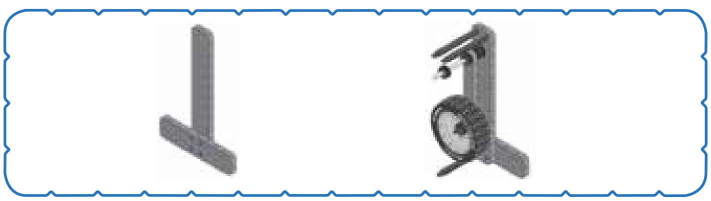
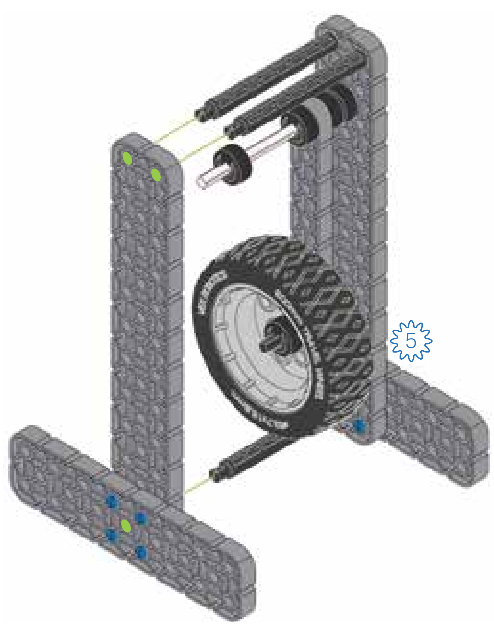
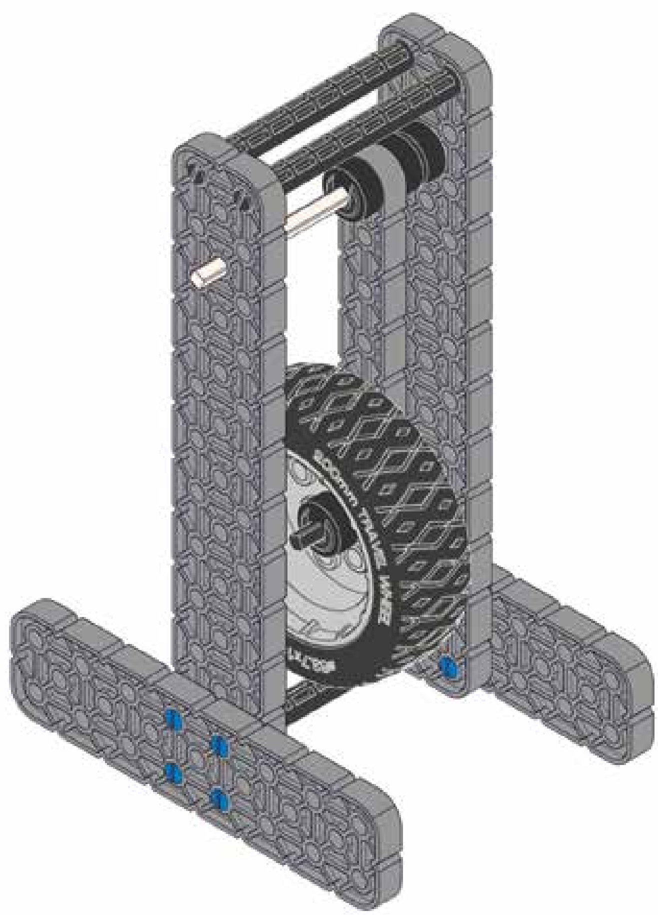


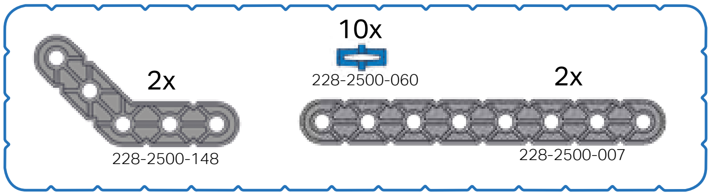


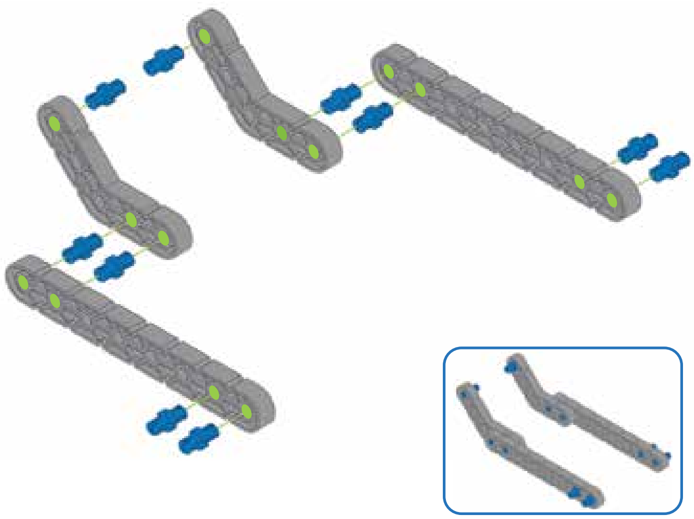


E.3 cont.

Connecting Simple Machines & Pendulum Assembly

1





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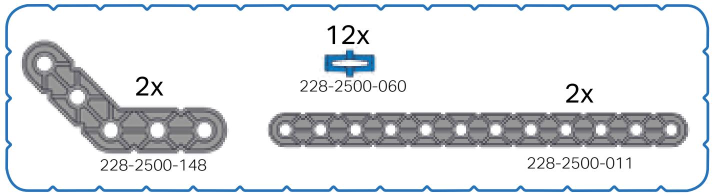

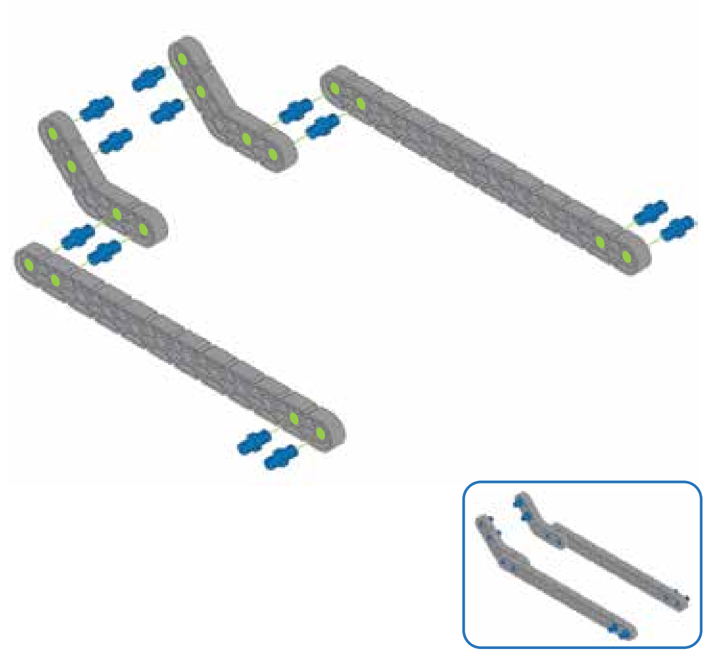

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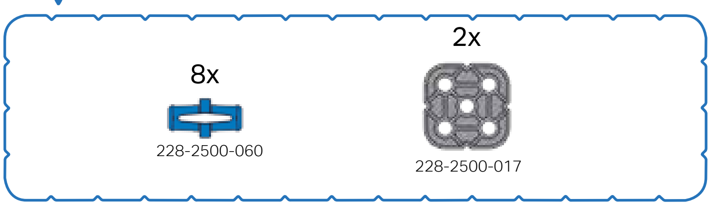

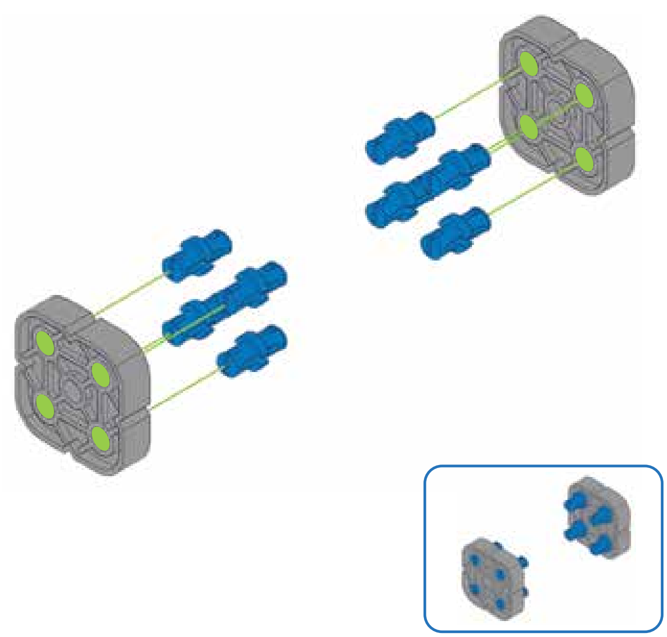

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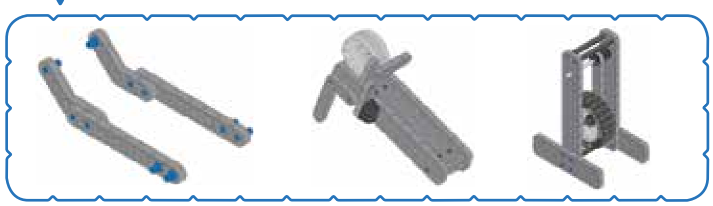

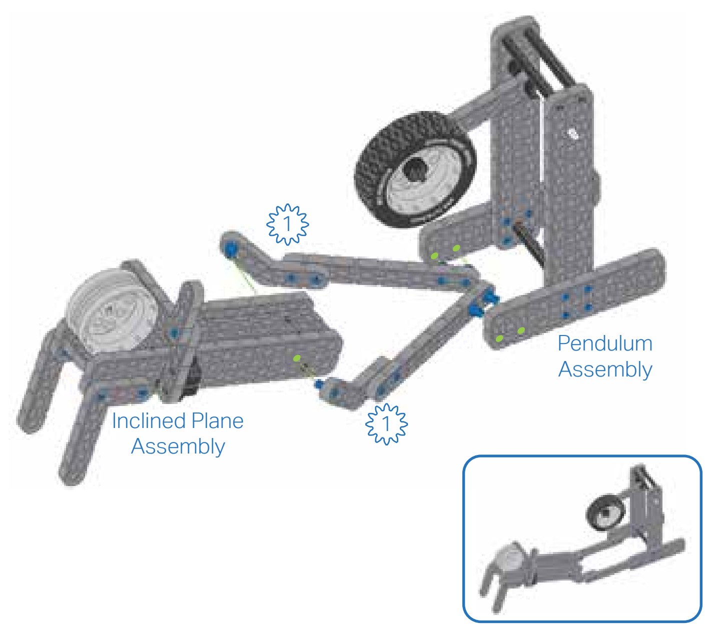

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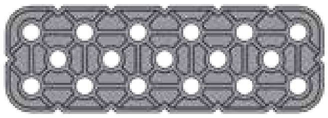
5

1x



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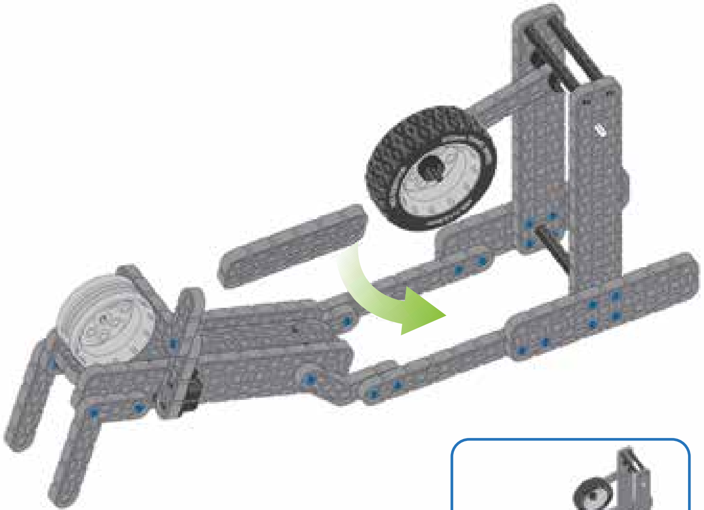

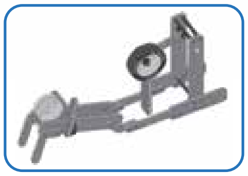

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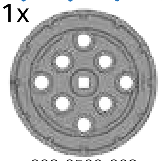

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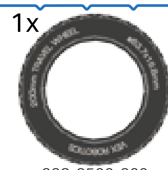

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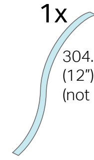
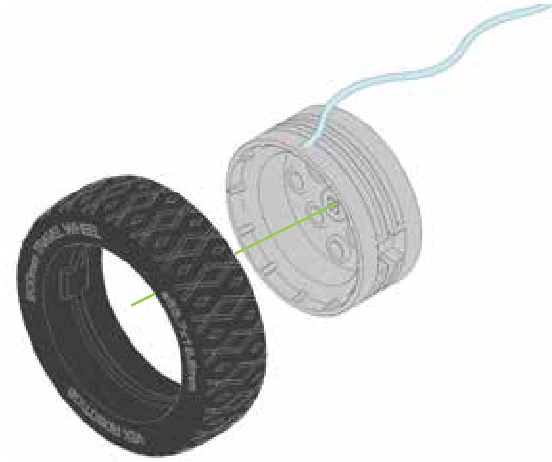
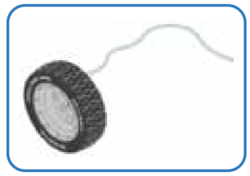


304.8mm
(12”) String
(not included)





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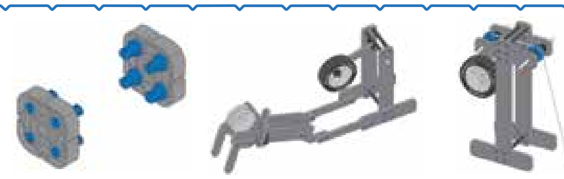

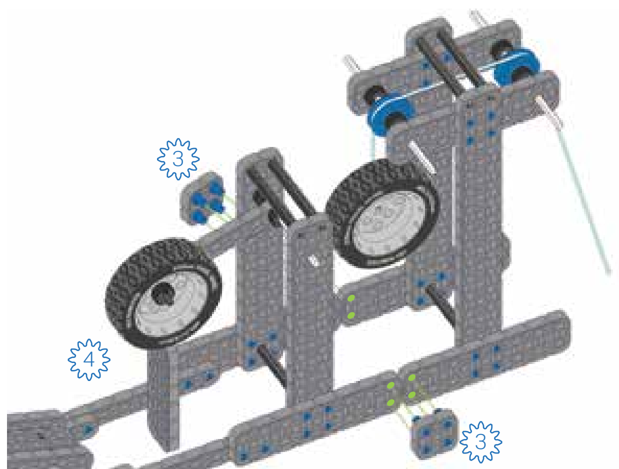

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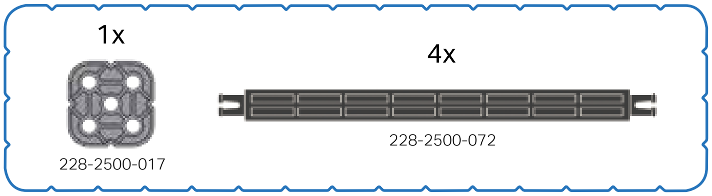

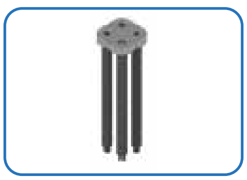

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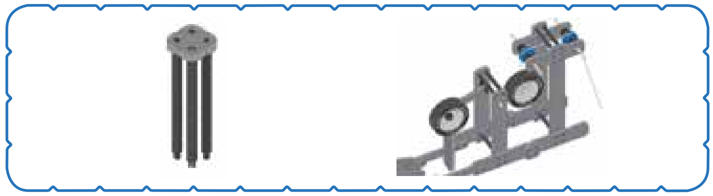

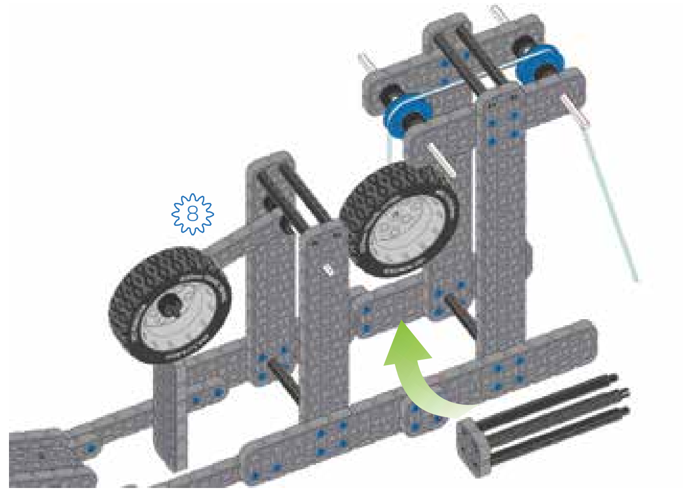

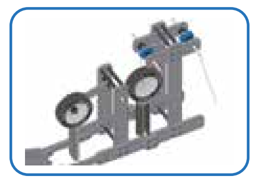

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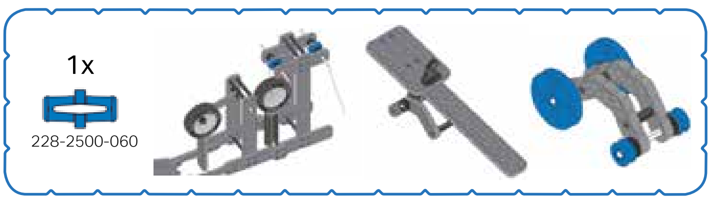

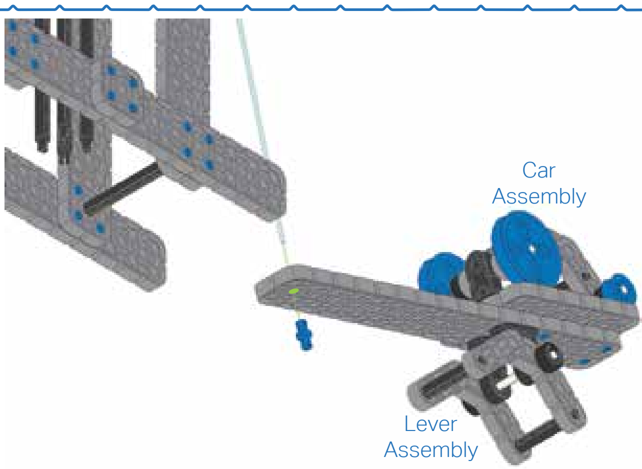

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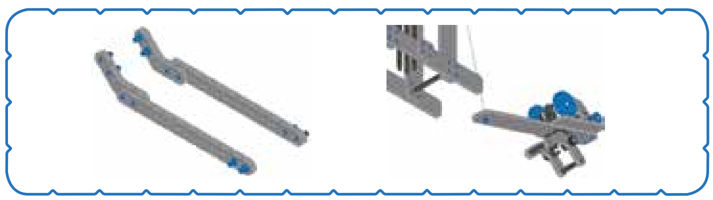

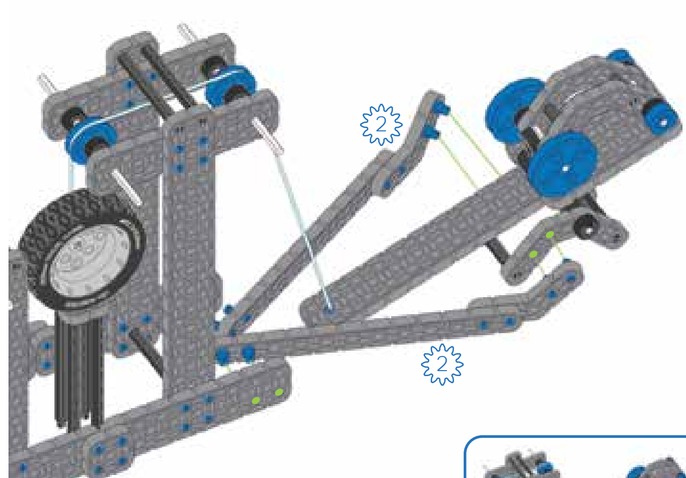

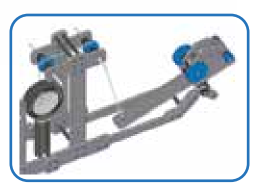

E.3 cont.

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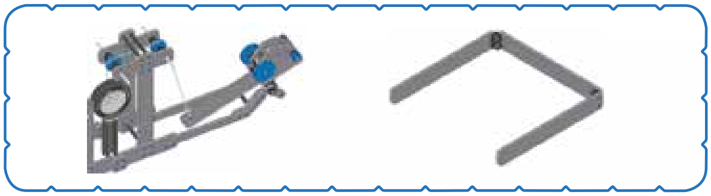
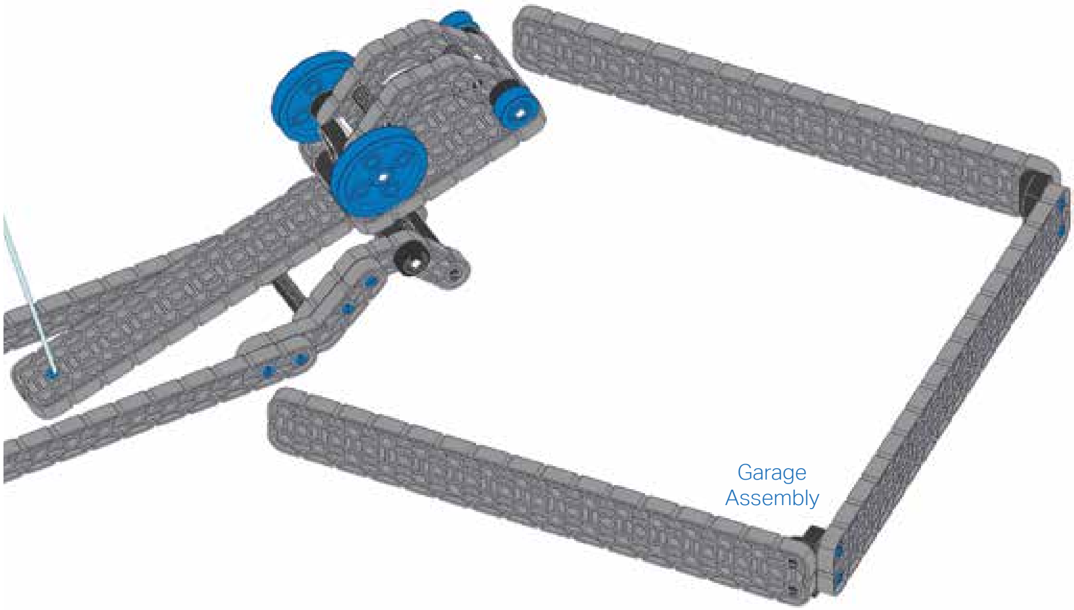
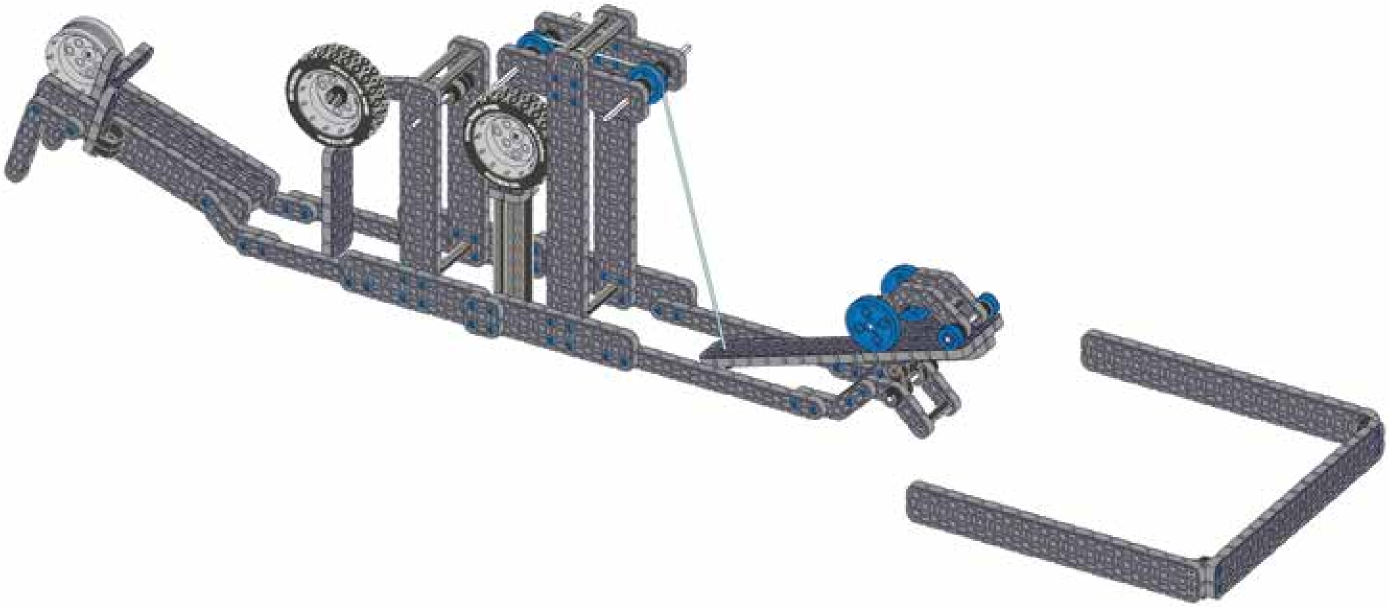


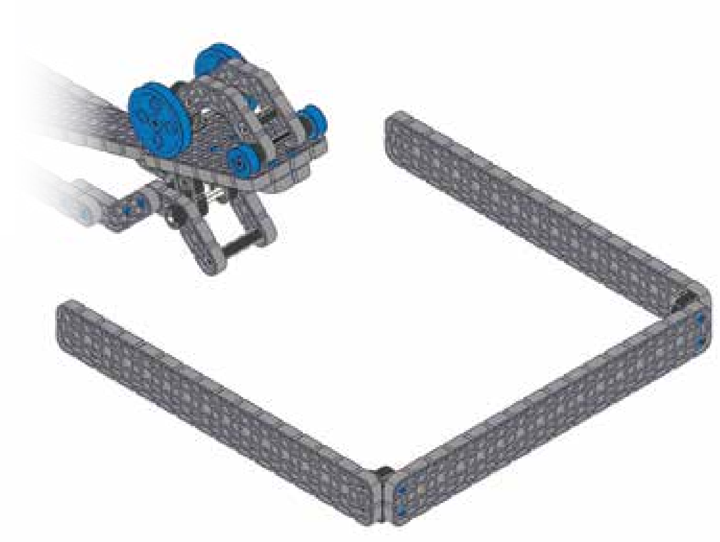




E.4

The Chain Reaction Challenge Rules: Parking the Car

Challenge Goal & Overview: The goal is to build a Chain Reaction Device that successfully parks the car in the garage. Your teacher will provide you with (or ask you to build) the car and garage models to be used in this challenge. In most cases you will be asked to work together in teams, but you may be asked to work alone.



Challenge Rules for Unpowered Chain Reaction Device (grades 4-6):

1. Build a four-stage Chain Reaction Device that parks the car in the garage.
2. Your Chain Reaction Device will be unpowered - no Smart Motors, Robot Brain, or Controller.
3. Use three or more of the following to construct your stages: Wheel & Axle, Inclined Plane, Wedge, Lever, Pulley, Screw, or Pendulum. You may use a type of simple machine or pendulum more than once if you wish.
4. Please see the Rubric to Evaluate Unpowered Chain Reaction Device for all of the details on how you will be evaluated.
5. Idea Book Pages can be used for planning and troubleshooting. Your teacher will provide further instructions on using the Idea Book Pages.

Challenge Rules for Powered Chain Reaction Device (grades 4-8):

1. Build a four-stage Chain Reaction Device that parks the car in the garage.
2. Your Chain Reaction Device will be powered using three or more Smart Motors, a Robot Brain, and a Controller. You will be expected to teleoperate your device with the Controller.
3. Use three or more of the following to construct your stages: Wheel & Axle, Inclined Plane, Wedge, Lever, Pulley, Screw, or Pendulum. You may use a type of simple machine or pendulum more than once if you wish.
4. NO sensors will be used and NO programming is required for this challenge.
5. Please see the Rubric to Evaluate Powered Chain Reaction Device for all of the details on how you will be evaluated.
6. Idea Book Pages can be used for planning and troubleshooting. Your teacher will provide further instructions on using the Idea Book Pages.

Rubric to Evaluate Unpowered Chain Reaction Device (grades 4-6)

Evaluation Criteria	Expert = 4	Proficient = 3	Emerging = 2	Novice = 1	Assessment	Comments
Design & Process Criteria						
Creating viable solutions to the given challenge: mechanism use	Four or more, well developed stages exist meeting all challenge rules	Three well developed stages exist meeting majority of challenge rules	Two or more partially developed stages are evident	A single stage that may or may not be developed is evident		
Simple machines and pendulum usage	Device uses three or more efficient simple machines/ pendulum	Device uses two functioning simple machines/ pendulum	One simple machine/ pendulum exists that functions	Attempt at using one simple machine/ pendulum		
Design Process (defined by the teacher, could be Idea Book use)	Design process utilized, documented & enhances product	Design process utilized and fully documented	Design process utilized consistently	Some evidence that design process was utilized		
Utilization of Resources (materials and parts, Information and instructions, people, and time)	Resources used fully within challenge rules and efficiency maximized	Resources utilized to maximize efficiency	Evidence that some resources utilized meeting challenge purpose	A few resources (e.g., tools & materials) partially utilized		
Technical Criteria						
Mechanical Systems (mechanisms & triggers)	Completely functional and consistent mechanical systems	Consistently functional mechanical systems	Functional, but inconsistent mechanical systems	Non-functional or incomplete/ unsafe mechanical systems		
Unifying Themes (This area emphasizes the Interaction of Science, Technology, & Human Endeavor)						
Communication (written, electronic and/or oral as defined by the teacher)	Sophisticated and highly efficient communication for stated audiences	Purposeful, consistent, effective communication	Purposeful, partially consistent communication	Communication very inconsistent and lacks purpose		
Teamwork	Teamwork that maximizes outcomes is evident	Team members define roles, goals, & work together	Team members partially define roles, goals, & work together	Participants function separately within a group		
Creativity	Device is unique, imaginative, and functional	Device is unique and/or imaginative in multiple ways	Device clearly shows a unique and/ or imaginative element	Unique and/ or imaginative element(s) unclear		

Rubric Adapted from Rubric and Evaluation Criteria for Standards-Based Robotics Competitions & Related Learning Experiences – TSA, 2005

Rubric to Evaluate Powered Chain Reaction Device (grades 4-8)

Evaluation Criteria	Expert = 4	Proficient = 3	Emerging = 2	Novice = 1	Assessment	Comments
Design & Process Criteria						
Creating viable solutions to the given challenge: mechanism use	Four or more, well developed stages exist meeting all challenge rules	Three well developed stages exist meeting majority of challenge rules	Two or more partially developed stages are evident	A single stage that may or may not be developed is evident		
Simple machines and pendulum usage	Device uses three or more efficient simple machines/ pendulum	Device uses two functioning simple machines/ pendulum	One simple machine/ pendulum exists that functions	Attempt at using one simple machine/ pendulum		
Design Process (defined by the teacher, could be Idea Book use)	Design process utilized, documented & enhances product	Design process utilized and fully documented	Design process utilized consistently	Some evidence that design process was utilized		
Utilization of Resources (materials and parts, information and instructions, people, and time)	Resources used fully within challenge rules and efficiency maximized	Resources utilized to maxi-mize efficiency	Evidence that some resources utilized meeting challenge purpose	A few resources (e.g., tools & materials) partially utilized		
Technical Criteria						
Mechanical Systems (mechanisms & triggers)	Completely functional and consistent mechanical systems	Consistently functional mechanical systems	Functional, but inconsistent mechanical systems	Non-functional or incomplete/ unsafe mechanical systems		
Electrical Systems	Battery charged. Wire routing safe, efficient, & completely functional	Battery charged. Wire routing safe & consistently functional	Functional, but inconsistent (battery or wiring issues)	Non-functional or incomplete (battery and wiring issues)		
Mechanical Systems (mechanisms & triggers)	Completely functional and consistent mechanical systems	Consistently functional mechanical systems	Functional, but inconsistent mechanical systems	Non-functional or incomplete/ unsafe mechanical systems		
Unifying Themes (This area emphasizes the Interaction of Science, Technology, & Human Endeavor)						
Communication (written, electronic and/or oral as defined by the teacher)	Sophisticated and highly efficient communication for stated audiences	Purposeful, consistent, effective communication	Purposeful, partially consistent communica-tion	Communica-tion very inconsistent and lacks purpose		
Teamwork	Teamwork that maximizes outcomes is evident	Team members define roles, goals, & work together	Team members partially define roles, goals, & work together	Participants function separately within a group		
Creativity	Device is unique, imaginative, and functional	Device is unique and/or imaginative in multiple ways	Device clearly shows a unique and/ or imaginative element	Unique and/ or imaginative element(s) unclear		

Rubric Adapted from Rubric and Evaluation Criteria for Standards-Based Robotics Competitions & Related Learning Experiences – TSA, 2005

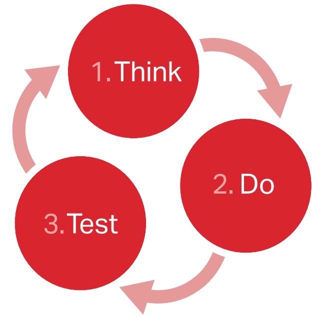
E.7

Chain Reaction Challenge Idea Book Page: Design Plan

Student Name(s): ____

Teacher/Class: ____________________ Date: _________ Page #: _____

Plan and design a Four-Stage Chain Reaction Device that meets challenge and rubric criteria on pages 1 and 2 below.



Sketch/Describe Stage 1 of your Device, Including Trigger Mechanism Here:

Machine Type (One of the Simple Machines or Pendulum): ________________________

Sketch/Describe Stage 2 of your Device Here:

Machine Type (One of the Simple Machines or Pendulum): ________________________

Sketch/Describe Stage 3 of your Device Here:

Machine Type (One of the Simple Machines or Pendulum): ________________________

Remember: Problems ARE NOT failures, they are an expected part of the design process!

Sketch/Describe Stage 4 of your Device Here:

Machine Type (One of the Simple Machines or Pendulum): ___________________________

Plans for Connecting Each Device Stage:

Follow through with your design plan and BUILD your device, then TEST and OBSERVE.

Testing Observations:

____

____

____

____

____

Does your Device function like you expected? YES NO

If you answered "YES" - Congratulations! You will score well on the Challenge Rubric. You may now move on to other lessons.

If you answered "NO" - Use your observations above and the Rubric to determine what problem needs troubleshooting, then use a copy of the Troubleshooting Idea Book Page to help solve that problem. Keep repeating this "THINK - DO - TEST" process with the troubleshooting pages, until your device functions correctly.

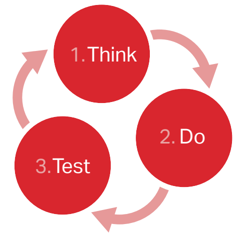
Remember: Problems ARE NOT failures, they are an expected part of the design process!

Chain Reaction Challenge Idea Book Page: Troubleshooting

Student Name(s): ____

Teacher/Class: _____________________ Date: __________ Page #: _____

Use a copy of this Idea Book Page for each device problem you have to troubleshoot.



Sketch/Describe Your Device Problem Here:

Sketch/Describe Your Solution to the Problem Here:

Follow through with your solution and MAKE PLANNED CHANGES to your device, then TEST and OBSERVE.

Testing Observations:

____

____

____

____

____

Does your Device function like you expected? YES NO

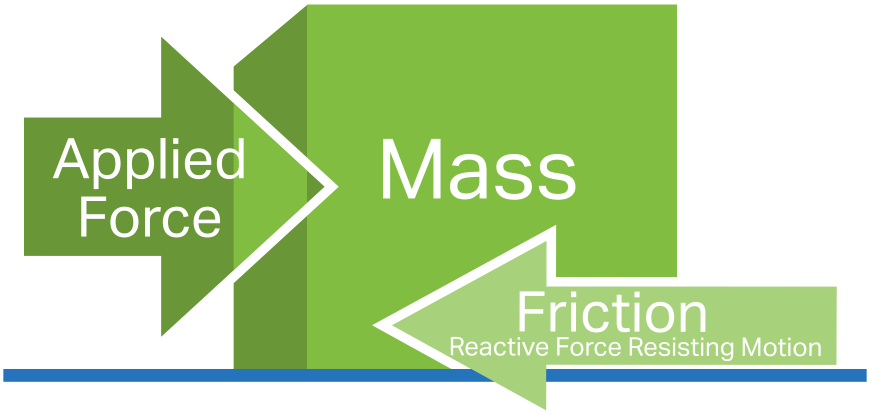
If you answered "YES" - Congratulations! You will score well on the Challenge Rubric. You may now move on to other lessons.

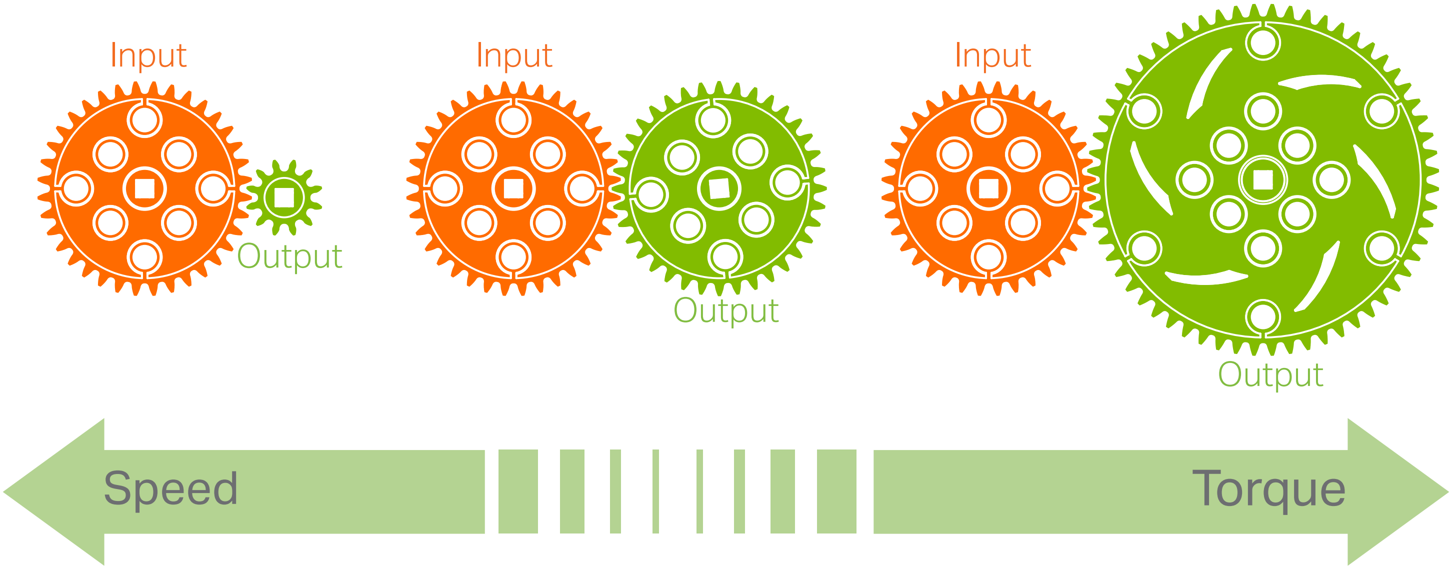
If you answered "NO" - Use your observations above and the Rubric to determine what problem needs troubleshooting next, then use another copy of this Idea Book Page to help solve that problem. Keep repeating this "THINK - DO - TEST" process with troubleshooting pages, until your device functions correctly.

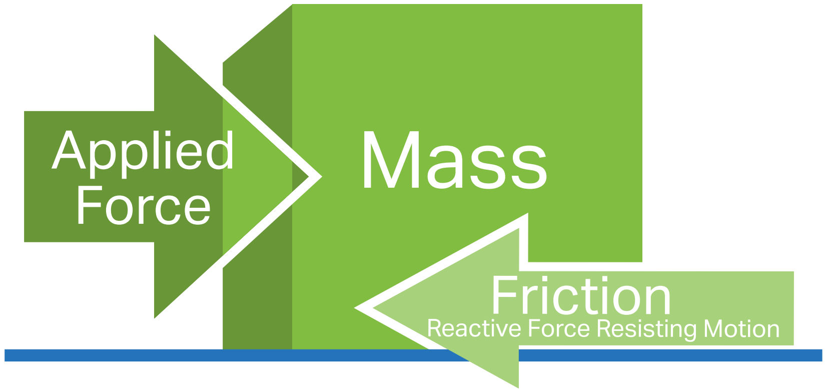
Remember: Problems ARE NOT failures, they are an expected part of the design process!

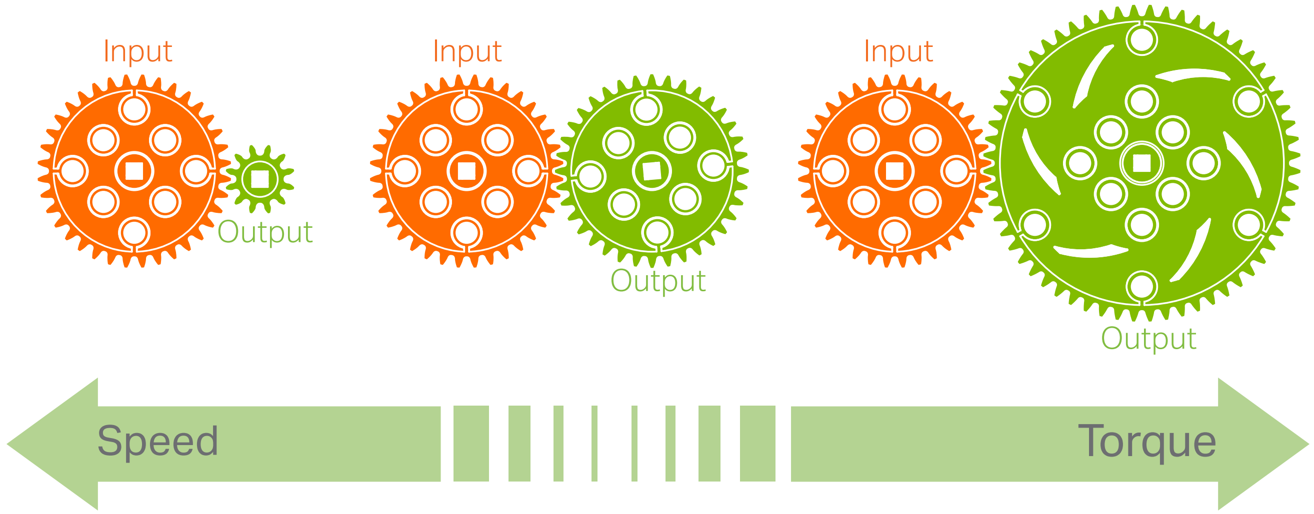
F

Key Concepts









F.1

Key Concepts

Unit Overview:

In this unit you will explore key STEM concepts that many engineers use in their everyday work. These concepts are also very useful when it comes to the design of mechanical systems.

Unit Content:

- Friction
- Center of Gravity
- Speed, Torque, and Power
- Mechanical Advantage

Unit Activities:

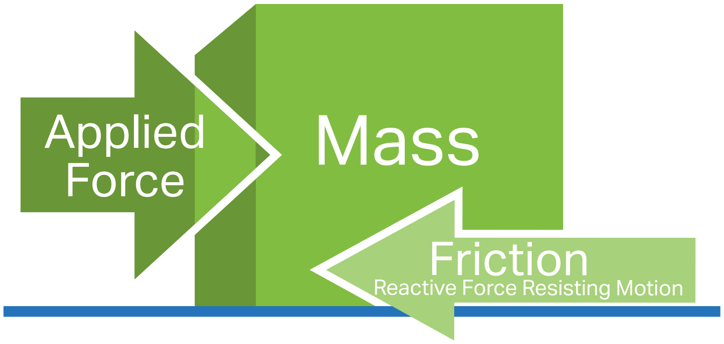
- Matching Exercise
- Idea Book Exercise

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

F.2

Friction

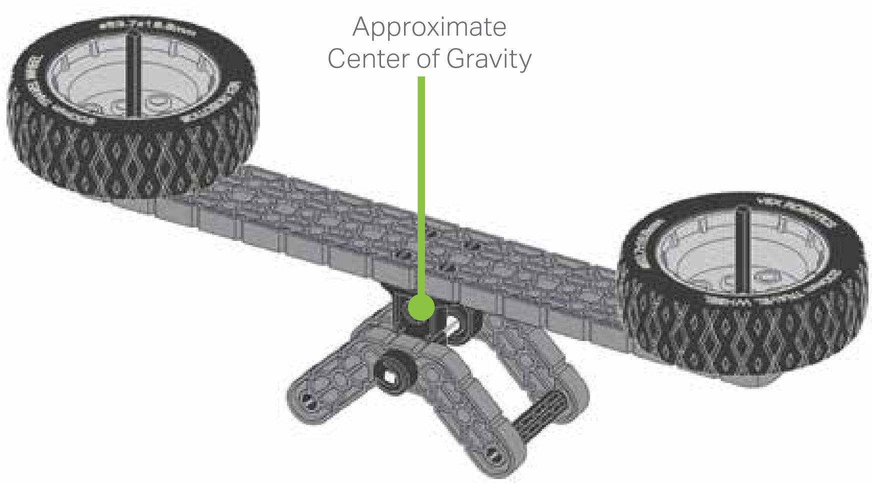
Friction is the force that resists motion through the rubbing of one object against another. It is a reaction force only. It occurs when two surfaces are in contact and a force is applied to a mass, causing the surfaces to slide against one another. If an object has no forces trying to cause motion, there is no friction. No applied force means no reaction force.



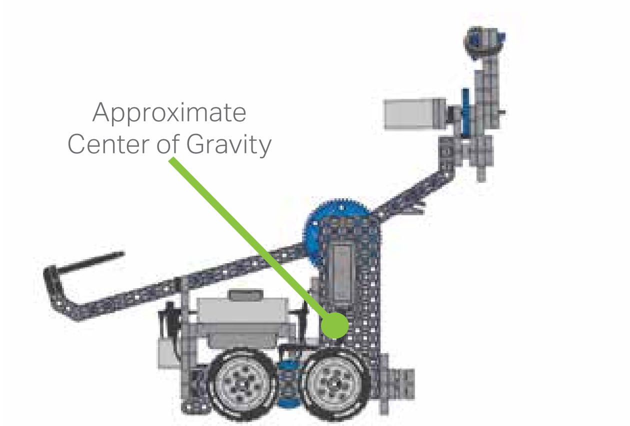
F.3

Center of Gravity

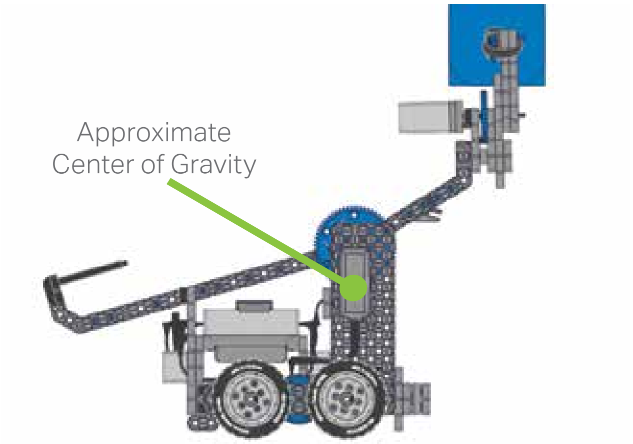
Center of Gravity is the place in a system or body (such as a robot) where the weight is evenly distributed and all sides are in balance. An example of center of gravity is the middle of a seesaw when it is balanced.



You can think of a robot's center of gravity as the "center position" of all the weight on the robot. Because **Center of Gravity** uses both weight and position, heavier objects have a greater effect than lighter ones in determining where the center of gravity is. For example, if your robot can collect, hold, and/or manipulate objects, those objects change the center of gravity as they are being manipulated because they add weight.



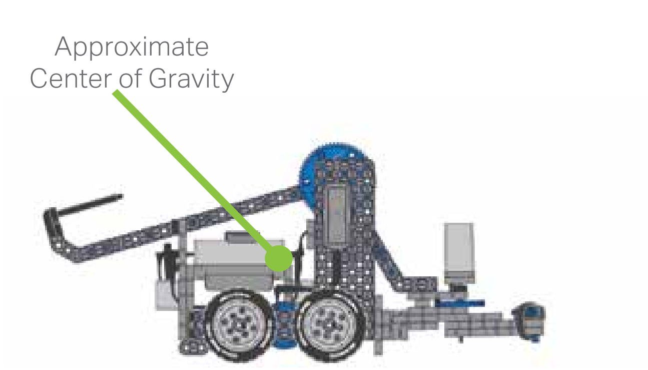
Robot Arm Empty



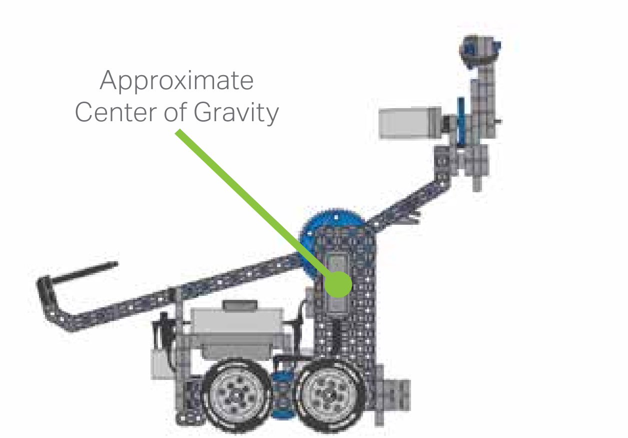
Robot Arm With Cube

F.3 cont.

Likewise, pieces that are farther out have a greater effect than pieces that are near the middle of the robot. So, if your robot has an arm that lifts and/or reaches, its center of gravity changes with that movement.



Robot Arm Down and In



Robot Arm Up and Out

F.4

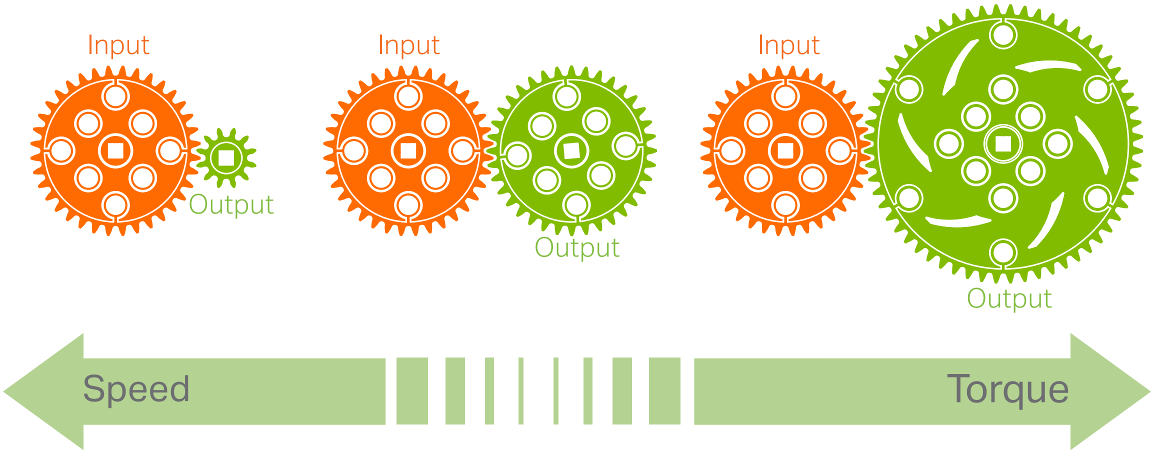
Speed, Torque, and Power

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

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

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

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



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

F.5

Mechanical Advantage

Mechanical Advantage is the calculation of how much faster and easier a machine makes your work. It compares the output force a mechanism or machine gives you to the input force that is applied to that mechanism or machine to get it to work. Mechanical advantage can be adjusted to meet specific needs. For example, bicycle gears can be set one way to ride uphill, then adjusted to ride downhill. The rider has limited power, but by adjusting the mechanical advantage to appropriate speed and torque outputs, the output from the rider's power can be maximized in varying conditions. With VEX IQ, changing gear ratios is also a great way to adjust mechanical advantage.

A bike's high-speed gear ratio can maximize its efficiency on a downhill or flat slope.

A high-torque gear ratio can help a bike to climb up hills easily using mechanical advantage.

F.6

Key Concepts Matching Exercise

Student Name(s): ____

Teacher/Class: ________________________________ Date: __________

Instructions:

Match terms from the word bank to the correct definition by writing terms on the correct line. Each term is only used once.

Word Bank:

Center of Gravity	Feet per Second	Friction	Inch-Pounds
Inverse	Speed	Weight	Mechanical Advantage
Torque	Position	Watts	Power

______________ is the force that resists motion when one object rubs against another.

______________ is the place in a system or body where the weight is evenly distributed and all sides are in balance.

Center of Gravity uses both ____________ and ___________.

______________ is a measure of how fast an object is moving.

______________ is a force directed in a circle, most often rotating an object.

______________ is the rate at which work is done.

Speed is measured in Miles per Hour or _________________.

Torque is measured in units of force × distance, such as ______________ or Newton-Meters.

Power is most commonly measured in __________________.

In Classical Mechanics, speed and torque have an ___________________ relationship.

______________ is the calculation of how much faster and easier a machine makes your work.

F.7

Key Concepts Idea Book Exercise: Mechanical Advantage

Student Name(s): ____

Teacher/Class: ____________________ Date: _________ Page #: _____

Mechanical Advantage is the calculation of how much faster and easier a machine makes your work. It compares the output force a mechanism or machine gives you to the input force that is applied to that mechanism or machine to get it to work. Mechanical advantage can be adjusted to meet specific needs.

Instructions:

Your task is to "imagine" a mechanism or device that can adjust its mechanical advantage to meet changing needs. For example, in the lesson on Mechanical Advantage we described a bicycle's ability to change gears for both uphill and downhill riding to meet varying speed and torque needs.

STEP 1. "THINK" - Think of any situation (other than the bicycle) where a machine, device, or mechanism with the ability to change its mechanical advantage would be helpful in some way. Describe that situation or "problem" in words below. Use terms from our unit matching exercise whenever possible (friction, center of gravity, speed, power, torque, etc.) in your description:

____

____

____

____

STEP 2. "DO" – Draw and describe your machine, device, or mechanism. Name it, label its parts, show and describe how it would work and how mechanical advantage would be changed. Use terms from our unit matching exercise where possible (friction, center of gravity, speed, power, torque, etc.) in your description.

Draw, name, and label your machine, device, or mechanism here:

Describe how it would work and how mechanical advantage would be changed below:

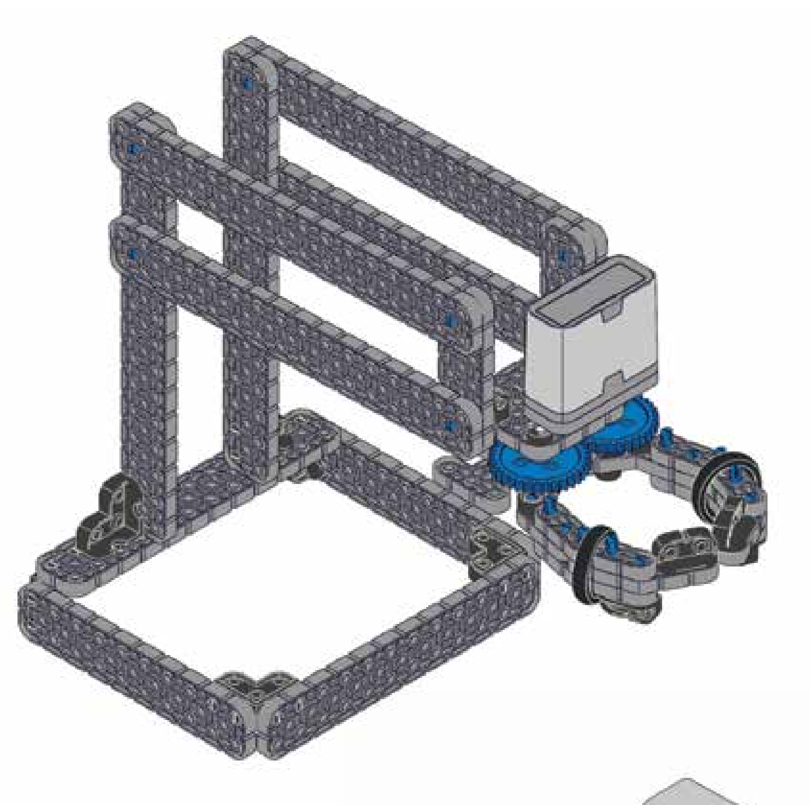
____

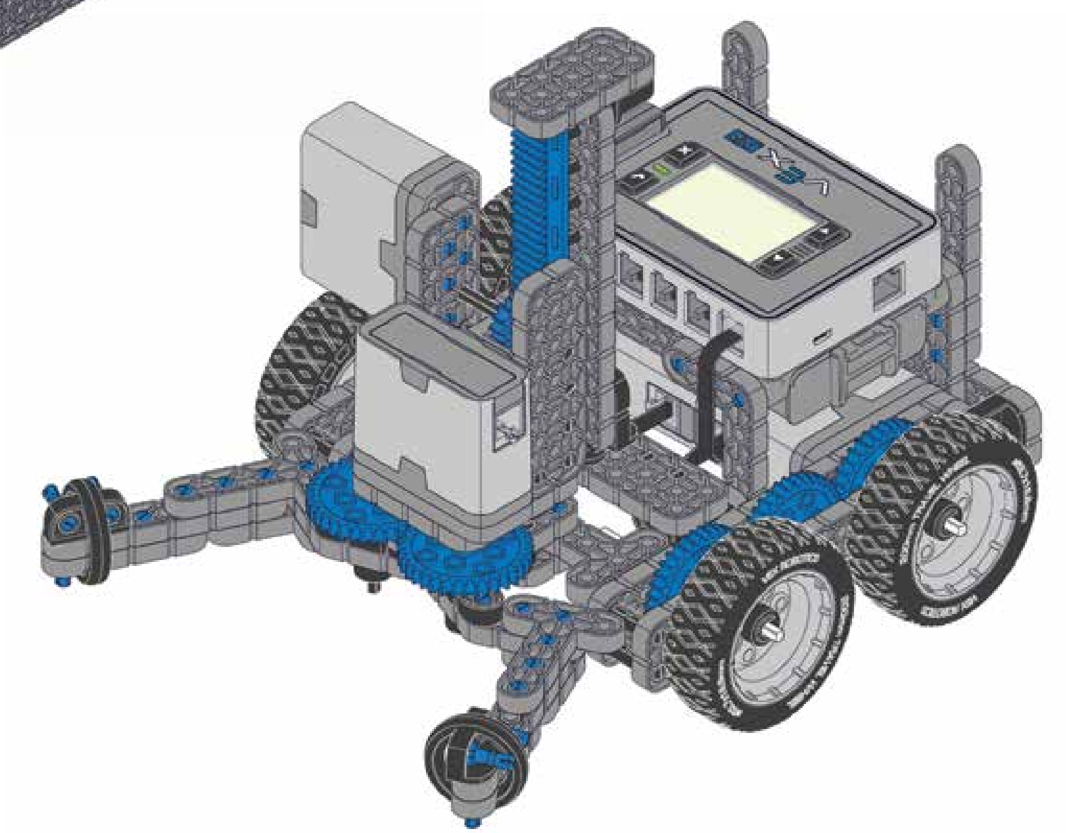
____

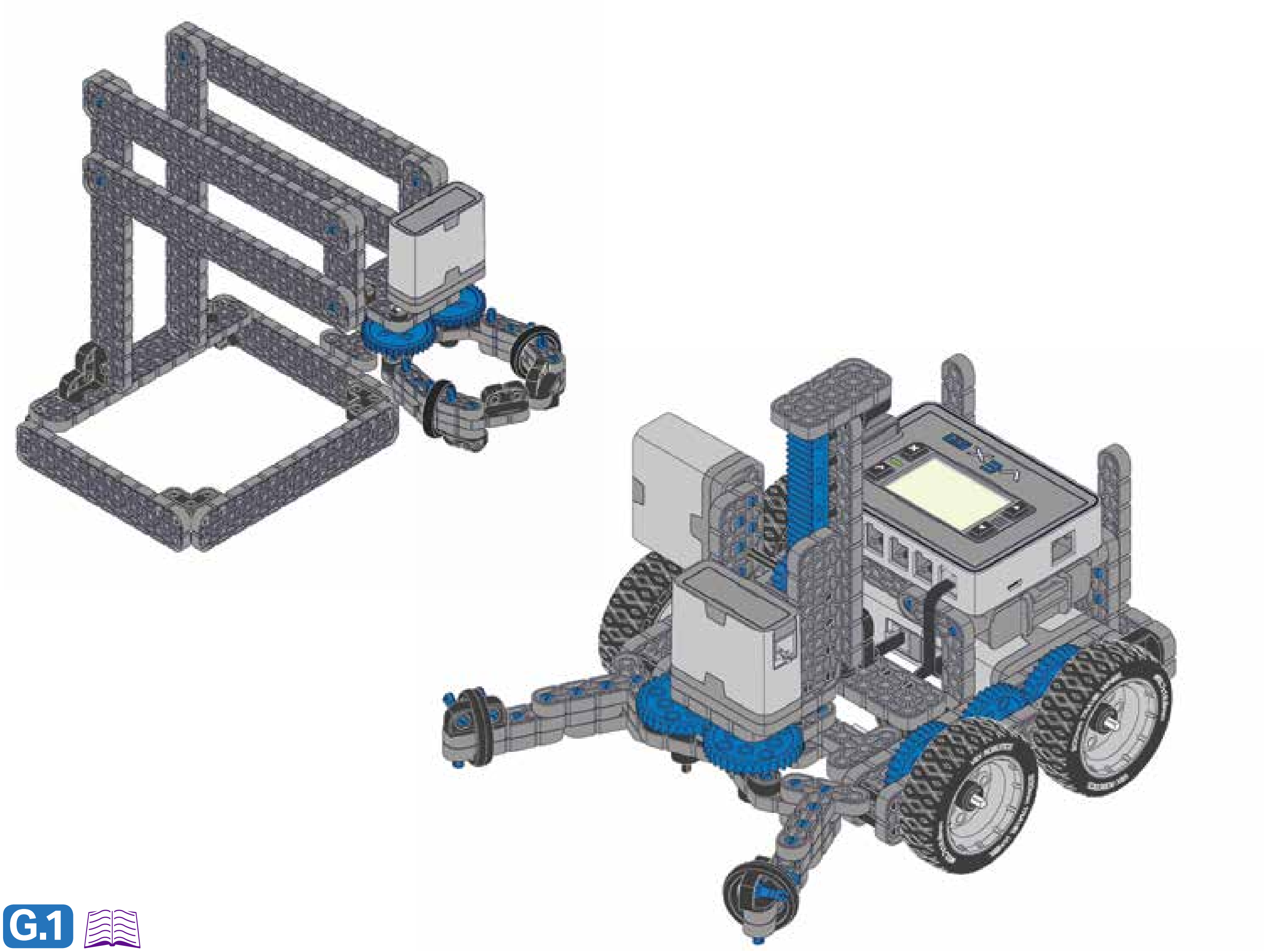
____

____

G
Mechanisms







G.1

Mechanisms

Unit Overview:

This unit builds on your knowledge from the Key Concepts unit by digging deeper into certain mechanical aspects of robotics systems. These new elements will lead to higher levels of engineering process and improved designs.

Unit Content:

- DC Motors
- Gear Ratio
- Drivetrains
- Object Manipulation
- Lifting Mechanisms

Unit Activities:

- Matching Exercise
- Gear Ratio Exercises using the Gear Ratio Simulator

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

G.2

Mechanisms: DC Motors (Grades 4-8)

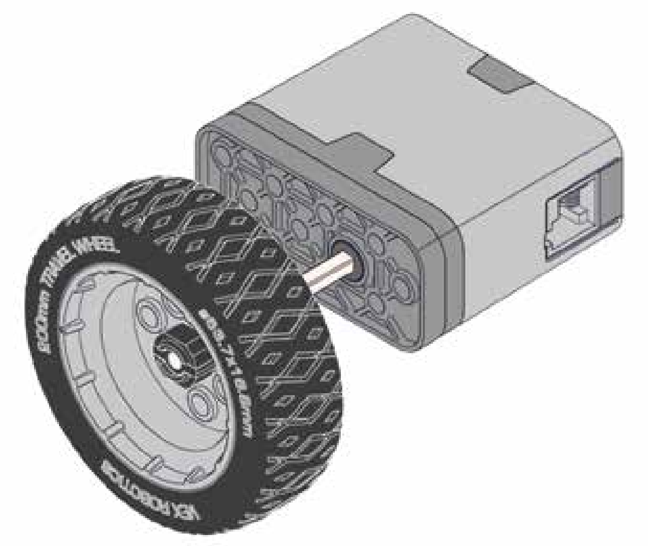
Actuators are used to act upon an environment, usually for moving or controlling a mechanism or system. Actuators drive everything that moves on a mobile robot. The most common type of actuator is a motor; in particular, VEX IQ utilizes **Direct Current (DC) Motors**.

DC Motors convert electrical energy into mechanical energy through the use of electromagnetic fields and rotating wire coils. When a voltage is applied to a motor, it outputs a fixed amount of mechanical power (usually to a shaft, gear, and/or wheel), spinning at some speed with some amount of torque.

Motor Loading

Motors apply torque in response to loading. **Motor Loading** happens when there is any opposing force (such as friction or a heavy mass) acting as a load and requiring the motor to output torque to overcome it. The higher the load placed on a motor output, the more the motor will “fight back” with an opposing torque. However, as you learned in the Key Concepts Unit, since the motor outputs a fixed amount of power, the more torque the motor outputs, the slower its rotational speed.

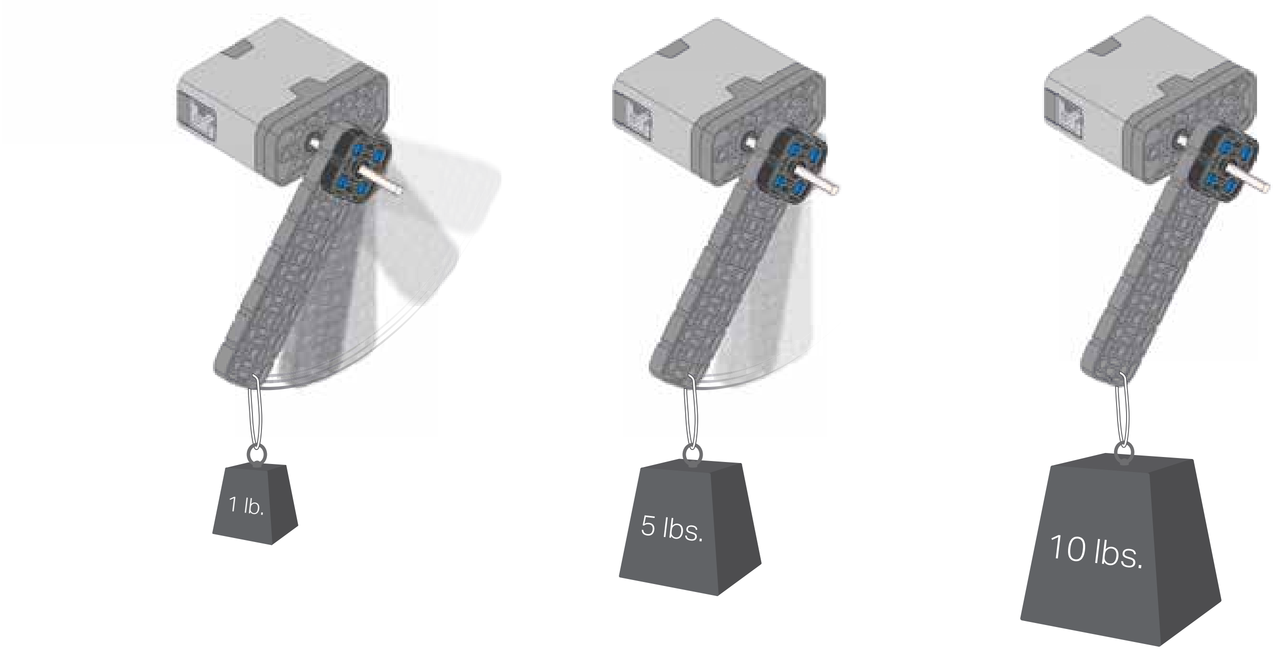
If you keep increasing the load on a motor it eventually stops spinning or **stalls**.



Motor applies torque to overcome friction of a wheel turning against the ground.

Current Draw

A DC Motor draws a certain amount of electrical current (measured in amps) depending on how much load is placed on it. As the load increases on the motor, the more torque the motor outputs to overcome it and the more current the motor draws.



G.3

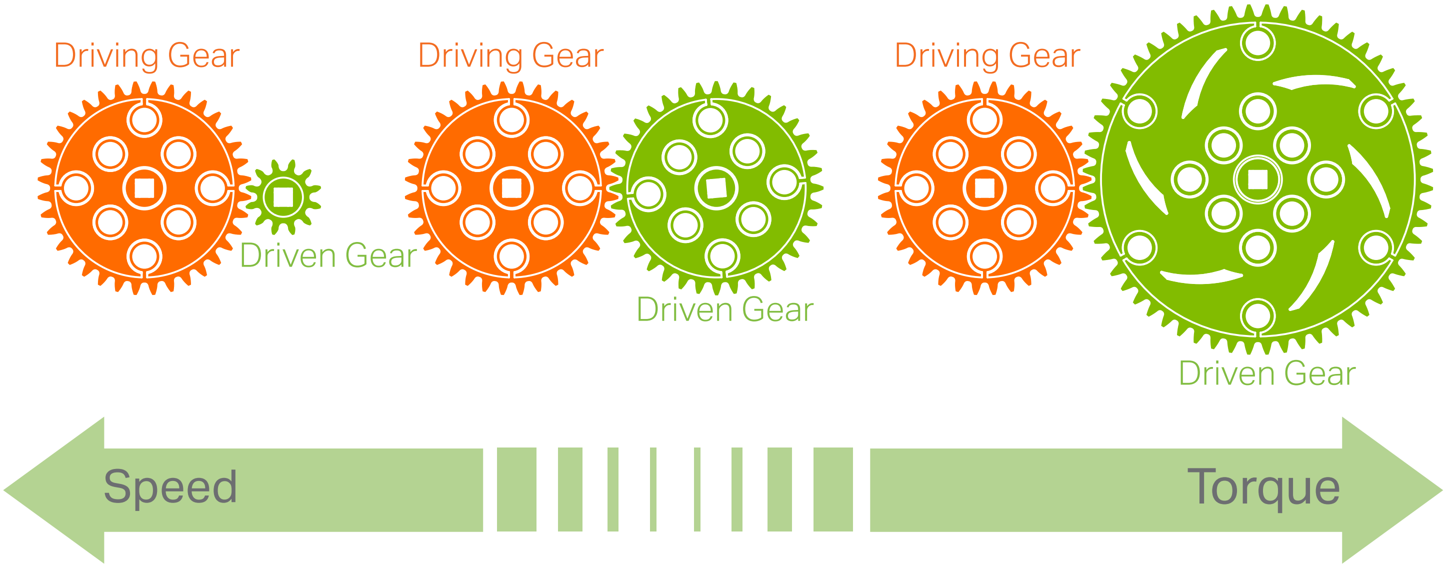
Mechanisms: Gear Ratio

Gear Ratio Basics (Grades 2-8)

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

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

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



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

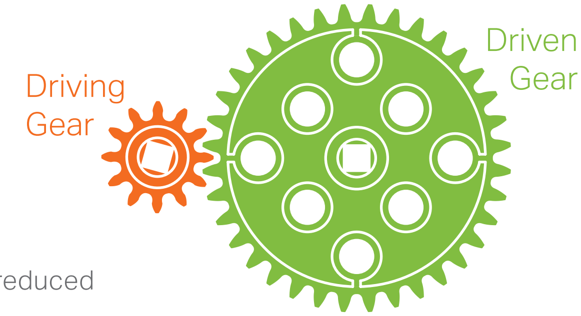
Making this kind of change to Mechanical Advantage is helpful when you are trying to lift or move faster mechanically, you don't require the ability to lift heavy objects, and/or you favor agility over pushing ability in a drivetrain.

G.3 cont.

Expressing Gear Ratio and Gear Reduction (Grades 4-8)

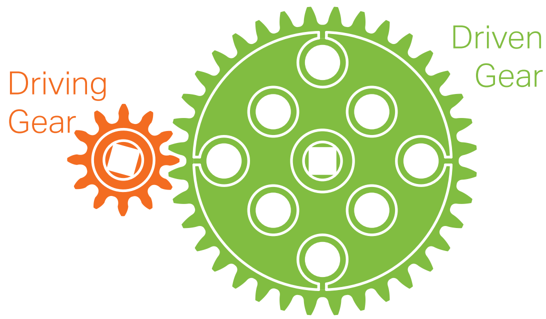
Both **Gear Ratio** and **Gear Reduction** are mathematical expressions that describe the relationship between a **Driving Gear** and a **Driven Gear**. However, it's important to understand the different but similar ways they are expressed. Both use the number of teeth on each gear as key values, although their order is reversed.

Gear Ratio is expressed this way:
(Driving Gear Teeth) : (Driven Gear Teeth)
Gear Reduction is expressed in reverse:
(Driven Gear Teeth) / (Driving Gear Teeth)



Note: Gear Reduction is seen as a fraction that is often reduced to simplify the expression Driven Gear.

Example 1



Gear Ratio 12 : 36

Gear Reduction 36 / 12

3 / 1

Say "12 to 36 Gear Ratio"

Say "3 to 1 Gear Reduction"

Example 2

Gear Ratio 12 : 60

Gear Reduction 60 / 12

5 / 1

Say "12 to 60 Gear Ratio"

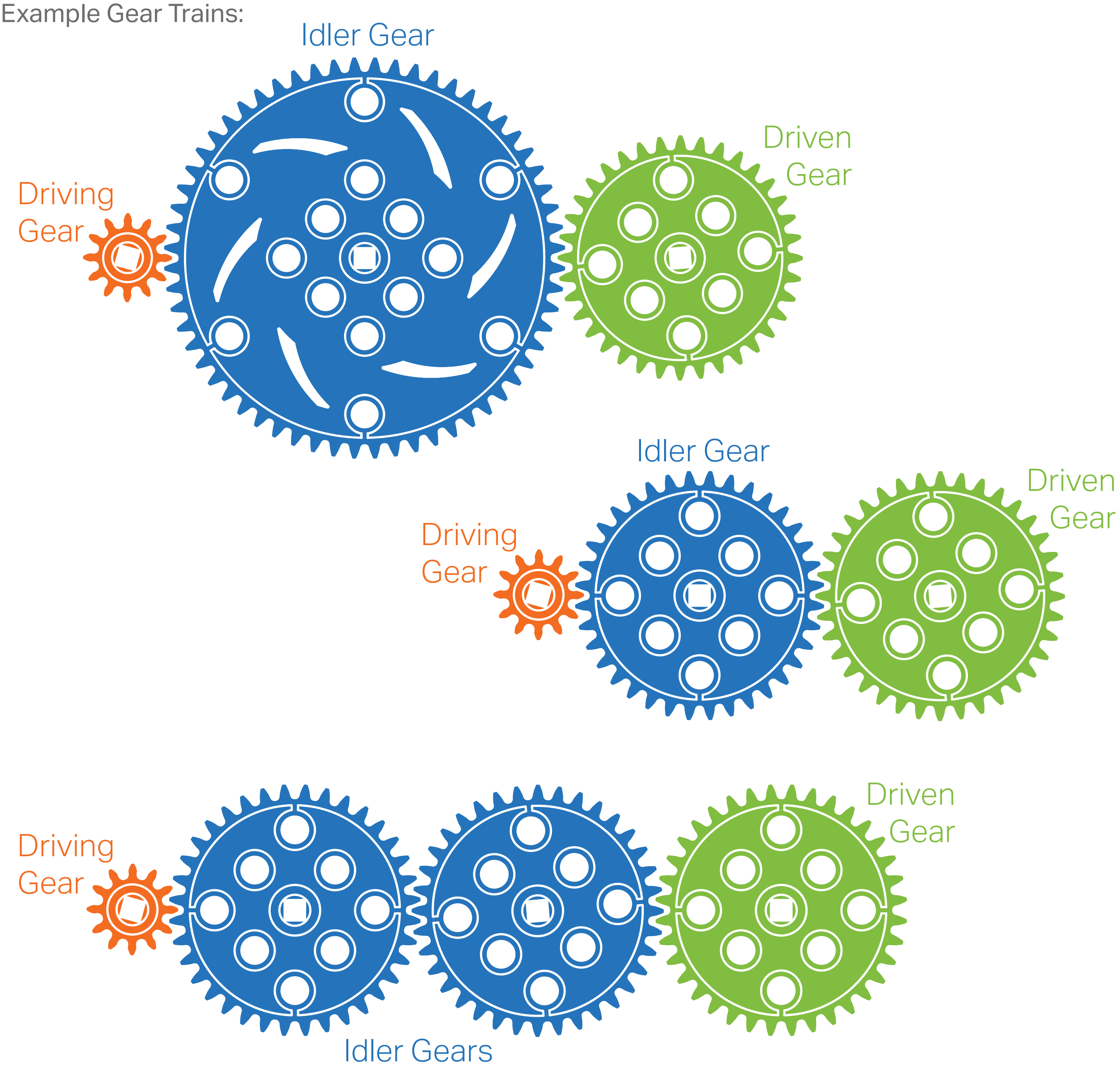
Say "5 to 1 Gear Reduction"

G.3 cont.

Gear Trains and Idler Gears (Grades 4-8)

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

Example Gear Trains:



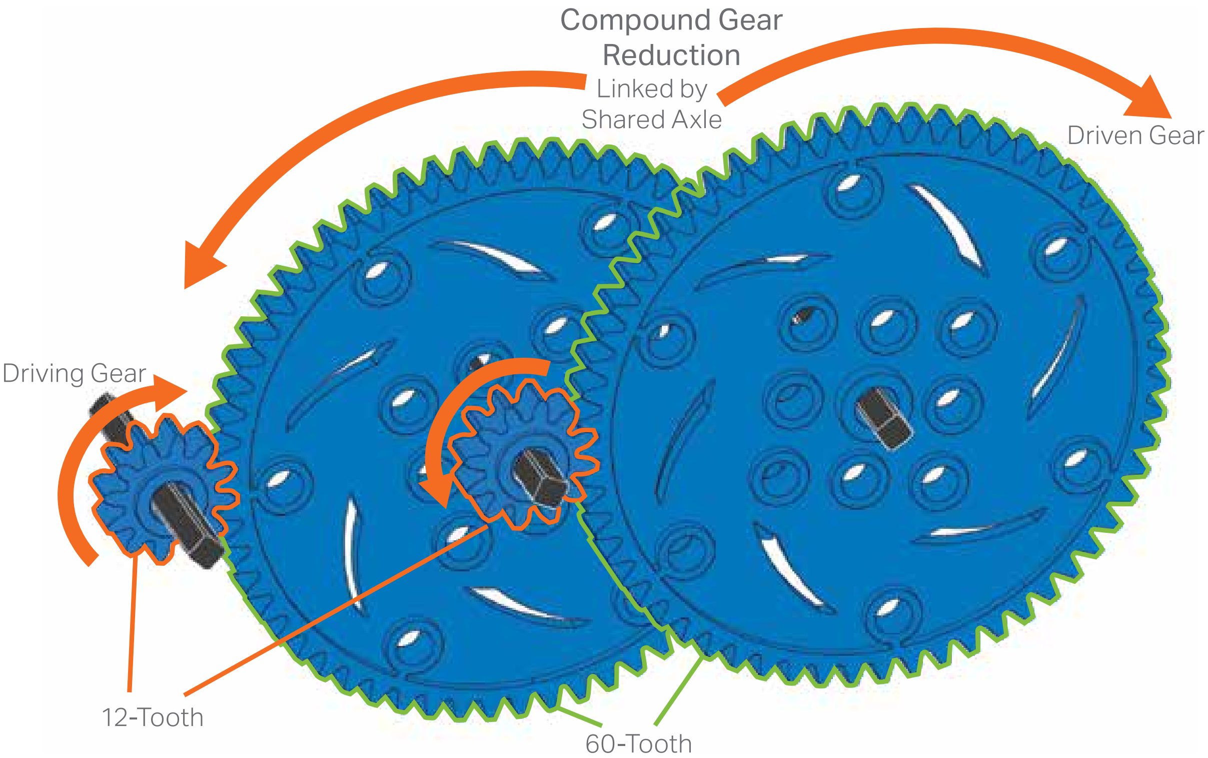
In all three of these example **Gear Trains**, the **Driving Gear** is 12-teeth and the **Driven Gear** is 36-teeth, thus the **Gear Ratio** for all three examples is the exact same - 12:36 . Size and number of **Idler Gears** have no effect on **Gear Ratio** or **Gear Reduction**, they just transmit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

G.3 cont.

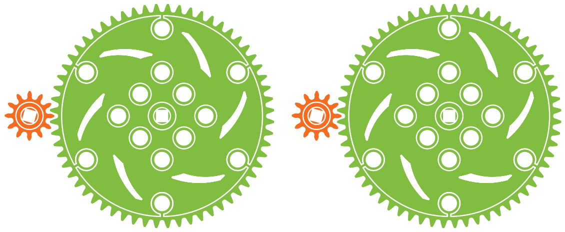
Compound Gears and Compound Gear Reductions (Grades 6-8)

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

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



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



Gear Reduction

(60 / 12) x (60 / 12)

↓

(5 / 1) x (5 / 1) = 25 / 1

Say "25 to 1 Compound Gear Reduction"

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

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

G.4

Mechanisms: Drivetrains (Grades 4-8)

Mobile and Competition robots will vary greatly depending on the tasks they are designed for. However, one thing common among them is that they usually have some method for moving. The robotic subsystem that provides the ability to move is often known as a **Drivetrain**. Drivetrains may come in many different forms – two examples are wheels or treads (like a tank). The wheeled, rolling drivetrain is the most common one found in competition robotics and one of the most popular in the entire industry.

Drivetrain Design

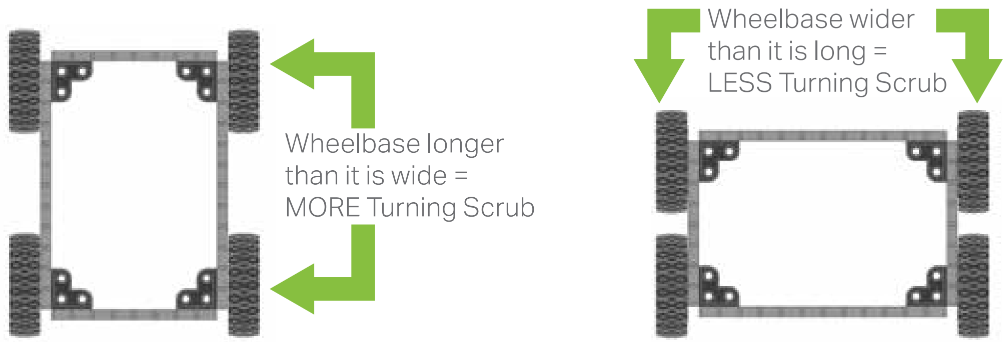
The most basic, multi-functional competition robot **Drivetrain** design consists of:

- 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.

The Clawbot IQ Standard Drive Base is one example that you can build. However, **Drivetrains** can come in all shapes and sizes - some don't provide power to all wheels, use different types of wheels, or are not even a rectangular shape! Whatever the details of your **Drivetrain**, you should always be aware of a property known as **Turning Scrub**.

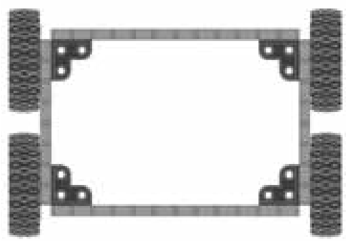
Turning Scrub is the friction that resists turning. This friction is created from the wheels dragging sideways on the ground as a robot (or other mobile vehicle) turns. The greater the **Turning Scrub** in a **Drivetrain**, the harder it is for a robot to turn. **Turning Scrub** in a basic **Drivetrain** can be easily managed and minimized in two ways:

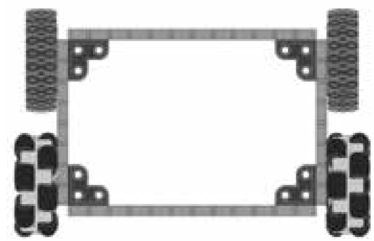
1. Make sure that the **Wheelbase** (distance between **Drivetrain** wheels) is wider (side-to-side) than it is long (front-to-back):



2. Use different wheel and/or tire types to reduce the friction of **Turning Scrub**:

Four regular VEX IQ Tires = MORE Turning Scrub





Two regular VEX IQ Tires + Two VEX IQ Omni-directional Wheels = LESS Turning Scrub

Try building the example **Drivetrains** above to see the **Turning Scrub** effect!

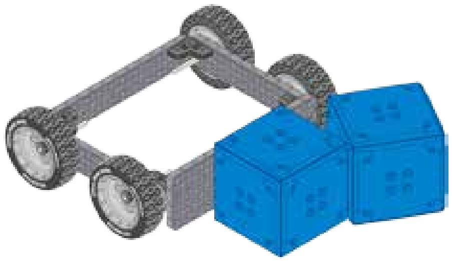
G.5

Mechanisms: Object Manipulation (Grades 4-8)

In mobile and competition robotics, an Object Manipulator is a mechanism that allows a robot to interact with objects in its environment. There are three basic categories of Object Manipulators: Plows, Scoops, and Friction Grabbers.

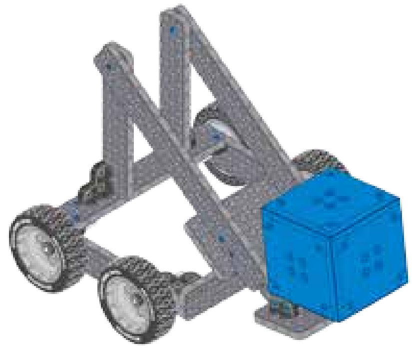
Plows

The first Object Manipulator category applies a single force to the side of an object. Plows move objects without actually picking them up and are by far the easiest manipulator type to design and build.



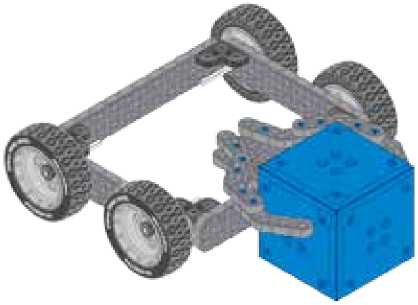
Scoops

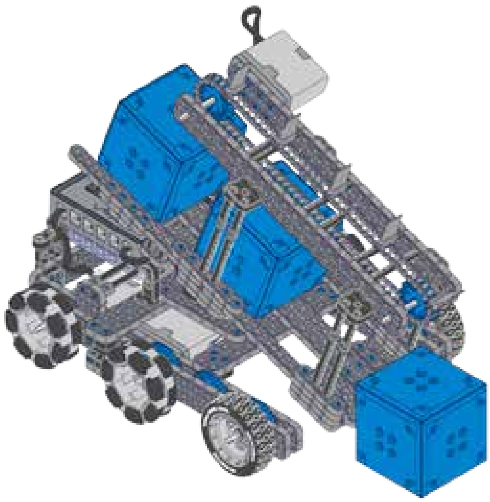
The second Object Manipulator category applies force underneath an object such that the object can be elevated and carried. Once an object is on a Scoop, it can be lifted and lowered relying on gravity to keep the object on or in the Scoop.



Friction Grabbers

The third Object Manipulator category applies a force to an object in at least two places, allowing the object to be pinched or grabbed. Thus, Friction Grabbers have the ability to hold objects securely and are generally the manipulator type that provides the most control over objects. The most common form of this manipulator type is a pinching claw.





Regardless of which category an Object Manipulator fits into, some are designed to handle single objects, while others are designed to collect and hold multiple objects. Any specialized Object Manipulator designed to collect and hold multiple objects at one time is known as an Accumulator. Accumulators, when desired, can allow for greater efficiency of an object manipulation system.

G.6

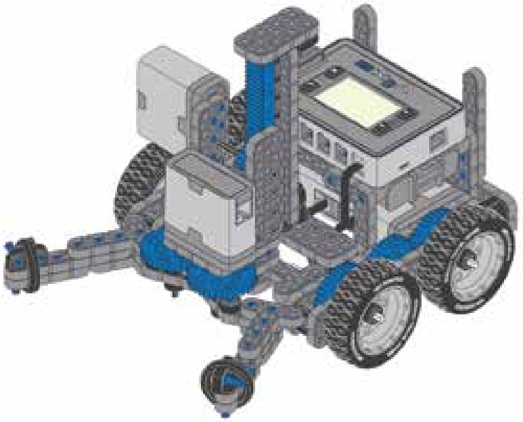
Mechanisms: Lifting Mechanisms (Grades 4-8)

Before discussing Lifting Mechanisms, it's important to know what a Degree of Freedom is. A Degree of Freedom refers to an object's ability to move in a single independent direction of motion. To be able to move in many directions means something has many Degrees of Freedom. Moving up and down is one degree of freedom, moving right and left is another; something that can move up/down and left/right has TWO Degrees of Freedom.

A Lifting Mechanism is any mechanism designed to move to perform tasks and/or lift objects. With that understood, let's look at Lifting Mechanism types. In competition robotics, there are three basic types of Lifting Mechanisms: Rotating Joints, Elevators, and Linkages.

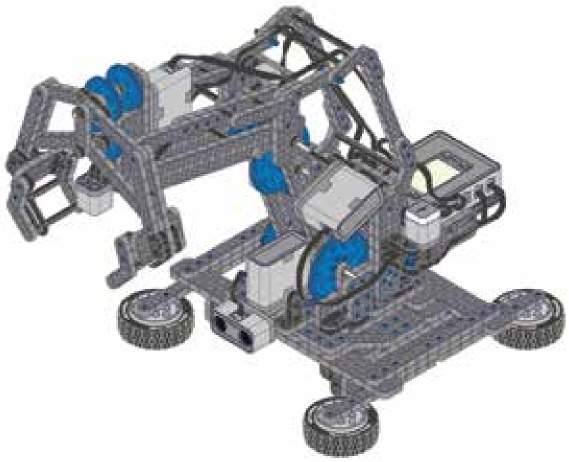
Rotating Joints

The most frequently used lifting mechanism in mobile and competition robotics is a Rotating Joint. Rotating Joints are the simplest Lifting Mechanisms to design and build. In VEX IQ, using a shaft and gears quickly creates an arm that will rotate and lift. This type of Lifting Mechanism moves on an arc, changing both the distance any manipulated objects are from a robot base, and changing the orientation of those objects (relative to their environment) on the way up.



Elevators

Another lifting mechanism used in mobile and competition robotics is an Elevator. While not as common as the Rotating Joint, the Elevator uses linear (straight line) motion to lift straight up. In VEX IQ, one way that elevators can be built is with Rack Gears and Linear Sliders, both sold as part of the Gear Kit. This type of Lifting Mechanism moves straight up and down, keeping the distance between any manipulated objects and the robot base, as well as the orientation of those objects, consistent on the way up.

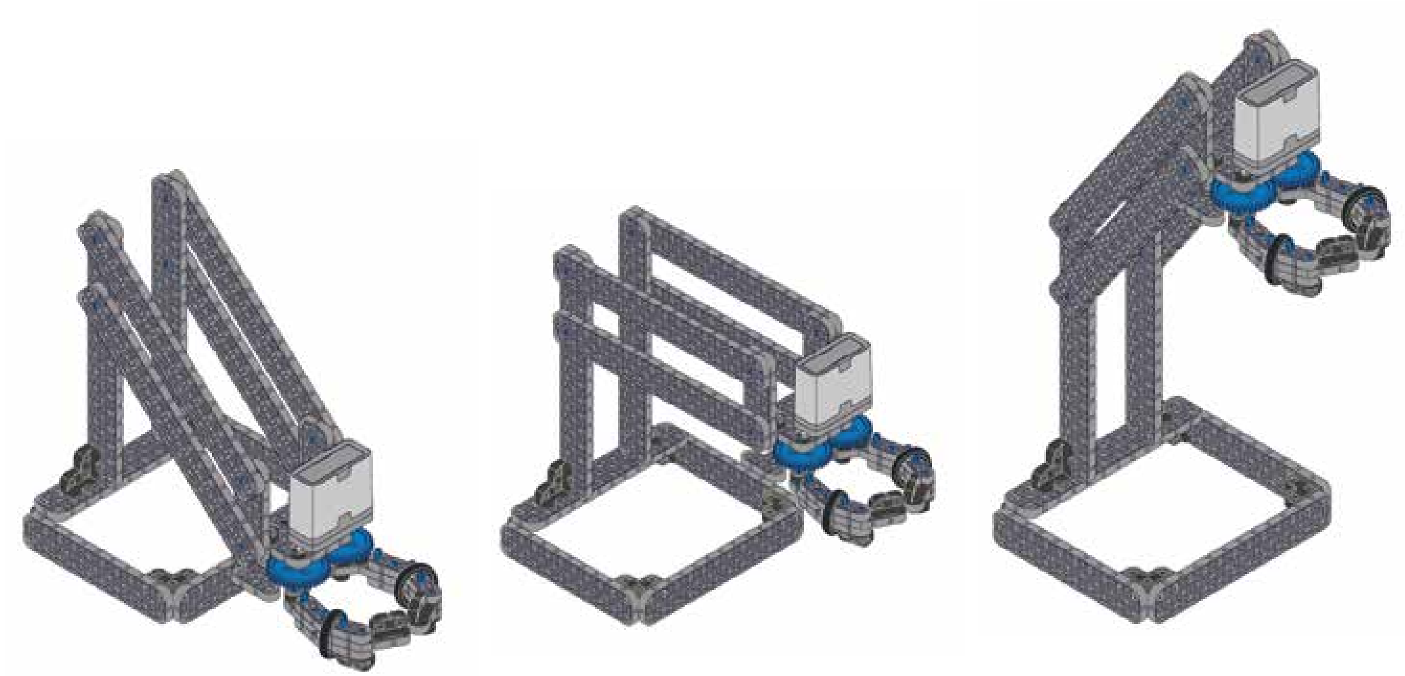


Linkages

Linkages can also be used to build Lifting Mechanisms. Linkages consist of a series of rigid bodies called links, connected together by freely rotating joints. Linkages convert an input motion into a different type of output motion and can be very consistent. For example the input motion could be a Rotating Joint, but the Linkage could produce Elevator-like output motion. In VEX IQ, combinations of different-sized beams, shafts, and/or connector pins can be used to construct a Linkage.

G.6 cont.

One of the simplest and most common linkage types is the Four-Bar **Linkage**. This is a linkage system that provides a wide variety of motions depending on its configuration. By varying the length of each link, one can greatly change the output motion. The most basic type of Four-Bar **Linkage** is one where link pairs are equal length and parallel to each other, as seen below:



If you have time, try building the Four-Bar linkage show here to see how a linkage works!

Rotating Joint, Elevator, or Linkage?

Elements to consider when deciding what type of **Lifting Mechanism** is best for your robot's needs:

- Elevation Required – How high do you have to lift?
- Object Orientation – Do the objects you are lifting have to remain in a certain orientation?
- Size Limitations – Are there design or environmental limitations to your robot's size?
- Complexity – How many degrees of freedom are desired? What type of hardware is required?
- Motors Required – Do you have enough? Is the total number limited?

G.7

Mechanisms Matching Exercise

Student Name(s): ______________________________

Teacher/Class: ______________________________ Date: ______________

Instructions:

Match terms from the word bank to the correct definition by writing terms on the correct line. Each term is only used once.

Word Bank:

Accumulator	Chassis	DC Motors
Gear Train	Degree of Freedom	Driven Gear
Driving Gear	Friction Grabbers	Drivetrain Elevator
Gear Ratio	Idler Gears	Lifting Mechanism
Object Manipulator	Linkages	Motor Loading
Plows	Rotating Joint	Scoop
Stalls	Turning Scrub	Wheelbase

From DC Motors (grades 4-8):

______________________________ convert electrical energy into mechanical energy through the use of electro-magnetic fields and rotating wire coils.

______________________________ happens when there is any opposing force (such as friction or a heavy mass) acting as a load and requiring the motor to output torque to overcome it.

If you keep increasing the load on a motor it will eventually stops spinning or ____________________.

From Gear Ratio (grades 2-8):

______________________________ expresses the relationship between a Driving Gear and a Driven Gear in a system.

A ______________________________ is the gear connected to the input power source, such as a motor.

A ______________________________ is the gear connected to the output, such as a wheel or mechanism in a system.

A simple ______________________________ is a connected set of rotating gears that transmits power from an input to an output. All gears in between the Driving Gear and the Driven Gear that only transmit power are known as ______________________________.

From Drivetrains (grades 4-8):

The robotic subsystem that provides the ability to move is often known as a ____________________ ________________.

A ______________________________ is the structure of a mobile robot that holds wheels, motors, and/or any other hardware used to make up a Drivetrain.

______________________________ is the friction that resists turning.

The ______________________________ is the distance between Drivetrain wheels.

G.7 cont.

From Object Manipulation (grades 4-8):

An ______________________________ is a mechanism that allows a robot to interact with objects in its environment.

______________________________ move objects without actually picking them up and they are by far the easiest manipulator type to design and build.

A ______________________________ applies force underneath an object such that the object can be elevated and carried.

______________________________ apply a force to an object in at least two places, allowing the object to be pinched or grabbed.

Any specialized Object Manipulator designed to collect and hold multiple objects at one time is known as an ______________________________.

From Lifting Mechanisms (grades 4-8):

A ______________________________ refers to an object's ability to move in a single independent direction of motion.

A ______________________________ is any mechanism designed to move to perform tasks and/or lift objects.

The most frequently used lifting mechanism in mobile and competition robotics is a ______________ ______________________ .

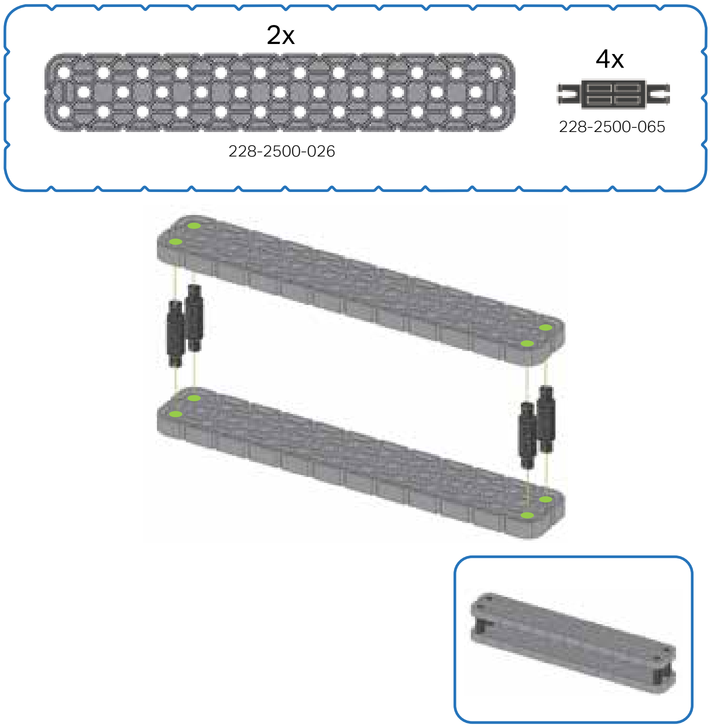
An ______________________________ uses linear (straight line) motion to lift straight up.

__________________________ convert an input motion into a different type of output motion.

G.8

VEX IQ Gear Ratio Simulator Assembly Instructions

1



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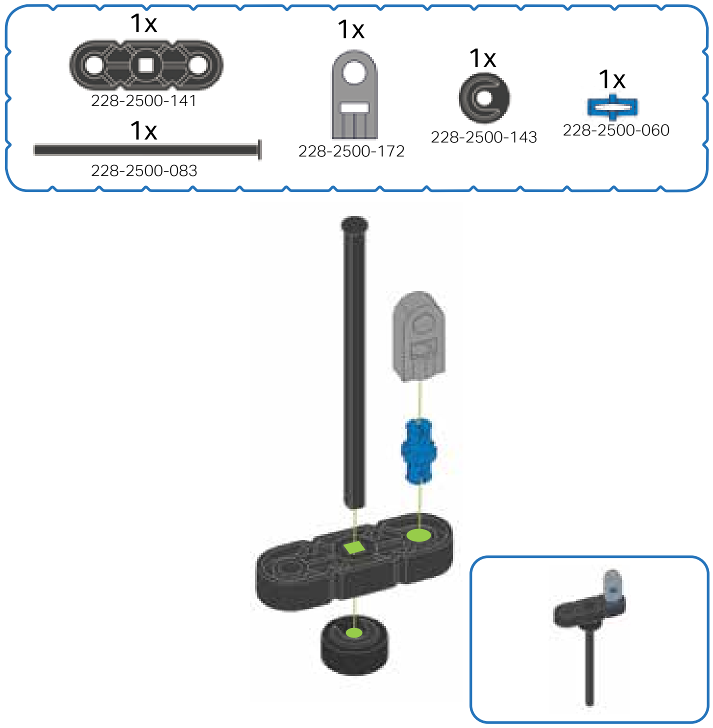

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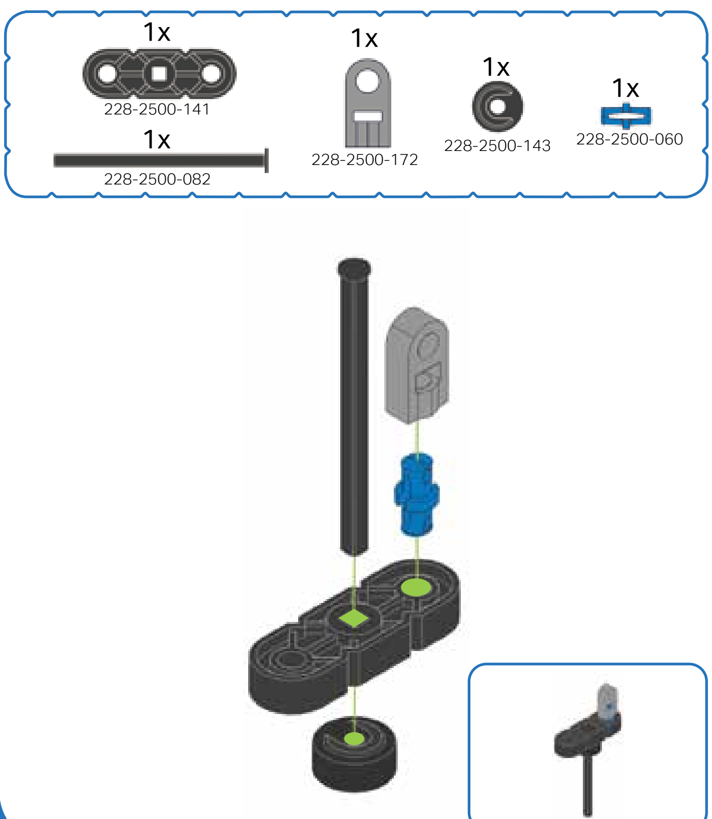

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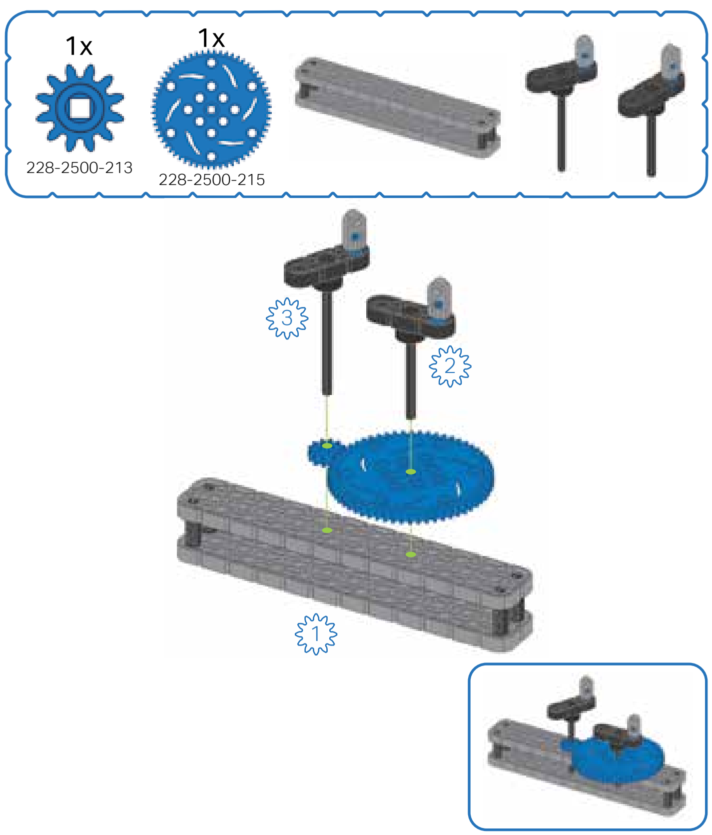
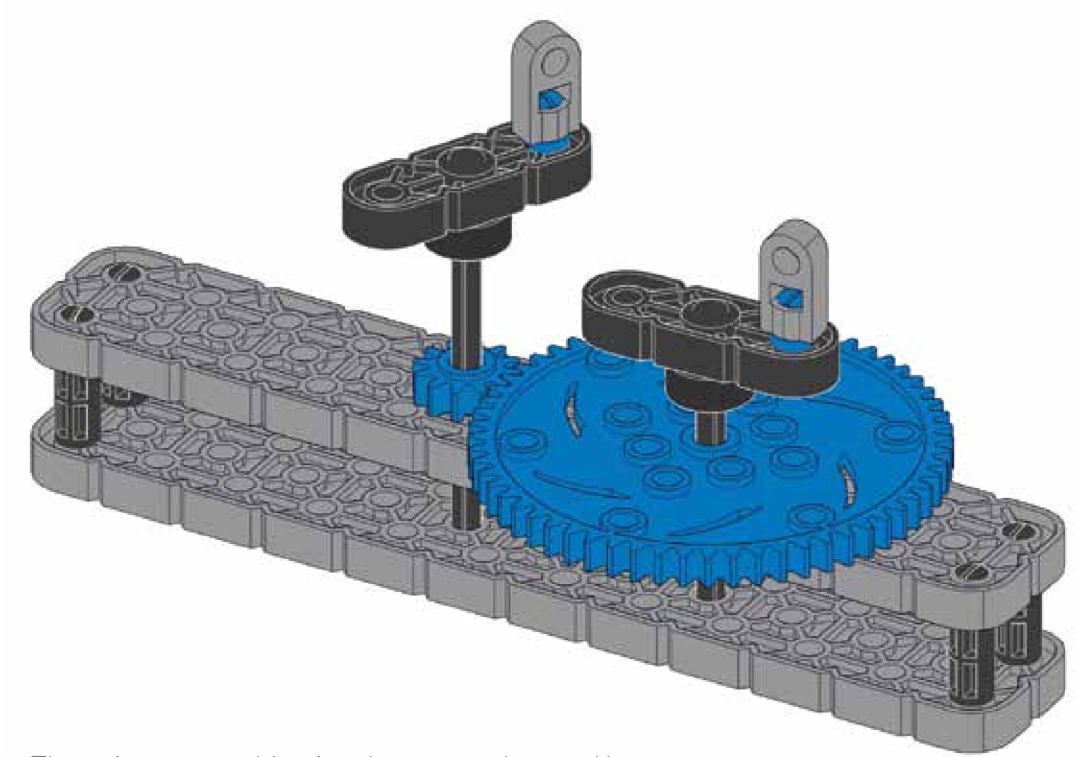


G.8 cont.

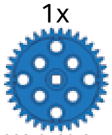
Basic Gear Assembly



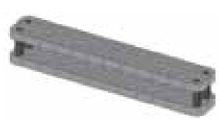
Note: The only gear combination that cannot be used is a 12-tooth gear on both input and output shafts.

5

1x

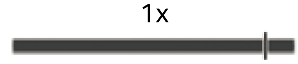


228-2500-214



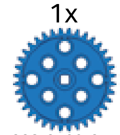
6

1x



228-2500-079

1x



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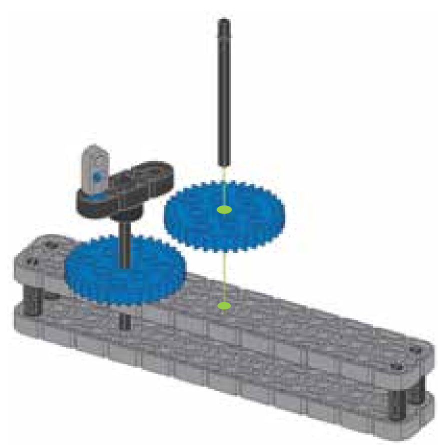
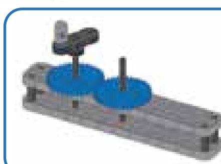
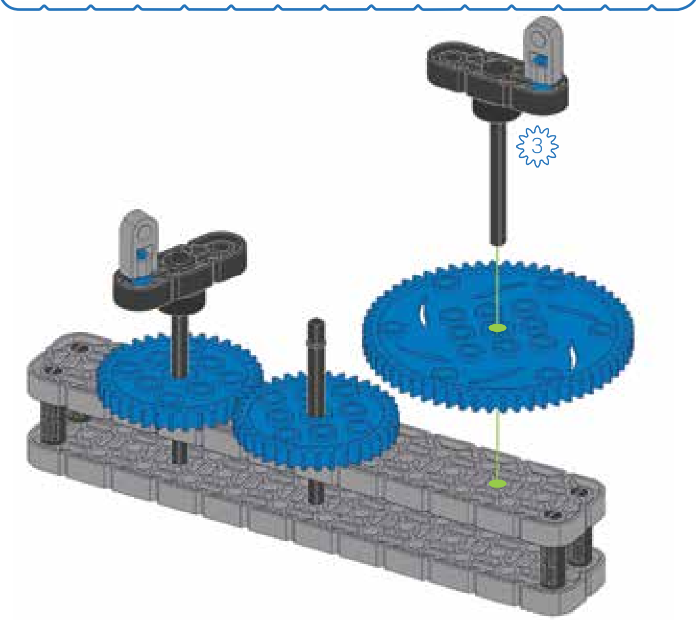


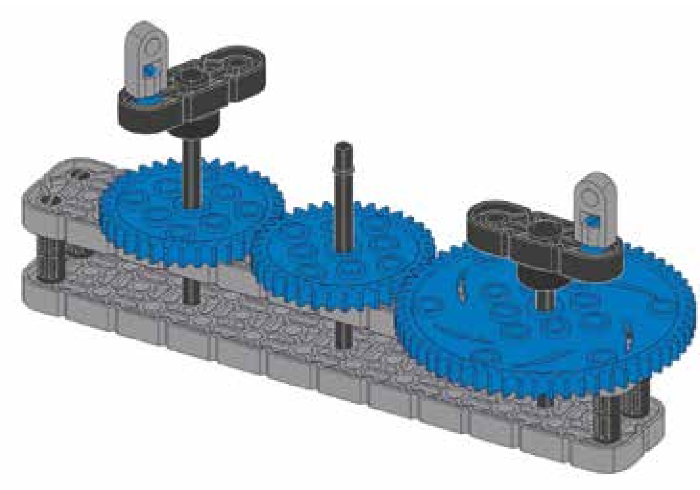


G.8 cont.

9



Assembly with Idler Gear



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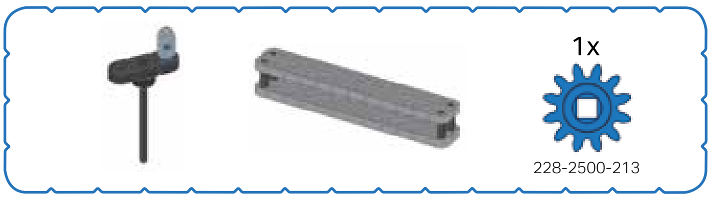

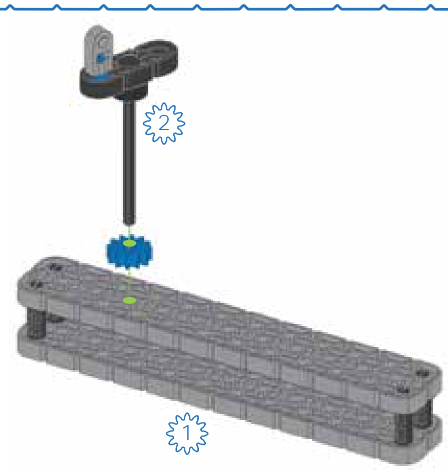

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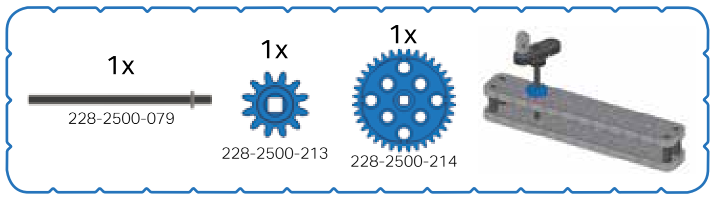
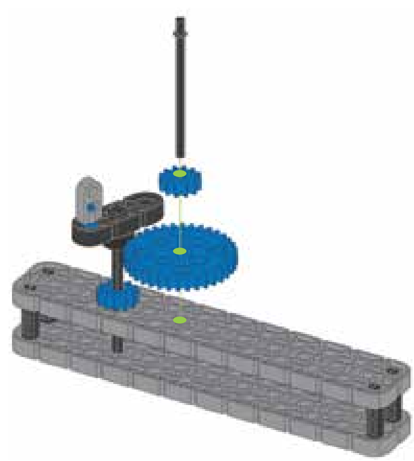
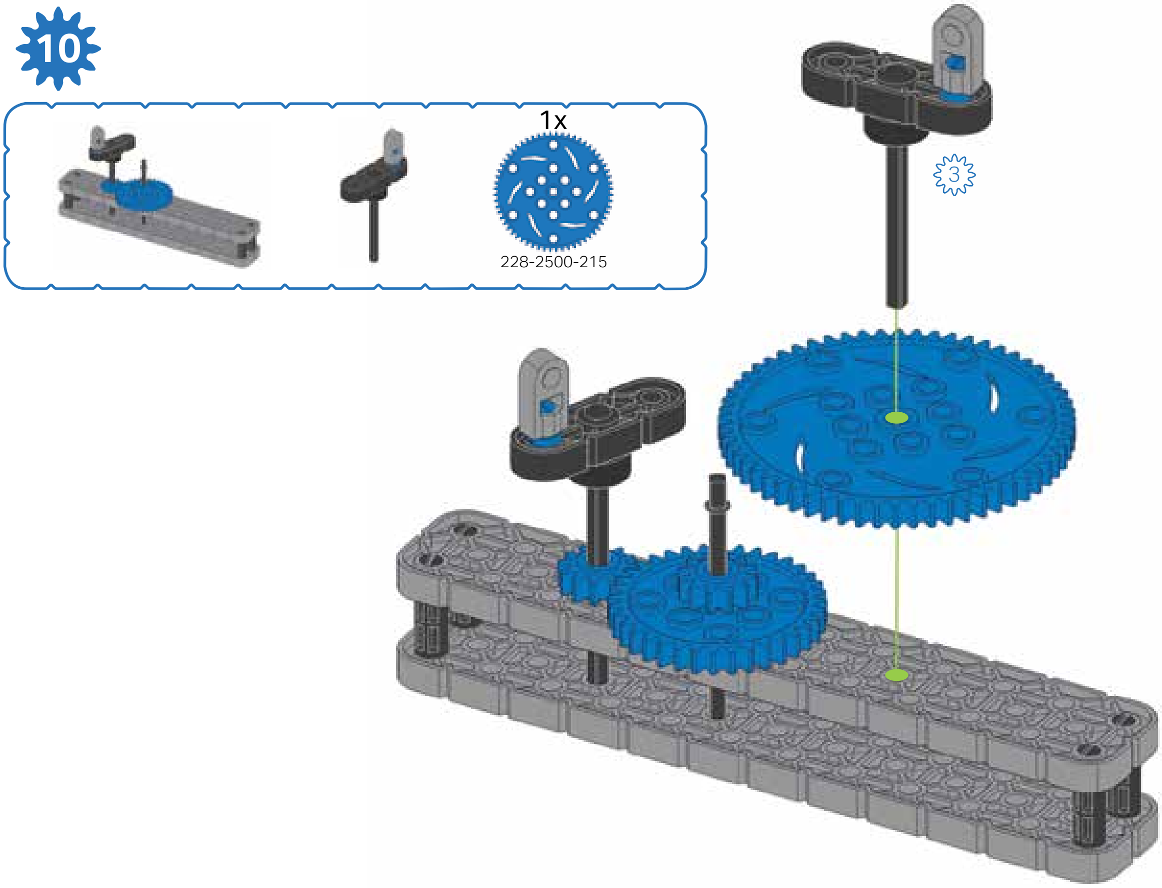
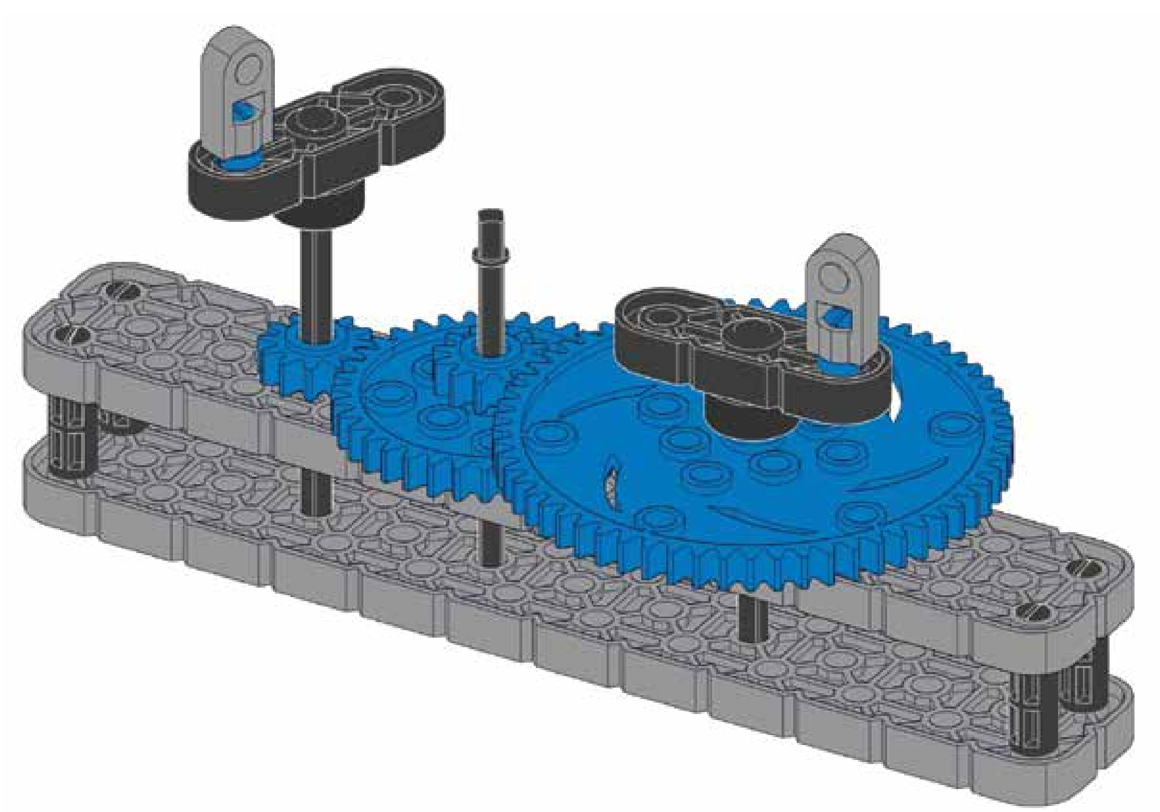




10



Assembly with Compound Gear Reduction



G.9

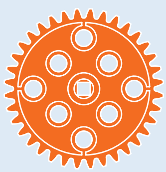
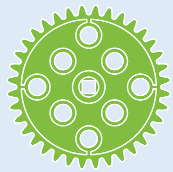
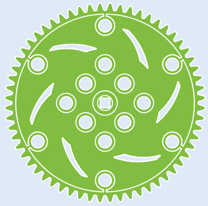
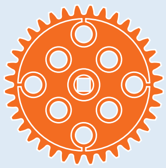
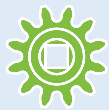
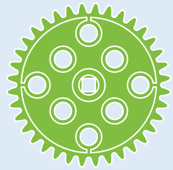
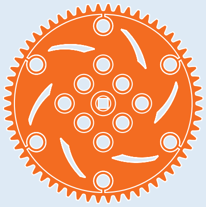
Mechanisms Gear Ratio Exercise #1: Gear Ratio Basics (Grades 2-8)

Student Name(s): ______________________________

Teacher/Class: ______________________________ Date: ______________

Instructions:

After learning about Gear Ratio Basics from section G.3, demonstrate what you have learned by circling correct answers below. You may also build and use the VEX IQ Gear Ratio Simulator along with 12-tooth, 36-tooth, and 60-tooth gears to help find answers.

Driving Gear (Input)	Driven Gear (Output)	What does this ratio create comparing output to input? (Circle the correct answer below)		
36-tooth 	36-tooth 	Equal: Speed ↑ Torque ↑	Torque ↑ Speed ↓	Speed ↑ Torque ↓
12-tooth 	60-tooth 	Equal: Speed ↑ Torque ↑	Torque ↑ Speed ↓	Speed ↑ Torque ↓
36-tooth 	12-tooth 	Equal: Speed ↑ Torque ↑	Torque ↑ Speed ↓	Speed ↑ Torque ↓
12-tooth 	36-tooth 	Equal: Speed ↑ Torque ↑	Torque ↑ Speed ↓	Speed ↑ Torque ↓
60-tooth 	12-tooth 	Equal: Speed ↑ Torque ↑	Torque ↑ Speed ↓	Speed ↑ Torque ↓

G.9 cont.

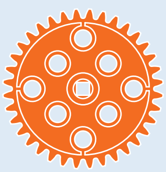
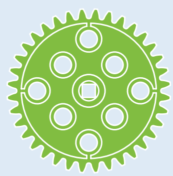
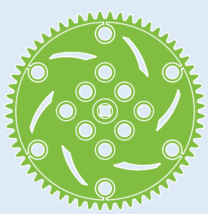
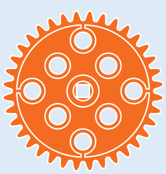
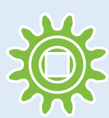
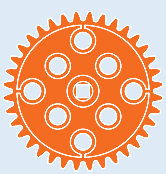
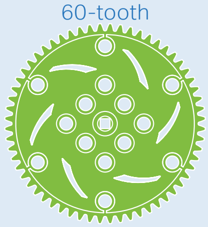
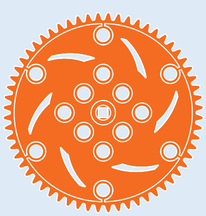
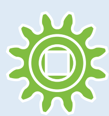
Mechanisms Gear Ratio Exercise #2: Expressing Ratio and Reduction (Grades 4-8)

Student Name(s): ____

Teacher/Class: ______________________________ Date: ______________

Instructions:

After learning about Expressing Gear Ratio and Gear Reduction from section G.3, demonstrate what you have learned by calculating and writing in correct answers. You may also build and use the VEX IQ Gear Ratio Simulator along with 12-tooth, 36-tooth, and 60-tooth gears to help find answers.

Driving Gear (Input)	Driven Gear (Output)	Gear Ratio	Gear Reduction	Simplified Gear Reduction	Is Speed or Torque increased?
36-tooth 	36-tooth 	____ : ____	____ / ____	____ / ____	__________
12-tooth 	60-tooth 	____ : ____	____ / ____	____ / ____	__________
36-tooth 	12-tooth 	____ : ____	____ / ____	____ / ____	__________
36-tooth 	60-tooth 	____ : ____	____ / ____	____ / ____	__________
60-tooth 	12-tooth 	____ : ____	____ / ____	____ / ____	__________

G.9 cont.

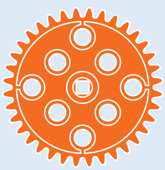
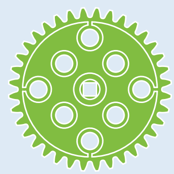
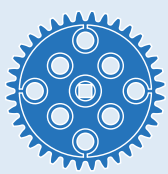
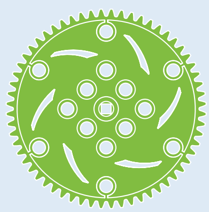
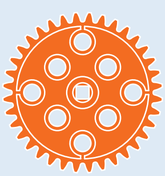
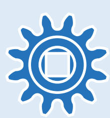
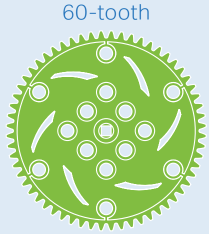
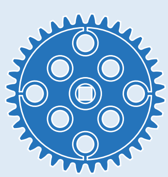
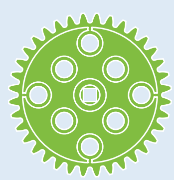
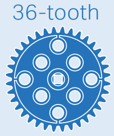
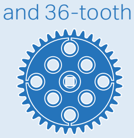
Mechanisms Gear Ratio Exercise #3: Gear Trains and Idler Gears (Grades 6-8)

Student Name(s): ______________________________

Teacher/Class: ______________________________ Date: ______________

Instructions:

After learning about Gear Trains and Idler Gears from G.3, demonstrate what you have learned by calculating and writing in correct answers. You may also build and use the VEX IQ Gear Ratio Simulator along with 12-tooth, 36-tooth, and 60-tooth gears to help find answers.

Driving Gear (Input)	Idler Gear	Driven Gear (Output)	Gear Ratio	Gear Reduction	Simplified Gear Reduction
36-tooth 	60-tooth 	36-tooth 	____ : ____	____ / ____	____ / ____
12-tooth 	36-tooth 	60-tooth 	____ : ____	____ / ____	____ / ____
36-tooth 	12-tooth 	60-tooth 	____ : ____	____ / ____	____ / ____
12-tooth 	36-tooth 	36-tooth 	____ : ____	____ / ____	____ / ____
12-tooth 	36-tooth  and 36-tooth 	60-tooth 	____ : ____	____ / ____	____ / ____

Mechanisms Gear Ratio Exercise #4: Compound Gear Reductions (Grades 6-8)

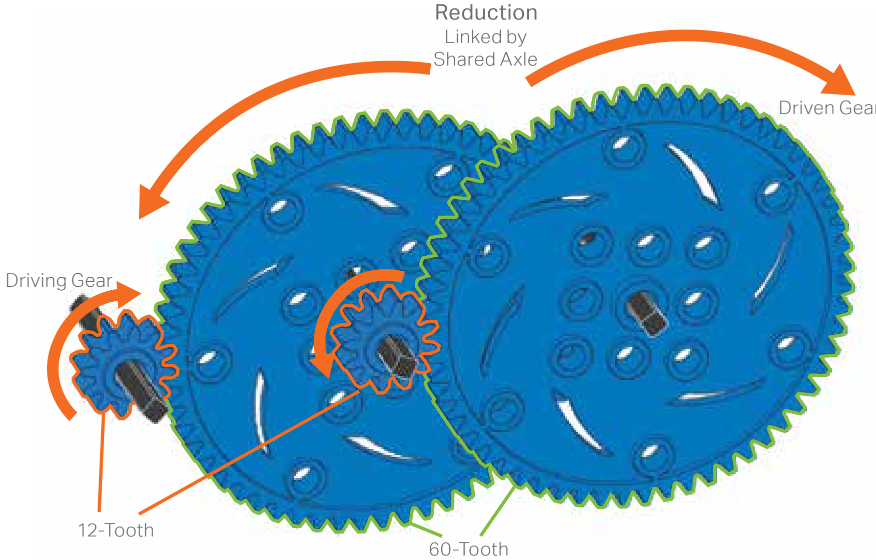
Student Name(s): ____

Teacher/Class: ______________________________ Date: ______________

Review of Key Points:

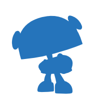
In a Compound Gear system, there are multiple gear pairs. Each pair has its own Gear Ratio, and a shared axle connects the pairs to each other. The resulting Compound Gear system still has a Driving Gear and a Driven Gear, and still has a Gear Reduction. However, it is now called a Compound Gear Reduction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

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



(60 / 12) x (60 / 12)

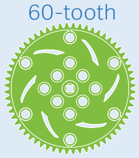
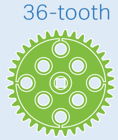
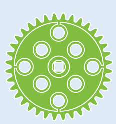
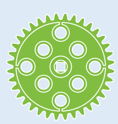
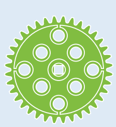
(5 / 1) x (5 / 1) = 25 / 1



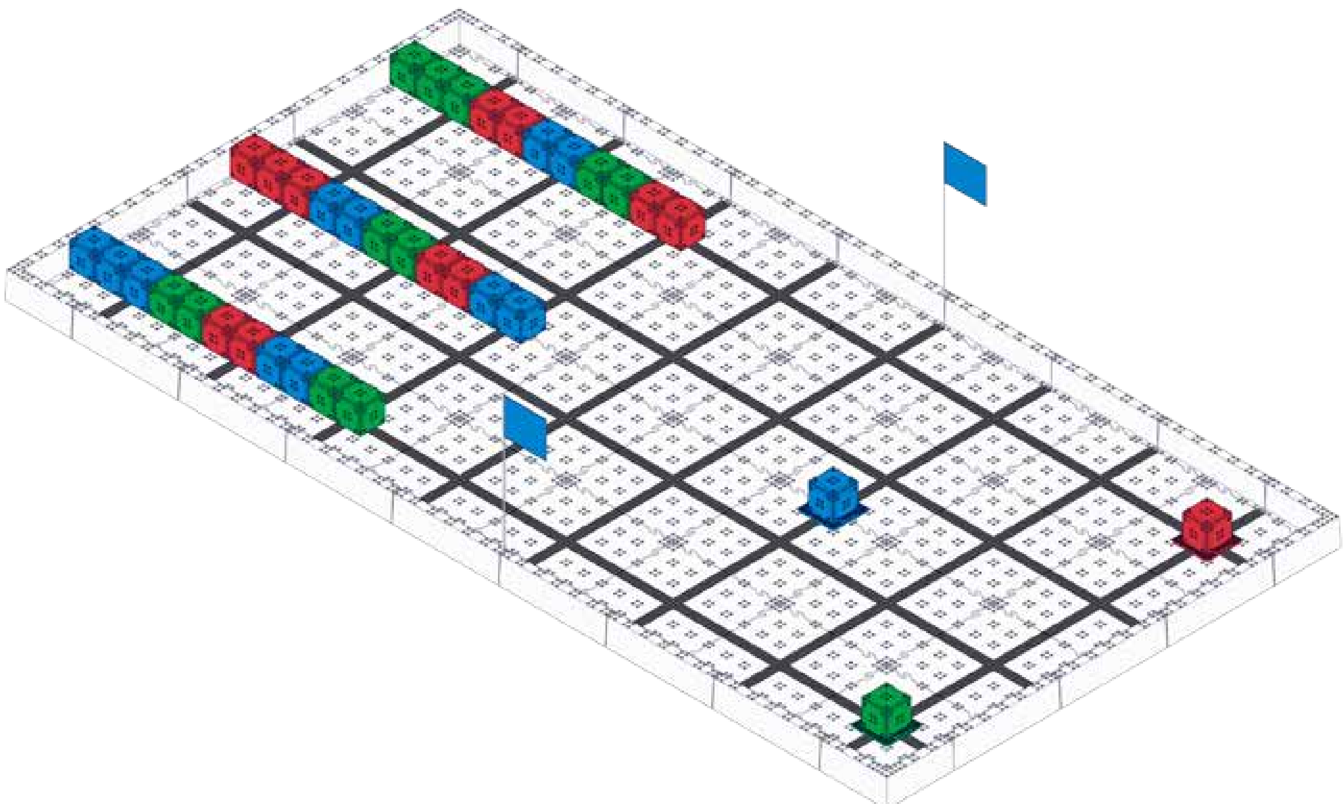
Say "25 to 1 Compound Gear Reduction"

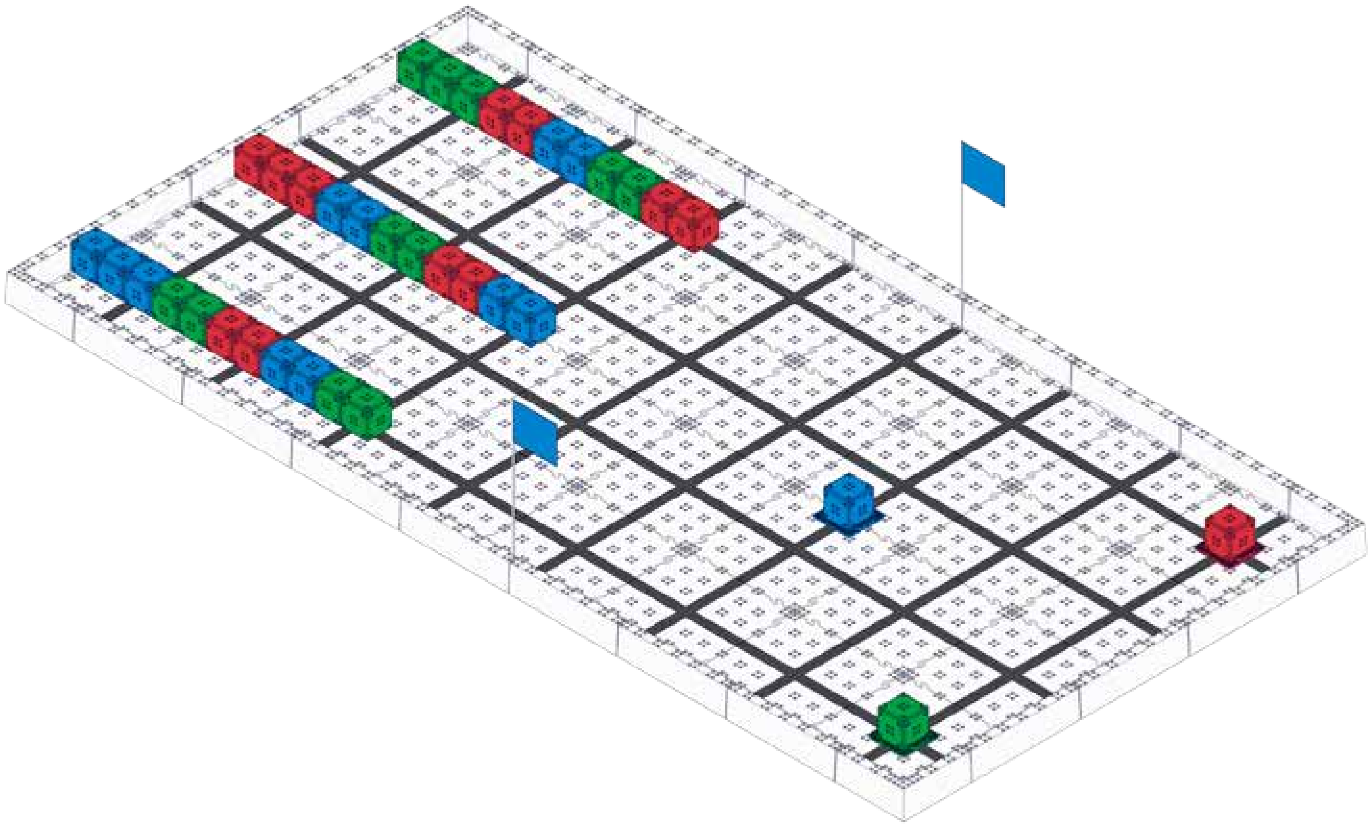
Instructions:

Using the information above from Compound Gears and Compound Gear Reductions (G.3), demonstrate what you have learned by calculating the correct Compound Gear Reductions. You may also build and use the VEX IQ Gear Ratio Simulator along with 12-tooth, 36-tooth, and 60-tooth kit gears to help find answers.

Gear Pair 1		Gear Pair 2				
Driving Gear 1	Driven Gear 1	Driving Gear 2	Driven Gear 2	Simplified Reduction 1	Simplified Reduction 2	Compound Gear Reduction
12-tooth 	60-tooth 	12-tooth 	36-tooth 	____ / ____	____ / ____	____ / ____
12-tooth 	36-tooth 	12-tooth 	36-tooth 	____ / ____	____ / ____	____ / ____
12-tooth 	36-tooth 	12-tooth 	60-tooth 	____ / ____	____ / ____	____ / ____

Highrise Challenge





H.1

Highrise Challenge

Unit Overview:

Feel the excitement of robotics competition as you apply you skills and knowledge from previous units to build a challenge-ready teleoperated robot capable of completing Teamwork Skills and Robot Skills matches in the VEX IQ Challenge game.

Unit Content:

- Challenge Overview
- Challenge Rules (http://www.vexiq.com/Highrise)

Note: Your teacher may also decide to use a different VEX IQ Challenge Game for this unit or a game of their own creation. See your teacher for details.

Unit Activities:

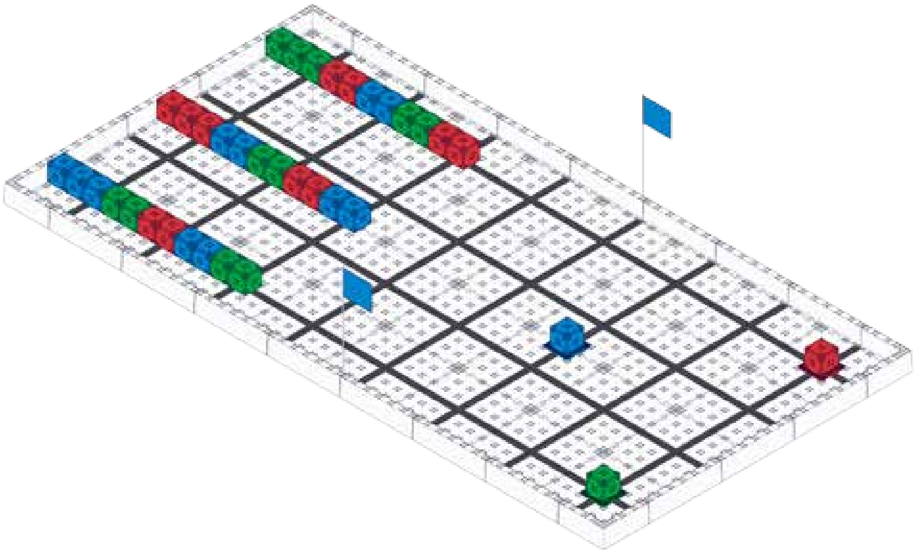
- Challenge Robot Build using Robot Challenge Evaluation Rubric
- Completion of Idea Book Pages (or Engineering Notebook) with robot build and testing

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

H.2

Challenge Overview

Whether you're going to attend an official VEX IQ Challenge Event, host your own event, or just play the game in your classroom, it's time to design and build a robot for a full teleoperated robotics game! Use your knowledge of the VEX IQ platform and all you've learned in previous lessons to create a **VEX IQ robot for the Teamwork Challenge and/or the Robot Skills Challenge portion of the VEX IQ Challenge Game, Highrise!**



H.3

The Game Rules:

All of the rules for playing the game and other important information can be found at the VEX IQ Challenge Highrise page: www.vexiq.com/Highrise

Important Notes

- Your teacher will need to obtain the Highrise Field & Game Elements and VEX IQ Challenge Field for this unit **OR** obtain just the Highrise Field & Game Elements and create a similar field from easy to obtain items.
- Alternatively, your teacher could get creative and challenge you to design and build for a brand new game that they design.

Idea Book Page: The Engineering Notebook

You are provided with an Idea Book Page in this unit that can be used to develop a full Engineering Notebook. Use as many of these pages as you need to document your robot ideas, builds, fixes, changes, and improvements for the game challenge. Alternatively, teachers and students are encouraged, when comfortable, to use the Robotics Engineering Notebook (provided to registered VEX IQ Challenge teams and also sold separately) for this purpose instead.

Robot Challenge Evaluation Rubric:

This rubric can be used to assess your challenge robot in up to eleven technical and non-technical categories. No matter how your teacher chooses to use the rubric, it will be obvious that your PROCESS and your PRODUCT (robot) are equally important.

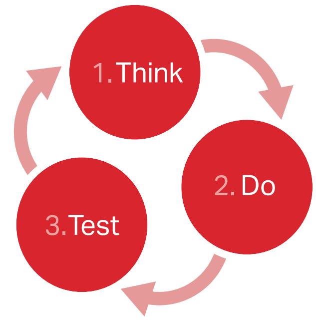
Robot Challenge Evaluation Rubric

Evaluation Criteria	Expert = 4	Proficient = 3	Emerging = 2	Novice = 1	Assessment	Comments
Design & Process Criteria						
Creating Viable Solutions to the stated Challenge	Multiple, well developed solutions exist meeting all critical criteria	Multiple solutions are evident & one is developed meeting majority of criteria	Multiple, undeveloped solutions are evident	A solution that may or may not be developed is evident		
Simple and/or Complex Systems	All simple and/ or complex systems are identified & function efficiently	Functioning simple and/ or complex systems exist	Multiple simple systems exist that may function	One functioning simple system exists (e.g. drivetrain only)		
Design Process (documented in Idea Book or Engineering Notebook)	Formal design process utilized, documented & enhances efficiency	Formal design process utilized and fully documented	Formal design process utilized consistently	Some evidence that formal design process was utilized		
Utilization of Resources (materials and parts, information and instructions, people, and time)	Resources used within constraints, efficiency maximized,	Resources utilized to maximize efficiency	Evidence that some resources utilized meet-ing intended purpose	A few resources (e.g. tools & materials) utilized randomly		
Technical Criteria						
Programming (Autonomous and/ or teleoperated)	Efficiency evident in all programming	Consistency evident in one or more parts of program-ming	Functional, but inconsistent programming	Programming incomplete or rarely functional		
Control Systems	Completely functional and consistent con-trol systems	Consistently functional con-trol systems	Functional, but inconsistent control systems	Non-functional or incomplete control systems		
Electrical Systems	Battery charged. Wire routing safe, efficient, & completely functional	Battery charged. Wire routing safe & consistently functional	Functional, but inconsistent (battery or wiring issues)	Non-functional or incomplete (battery and wiring issues)		
Mechanical Systems	Completely functional and consistent mechanical systems	Consistently functional mechanical systems	Functional, but inconsistent mechanical systems	Non-functional or incom-plete/ unsafe mechanical systems		
Unifying Themes (This area emphasizes the Interaction of Science, Technology, & Human Endeavor)						
Communication (written, electronic and/or oral as defined by the teacher)	Sophisticated and highly effi-cient commu-nication for all audiences	Purposeful, consistent, effective communication	Purposeful, fairly consis-tent communi-cation	Communica-tion very inconsistent and lacks purpose		
Teamwork	Integrated team-work that maxi-mizes outcomes is evident	Teammates fully define roles, goals, & work together	Teammates partially define roles, goals, & work together	Participants function separately within a group		
Creativity	Robot is unique, imaginative, and functional	Robot is unique and/or imagina-tive in multiple ways	Robot clearly shows a unique and/ or imagi-native element	Unique and/ or imaginative element(s) unclear		

Rubric Adapted from Rubric and Evaluation Criteria for Standards-Based Robotics Competitions & Related Learning Experiences – TSA, 2005

H.5

Idea Book Page: The Engineering Notebook



Student Name(s): ____

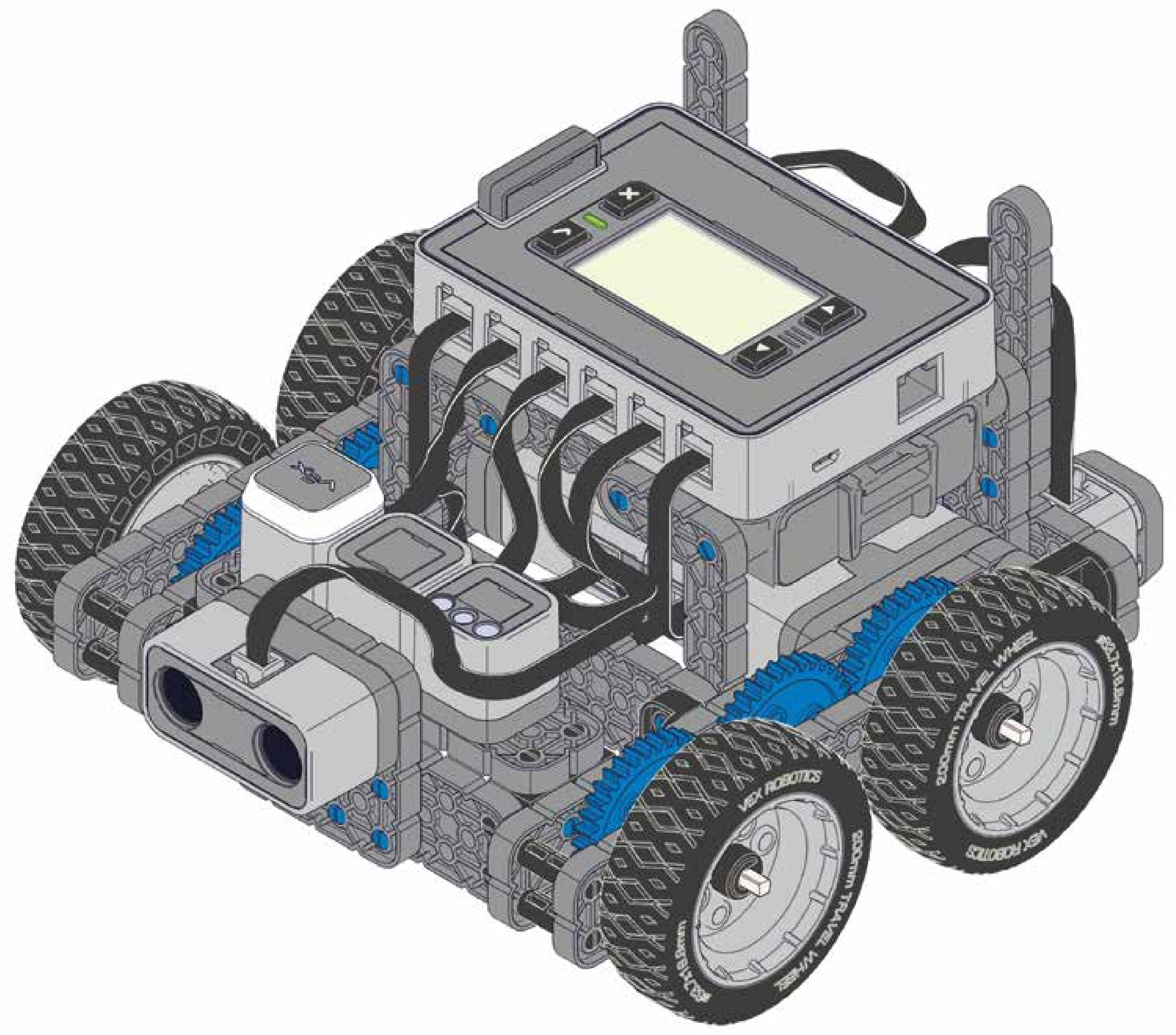
Teacher/Class: ____________________ Date: _________ Page #: _____

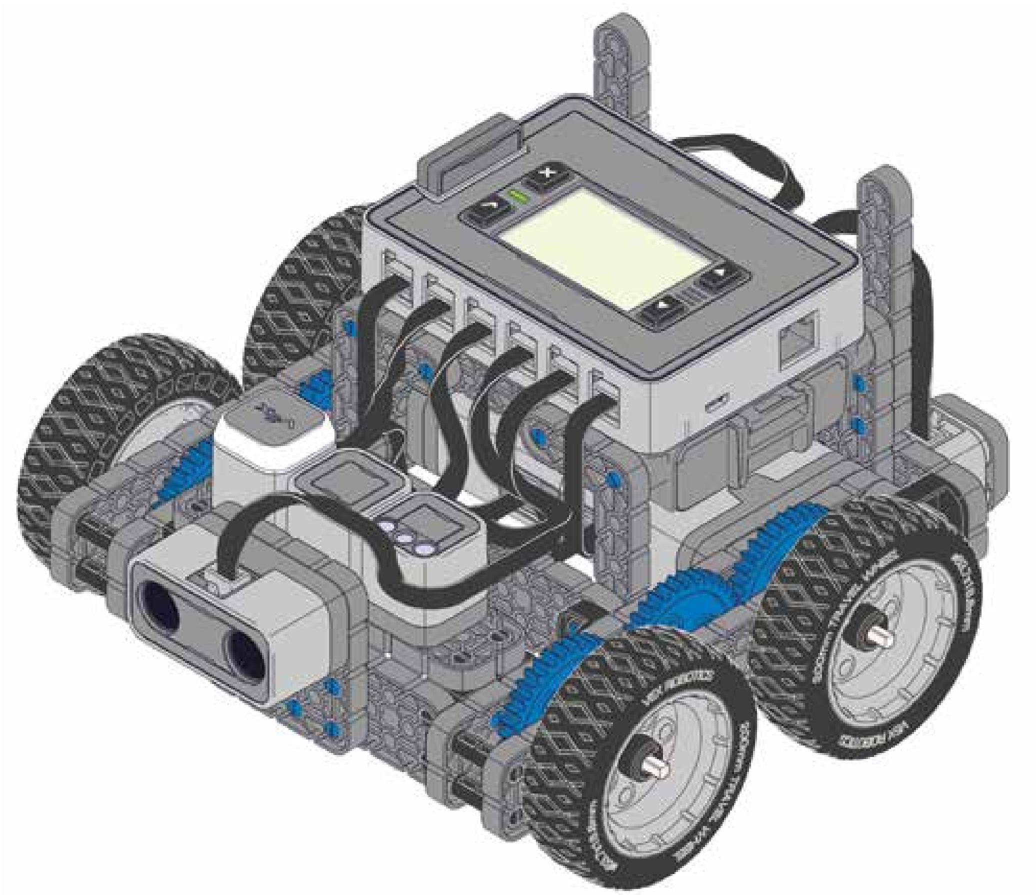
Use as many of these pages as you need to document your robot ideas, build, fixes, changes, and improvements for the game challenge. Remember the “Think-Do-Test Loop” you learned in the Your First Robot Unit. Number each page and use the space as you see fit for ideas, notes, observations, drawings with labels, calculations, and more. Alternatively, teachers and students are encouraged, when comfortable, to use the Robotics Engineering Notebook (P/N 276-3023, provided to registered VEX IQ Challenge teams and also sold separately) for this purpose instead. **Be sure to make as many copies of this page as you think you’ll need BEFORE writing in it!**

Remember: Problems ARE NOT failures, they are an expected part of the design process!

I

Smart Machines





I.1

Smart Machines

Unit Overview:

This unit introduces students to Sensors and Programming with VEX IQ. VEX IQ Sensors allow for autonomous and hybrid control of VEX IQ robots and other creations. VEX IQ Sensors connect to a robot or mechanism quickly and are easily programmed to help measure time, position distance, rotation, sense touch, provide feedback, allow for human-to-robot interaction, and much more.

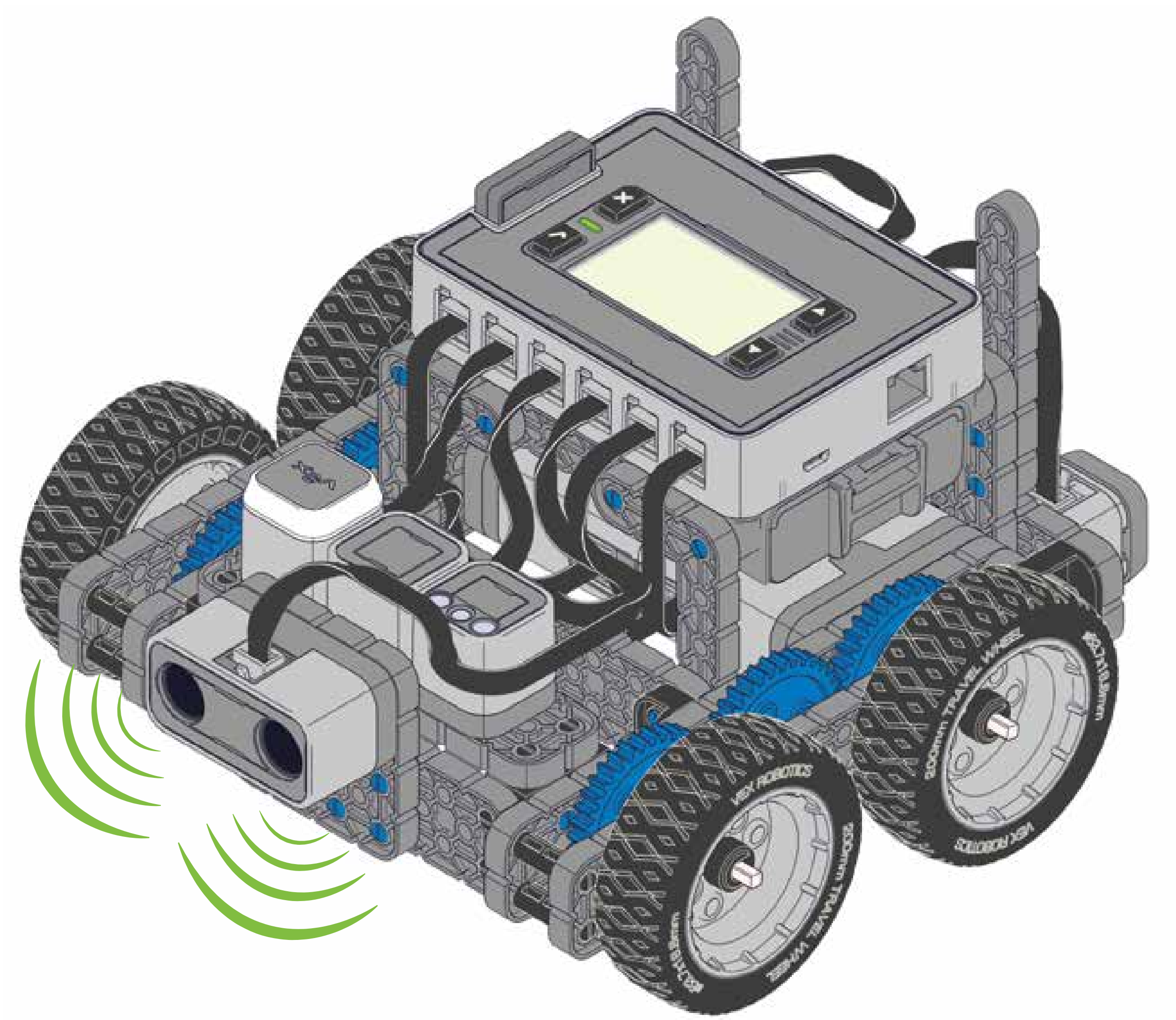
Unit Content:

- Key Terms: Sensor, Programming, Ultrasonic Sound Waves, Distance Sensor, Gyroscope, Degrees of Turn, Encoder
- VEX IQ Sensor Overview

Unit Activities:

- Matching Exercise
- Autopilot Robot Build with assembly instructions (included with kit)
- Run Autopilot Modes (instructions included with kit documentation)
- Default Sensor Functionality Exercises
- Simple Programming Exercises using only the Robot Brain
- Simple Programming Exercises using Programming Software
- Completion of Idea Book Pages with robot programming and testing

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!



I.2

Key Terms

A **Sensor** is a device that detects and responds to some type of input from the physical environment. VEX IQ sensors can detect light, color, objects, motion, and more!

Programming is the process of providing a computer or other machine, such as a robot and its components, with coded instructions for the automatic performance of a particular task.

Ultrasonic Sound Waves are sounds that are too high of a frequency to be heard by humans. The VEX IQ **Distance Sensor** sends ultrasonic sound waves out that will bounce back if something is in its path, measuring distance by the amount of time it takes the sound to return.

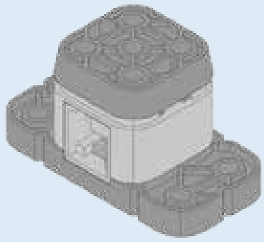
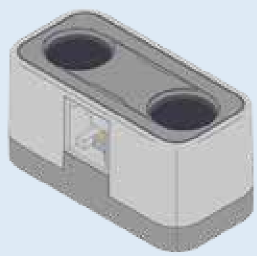
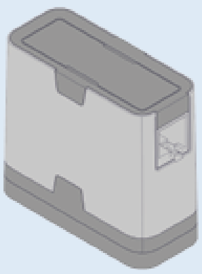
A **Gyroscope** (or **Gyro**) is a sensor that can detect and measure rotation or turning of an object.

Degrees of Turn describes how far an object, like a robot, has turned. An object that spins completely around to its original starting position has turned 360 degrees. An object that has turned to face the opposite direction has turned 180 degrees. VEX IQ **Sensors** can measure **Degrees of Turn**, allowing for precise control.

An **Encoder** senses mechanical motion and translates the information (velocity, position, acceleration) into useful data. VEX IQ Smart Motors have built in **Encoders**.

I.3

VEX IQ Sensor Overview

Sensor Name	Sensor Image	Sensor Specs & Use	Default Functionality
Bumper Switch		Allows for the sense of touch in the VEX IQ platform. Detect a wall, obstacle, or limit mechanism movement.	With a Bumper Switch in port 2, it disables/ enables a Smart Motor in port 4.
Touch LED		Smart Sensor with red, green, blue LEDs. Constant on, off, or blink at any desired rate. Touch sensor with finger for interaction.	Enables and disables Autopilot or similar robot running Driver Control Program when dome of sensor is tapped. Glows green when enabled, red when disabled.
Distance Sensor		Uses ultrasonic sound waves to measure distance. Measures distance from 1 inch to 10 feet. Commonly used to avoid obstacles.	Slows down and eventually stops as Autopilot or similar robot running Driver Control Program as the robot approaches an obstacle.
Color Sensor		Detects the color of objects. Measures independent red, green, and blue in 256 levels each.	Enables and disables Autopilot or similar robot running Driver Control Program when the sensor is "shown" a green card (enabled) or red card (disabled).
Gyro Sensor		Measures turn rate and calculates direction. Frequently used in autonomous robot navigation and turning.	With Autopilot or similar robot running Driver Control Program, it returns a robot to its original direction when driving stops.
Smart Motor		Commands and measures speed, direction, time, revolutions and/or degrees of turn using its Encoder.	No extra default functionality, but Encoders allow for superior motor control with simple programming.

I.4

Smart Machines Matching Exercise

Student Name(s): ____

Teacher/Class: ____________________ Date: ___________ Page#: ________

Part I Instructions:

Match terms from the word bank to the correct definition or statement by writing terms on the correct line. Each term is only used once.

Part I Word Bank:

Degrees of Turn	Gyroscope	Sensor
Encoder	Programming	Ultrasonic Sound Waves

A(n) ____________________ is a device that detects and responds to some type of input from the physical environment.

____________________ is the process of providing a computer or other machine, such as a robot and its components, with coded instructions for the automatic performance of a particular task.

____________________ are sounds that are too high of a frequency to be heard by humans.

A(n) ____________________ is a sensor that can detect and measure rotation or turning of an object.

____________________ describes how far an object, like a robot, has turned.

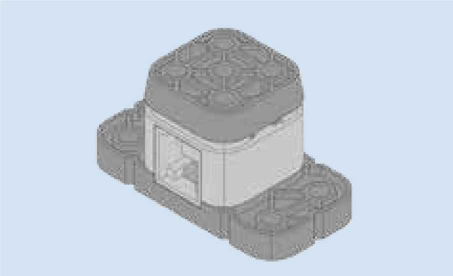
A(n) ____________________ senses mechanical motion and translates the information into useful data.

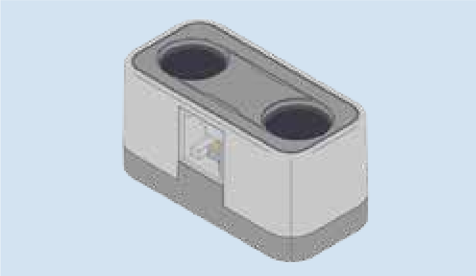
Part II Instructions:

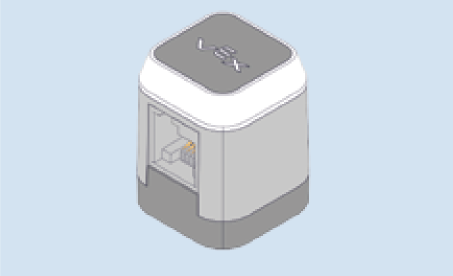
Match terms from the word bank and label correctly below each image (images are NOT to scale)

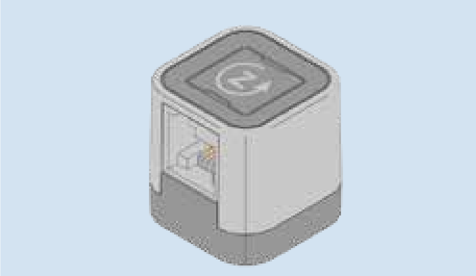
Part II Word Bank:

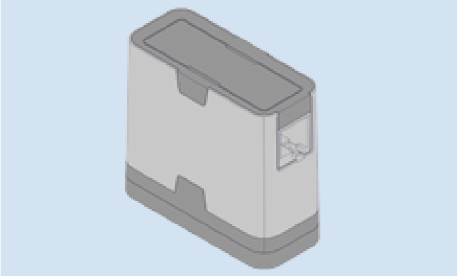
Bumper Switch	Distance Sensor	Smart Motor
Color Sensor	Gyro Sensor	Touch LED











I.5

Autopilot Robot Build

See the Autopilot Robot Assembly Instructions in your kit documentation. 1+4

I.6

Running Autopilot Modes

Your teacher will decide what of the lessons below you will complete as part of the unit. Below are the lessons along with necessary information.

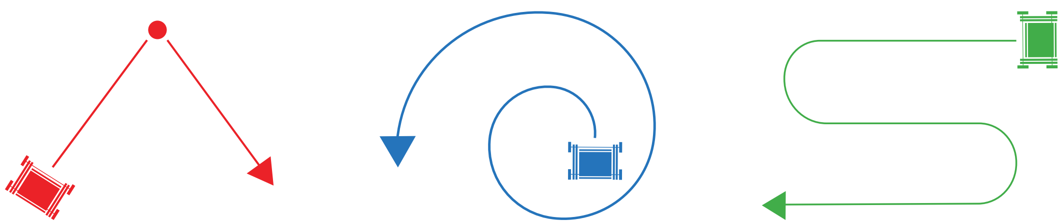
I. Read and review Key Terms and Sensor Overview with your classmates and teacher.

II. Complete the unit Matching Exercise. See separate handout.

III. Build Autopilot Robot. See the Autopilot Robot Assembly Instructions in your User Guide.

IV. Use Autopilot Robot to run the three Autopilot Modes.

These are demonstrations of different ways Sensors can work together in a Smart Machine. See your kit documentation for details. 6.2



V. Default Sensor Functionality Exercises

See your kit documentation for details in addition to information below. 6.1

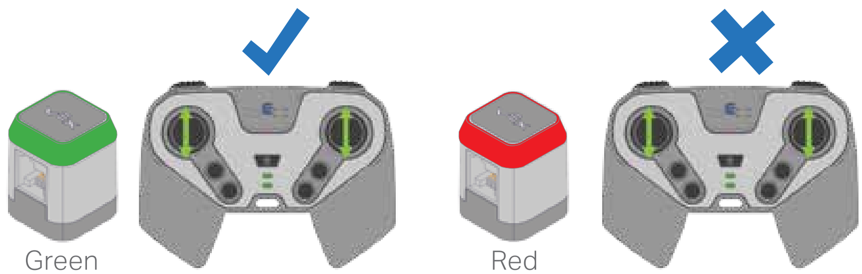
I.7

Default Sensor Functionality Exercises

Touch LED Default Functionality Exercise: “Stop and Go”

The default Touch LED functionality in the Driver Control program is to act like a traffic light for the robot. Using the Autopilot or similar robot with ONLY Smart Motors and Touch LED connected to any unused port in the Robot Brain:

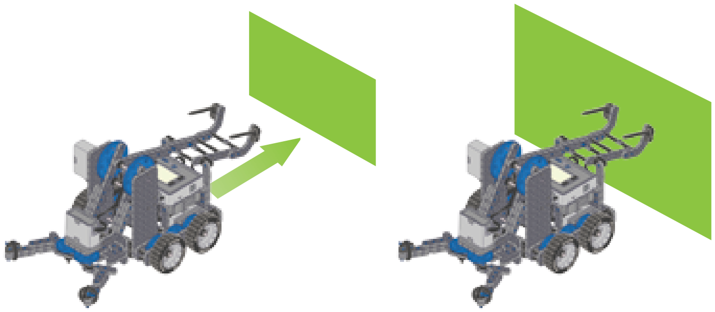
- Turn ON the Robot Brain and Controller.
- Select and run the Driver Control program.
- The robot starts in enabled mode with the Touch LED glowing green. Tap the top dome of the Touch LED to change between enabled (glowing green) and disabled (glowing red).
- Try to drive when green
- Try to drive when red



1.7 cont.

Distance Sensor Default Functionality Exercise: "Collision Avoidance"

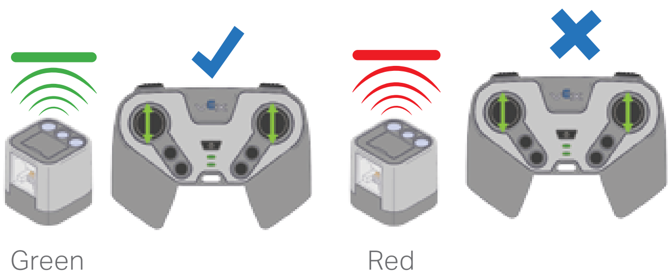
The default Distance Sensor functionality in the Driver Control program is to prevent a robot from running into an object or wall. When the Distance Sensor sees an object, it will slow down the Autopilot Robot as it approaches the object, eventually stopping to avoid collision. Using the Autopilot or similar robot with ONLY Smart Motors and a Distance Sensor connected to any unused port in the Robot Brain:



- Turn ON the Robot Brain and Controller.
- Select and run the Driver Control program.
- Use the Controller to drive the robot toward a wall. When the Distance Sensor sees an object that is too close to the robot, it will stop the robot from hitting that object.

Color Sensor Default Functionality Exercise: "Red Light, Green Light"

The default Color Sensor functionality in the Driver Control program is to act like a traffic light for the robot, much like the Touch LED. When the Color Sensor "sees" a green card (or other object) you can drive the robot. When it "sees" a red card (or other object) you cannot drive the robot. Using the Autopilot or similar robot with ONLY Smart Motors and a Color Sensor connected to any unused port in the Robot Brain:

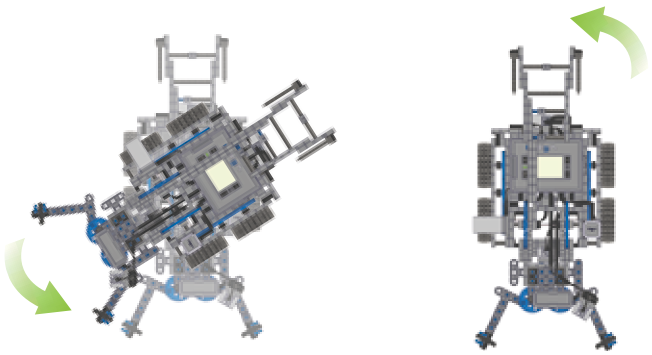


- Turn ON the Robot Brain and Controller.
- Select and run the Driver Control program.
- The robot will start in enabled mode. When a red card or object is shown in front of the color sensor, the robot will be disabled. When a green card is shown in front of the color sensor, the robot will be enabled.

Gyro Sensor Default Functionality Exercise: "Home Direction"

The default Gyro Sensor functionality in the Driver Control program is to keep the robot pointed in the same direction when not being driven by the Controller. If a robot is pushed or spun by anything other than being driven by the Controller, the robot will use the Gyro Sensor to measure how much it spun. The robot will then automatically spin back to the original direction it was pointing. Using the Autopilot or similar robot with ONLY Smart Motors and a Gyro Sensor connected to any unused port in the Robot Brain:

- Turn ON the Robot Brain and Controller.
- Select and run the Driver Control program.
- Use the Controller to turn the Robot to a new direction. When you stop driving, the robot will automatically turn back to the original direction.



I.8

Simple Programming Exercises Using Only the Robot Brain

You can make some changes to the way a robot is programmed by making simple configuration changes using only the LED screen and buttons on the VEX IQ Robot Brain. Please see your kit documentation and follow instructions to make configuration changes, testing out each change.

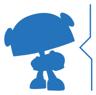
6

I.9

Simple Programming Exercises Using Programming Software

Before you complete any of the exercises below, you will need to:

1. RETURN THE DRIVER CONTROL PROGRAM TO ITS DEFAULT SETTINGS.
2. Become familiar with your programming software. Specifically, you should be able to open and use your programming software, save custom programs, connect your programming computer to your VEX IQ robot, successfully transfer custom programs to your Robot Brain, and run custom programs after they are transferred. Your teacher will decide the best way to get you comfortable with your programming software.

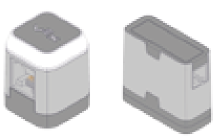


Notes: All of the possible exercises below utilize an Autopilot or similar robot with ONLY Smart Motors and the featured sensor connected to any unused port in the Robot Brain. Be sure to use the unit Idea Book Page to plan and troubleshoot your custom programs as part of these exercises. A sample Idea Book Page is provided for reference as needed.

Possible Programming Exercises with Bumper Switch & Smart Motors:

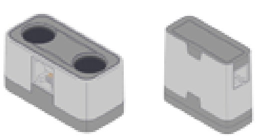
1. Robot backs up autonomously to a wall until one or both of the bumper switches on the Autopilot Robot is/ are activated by the wall, stopping the robot.
2. Teacher-created exercise.

Possible Programming Exercises with Touch LED Sensor & Smart Motors:



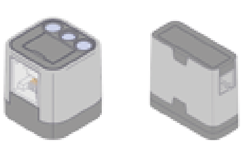
1. Robot drives autonomously forward 5 motor revolutions with Touch LED glowing green.
2. LED starts out red. Tap Touch LED, it glows green and robot drives forward autonomously. Tap LED again to change it back to red and robot stops.
3. Teacher-created exercise.

Possible Programming Exercises with Distance Sensor & Smart Motors:



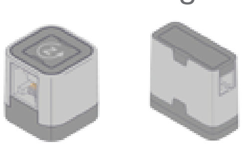
1. Robot drives autonomously toward a wall. Robot stops driving 6 inches from wall.
2. Robot drives autonomously toward a wall. Robot stops driving 6 inches from wall, then backs up 5 motor revolutions in return direction.
3. Teacher-created exercise.

Possible Programming Exercises with Color Sensor & Smart Motors:



1. Robot drives autonomously forward when Color Sensor is shown a green card. Robot stops when Color Sensor is shown a red card.
2. Robot drives autonomously forward when Color Sensor is shown a green card. Robot drives autonomously backwards when Color Sensor is shown a blue card. Robot stops when Color Sensor is shown a red card.
3. Teacher-created exercise.

Possible Programming Exercises with Gyro Sensor & Smart Motors:



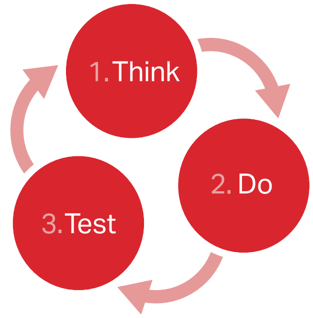
1. Robot drives autonomously forward 5 motor revolutions, then spins 180 degrees and stops.
2. Robot spins 90 degrees, then pauses for 5 seconds, then spins another 90 degrees, then pauses another 5 seconds, and keeps repeating the pattern until program is stopped.
3. Teacher-created exercise.

I.10

Smart Machines Idea Book Page: Simple Programming Exercises Using Programming Software

Student Name(s): ____

Teacher/Class: ____________________ Date: _________ Page #: _____



Instructions:

Before completing these exercises, be sure you are familiar with your programming software and how it works. Follow the steps on this page to document, test, troubleshoot, and refine your program. If your program includes more steps than fit on one page, use multiple copies as necessary.

Describe what you want your program to be able to do here:	
Describe the device/robot you will be programming:	List the sensors that will be used in your program:

"THINK" Write step-by-step program instructions here.	"DO" Write your program using programming software and make notes here as you work.	"TEST" Does this step of your program function as expected? What needs improvement (NI)?
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:

If ALL program steps do NOT function as expected, address your "NI" items using as many copies of this page as necessary until all parts of your program function as expected.

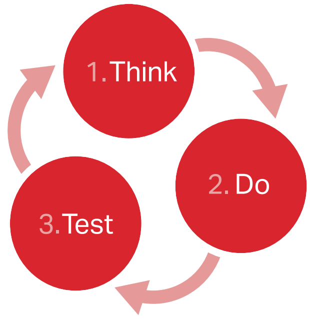
Remember: Problems ARE NOT failures, they are an expected part of the design process!

I.10 cont.

Smart Machines Idea Book Page: Simple Programming Exercises Using Programming Software

Student Name(s): John and Jane Doe

Teacher/Class: Mr. Smith Date: 9/1/2013 Page #: 1



Instructions:

Before completing these exercises, be sure you are familiar with your programming software and how it works. Follow the steps on this page to document, test, troubleshoot, and refine your program. If your program includes more steps than fit on one page, use multiple copies as necessary.

Describe what you want your program to be able to do here:
Drive autonomously straight forward for five motor revolutions Touch LED glowing green.

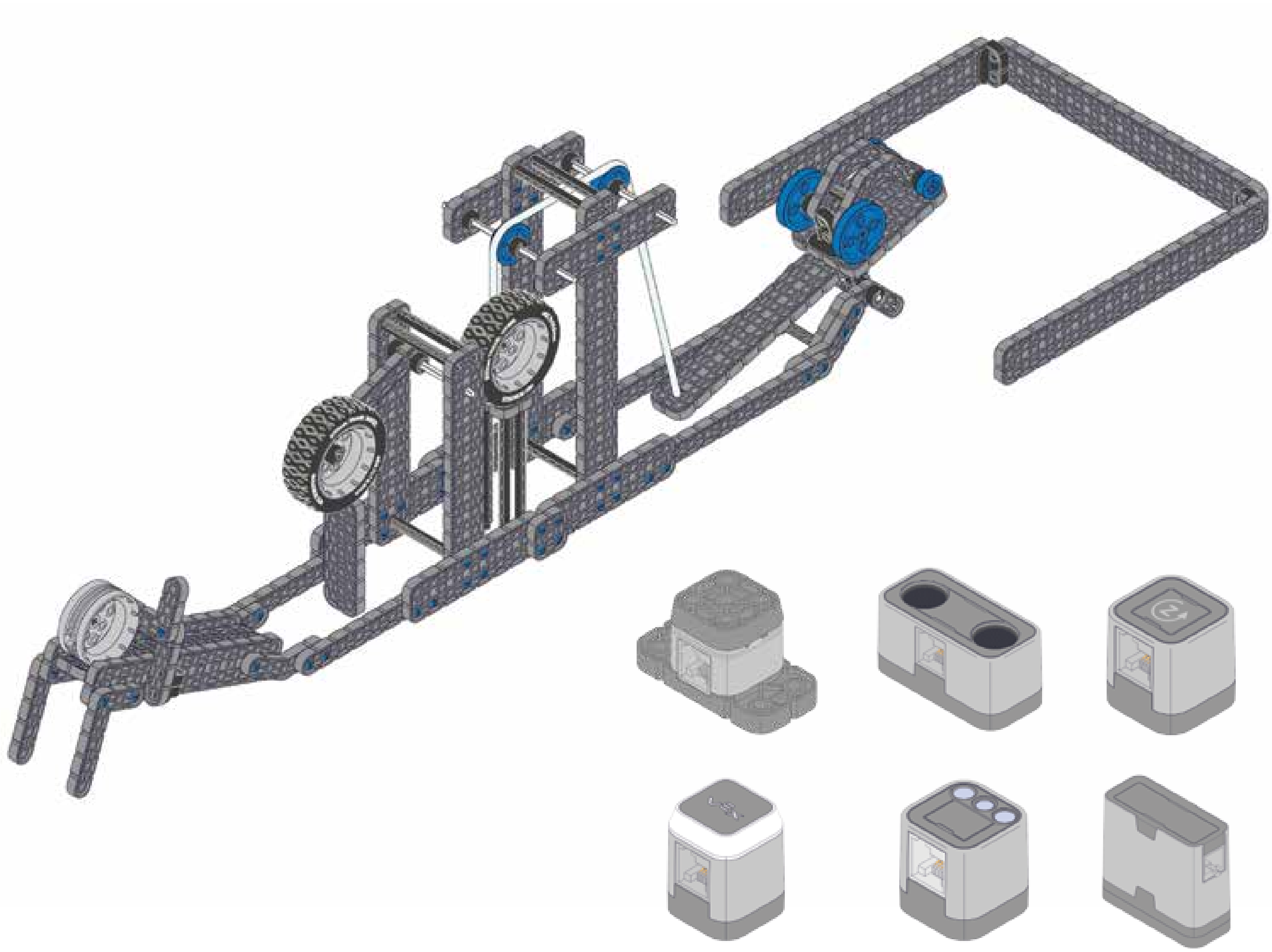
Describe the device/robot you will be programming:	List the sensors that will be used in your program:
Autopilot Robot with only Touch LED and Smart Motors plugged into Robot Brain.	Touch LED, Smart Motor Encoders

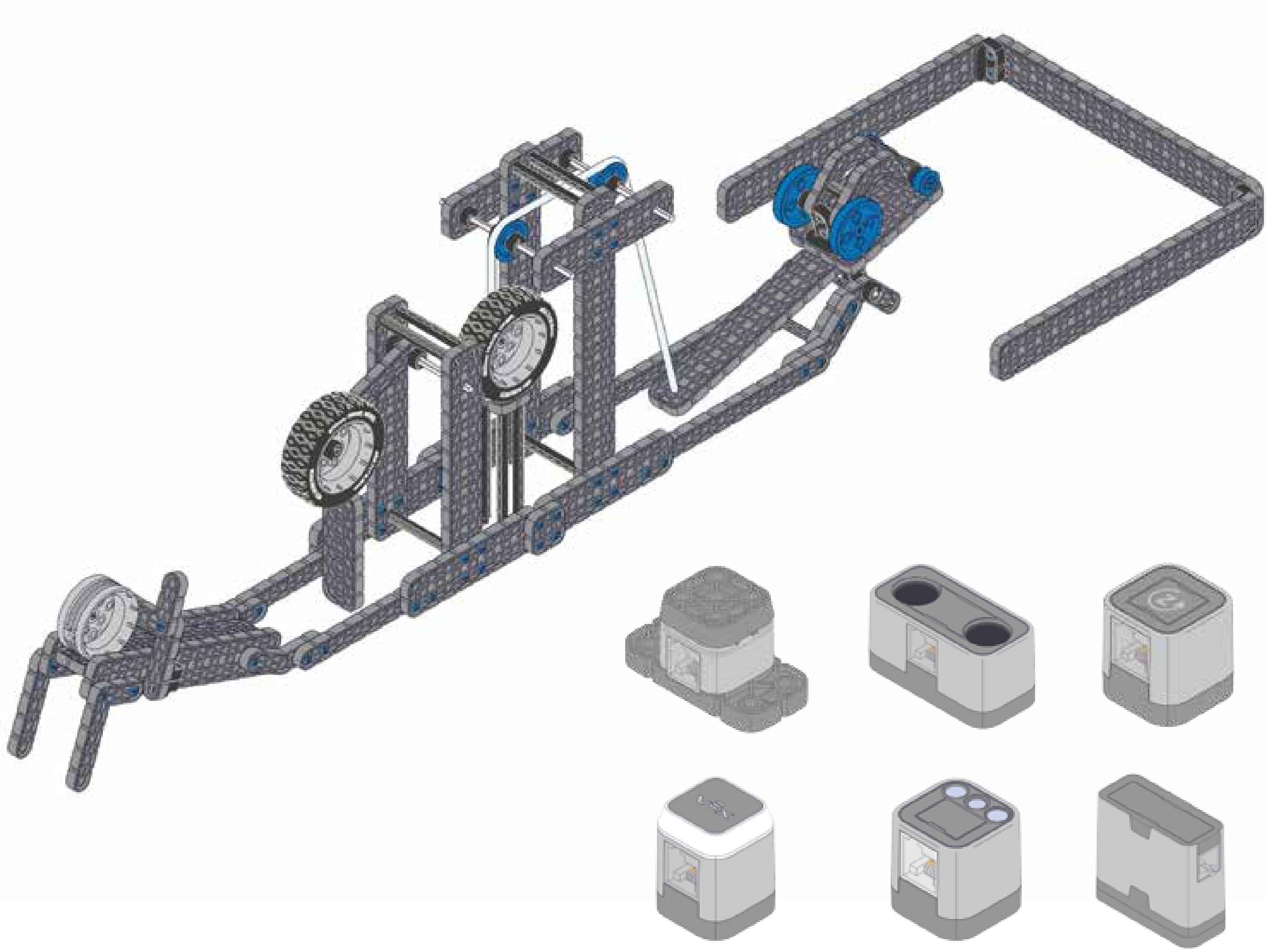
"THINK" Write step-by-step program instructions here.	"DO" Write your program using programming software and make notes here as you work.	"TEST" Does this step of your program function as expected? What needs improvement (NI)?
Power up Robot Brain, select and run custom autonomous program	Be sure to select custom program to run	**Yes** No NI: Nothing
Robot drives autonomously straight forward for five motor revolutions	Use Smart Motor Encoders for this task	**Yes** No NI: Nothing
Touch LED turns on green and glows while robot is driving forward	Use Touch LED for this task	Yes **No** NI: LED did not turn on
Robot stops driving after five motor revolutions and Touch LED turns off	Power is cut to the Smart Motors and Touch LED at the end of the program	Yes **No** NI: Program repeats and doesn't stop
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:

If ALL program steps do NOT function as expected, address your "NI" items using as many copies of this page as necessary until all parts of your program function as expected.
Remember: Problems ARE NOT failures, they are an expected part of the design process!

J

Chain Reaction Programming Challenge





J.1

Chain Reaction Programming Challenge

Unit Overview:

In this unit you will use your knowledge of simple machines, sensors and programming to build and test autonomous Chain Reaction Devices.

Unit Content:

- Chain Reaction Programming Challenge Rules

Unit Activities:

- Chain Reaction Challenge Device Build using Autonomous Chain Reaction Device Rubric
- Completion of Idea Book Pages with device build and testing

Note: You may be asked to use your Chain Reaction Device from Unit 5 and add sensors, then program them rather than build a new Device. See your teacher for instructions.

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

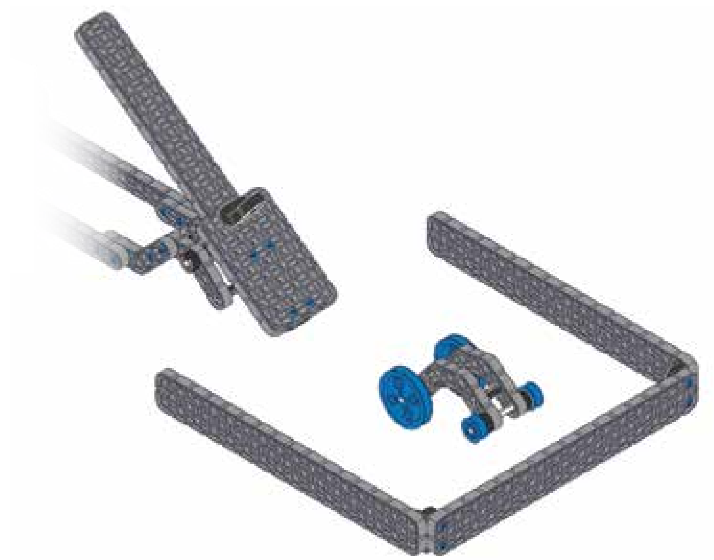
J.2

Chain Reaction Programming Challenge:

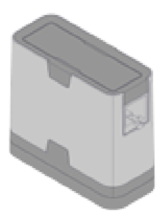
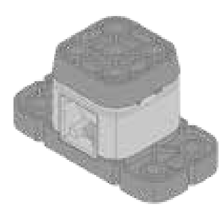
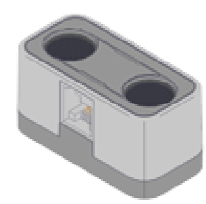
The Chain Reaction Programming Challenge Rules: Parking the Car Autonomously

Challenge Goal & Overview: The goal is to successfully build and program a fully autonomous Chain Reaction Device that successfully parks the car in the garage. Your teacher will provide you with (or ask you to build) the car and garage models to be used in this challenge. In most cases you will be asked to work together in teams, but you may be asked to work alone.

Note: Depending on time and your teacher's plans, you may be asked to use and modify your Chain Reaction Devices previously built for the Chain Reaction Challenge in an earlier unit (adding additional motor(s), sensors, and programming). Otherwise, you may be asked to design, build, and program this challenge from scratch. Please see your teacher for details.






Challenge Rules for Autonomous Chain Reaction Device (grades 4-8):

1. Build a four-stage Chain Reaction Device that parks the car in the garage.
2. Your Chain Reaction Device will be autonomous – using four or more Smart Motors, four or more sensors, a Robot Brain, and programming techniques to customize control. Smart Motors ARE considered a sensor in this challenge IF control is customized through the use of programming techniques.
3. Use three or more of the following to construct your stages: Wheel & Axle, Inclined Plane, Wedge, Lever, Pulley, Screw, or Pendulum. You may use a type of simple machine or pendulum more than once if you wish.
4. Please see the **Rubric to Evaluate Autonomous Chain Reaction Device** for all of the details on how you will be evaluated.
5. Idea Book Pages can be used for planning and troubleshooting. Your teacher will provide further instructions on using the Idea Book Pages.

J.3

Rubric to Evaluate Autonomous Chain Reaction Device (grades 4-8)

Evaluation Criteria	Expert = 4	Proficient = 3	Emerging = 2	Novice = 1	Assessment	Comments
Design & Process Criteria						
Creating viable solutions to the given challenge: mechanism use	Four or more, well developed stages exist meeting all challenge rules	Three well developed stages exist meeting majority of challenge rules	Two or more partially developed stages are evident	A single stage that may or may not be developed is evident		
Simple machines and pendulum usage	Device uses three or more efficient simple machines/ pendulum	Device uses two functioning simple machines/ pendulum	One simple machine/ pendulum exists that functions	Attempt using one simple machine/ pendulum		
Design Process (defined by the teacher, could be Idea Book use)	Design process utilized, documented & enhances product	Design process utilized and fully documented	Design process utilized consistently	Some evidence that design process was utilized		
Utilization of Resources (materials and parts, information and instructions, people, and time)	Resources used fully within challenge rules and efficiency maximized	Resources utilized to maximize efficiency	Evidence that some resources utilized meeting challenge purpose	A few resources (e.g., tools & materials) partially utilized		
Technical Criteria						
Autonomous Programming	Efficiency and consistency of program execution	Consistency evident in program execution	Functional, but inconsistent control system	Program incomplete or rarely functional		
Control System (Sensor & Motor use)	Completely functional control system with four or more motors & four or more sensors used	Consistently functional control system three or more motors & three or more sensors used	Functional, but inconsistent control system (regardless of # of motors & sensors)	Non-functional or incomplete control system (regardless of # of motors & sensors)		
Electrical Systems	Battery charged. Wire routing safe, efficient, & completely functional	Battery charged. Wire routing safe & consistently functional	Functional, but inconsistent (battery or wiring issues)	Non-functional or incomplete (battery and wiring issues)		
Mechanical Systems (mechanisms & triggers)	Completely functional and consistent mechanical systems	Consistently functional mechanical systems	Functional, but inconsistent mechanical systems	Non-functional or incomplete/ unsafe mechanical systems		
Unifying Themes (This area emphasizes the Interaction of Science, Technology, & Human Endeavor)						
Communication (written, electronic and/or oral as defined by the teacher)	Sophisticated and highly efficient communication for stated audiences	Purposeful, consistent, effective communication	Purposeful, partially consistent communication	Communication very inconsistent and lacks purpose		
Teamwork	Integrated teamwork that maximizes outcomes is evident	Teammates fully define roles, goals, & work together	Teammates partially define roles, goals, & work together	Participants function separately within a group		
Creativity	Device is unique, imaginative, and functional	Device is unique and/or imaginative in multiple ways	Device clearly shows a unique and/ or imaginative element	Unique and/ or imaginative element(s) unclear		

Rubric Adapted from Rubric and Evaluation Criteria for Standards-Based Robotics Competitions & Related Learning Experiences – TSA, 2005

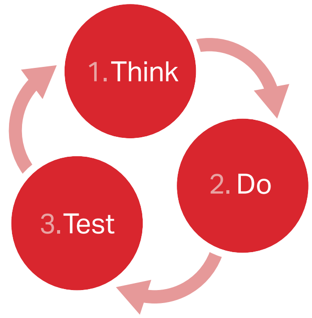
J.4

Chain Reaction Programming Challenge Idea Book Page: Design Plan

Student Name(s): ____

Teacher/Class: ____________________ Date: _________ Page #: _____

Plan and design a Four-Stage Chain Reaction Device that meets challenge and rubric criteria on pages 1 and 2 below.



Sketch/Describe Stage 1 of your Device, including Trigger Mechanism Here:

Machine Type (One of the Simple Machines or Pendulum): ____________________________________

Sensor(s) to be used in this stage (if any) and function of each sensor:

____

Sketch/Describe Stage 2 of your Device Here:

Machine Type (One of the Simple Machines or Pendulum): ____________________________________

Sensor(s) to be used in this stage (if any) and function of each sensor:

____

Sketch/Describe Stage 3 of your Device Here:

Machine Type (One of the Simple Machines or Pendulum): ____________________________________

Sensor(s) to be used in this stage (if any) and function of each sensor:

____

Remember: Problems ARE NOT failures, they are an expected part of the design process!

J.4 cont.

Sketch/Describe Stage 4 of your Device Here:

Machine Type (One of the Simple Machines or Pendulum): ____________________

Sensor(s) to be used in this stage (if any) and function of each sensor:

____

Plans for Connecting Each Device Stage:

Follow through with your design plan and BUILD/PROGRAM your device, then TEST and OBSERVE.

Testing Observations:

____

____

____

____

____

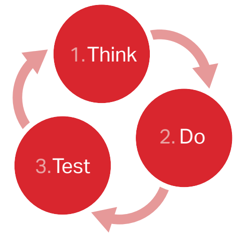
Does your Device function like you expected? YES NO

If you answered "YES" - Congratulations! You will score well on the Challenge Rubric. You may now move on to other lessons.

If you answered "NO" - Use your observations above and the Rubric to determine what problem needs troubleshooting, then use a copy of the Troubleshooting Idea Book Page to help solve that problem. Keep repeating this "THINK - DO - TEST" process with the troubleshooting pages, until your device functions correctly.

Remember: Problems ARE NOT failures, they are an expected part of the design process!

Chain Reaction Programming Challenge Idea Book Page: Troubleshooting



Student Name(s): ____

Teacher/Class: ____________________ Date: __________ Page #: __________

Use a copy of this Idea Book Page for each device problem you have to troubleshoot.

Sketch/Describe Your Device Problem Here:

Sketch/Describe Your Solution to the Problem Here:

Follow through with your solution and MAKE PLANNED CHANGES to your device, then TEST and OBSERVE.

Testing Observations:

____

____

____

____

____

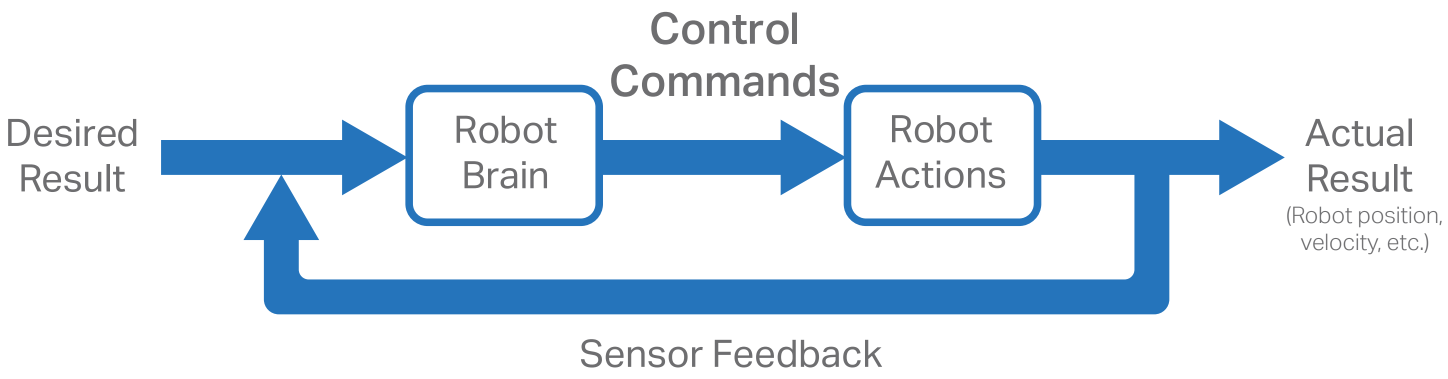
Does your Device function like you expected? YES NO

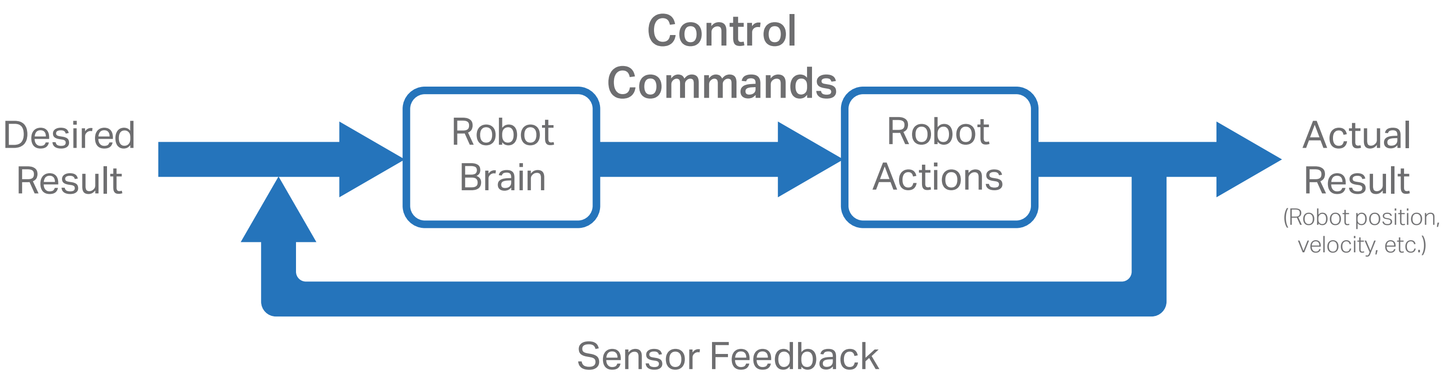
If you answered "YES" - Congratulations! You will score well on the Challenge Rubric. You may now move on to other lessons.

If you answered "NO" - Use your observations above and the Rubric to determine what problem needs troubleshooting next, then use another copy of this Idea Book Page to help solve that problem. Keep repeating this "THINK - DO - TEST" process with troubleshooting pages, until your device functions correctly.

Remember: Problems ARE NOT failures, they are an expected part of the design process!

Smarter Machines





K.1

Smarter Machines

Unit Overview:

This unit will allow students to further explore sensors and programming with VEX IQ. Students will also use the VEX IQ robots they have created thus far to develop a better understanding of control.

Unit Content:

- Key Terminology: Control, Open-Loop Control Systems, Closed-Loop Control Systems
- Sensor Review

Unit Activities:

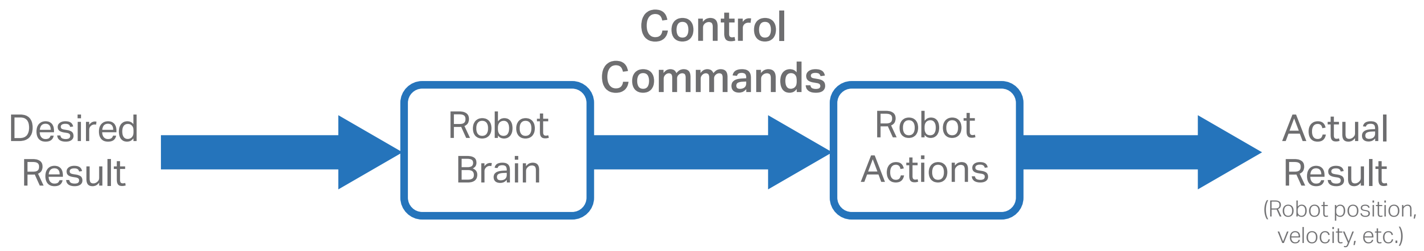
- Robot Build using Robot Challenge Evaluation Rubric. You may be instructed to build or use a specific robot in this unit. See your teacher for details.
- Unit Challenges. You will be instructed to tackle one or more of the given unit challenges for Clawbot IQ with Sensors, Armbot IQ, or a custom created VEX IQ robot.
- Completion of Idea Book Pages with robot programming and testing

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

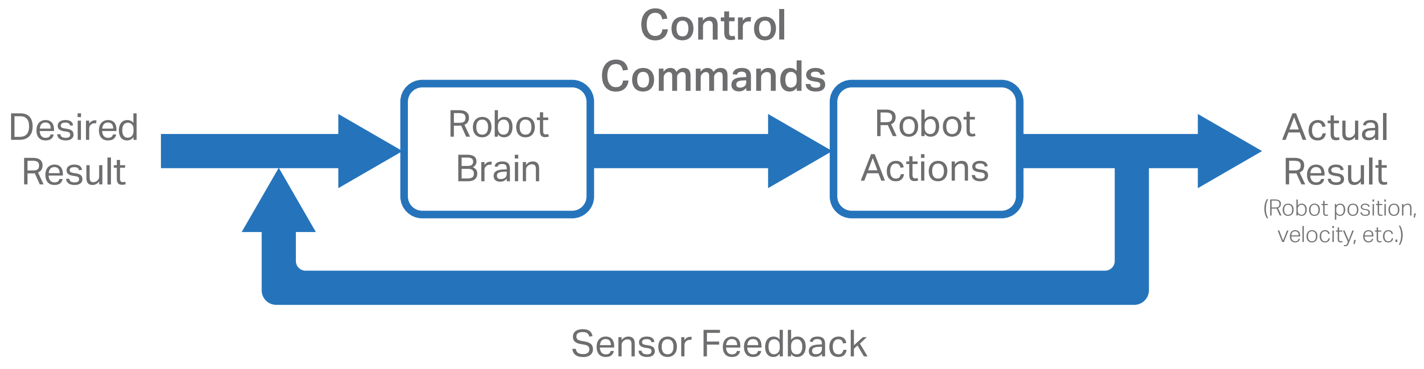
Key Concepts and Terminology

Learning to manipulate and use your VEX IQ controller well is one way to gain better control over your robot, but that is a purely Teleoperated solution. What about Autonomous and Hybrid robots? Well, you've already seen in the Smart Machines Unit that using sensors and programming to create desirable Autonomous and Hybrid solutions can lead to some amazing solutions. Before furthering your programming skills to create more advanced solutions, you must first have an understanding of what **Control** is and the types of control systems that can be created.

Control, simply, is defined as the ability to direct the actions or function of something. Having better **Control** over your VEX IQ creations will lead to seeing more expected repeatable behavior and more positive results in general. **Open-Loop Control Systems** are also called **Non-Feedback Control Systems**. This type of control system is generally more simplistic and easier to implement. It cannot correct for errors or disturbances along the way. In the **Open-Loop Control System** shown below, a desired result is programmed and/or sent to the Robot Brain, the Robot Brain sends control commands to the robot's subsystems, telling them to take certain actions, and those actions lead to an actual result. Using the VEX IQ Smart Motors to drive straight forward autonomously for five seconds is one example of **Open-Loop Control**.



Systems that utilize feedback are called **Closed-Loop Control Systems**. These systems tend to be more complex and more difficult to implement, but can often lead to more repeatable and predictable control. The feedback in a **Closed-Loop Control System**, like the one shown below, is used to recognize +/- differences between desired and actual results and correct for those differences along the way. Using the VEX IQ Gyro Sensor to maintain a constant heading/direction while a robot drives autonomously is one example of **Closed-Loop Control**.



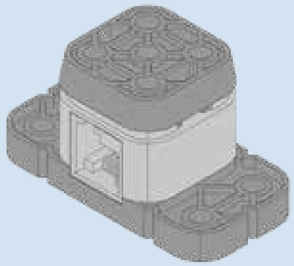
Open-Loop or Closed-Loop, Which is Best for Me?

There is no one answer. Control System type choices depend on your time, resources, expertise, the environment your robot will be operating in, the level of control and error correction that you need or desire, and any other constraints that are presented before you.

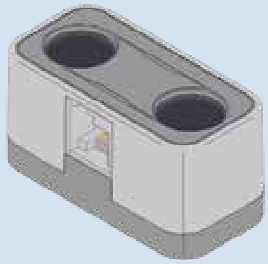
K.3

VEX IQ Sensor Review

Here is a brief review of what you learned about each VEX IQ Sensor in the Smart Machines unit. Use this chart to help make decisions about how you might solve the challenges in this unit.



Bumper Switch
Allows for the sense of touch in the VEX IQ platform. Detect a wall, obstacle, or limit mechanism movement.

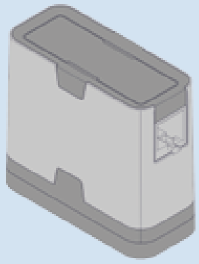


Distance Sensor
Uses ultrasonic sound waves to measure distance. Measures distance from 1 inch to 10 feet. Commonly used to avoid obstacles.

Gyro Sensor
Measures turn rate and calculates direction. Frequently used in autonomous robot navigation and turning.

Touch LED
Smart Sensor with red, green, blue LEDs. Constant on, off, or blink at any desired rate. Touch sensor with finger for interaction.

Color Sensor
Detects the color of objects. Measures independent red, green, and blue in 256 levels each.



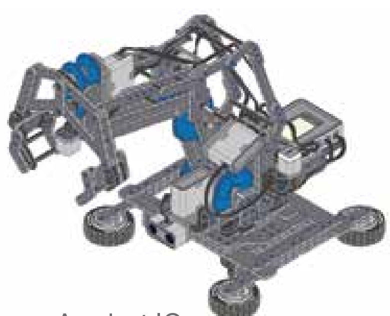
Smart Motor
Commands and measures speed, direction, time, revolutions and/or degrees of turn using its Encoder.

K.4

Smarter Machines Unit Robots

Your teacher might instruct you to build or use one or more of these robots to solve a Smarter Machines challenge. Follow your teacher's instructions for details!

Clawbot IQ with Sensors
Separate Assembly Instructions



Armbot IQ
Separate Assembly Instructions

?

Your Own Creation
See Your Teacher For Details

K.5

Smarter Machines Unit Challenges

You will be completing one or more of the challenges below. Use a VEX IQ Robot, the VEX IQ Sensors, your VEX IQ Programming Software (there are multiple options and you should be familiar with your software from the Smart Machines unit), the Robot Challenge Evaluation Rubric, and as many copies of the Idea Book Page as necessary to solve the challenge problem and document your process.

Possible Clawbot IQ with Sensors Challenges:

1. Program the robot AUTONOMOUSLY as follows (no Controller):

- The robot claw should start by holding an object, like a ball, cube or plastic cup in the claw
- Your program should start running autonomously with a tap of the Touch LED
- Then turn 360 degrees using the Gyro and Smart Motors or just the Smart Motors
- Have the robot arm lift up, open its claw, and drop the object
- Have the Robot Brain display, "I AM DONE" and the Touch LED glow Red at conclusion of the program

2. Program the robot for the following HYBRID functions (Robot is controlled with Controller):

- Program the robot arm joint to stop turning in the downward direction when the arm presses the Bumper Switch in. Each time the arm is lifted and dropped, the Bumper Switch should protect a robot driver from dropping the arm too far.
- Program the color sensor to recognize an object's color when holding it and print that color name on the robot LCD screen when the object is being held. The object should be red, blue, or green and easy to manipulate (ball, cube, or plastic cup for example)
- Program the Distance Sensor to stop the robot 100 mm away from a wall or obstacle, preventing a driver from hitting that obstacle.

*Test these functions out one at a time or all together using your controller

3. Teacher Created Challenge

Possible Armbot IQ Challenges:

1. Program the robot AUTONOMOUSLY as follows (no Controller):

- Item delivery. Program the robot to pick up items (balls, cubes, etc) from a specific location and deliver them to a second specific location, one at a time.

*Note objects may be placed/and removed one at a time by a teacher or classmate

2. Program the robot AUTONOMOUSLY as follows (no Controller):

- Color sorter. Program the robot to pick up items (balls, cubes, etc) that are 2 or 3 different colors (use red, blue, and/or green items), one at a time, from a specific location and deliver them to color specific destinations (one destination for red, another for blue, a third for green).

*Note objects may be placed/and removed one at a time by a teacher or classmate

3. Teacher Created Challenge

Possible Challenges Using a Custom Created VEX IQ Robot:

1. Create & Program a VEX IQ robot that successfully navigates a maze autonomously using sensors
2. Create & Program a VEX IQ robot that successfully delivers an object to an exact location autonomously using sensors
3. Teacher Created Challenge

Robot Challenge Evaluation Rubric

Evaluation Criteria	Expert = 4	Proficient = 3	Emerging = 2	Novice = 1	Assessment	Comments
Design & Process Criteria						
Creating Viable Solutions to the stated Challenge	Multiple, well developed solutions exist meeting all critical criteria	Multiple solutions are evident & one is developed meeting majority of criteria	Multiple, undeveloped solutions are evident	A solution that may or may not be developed is evident		
Simple and/or Complex Systems	All simple and/ or complex systems are identified & function efficiently	Functioning simple and/ or complex systems exist	Multiple simple systems exist that may function	One functioning simple system exists (e.g. drivetrain only)		
Design Process (documented in Idea Book or Engineering Notebook)	Formal design process utilized, documented & enhances efficiency	Formal design process utilized and fully documented	Formal design process utilized consistently	Some evidence that formal design process was utilized		
Utilization of Resources (materials and parts, information and instructions, people, and time)	Resources used within constraints, efficiency maximized	Resources utilized to maximize efficiency	Evidence that some resources utilized meeting intended purpose	A few resources (e.g. tools & materials) utilized randomly		
Technical Criteria						
Programming (Autonomous and/ or teleoperated)	Efficiency evident in all program-ming	Consistency evident in one or more parts of pro-gramming	Functional, but inconsistent program-ming	Program-ming incomplete or rarely functional		
Control Systems	Completely functional and consistent control systems	Consistently functional control systems	Functional, but inconsistent control systems	Non-functional or incomplete control systems		
Electrical Systems	Battery charged. Wire routing safe, efficient, & completely functional.	Battery charged. Wire routing safe & consistently functional.	Functional, but inconsistent (battery or wiring issues)	Non-functional or incomplete (battery and wiring issues)		
Mechanical Systems	Completely functional and consistent mechanical systems	Consistently functional mechanical systems	Functional, but inconsistent mechanical systems	Non-functional or incomplete/ unsafe mechanical systems		

Robot Challenge Evaluation Rubric

Evaluation Criteria	Expert = 4	Proficient = 3	Emerging = 2	Novice = 1	Assessment	Comments
Unifying Themes (This area emphasizes the Interaction of Science, Technology, & Human Endeavor)						
Communication (written, electronic and/or oral as defined by the teacher)	Sophisticated and highly efficient communication for all audiences	Purposeful, consistent, effective communication	Purposeful, fairly consistent communication	Communication very inconsistent and lacks purpose		
Teamwork	Integrated teamwork that maximizes outcomes is evident	Teammates fully define roles, goals, & work together	Teammates partially define roles, goals, & work together	Participants function separately within a group		
Creativity	Robot is unique, imaginative, and functional	Robot is unique and/or imaginative in multiple ways	Robot clearly shows a unique and/or imaginative element	Unique and/or imaginative element(s) unclear		

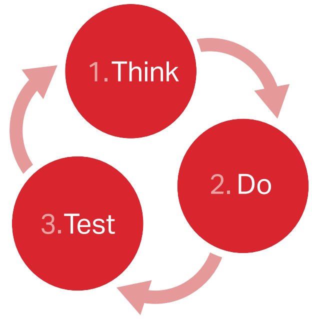
Rubric Adapted from Rubric and Evaluation Criteria for Standards-Based Robotics Competitions & Related Learning Experiences – TSA, 2005

K.7

Smarter Machines Idea Book Page: Program Planning & Troubleshooting

Student Name(s): ____

Teacher/Class: ____________________ Date: _________ Page #: _____



Instructions:

Use as many copies of this Idea Book Page as you need to help plan, execute, and troubleshoot a custom program written for your VEX IQ robot with your programming software.

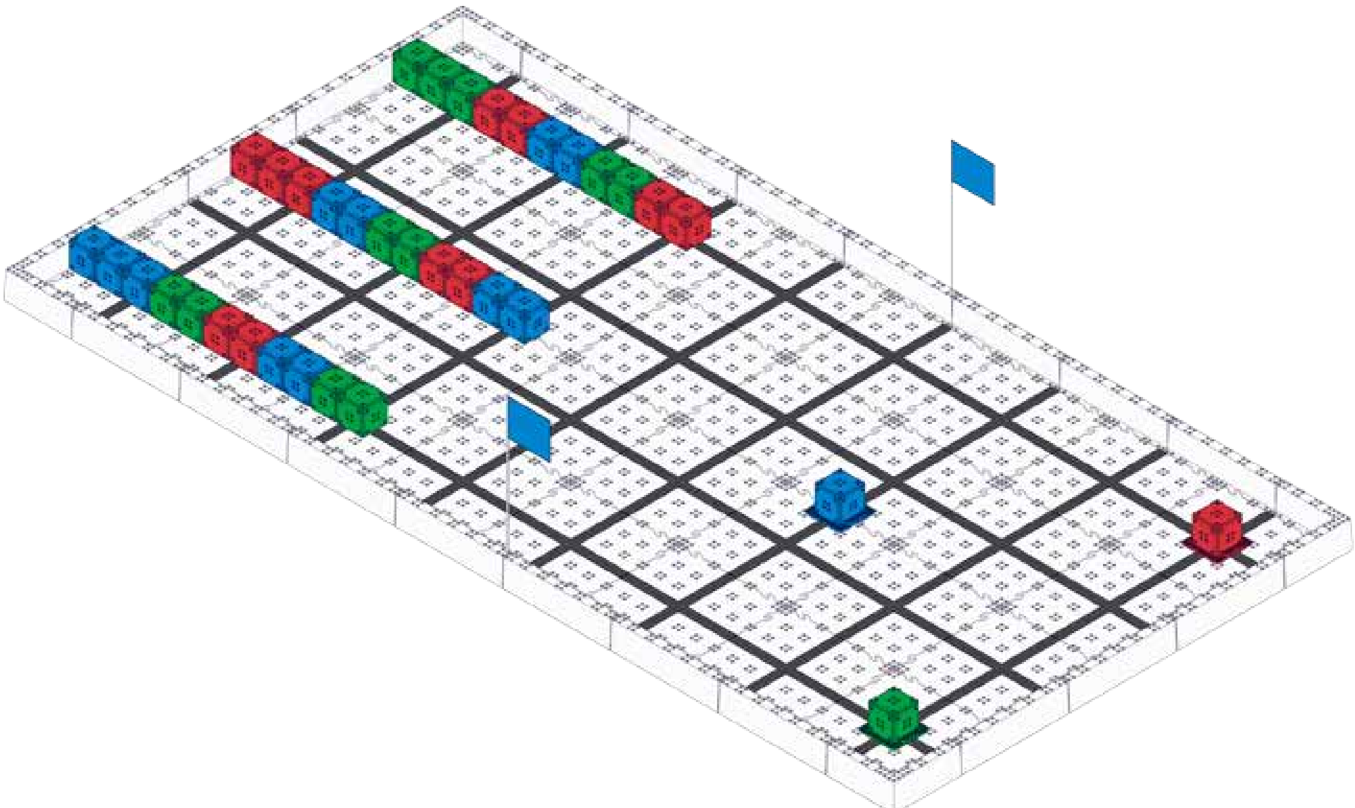
Describe what you want your program to be able to do here:	
Describe the device/robot you will be programming:	List the sensors that will be used in your program:

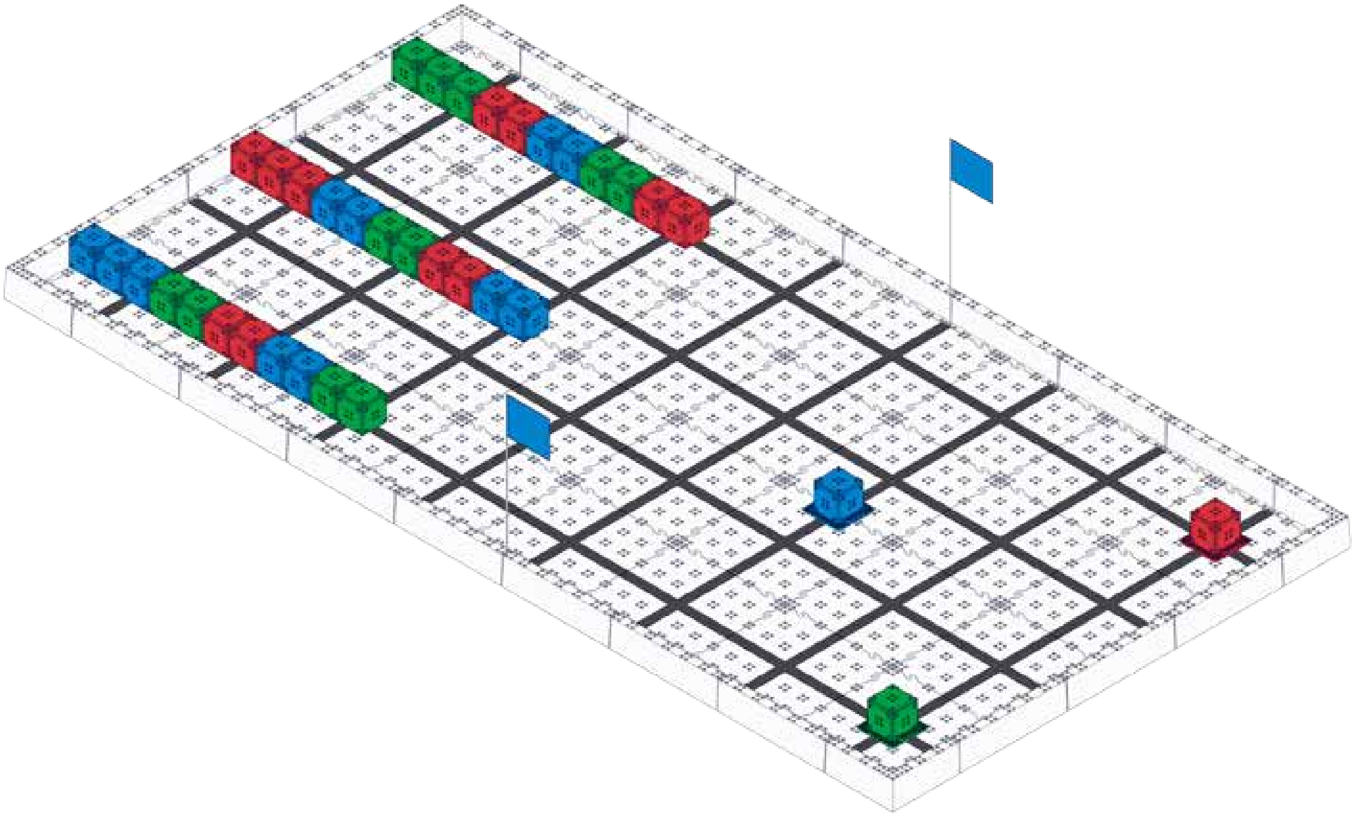
"THINK" Write step-by-step program instructions here.	"DO" Write your program using programming software and make notes here as you work.	"TEST" Does this step of your program function as expected? What needs improvement (NI)?
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:
		Yes No NI:

Remember: Problems ARE NOT failures, they are an expected part of the design process!

L

Highrise Programming Challenge





L.1

Highrise Programming Challenge

Unit Overview:

Feel the excitement of robotics competition as you apply you skills and knowledge from previous units to build a challenge-ready autonomous robot capable of completing Programming Skills matches in the VEX IQ Challenge game.

Unit Content:

- Challenge Overview
- Challenge Rules (http://www.vexiq.com/Highrise)

Note: Your teacher may also decide to use a different VEX IQ Challenge Game for this unit or a game of their own creation. See your teacher for details.

Unit Activities:

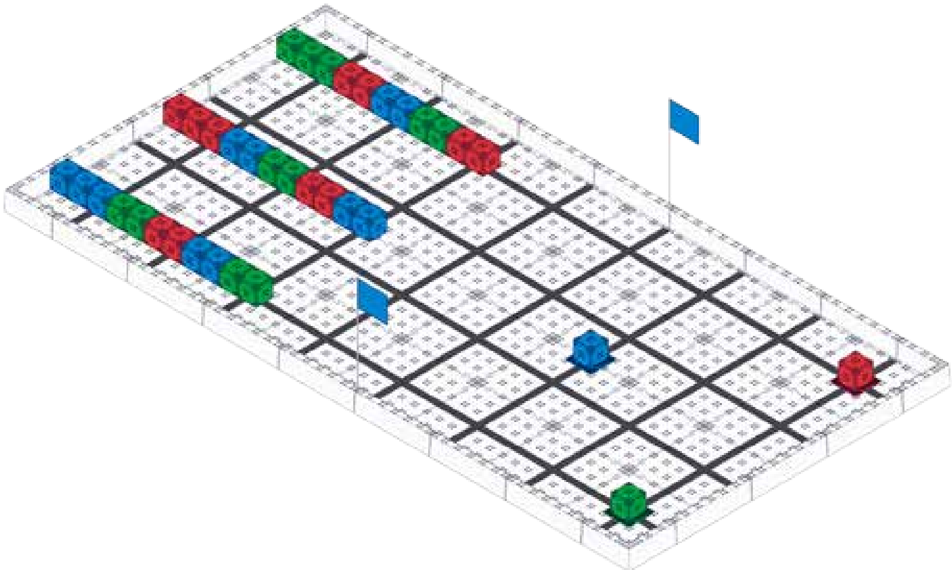
- Challenge Robot Build (or use of robot from Unit H) and Programming using Robot Challenge Evaluation Rubric
- Completion of Idea Book Pages (or Engineering Notebook) with robot build, programming and testing

Note: Separate copies and/or printouts of activities may be used for student work. Please see your teacher BEFORE writing in this guide. Visit www.vexiq.com/curriculum to download and print PDFs of all exercises!

L.2

Challenge Overview

Whether you're going to attend an official VEX IQ Challenge Event, host your own event, or just play the game in your classroom, it's time to design and build a robot for a full autonomous robotics game! Use your knowledge of the VEX IQ platform and all you've learned in previous lessons to create a VEX IQ robot for the Programming Skills Challenge portion of the VEX IQ Challenge Game, Highrise!



L.3

The Game Rules:

All of the rules for playing the game and other important information can be found at the VEX IQ Challenge Highrise page: www.vexiq.com/Highrise

Important Notes

- Your teacher will need to obtain the Highrise Field & Game Elements and VEX IQ Challenge Field for this unit OR obtain just the Highrise Field & Game Elements and create a similar field from easy to obtain items.
- Alternatively, your teacher could get creative and challenge you to design and build for a brand new game that they design.
- If you've already built a robot for the teleoperated portions of the Highrise Challenge, you only need to add sensors and then program your robot to complete the challenge autonomously!

Idea Book Page: The Engineering Notebook

You are provided with an Idea Book Page in this unit that can be used to develop a full Engineering Notebook. Use as many of these pages as you need to document your robot ideas, builds, fixes, changes, and improvements for the game challenge. Alternatively, teachers and students are encouraged, when comfortable, to use the Robotics Engineering Notebook (provided to registered VEX IQ Challenge teams and also sold separately) for this purpose instead.

Robot Challenge Evaluation Rubric:

This rubric can be used to assess your challenge robot in up to eleven technical and non-technical categories. No matter how your teacher chooses to use the rubric, it will be obvious that your PROCESS and your PRODUCT (robot) are equally important.

L.4

Robot Challenge Evaluation Rubric

Evaluation Criteria	Expert = 4	Proficient = 3	Emerging = 2	Novice = 1	Assessment	Comments
Design & Process Criteria						
Creating Viable Solutions to the stated Challenge	Multiple, well developed solutions exist meeting all critical criteria	Multiple solutions are evident & one is developed meeting majority of criteria	Multiple, undeveloped solutions are evident	A solution that may or may not be developed is evident		
Simple and/or Complex Systems	All simple and/ or complex systems are identified & function efficiently	Functioning simple and/ or complex systems exist	Multiple simple systems exist that may function	One functioning simple system exists (e.g. drivetrain only)		
Design Process (documented in Idea Book or Engineering Notebook)	Formal design process utilized, documented & enhances efficiency	Formal design process utilized and fully documented	Formal design process utilized consistently	Some evidence that formal design process was utilized		
Utilization of Resources (materials and parts, information and instructions, people, and time)	Resources used within constraints, efficiency maximized, environmental harm minimized	Resources utilized to maximize efficiency	Evidence that some resources utilized meeting intended purpose	A few resources (e.g. tools & materials) utilized randomly		
Technical Criteria						
Programming (Autonomous and/ or teleoperated)	Efficiency evident in all programming	Consistency evident in one or more parts of programming	Functional, but inconsistent programming	Programming incomplete or rarely functional		
Control Systems	Completely functional and consistent control systems	Consistently functional control systems	Functional, but inconsistent control systems	Non-functional or incomplete control systems		
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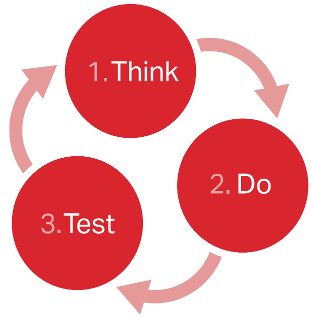
Rubric Adapted from Rubric and Evaluation Criteria for Standards-Based Robotics Competitions & Related Learning Experiences – TSA, 2005

L.5

Idea Book Page: The Engineering Notebook

Student Name(s): ______________________________

Teacher/Class: ______________ Date: ________ Page #: ____



Use as many of these pages as you need to document your robot ideas, build, fixes, changes, and improvements for the game challenge. Remember the "Think-Do-Test Loop" you learned in the My First Robot Unit. Number each page and use the space as you see fit for ideas, notes, observations, drawings with labels, calculations, and more. Alternatively, teachers and students are encouraged, when comfortable, to use the Robotics Engineering Notebook (P/N 276-3023, provided to registered VEX IQ Challenge teams and also sold separately) for this purpose instead.

Remember: Problems ARE NOT failures, they are an expected part of the design process!

Robotics Education Guide
Ages 8+

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This product is solely intended to be used as part of the VEX IQ system.

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