LEGO MINDSTORMS™

Power of Robotics @ Your Command™

ROBOTICS

INVENTION SYSTEM™

CONSTRUCTOPEDIA™

9719

The Constructopedia™ is a building guide for the Robotics Invention System™ that offers suggestions, hints, and tips to get you started on the CD-ROM Challenges and robotic inventions of your own design.

To master a Challenge, you must follow three basic steps:

1. Construct – To start, review the Design Brief. Then gather the pieces you need to meet the Challenge and start building. (Don't hesitate to customize your robot with additional parts and pieces.)

2. Program – Once your robot is built, you can program it using the simple, but powerful, programming language included on the CD-ROM. Your program will determine how your model reacts to its environment.

3. Test – Now it's time to test your program and design. Once you have downloaded your program from your PC to your RCX using the infrared transmitter, your robot can run independent of your computer. Now let it loose and watch what happens!

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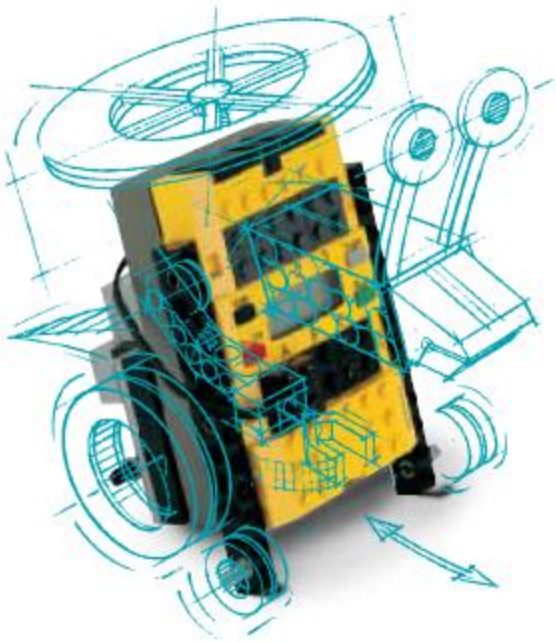
Project Ideas

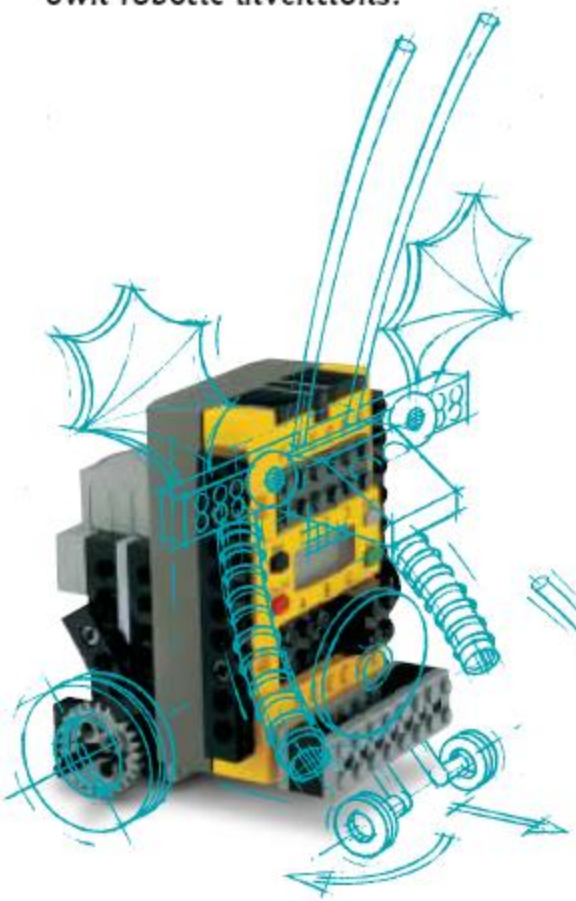
What follows are basic instructions for building the six subassemblies associated with the CD-ROM Challenges. The same instructions can be used for building your own robotic inventions.



ROBO 1

- Slowly moves back and forth.
- Requires one motor.

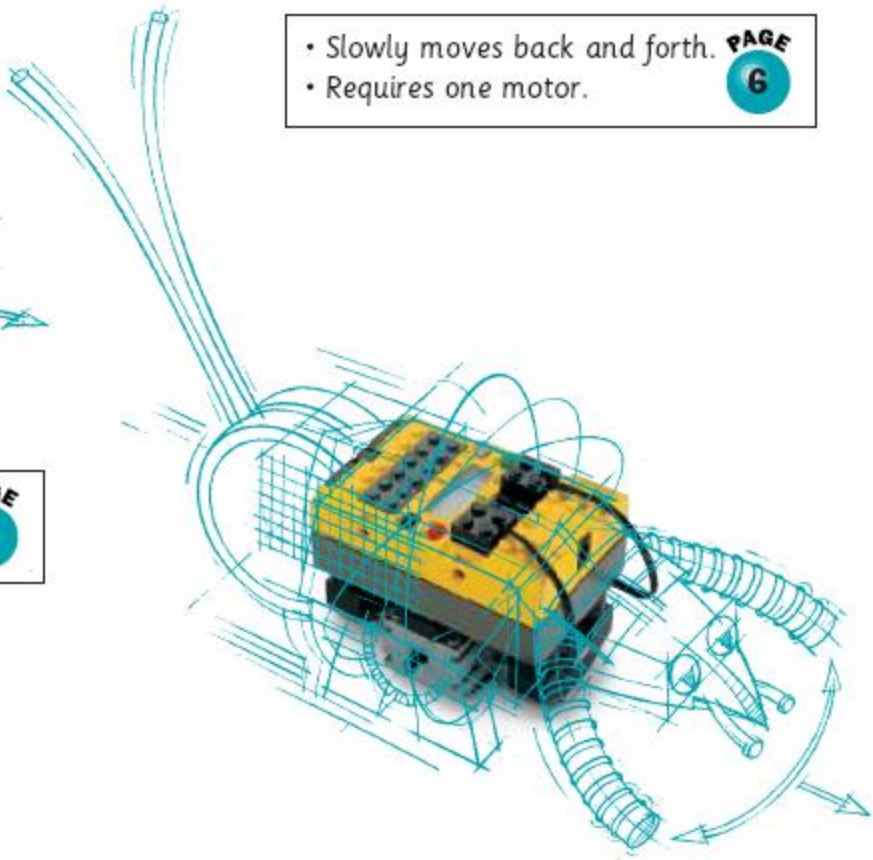
PAGE 6



ROBO 2

- Slowly rotates in one direction.
- Requires one motor.

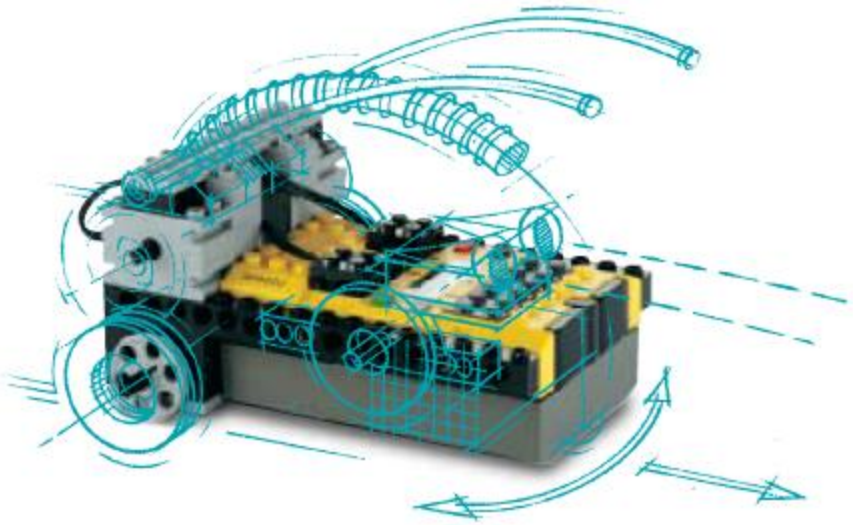
PAGE 9



PATHFINDER 1

- Quickly turns left and right.
- Requires two motors.

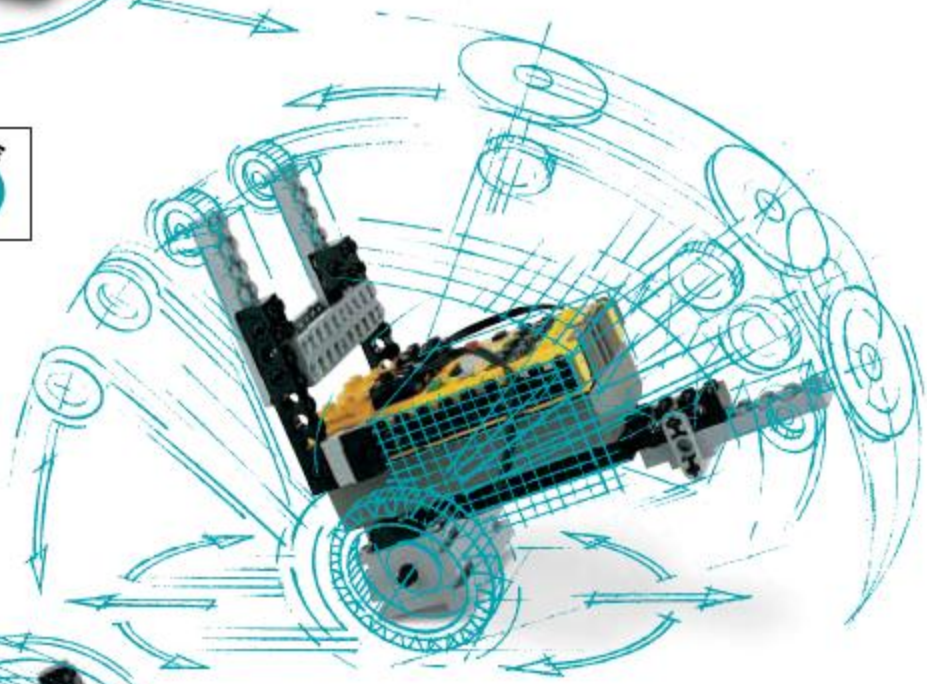
PAGE 13



PATHFINDER 2

- Slowly turns left and right.
- Requires two motors.

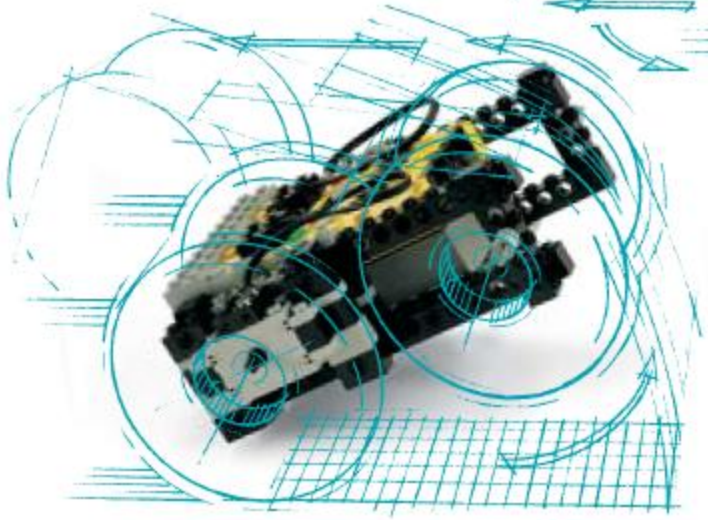
PAGE 15



ACROBOT 1

- Quickly turns left and right. Even does "wheelies."
- Requires two motors.

PAGE 17



ACROBOT 2

- Moves fast and flips upside down.
- Requires two motors.

PAGE 20

Robo 1

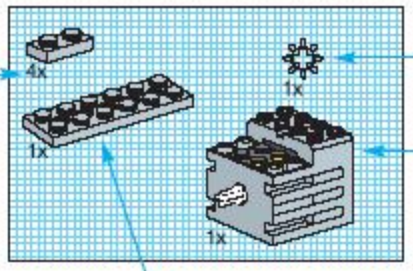
To get started on Robo 1, follow these five steps.

BEFORE YOU GET STARTED...

Make sure there are batteries in your RCX. For help installing batteries, turn to page 38.

1

For this step, you need:



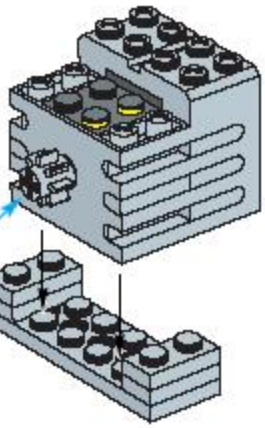
8-tooth gear

Motor

4x means you need 4 of these.

2 x 6 plate with holes

Put the 8-tooth gear on the motor.

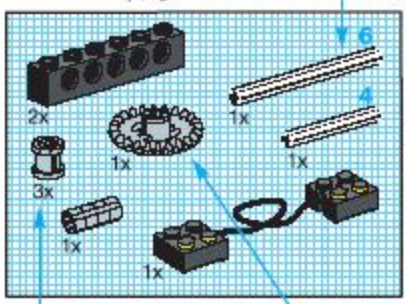


Put the motor on the 2 x 6 plate with holes.

2

To measure an axle, see page 37.

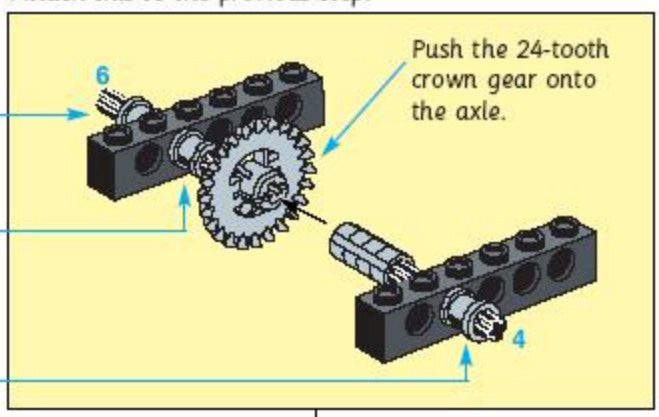
For this step, you need:



Bushing

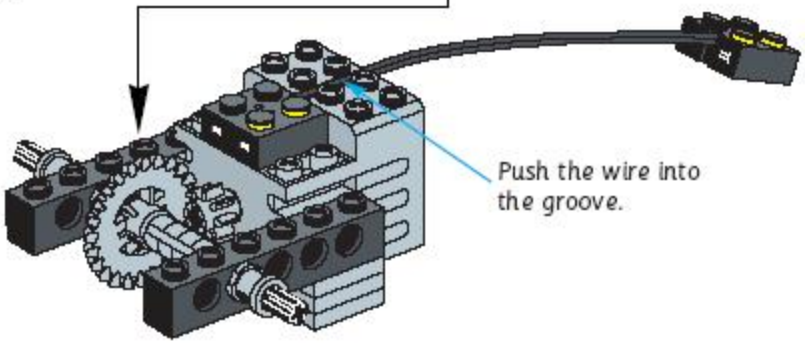
24-tooth crown gear

Attach this to the previous step.



Push the 24-tooth crown gear onto the axle.

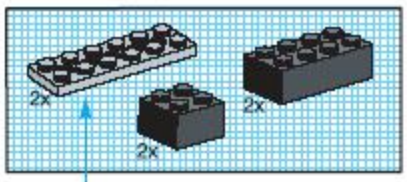
Put the bushings here.



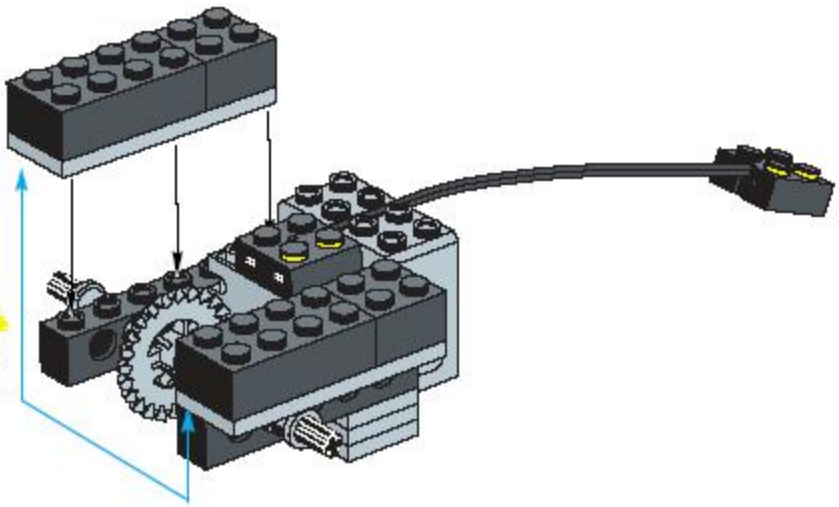
Push the wire into the groove.

3

For this step, you need:



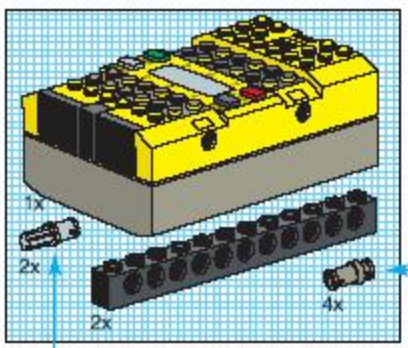
2 x 6 plate with holes



Do this first!
Put the 2 x 6 plate with holes here.

4

For this step, you need:

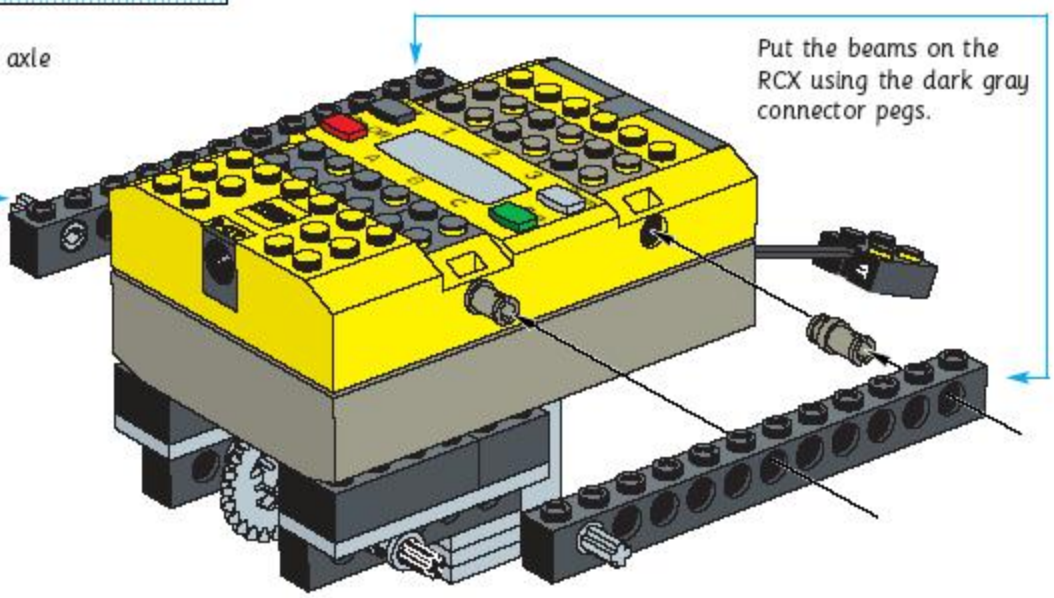


Dark gray connector peg

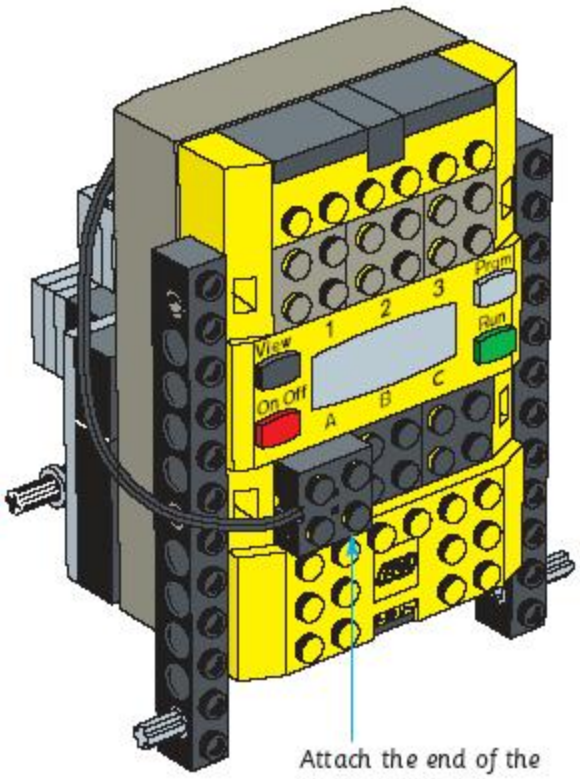
Connector peg with axle

Put the beams on the RCX using the dark gray connector pegs.

Put the connector peg with axle here.



5



HINT: Try this wheel.

HINT: Try this wheel.

Attach the end of the wire to port "A".

IF YOU NEED HELP COMPLETING YOUR ROBOT...

- Check out "Special Features" on page 26.
- Turn to "Tips and Tricks" on page 32.

TO PROGRAM YOUR INVENTION...

- Go to the MoboRobo challenge or the Robo Bumper challenge on the CD-ROM.

Robo 2

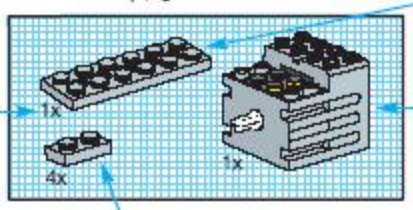
Build the foundation for Robo 2 by following these eight steps.

BEFORE YOU GET STARTED...

Make sure there are batteries in your RCX. For help installing batteries, turn to page 38.

1

For this step, you need:

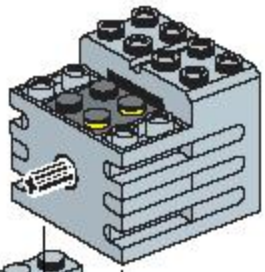


2 x 6 plate with holes

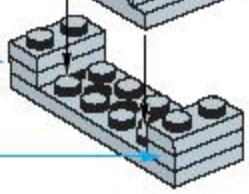
Motor

1x means you need 1 of these.

1 x 2 plate



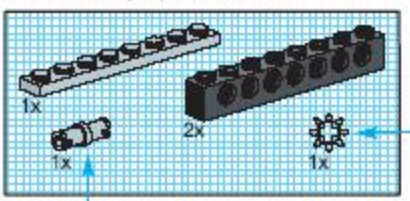
Put the motor onto the 2 x 6 plate with holes.



Put the 1 x 2 plates here.

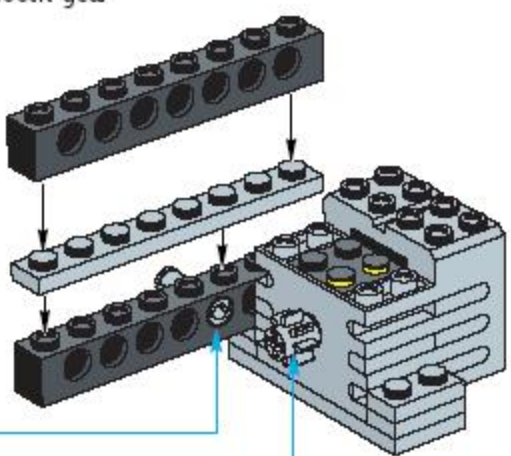
2

For this step, you need:



8-tooth gear

Gray connector peg

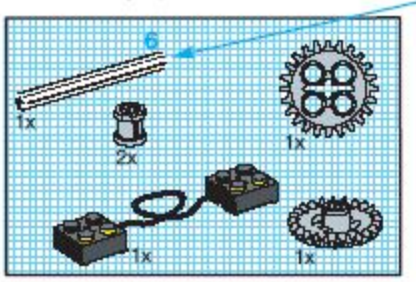


This is the gray connector peg.

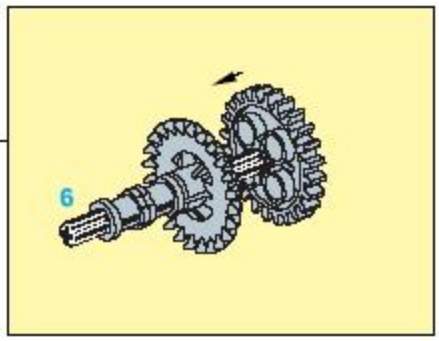
Put the 8-tooth gear on the motor.

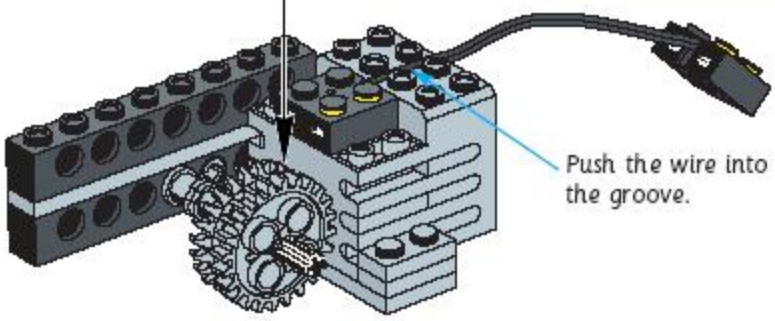
3

For this step, you need:



To measure an axle, see page 37.

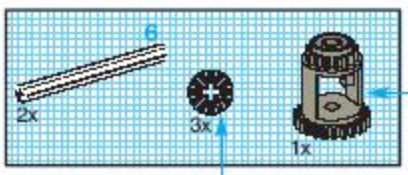




Push the wire into the groove.

4

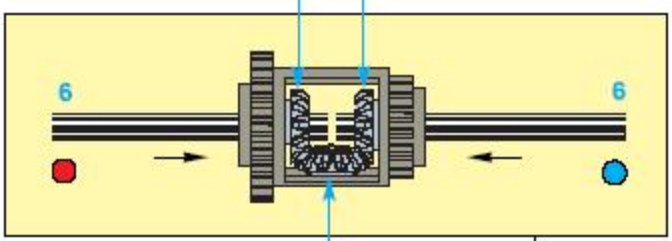
For this step, you need:



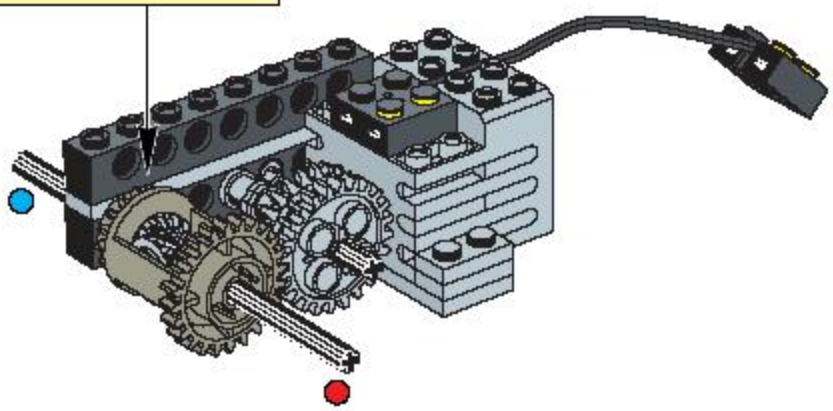
Differential

Bevel gear

Put the bevel gear in place and push the axle into it.

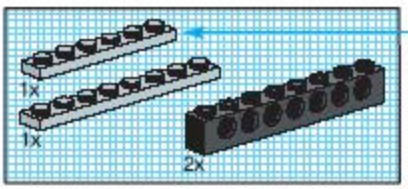


Do this first!
Put the bevel gear on the differential.

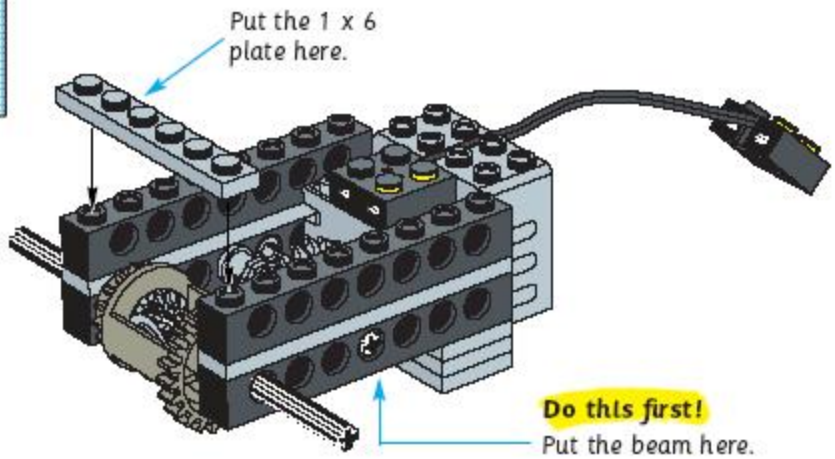


5

For this step, you need:

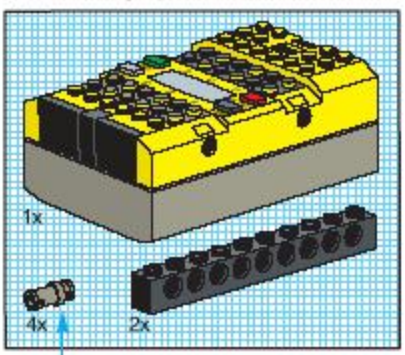


1 x 6 plate

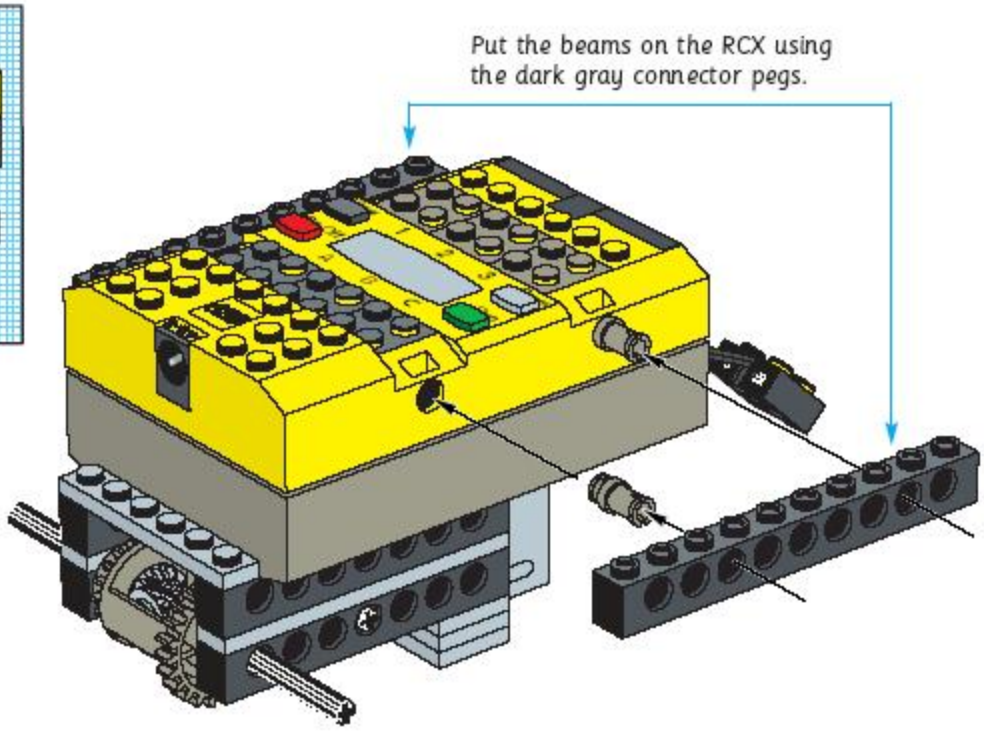


6

For this step, you need:

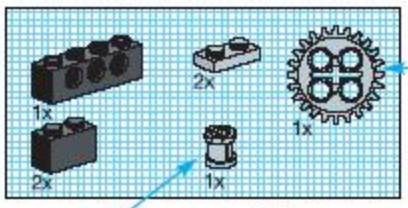


Dark gray connector peg



7

For this step, you need:



24-tooth gear

Bushing

Put the bushing on the axle.

Put the 24-tooth gear here.

Put the beam onto the gray connector peg.

8

For this step, you need:

2 x 8 plate with holes

IF YOU NEED HELP COMPLETING YOUR ROBOT...

- Check out "Special Features" on page 26.
- Turn to "Tips and Tricks" on page 32.

Put the 2 x 8 plate with holes here.

Make sure the beam touches the gear.

HINT: Try this wheel.

TO PROGRAM YOUR INVENTION...

- Go to the Robobeeper challenge or the Robioptic challenge on the CD-ROM.

HINT: Try this wheel.

Pathfinder 1

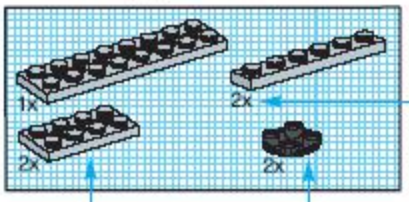
To start building Pathfinder 1, follow these four steps.

BEFORE YOU GET STARTED...

Make sure there are batteries in your RCX. For help installing batteries, turn to page 38.

1

For this step, you need:

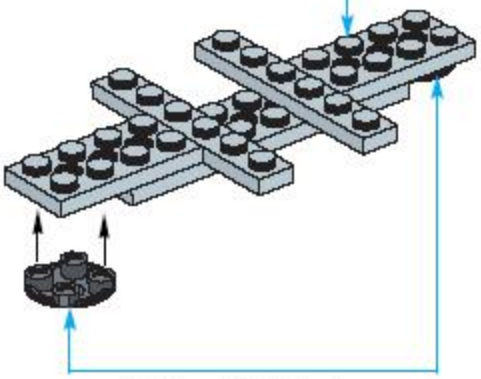


2x means you need 2 of these.

2 x 4 plate with holes

Skid plate

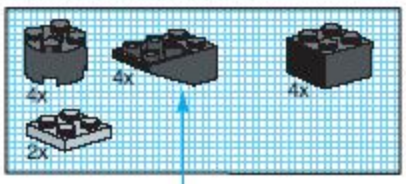
Put the 2 x 4 plate with holes here.



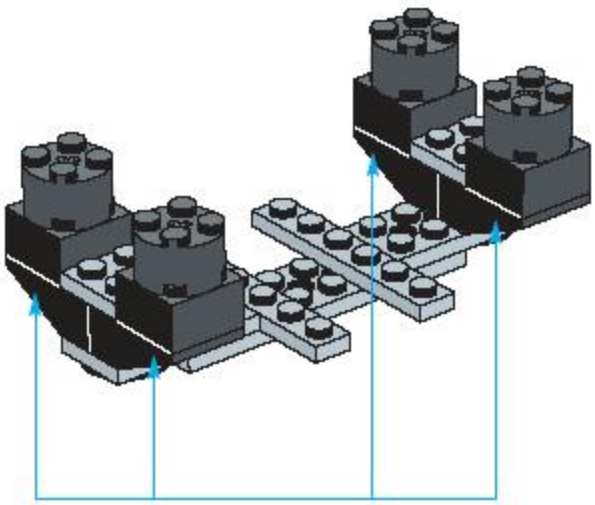
Put the skid plates here.

2

For this step, you need:



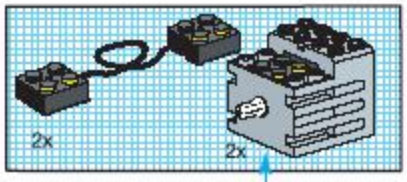
Inverted roof brick



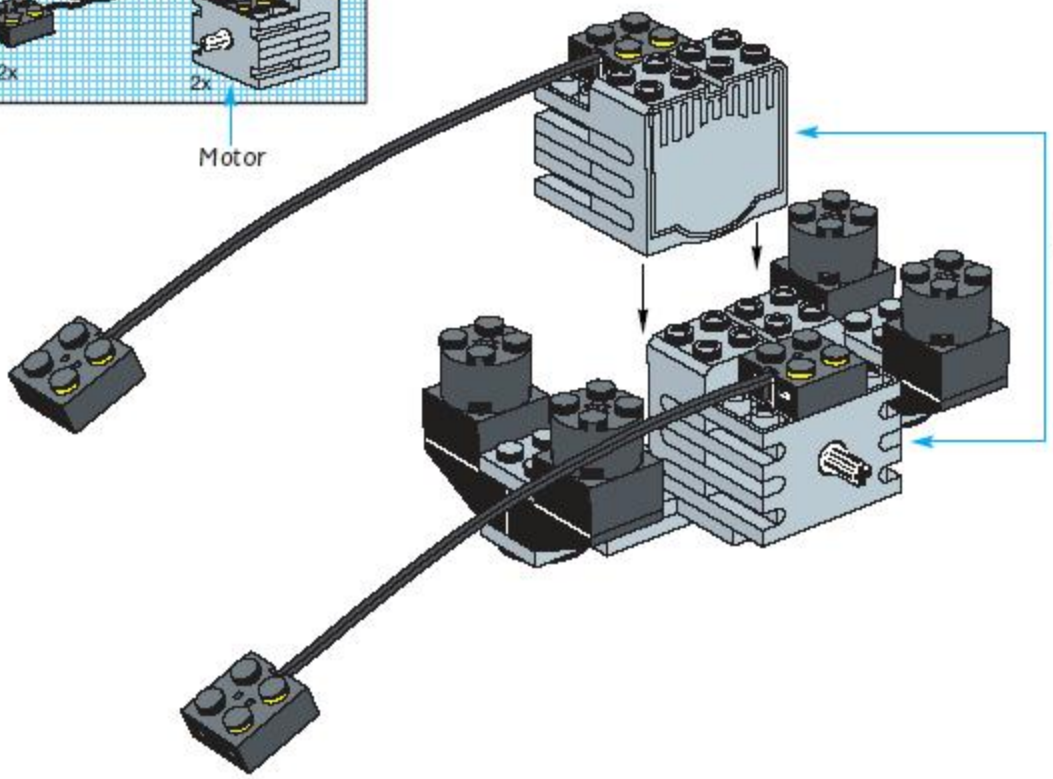
Put the inverted roof bricks here.

3

For this step, you need:

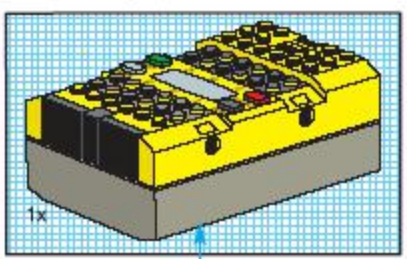


Motor

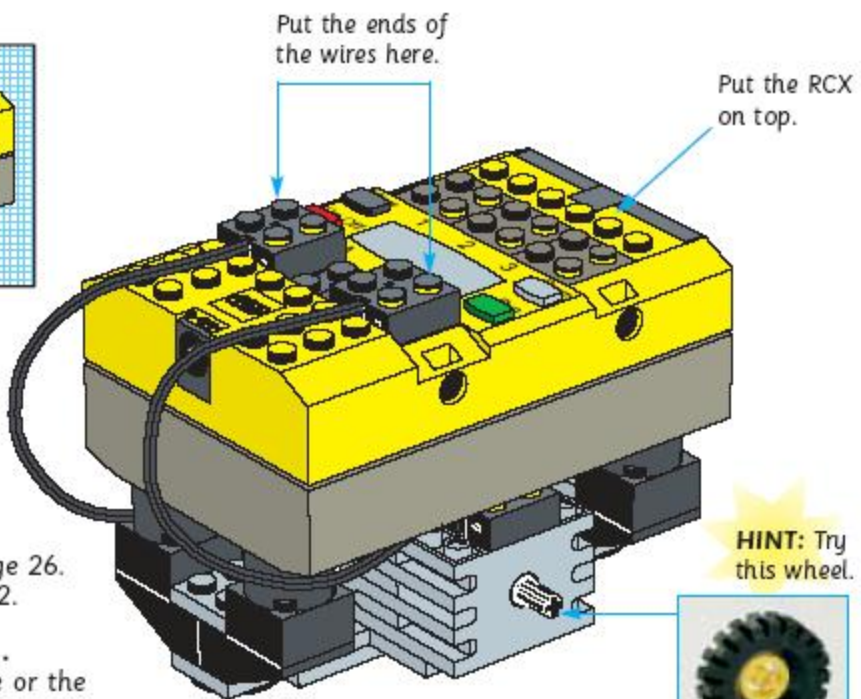


4

For this step, you need:



RCX



IF YOU NEED HELP COMPLETING YOUR ROBOT...

- Check out "Special Features" on page 26.
- Turn to "Tips and Tricks" on page 32.

TO PROGRAM YOUR INVENTION...

- Go to the Outback Tracker challenge or the Light Tracker challenge on the CD-ROM.

HINT: Try this wheel.

Pathfinder 2

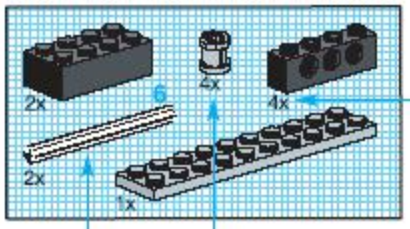
To get started on Pathfinder 2, follow these four steps.

BEFORE YOU GET STARTED...

Make sure there are batteries in your RCX. For help installing batteries, turn to page 38.

1

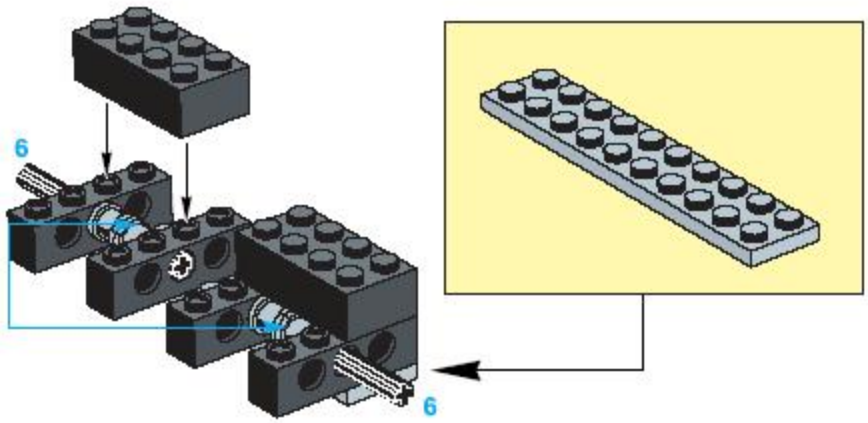
For this step, you need:



4x means you need 4 of these.

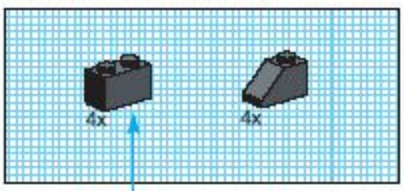
To measure an axle, see page 37.

Bushing

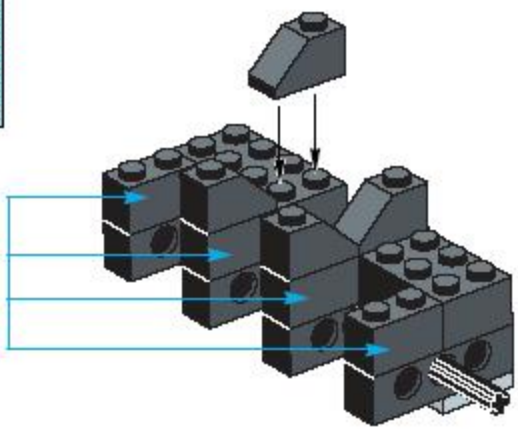


2

For this step, you need:

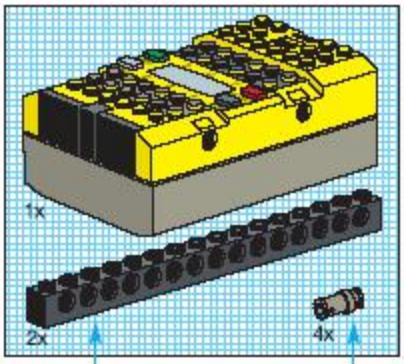


1 x 2 brick



3

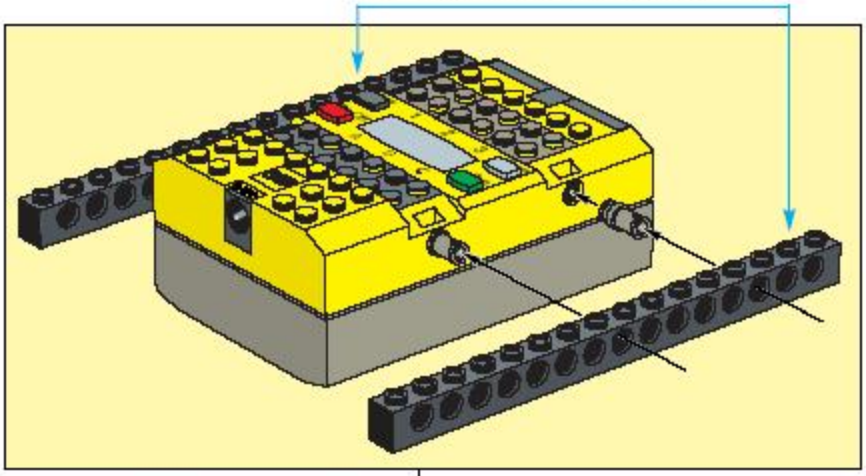
For this step, you need:



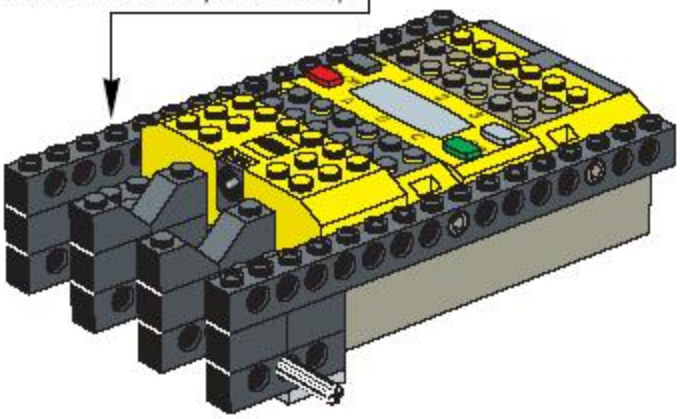
1 x 16 beam

Dark gray connector peg

Put the 1 x 16 beams on the RCX using the dark gray connector pegs.



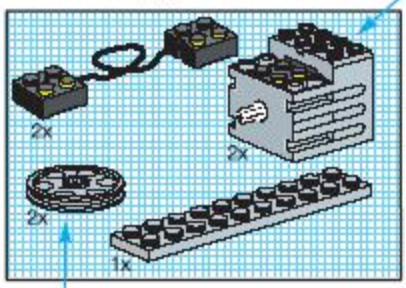
Attach this to theprevious step.



4

For this step, you need:

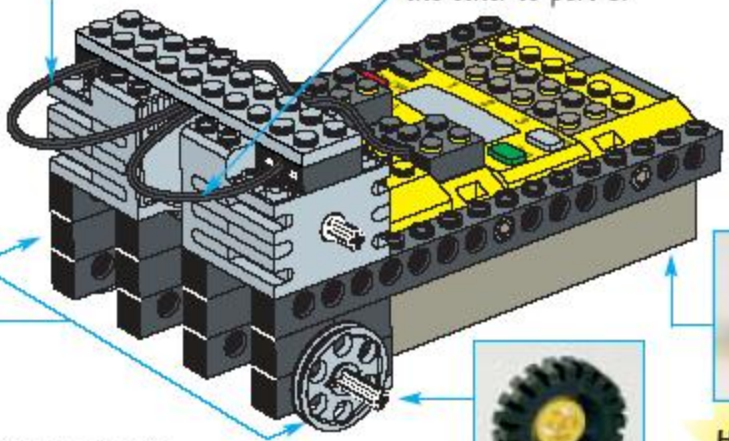
Motor



Large pulley

Attach one end to the motor, the other to port A.

Attach one end to the motor, the other to port C.



Put the large pulleys onto the axles.

HINT: Try this wheel.

HINT: Try this skid plate.

IF YOU NEED HELP COMPLETING YOUR ROBOT...

- Check out "Special Features" on page 26.
- Turn to "Tips and Tricks" on page 32.

TO PROGRAM YOUR INVENTION...

- Go to the Trail Tracker challenge or the Track Talker challenge on the CD-ROM.

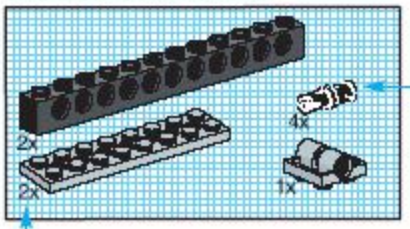
Acrobot 1

To get started on Acrobot 1, follow these five steps.

BEFORE YOU GET STARTED...
Make sure there are batteries in your RCX. For help installing batteries, turn to page 38.

1

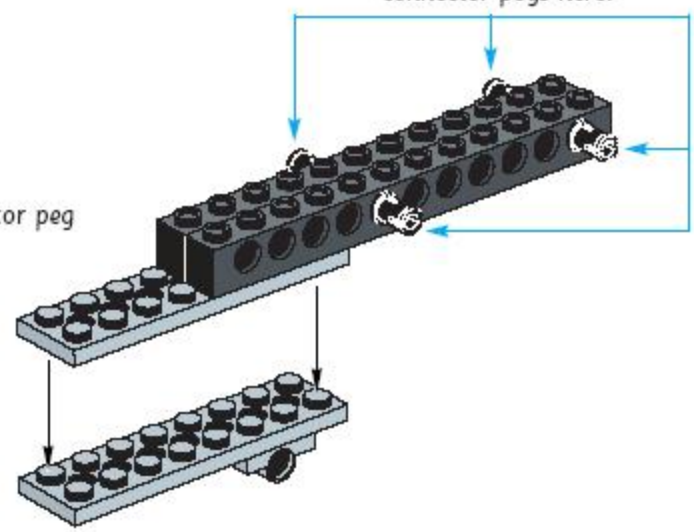
For this step, you need:



Black connector peg

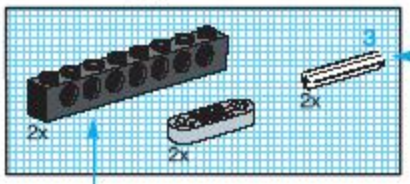
2x means you need 2 of these.

Put the black connector pegs here.



2

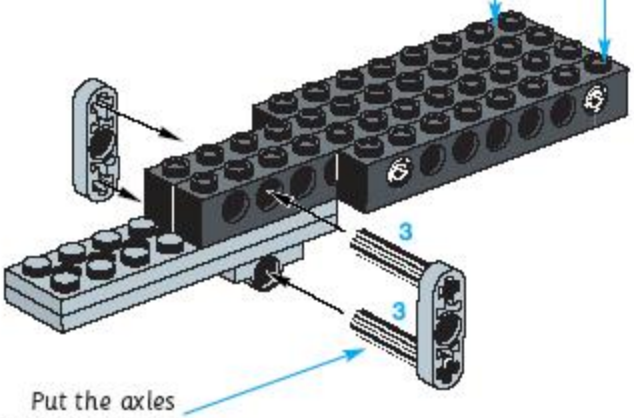
For this step, you need:



To measure an axle, see page 37.

1 x 8 beam

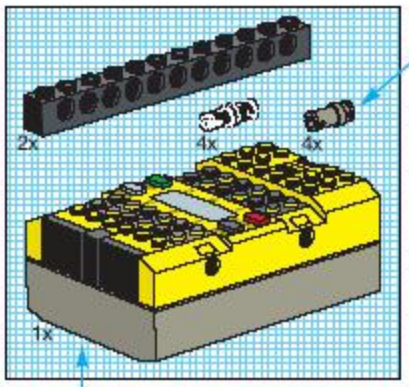
Put the 1 x 8 beams here.



Put the axles through the holes.

3

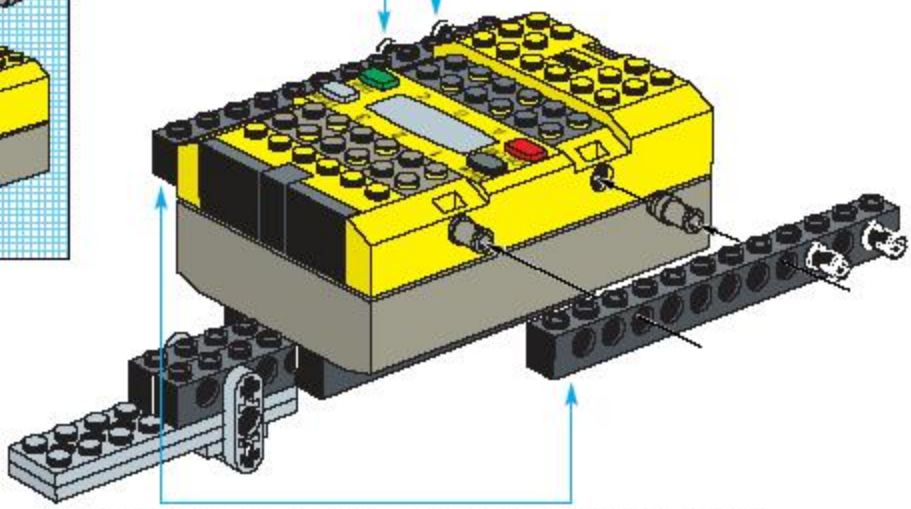
For this step, you need:



Dark gray connector peg

RCX

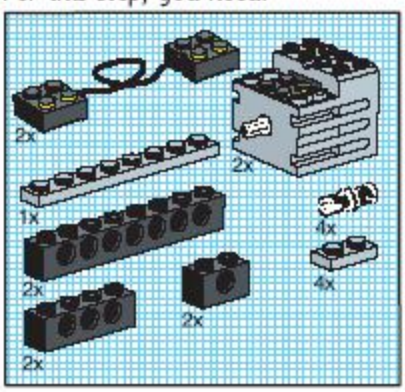
Put the black connector pegs here.

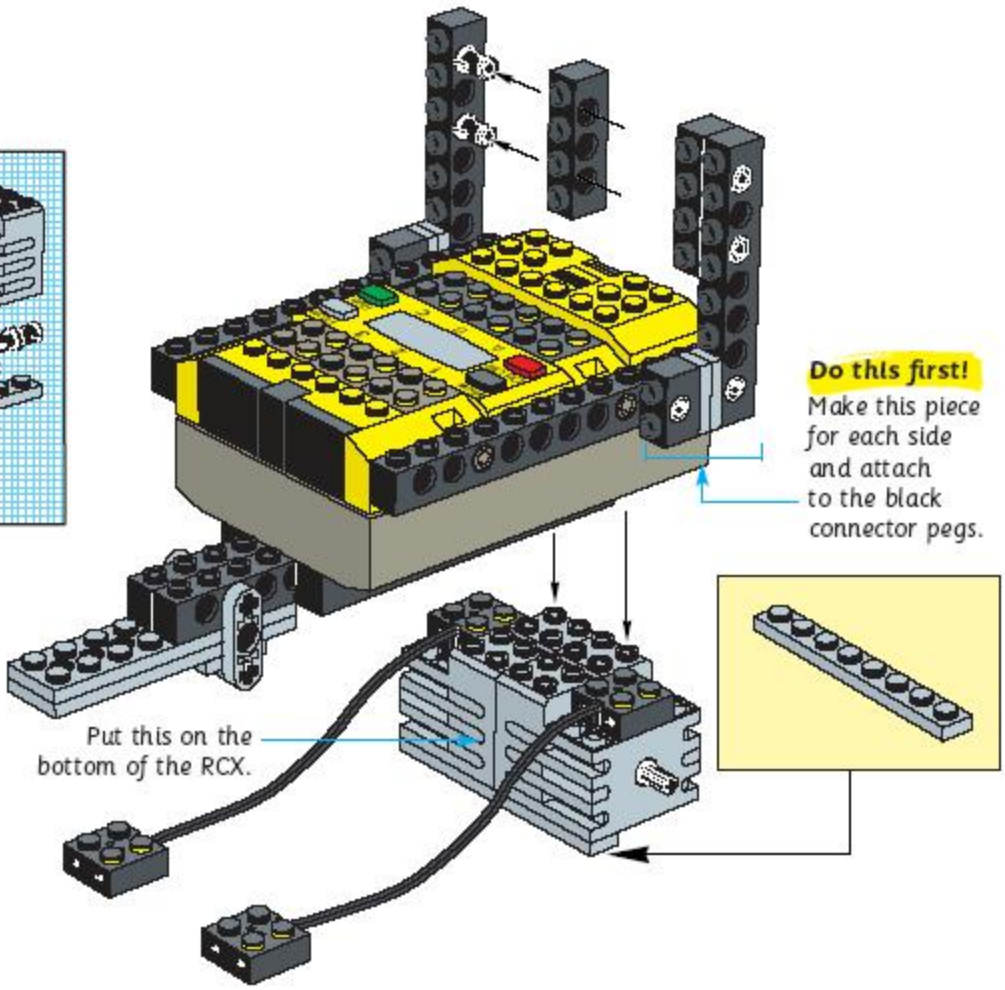


Put the beams on the RCX using the dark gray connector pegs.

4

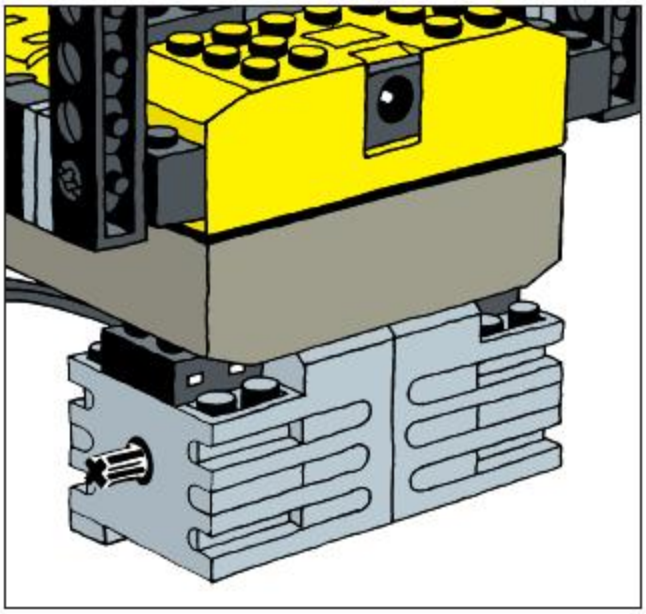
For this step, you need:





Do this first!
Make this piece for each side and attach to the black connector pegs.

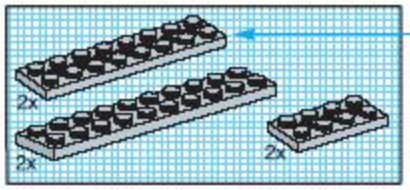
Put this on the bottom of the RCX.



Use this to make sure your motors are in the correct location.

5

For this step, you need:



2 x 8 plate with holes

Do this first!
Put the 2 x 8 plates with holes here.

HINT: Try this wheel

HINT: Try this wheel

IF YOU NEED HELP COMPLETING YOUR ROBOT...

- Check out "Special Features" on page 26.
- Turn to "Tips and Tricks" on page 32.

TO PROGRAM YOUR INVENTION...

- Go to one of the Robo challenges on the CD-ROM.

Acrobot 2

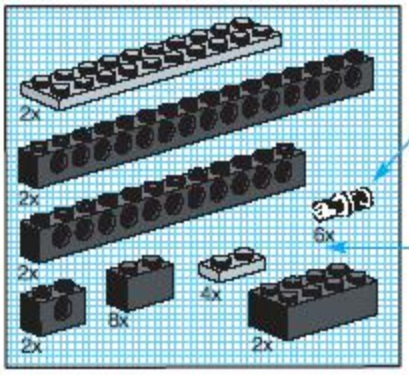
For a jump start on Acrobot 2, follow these six steps.

BEFORE YOU GET STARTED...

Make sure there are batteries in your RCX. For help installing batteries, turn to page 38.

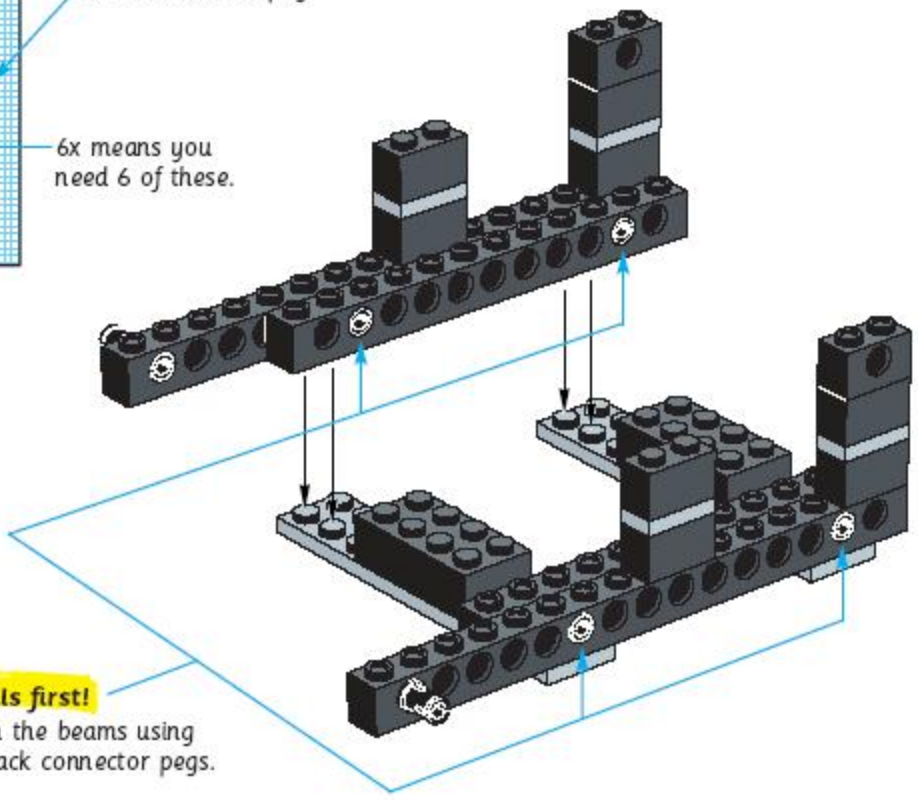
1

For this step, you need:



Black connector peg

6x means you need 6 of these.

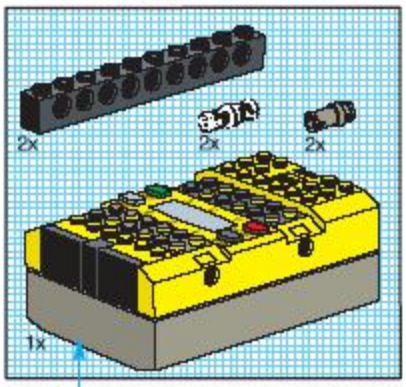


Do this first!

Attach the beams using the black connector pegs.

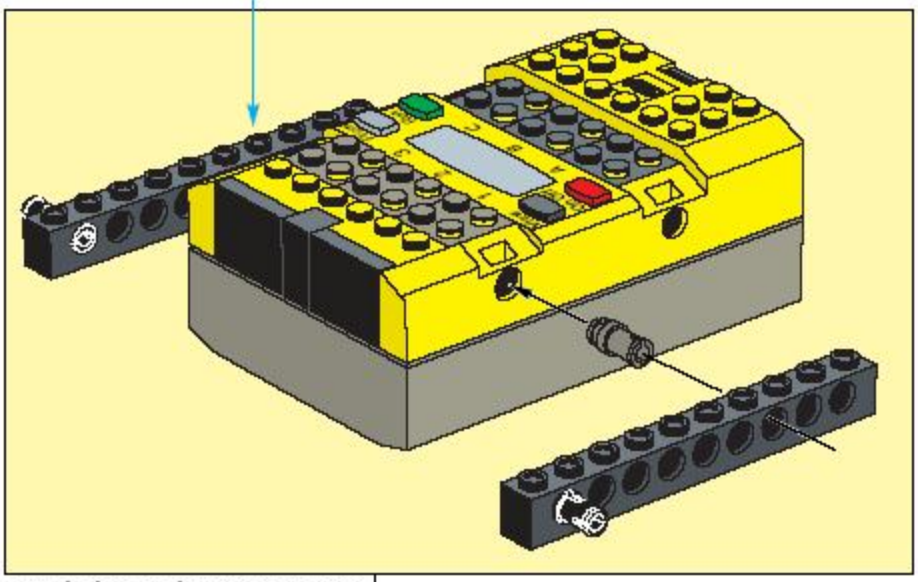
2

For this step, you need:

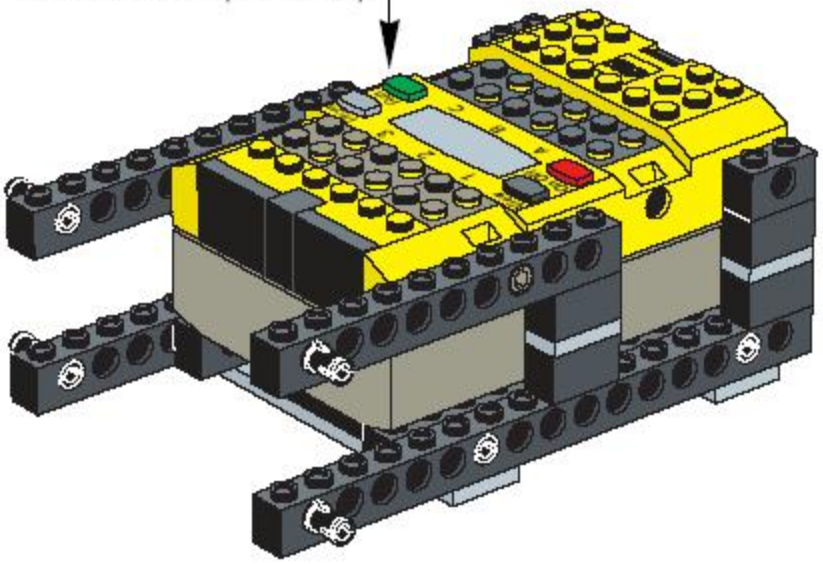


RCX

Attach the beam to the RCX.

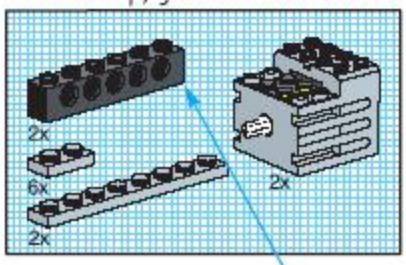


Attach this to the previous step.

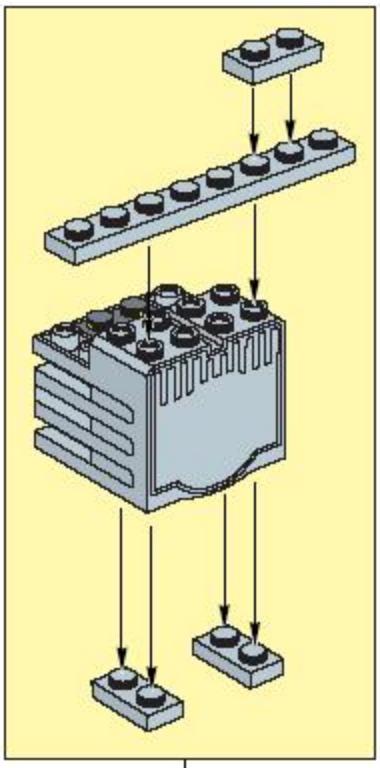


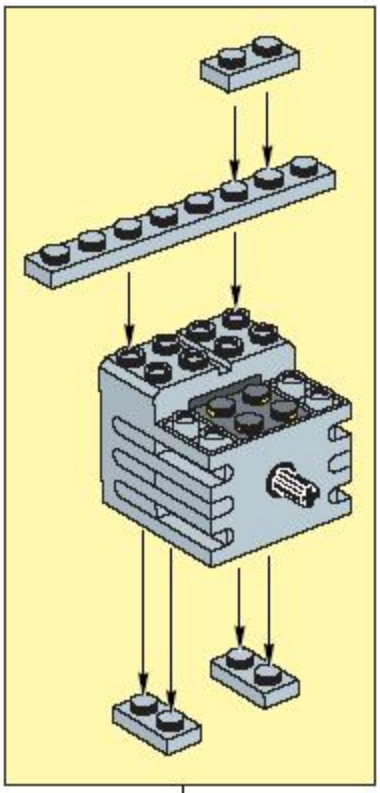
3

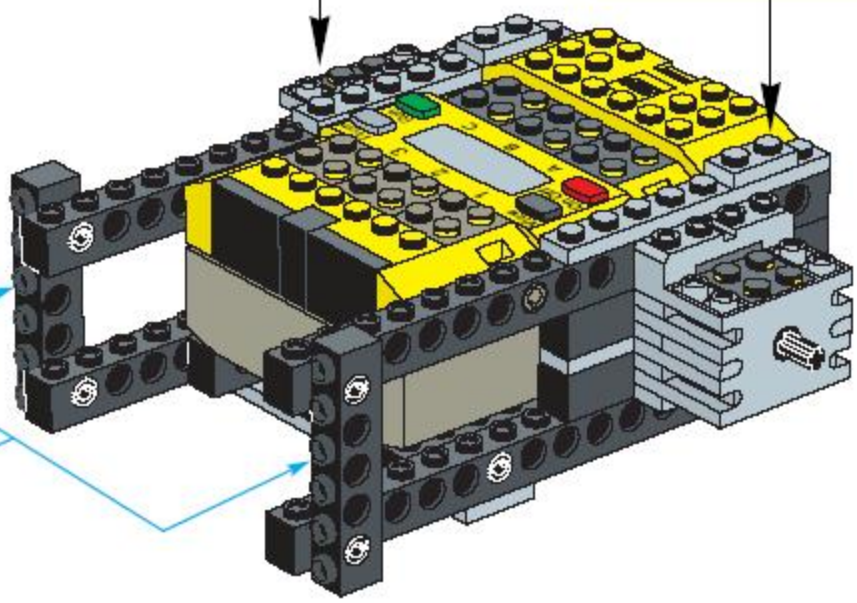
For this step, you need:



1 x 6 beam



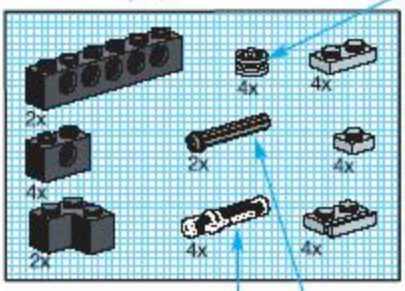




Put the 1 x 6 beams here.

4

For this step, you need:



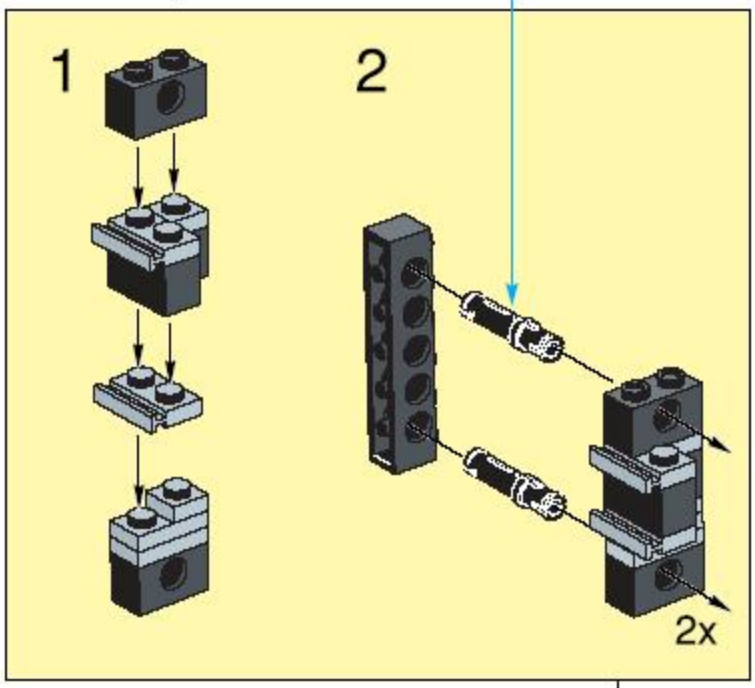
1/2 bushing

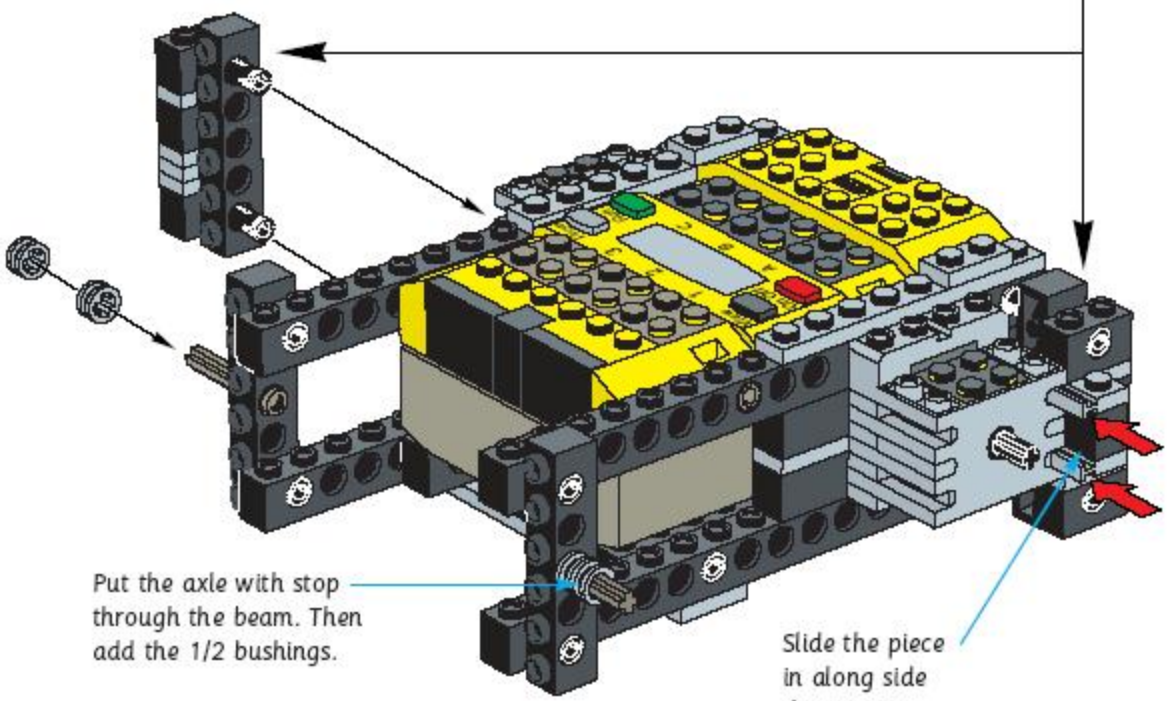
Axle with stop

Long black connector peg

Make two of these.

The long black connector peg must be put in like this.



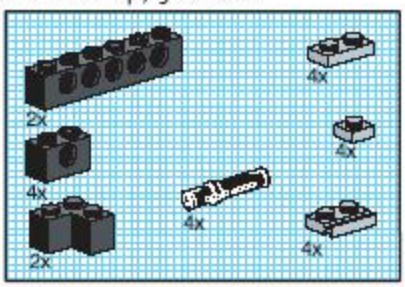


Put the axle with stop through the beam. Then add the 1/2 bushings.

Slide the piece in along side the motor.

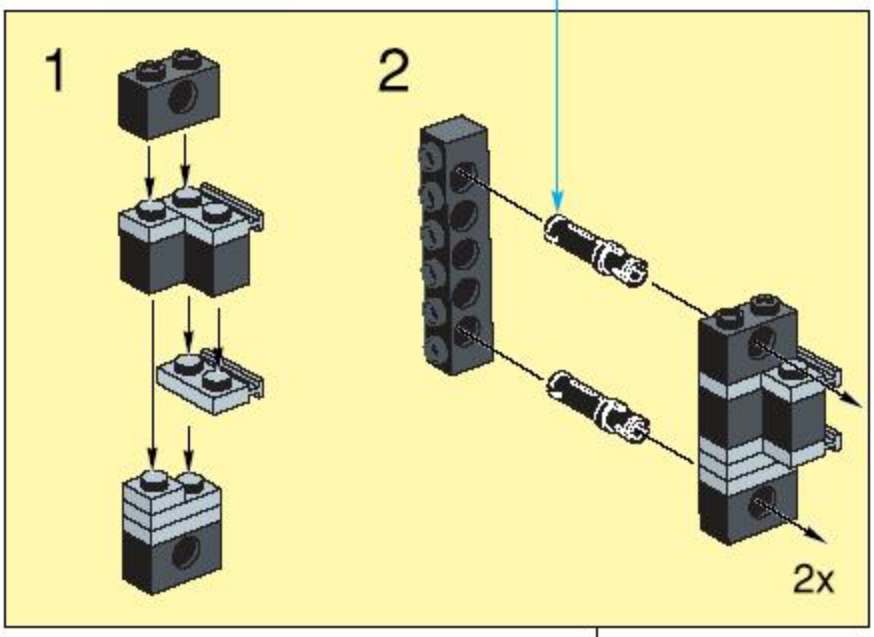
5

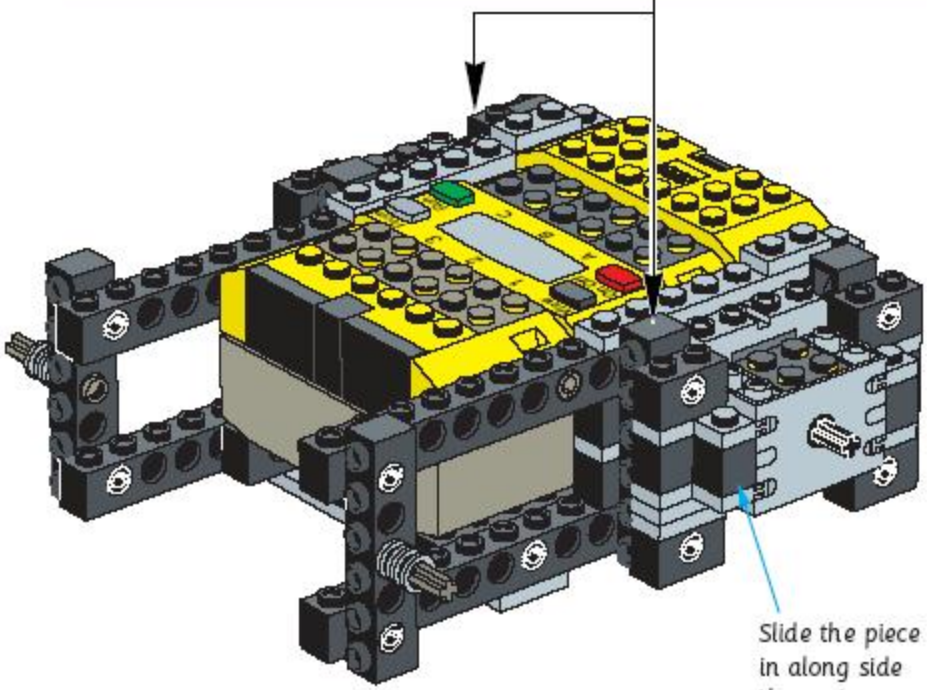
For this step, you need:



Make two of these.

The long black connector peg must be put in like this.

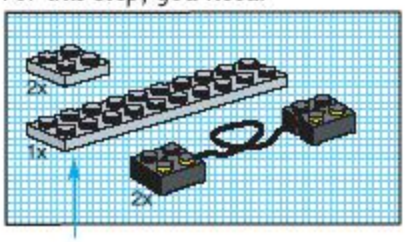




Slide the piece in along side the motor.

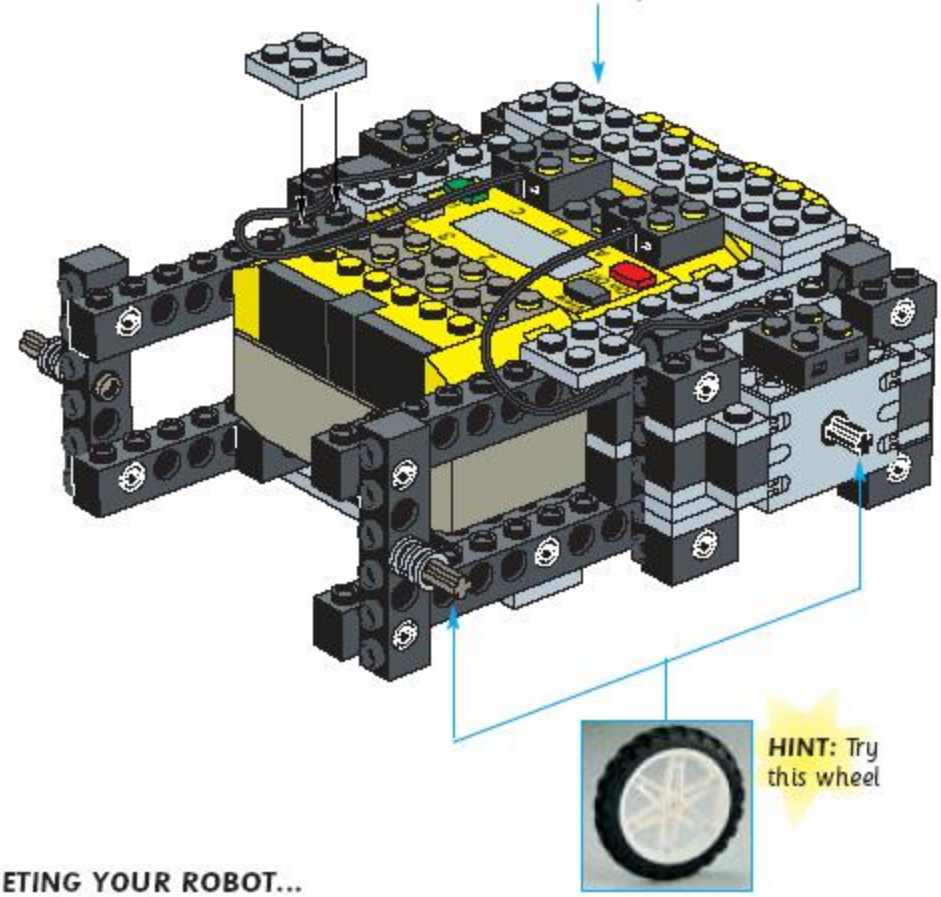
6

For this step, you need:



2 x 10 plate

Put the 2 x 10 plate here.



HINT: Try this wheel

IF YOU NEED HELP COMPLETING YOUR ROBOT...

- Check out "Special Features" on page 26.
- Turn to "Tips and Tricks" on page 32.

TO PROGRAM YOUR INVENTION...

- Go to one of the Robo challenges on the CD-ROM.

Special Features

MOVEMENT

There's more than one way to get things moving. Here are a few ideas to get your mind in gear.

Push the hub into the tire.

1

Large and small tires can be used on the same model.

2

Put a 16-tooth gear here.

For more details on how to build this, see Tips & Tricks on page 34.

3

Even gears can be used as wheels!

4

There are two ways to make your wheels swivel.

5

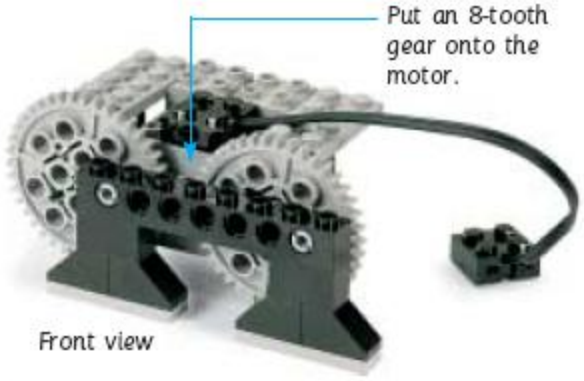
Big wheels lift your robot higher off the ground. (This is especially useful on Acrobot 2. See page 25).

6

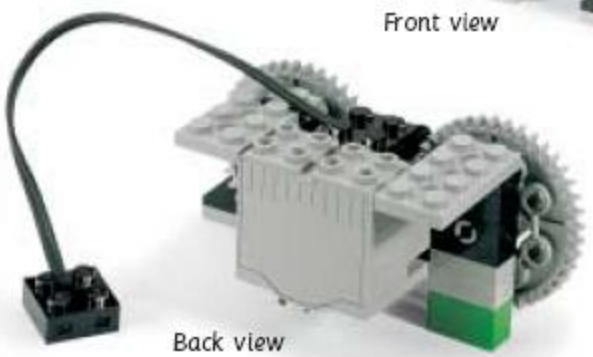
A Walking Mechanism

Look closely at the photograph to make sure you build it correctly.

For help, turn to Tips & Tricks on page 36.



Front view



Back view

7

8

This wheel can be attached directly to the motor.

9

This wheel requires some building before you attach it to the motor.

10

NATURAL

MECHANICAL

Special Features

SENSORS

Sensors make it possible for a robotic invention to respond to its environment. Here are a few ideas on how to use light sensors and touch sensors.

Light Sensor

The sensor "reads" the light here.

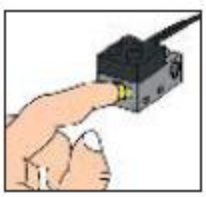
Connect this end to the gray ports on the RCX.

1

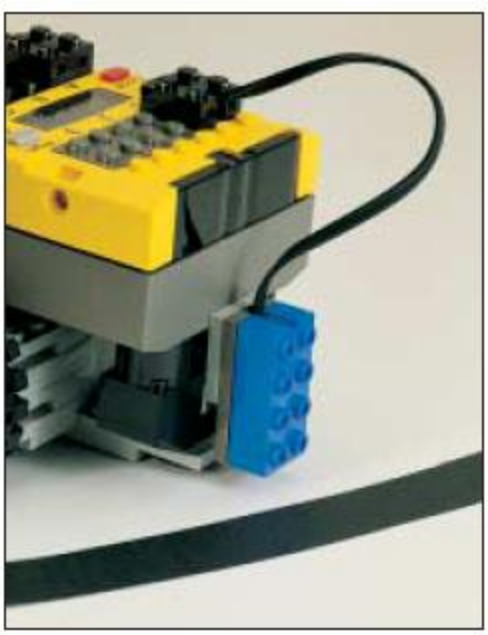
Touch Sensor

Push the touch sensor here.

Connect this end to one of the gray ports on the RCX.



2



Use a light sensor "facing" down to locate a line.

3

Make a bumper with a touch sensor.

4

Hand-Held Controller

Here is how you can build a hand-held controller using two touch sensors.

Step 1

1 x 2 beam

Steering wheel

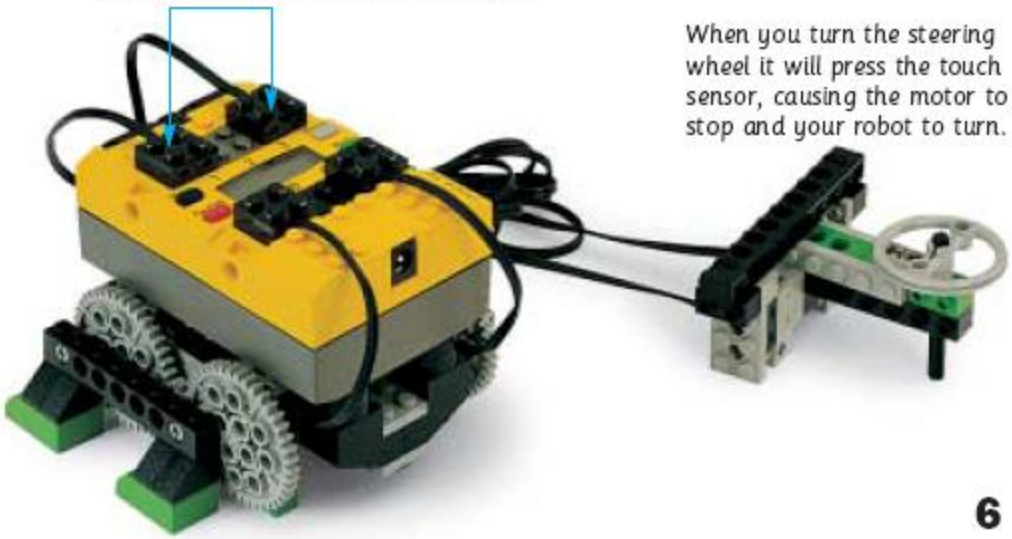
Step 2

Step 3

5

Attach the two wires from the hand-held controller to the RCX on ports 1 and 3.

When you turn the steering wheel it will press the touch sensor, causing the motor to stop and your robot to turn.



6

NATURAL

MECHANICAL

Special Features

SENSORS

Here are more examples of how you can use sensors. There are also ideas for decorations such as "eyes" and "noses."

A light sensor that looks down

1

A light sensor that looks down

2

A light sensor that looks up

3

A bumper that uses one touch sensor

4

A bumper that uses one touch sensor

5

A bumper that uses two touch sensors

6

Eyes for decoration

7

A face for decoration

8

These eyes are just for decoration.

This eye is the one that really "sees."

9

A light sensor facing down

10

A touch sensor added to the end of an arm

11

A touch sensor in the middle of a hand

12

An eye for decoration

13

Arms for decoration

14

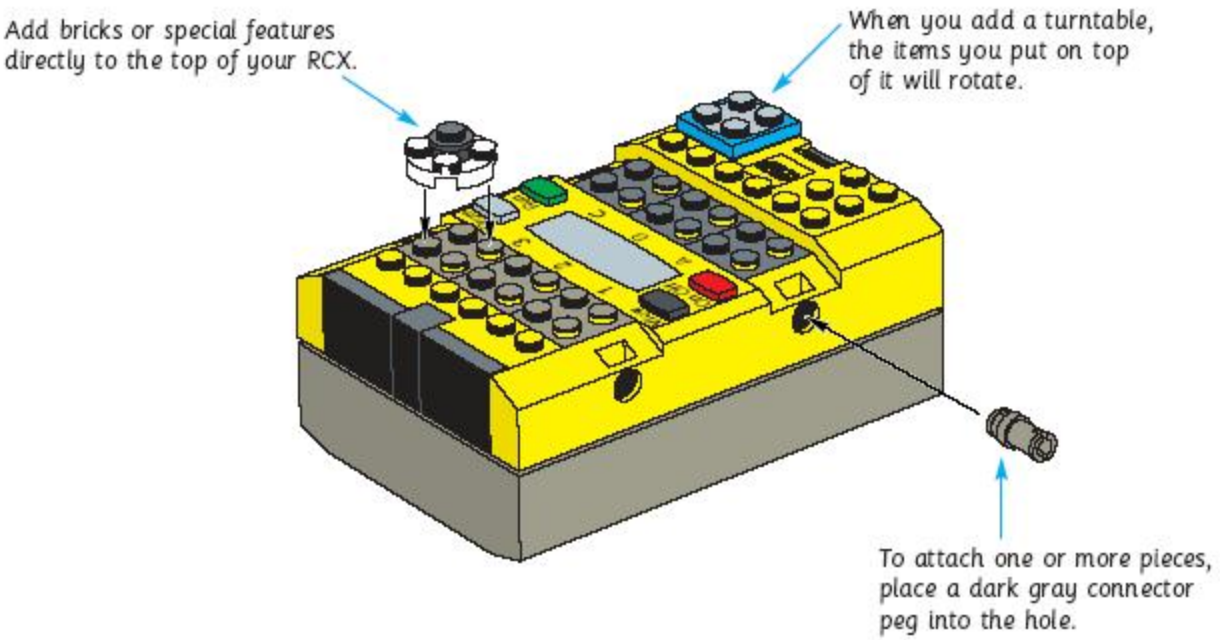
NATURAL

MECHANICAL

Tips & Tricks

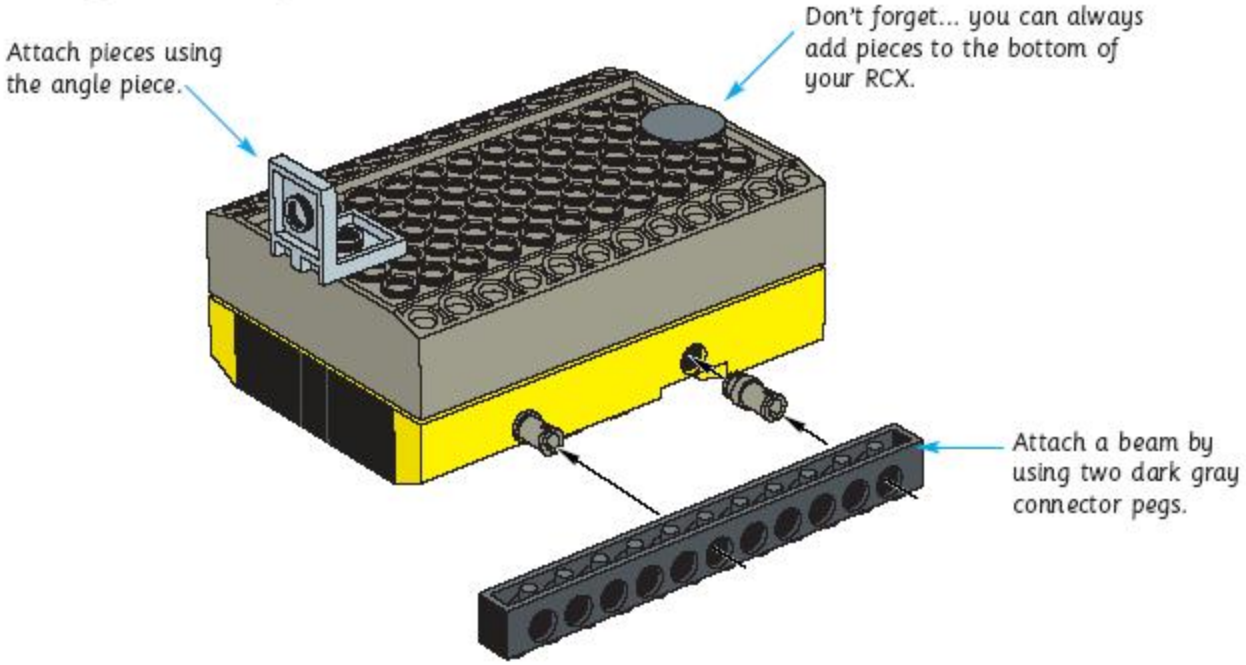
If you want to make your invention bigger, stronger, faster, or work even better, try using these tips and tricks.

Adding features to your RCX



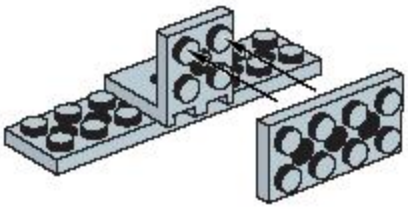
1

Attaching different pieces



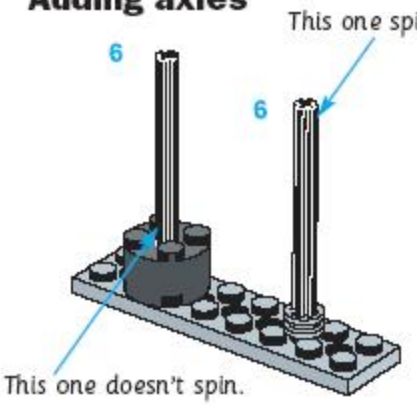
2

Making angles



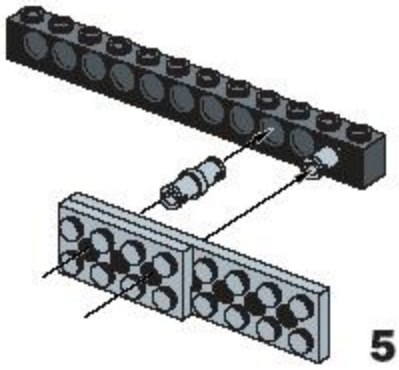
3

Adding axles



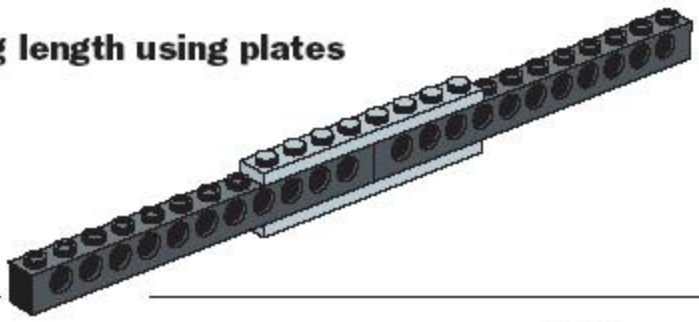
4

Adding plates to a beam



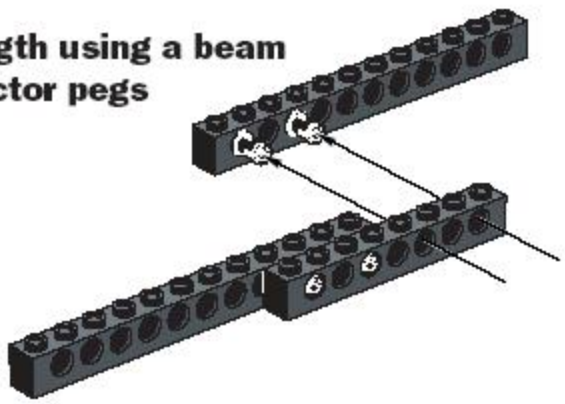
5

Adding length using plates



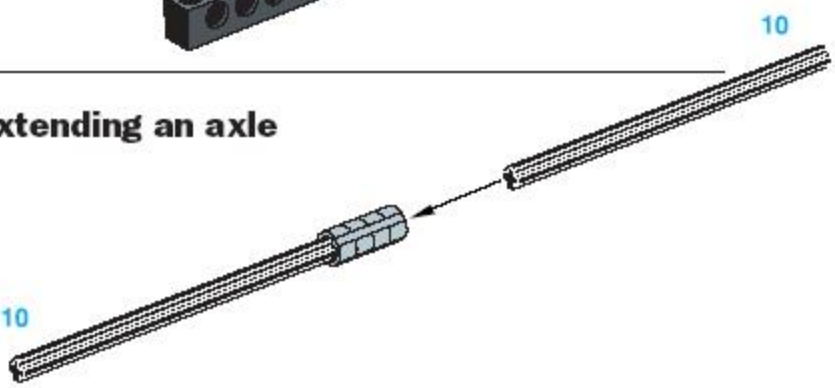
6

Adding length using a beam and connector pegs



7

Extending an axle



8

Adding height

9

Tips & Tricks

Making a hand

Push these four pieces together to make a hand.

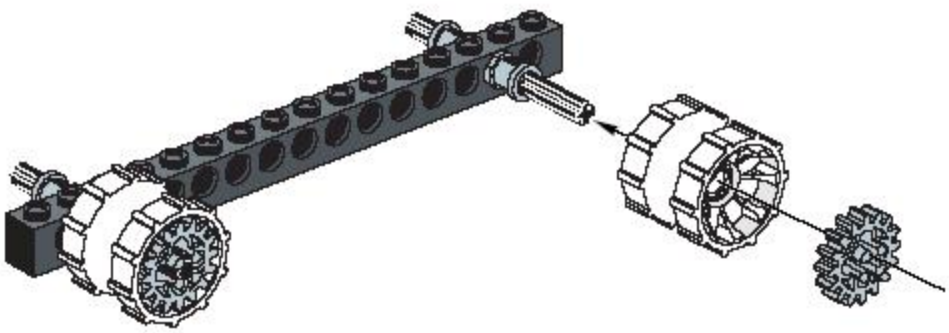
10

Adding pieces to a beam

Push the cone into the hole of the beam.

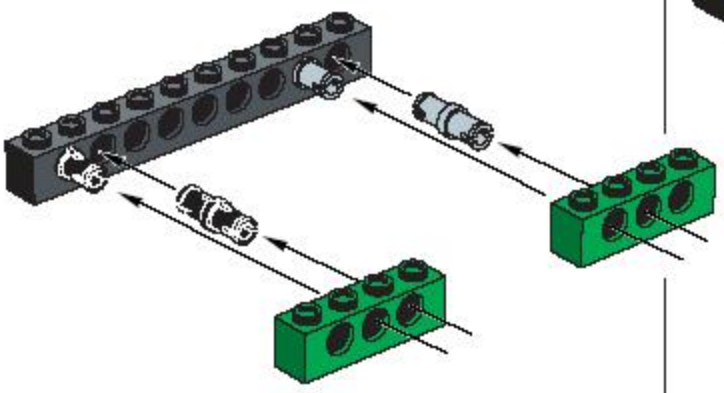
11

Adding hubs for caterpillar treads



12

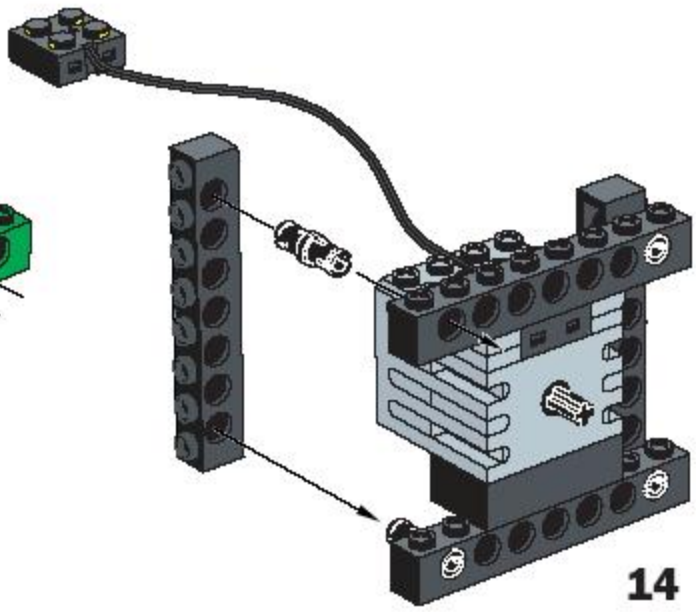
Using connector pegs



The black connector pegs hold pieces more tightly than the gray connector pegs.

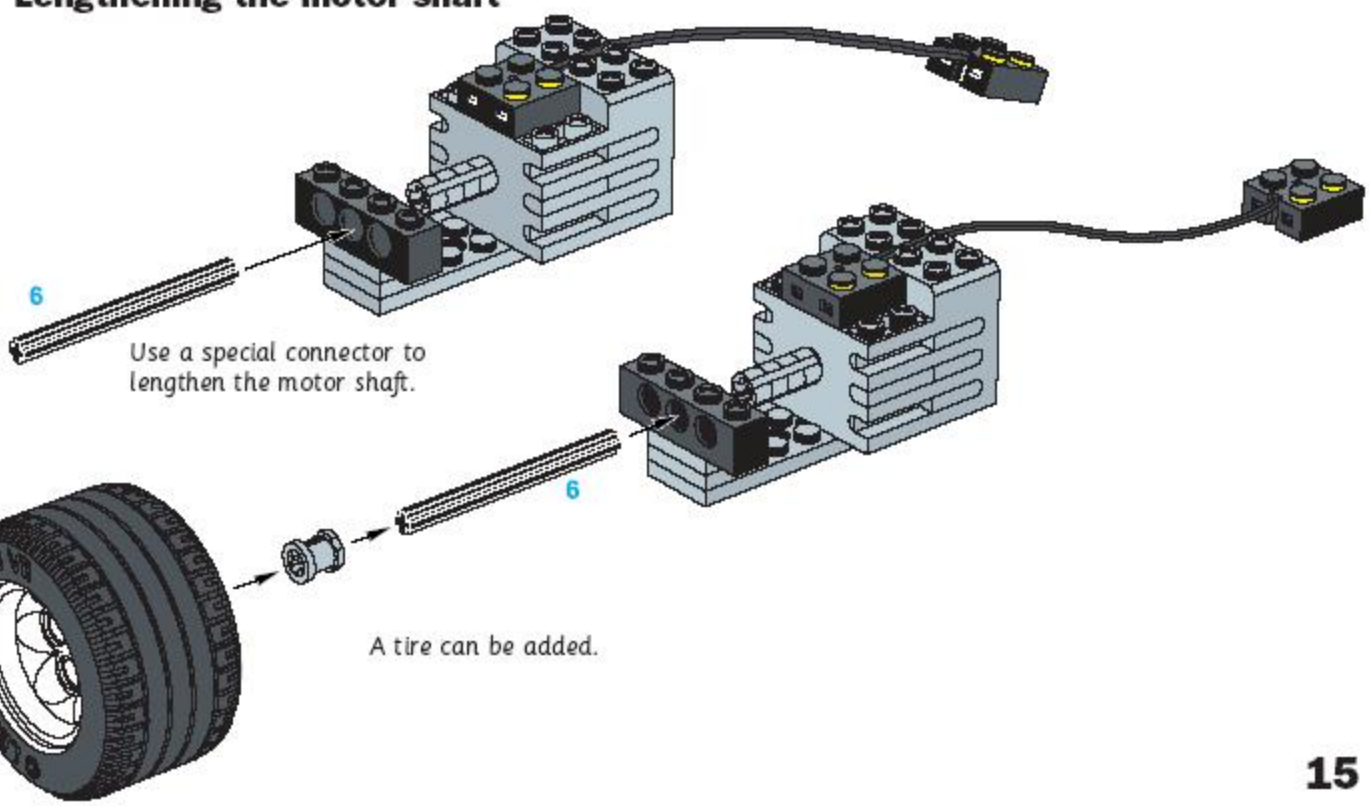
13

Building a frame around a motor



14

Lengthening the motor shaft



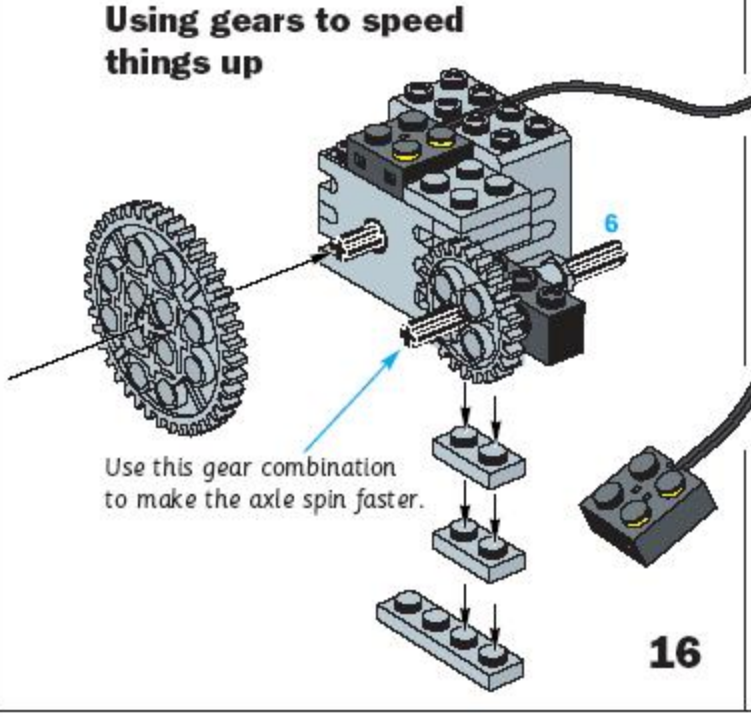
Use a special connector to lengthen the motor shaft.

A tire can be added.

15

Tips & Tricks

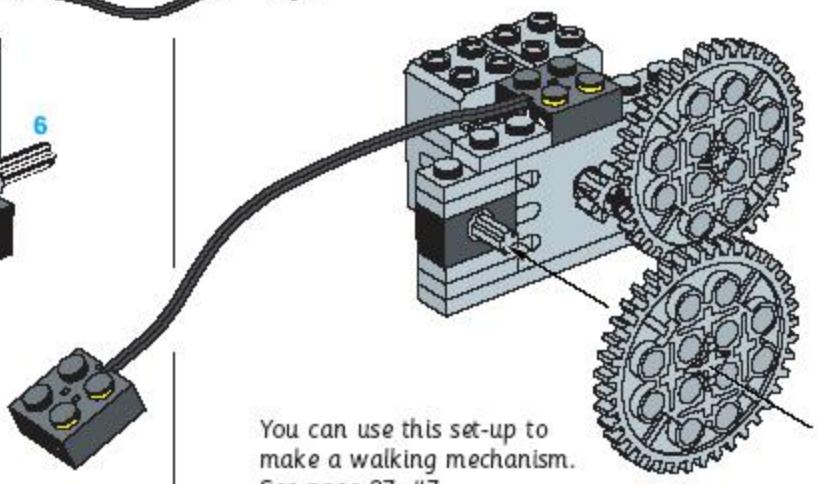
Using gears to speed things up



Use this gear combination to make the axle spin faster.

16

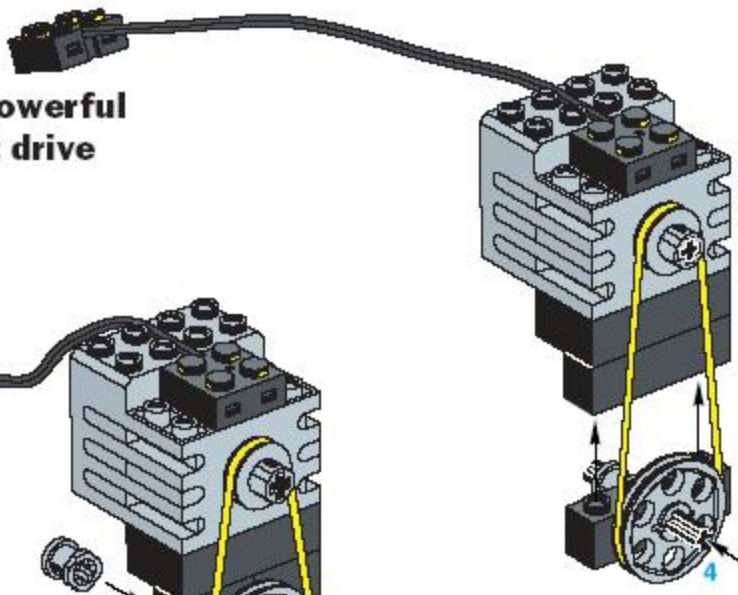
Using one motor to drive two gears

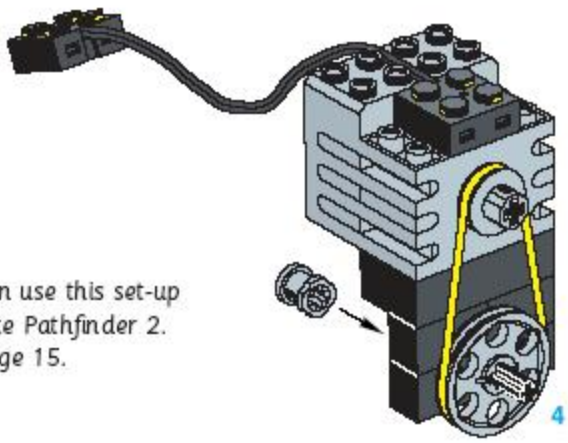


You can use this set-up to make a walking mechanism. See page 27, #7.

17

Creating a more powerful motor using a belt drive



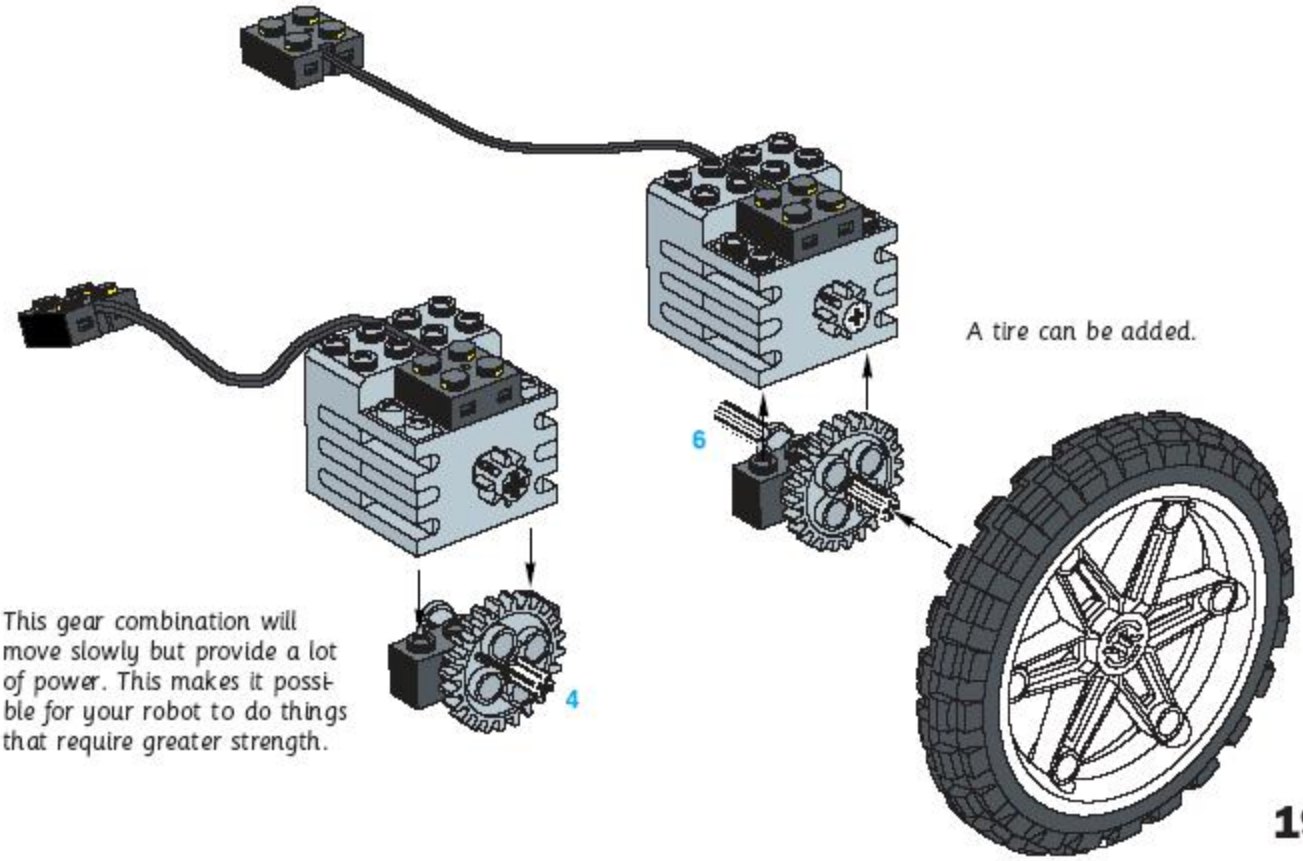


You can use this set-up to make Pathfinder 2. See page 15.

A tire can be added.

18

Changing speed using different-sized gears

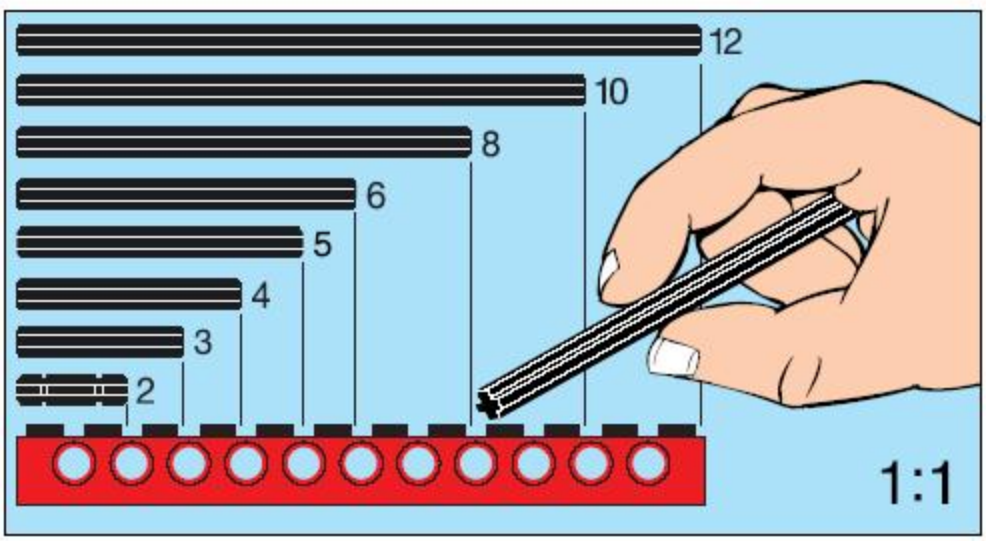


This gear combination will move slowly but provide a lot of power. This makes it possible for your robot to do things that require greater strength.

19

How to measure an axle

Use this chart to measure the length of an axle.

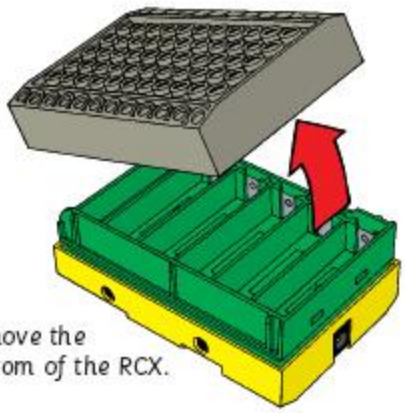


Tips & Tricks

Battery installation for the RCX

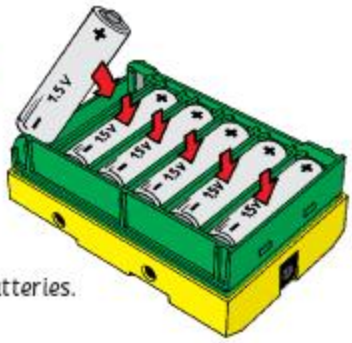
Instructions for use of battery box
Never mix different types of batteries or old and new batteries in one battery box. Always remove the batteries from the battery box for long-term storage or if they have reached the end of their life. Liquid leaking from dead batteries will damage the battery box. Rechargeable batteries can be used but power may be reduced. Do not recharge the batteries in the battery box. Rechargeable batteries are only to be charged under adult supervision.

1



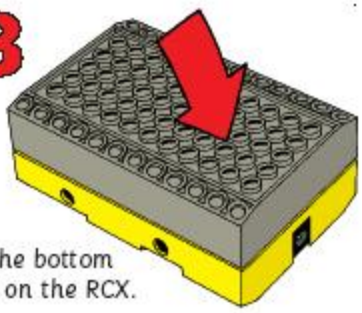
Remove the bottom of the RCX.

2



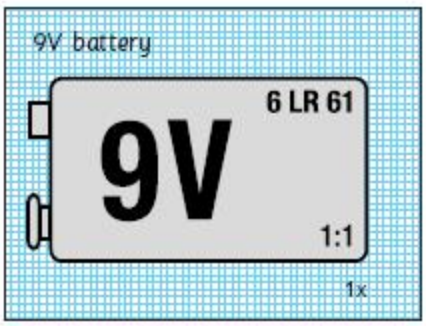
Insert 6 AA (LR6) batteries.

3



Put the bottom back on the RCX.

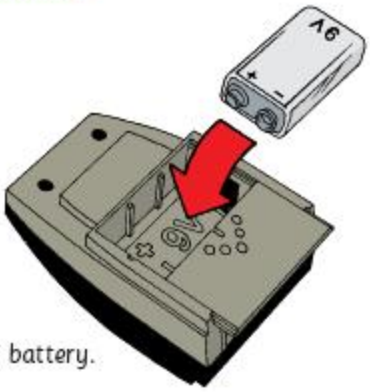
Battery installation for the Infrared Transmitter



1

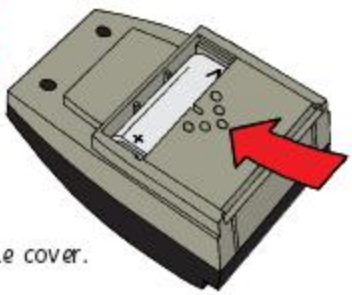
Slide the cover back.

2



Insert the 9V battery.

3



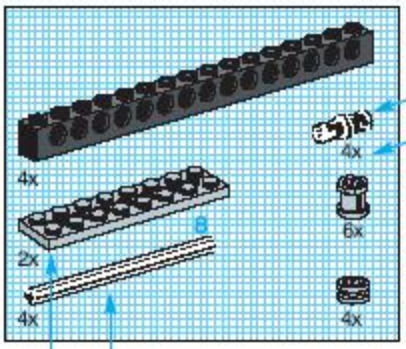
Close the cover.

Top Secret Plans

The Torbot is a robot that gets around on caterpillar treads and is able to travel on top of a table with no risk of falling. Its secret lies in the strategic placement of its touch sensors. To build the Torbot, follow these 12 steps.

1

For this step, you need:

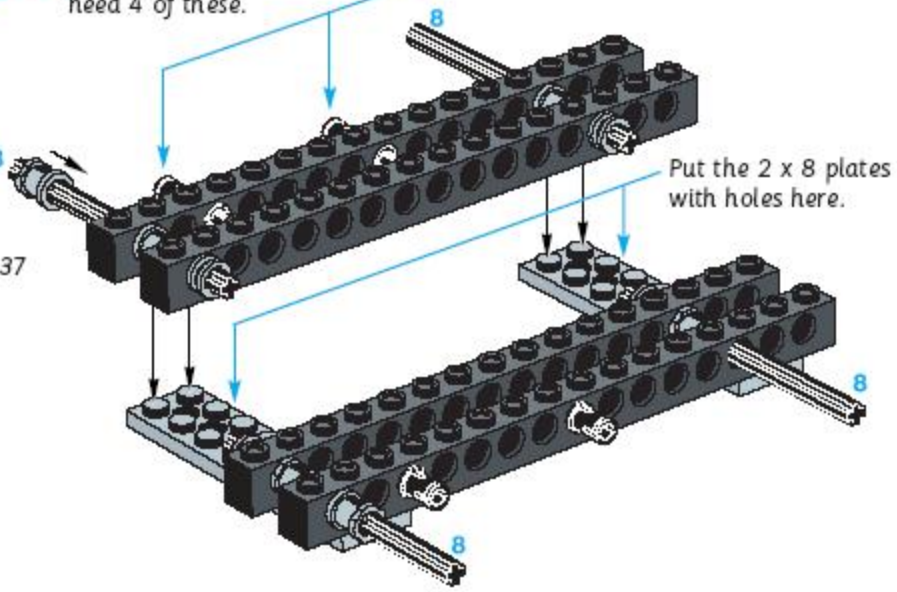


Black connector peg.

4x means you need 4 of these.

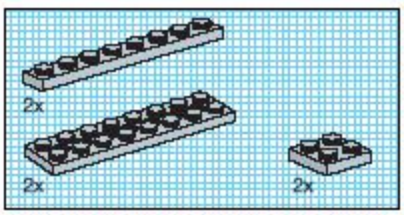
To measure an axle see page 37

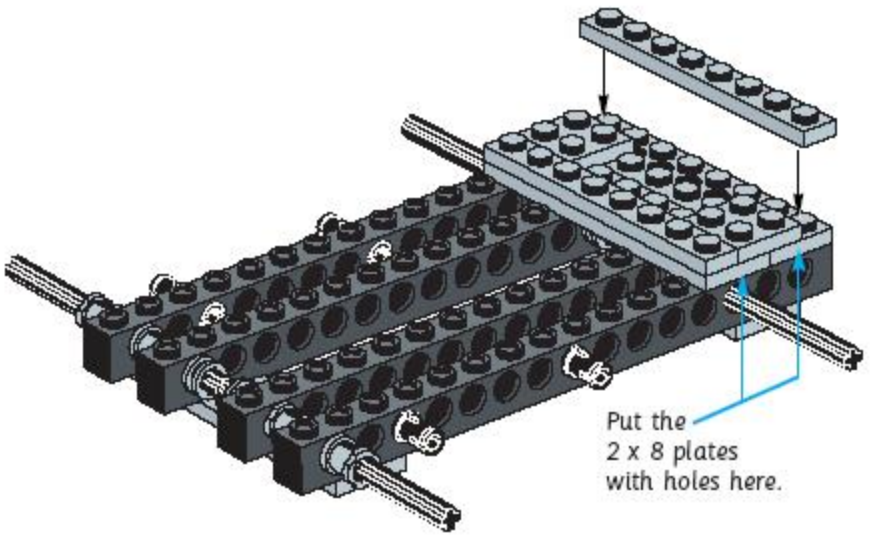
2 x 8 plate with holes



2

For this step, you need:

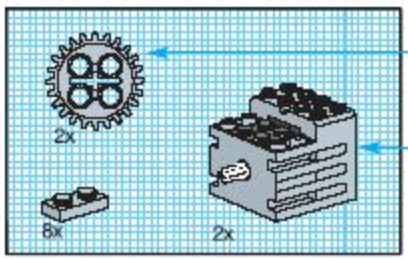




Top Secret Plans

3

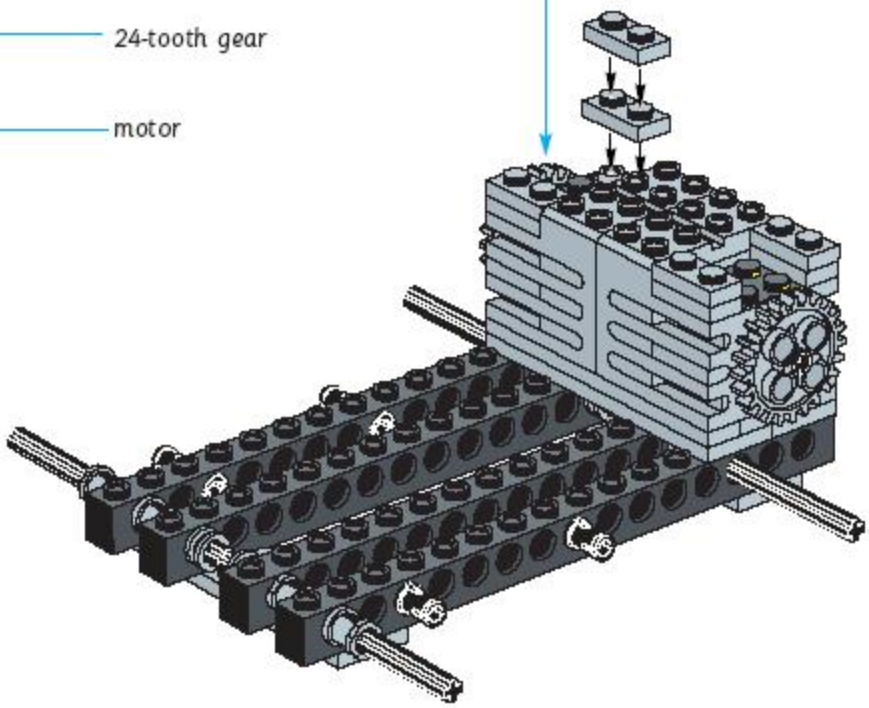
For this step, you need:



24-tooth gear

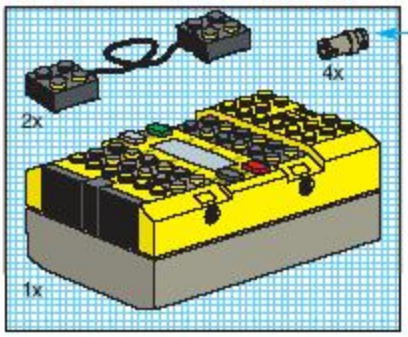
motor

Put the 24-tooth gear onto the motor.



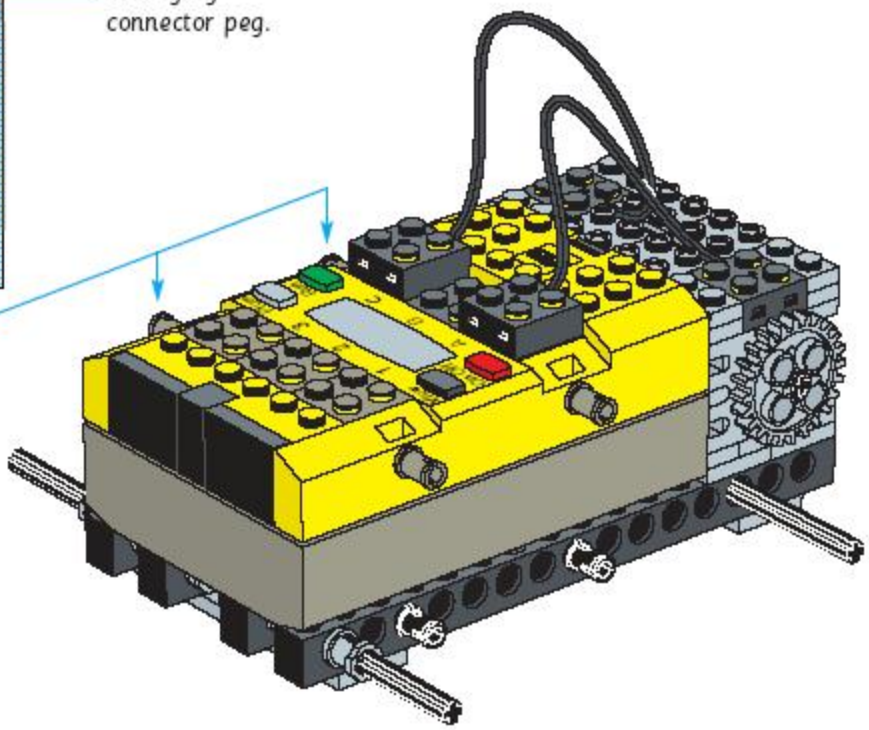
4

For this step, you need:



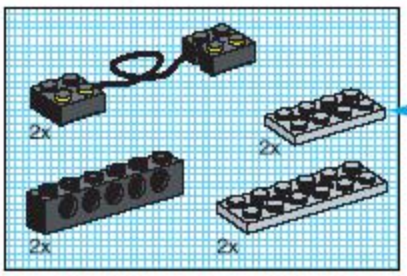
Dark gray connector peg.

Put the dark gray connector pegs here.



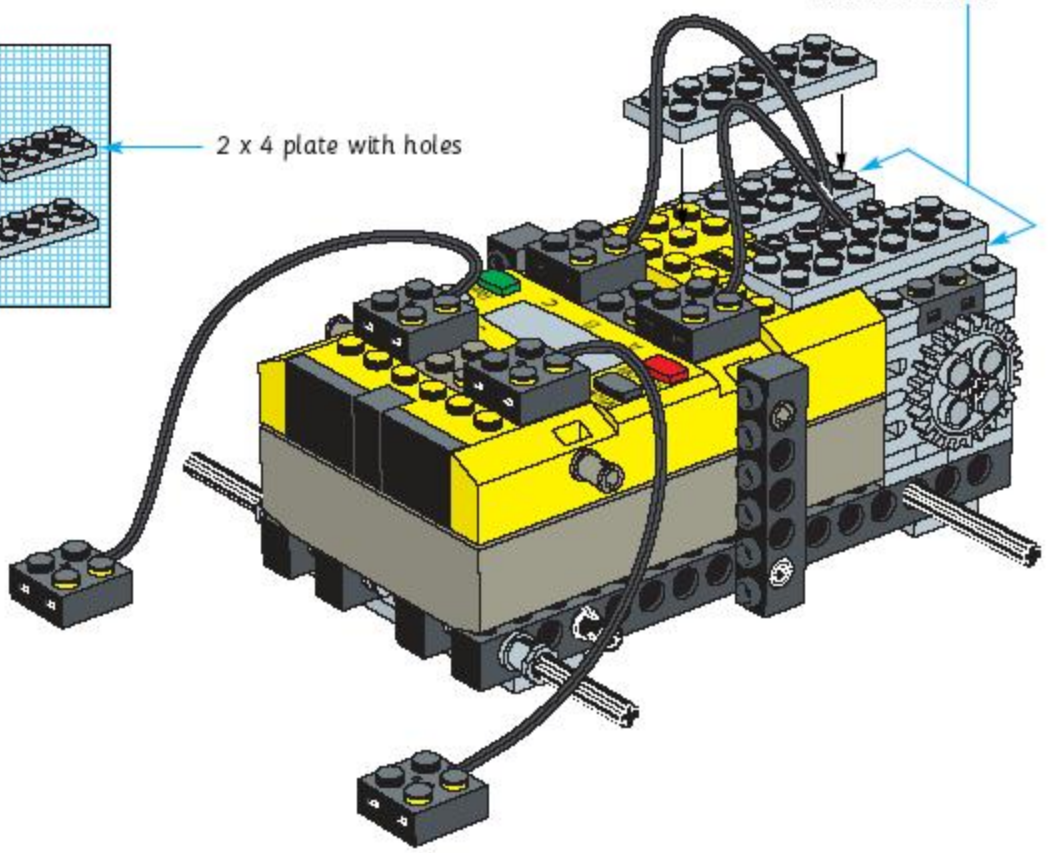
5

For this step, you need:



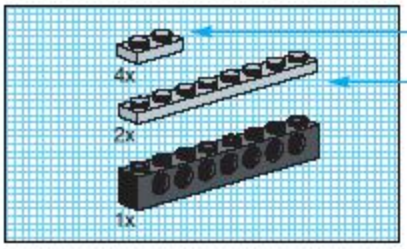
2 x 4 plate with holes

Put the 2 x 4 plates with holes here.



6

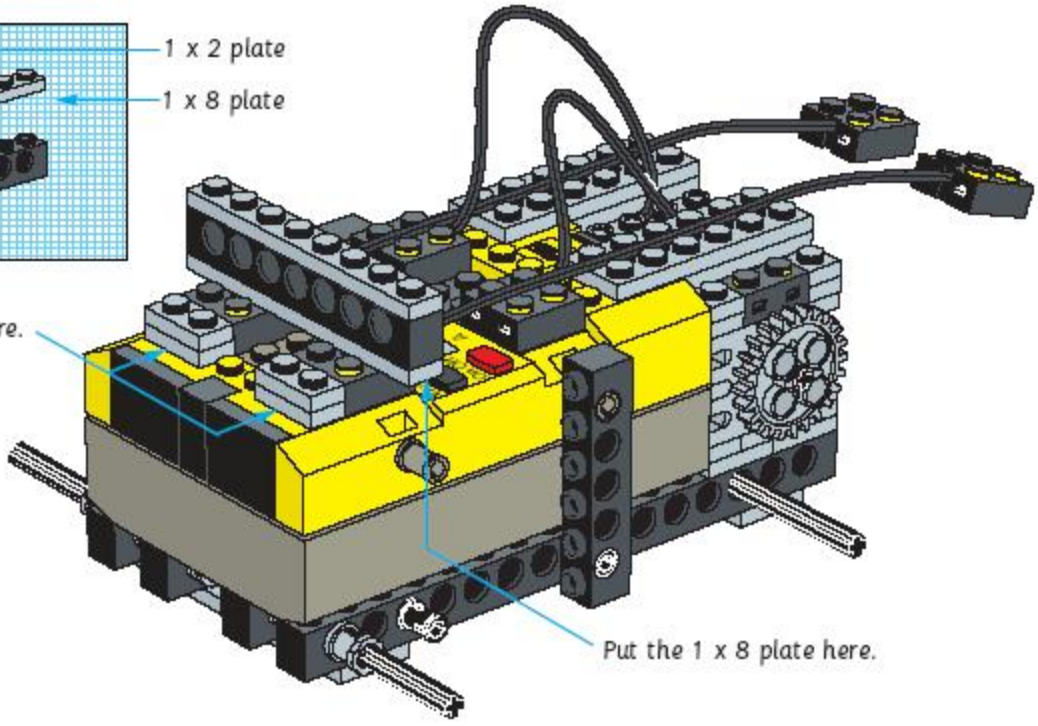
For this step, you need:



1 x 2 plate

1 x 8 plate

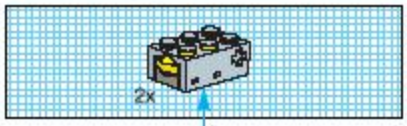
Put the 1 x 2 plates here.



Put the 1 x 8 plate here.

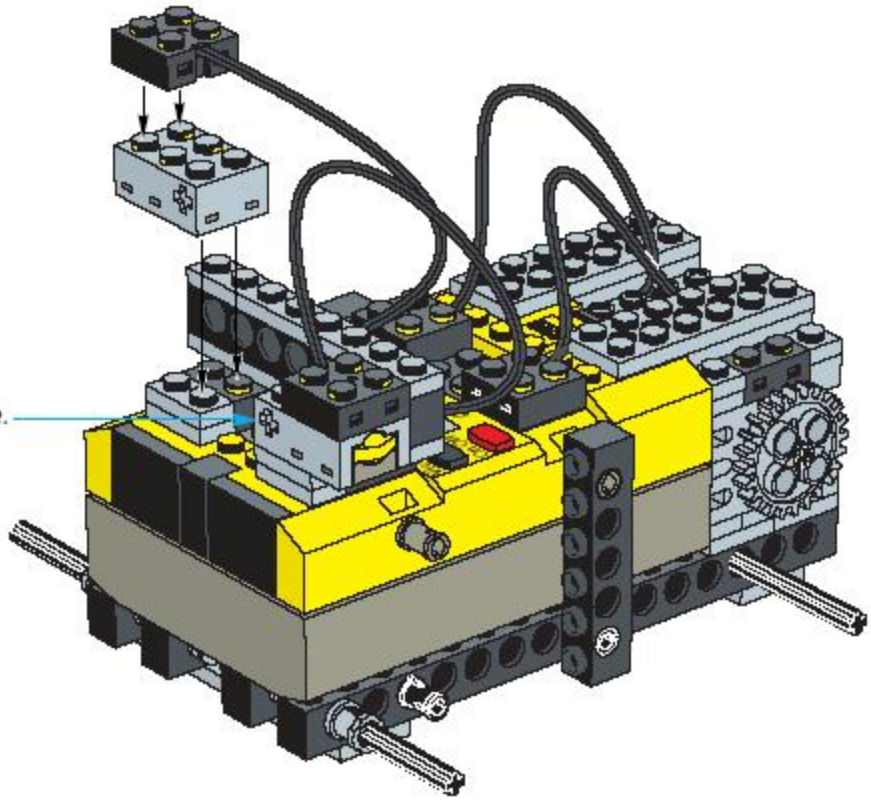
7

For this step, you need:



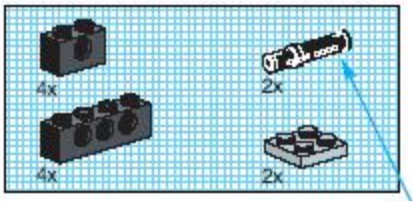
Touch Sensor

Put the touch sensor here.



8

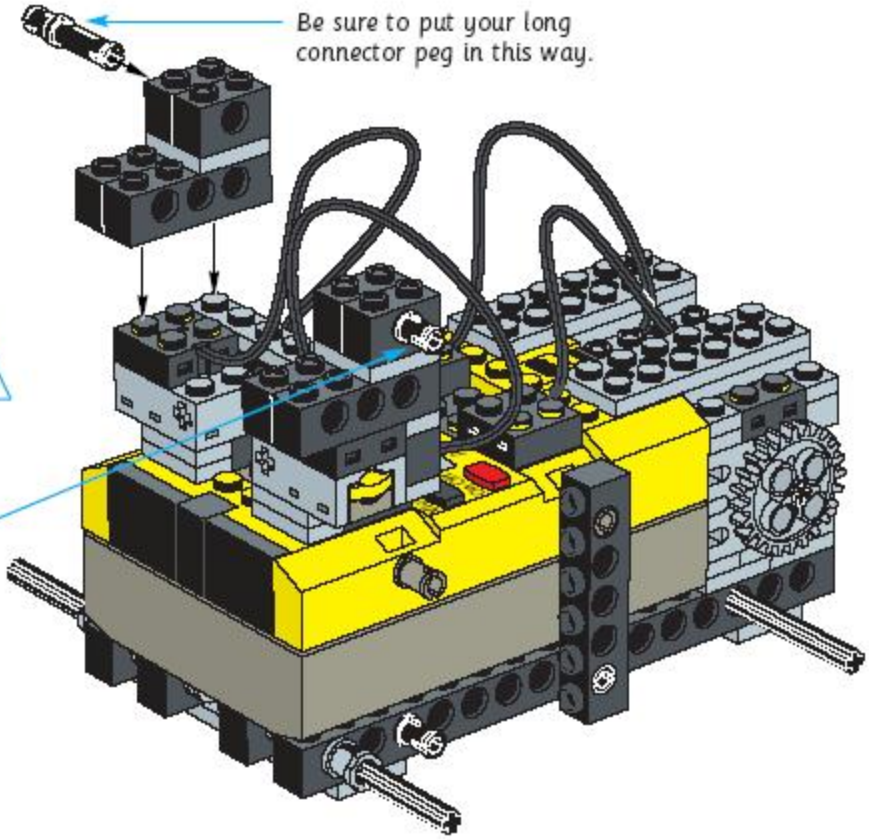
For this step, you need:



Long black connector peg

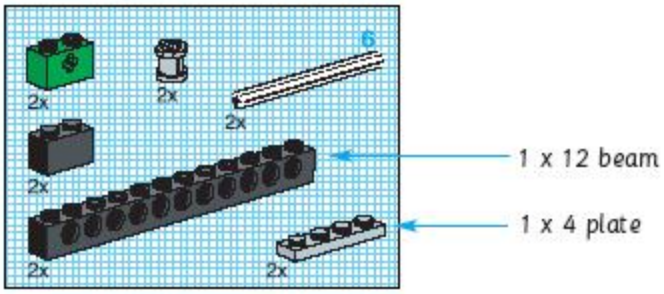
Put the long black connector peg here.

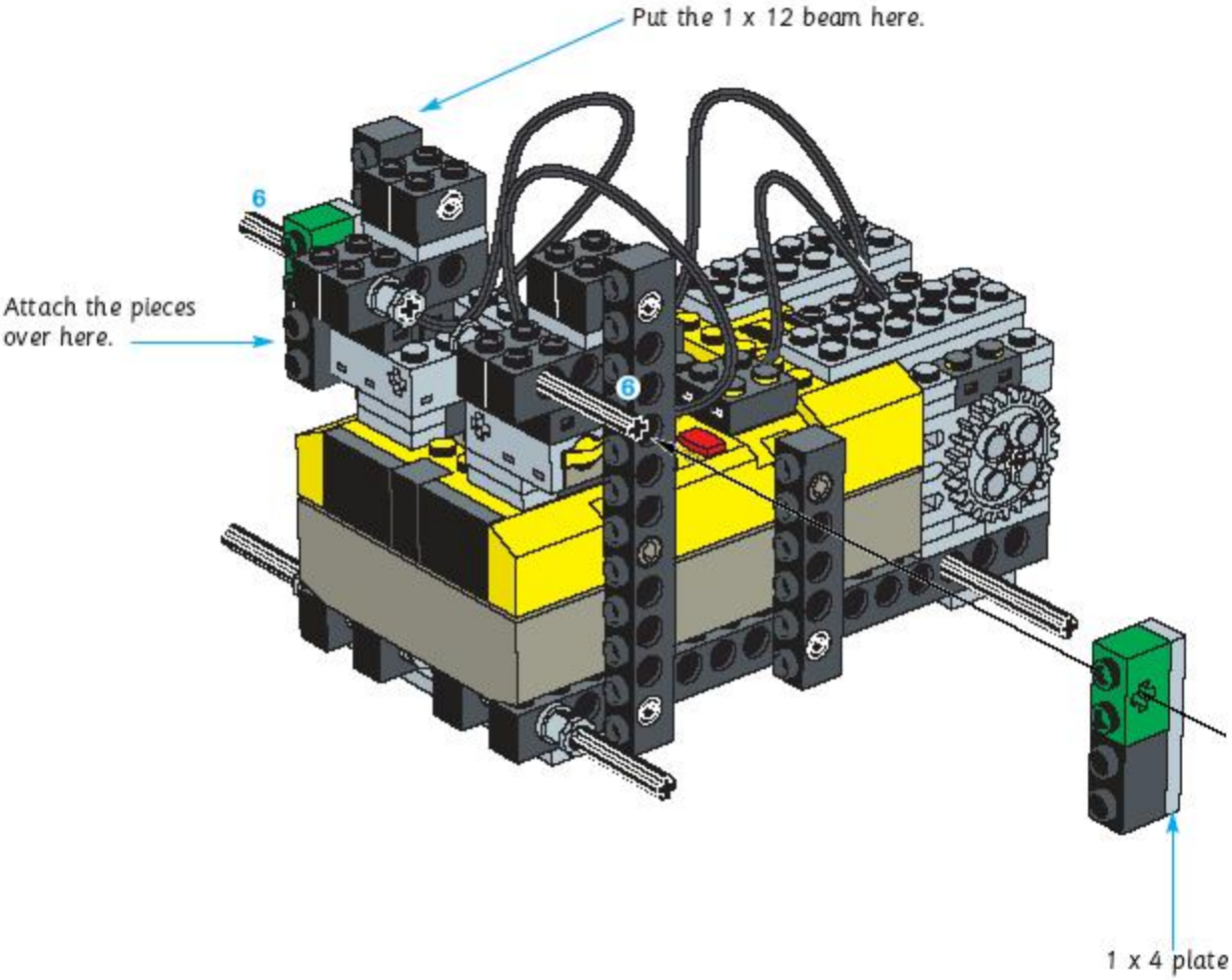
Be sure to put your long connector peg in this way.



9

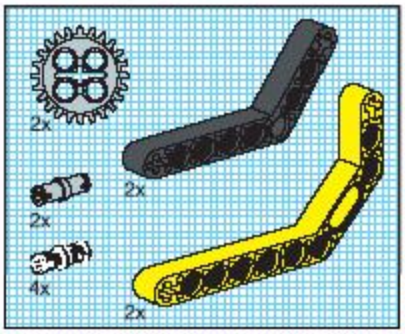
For this step, you need:

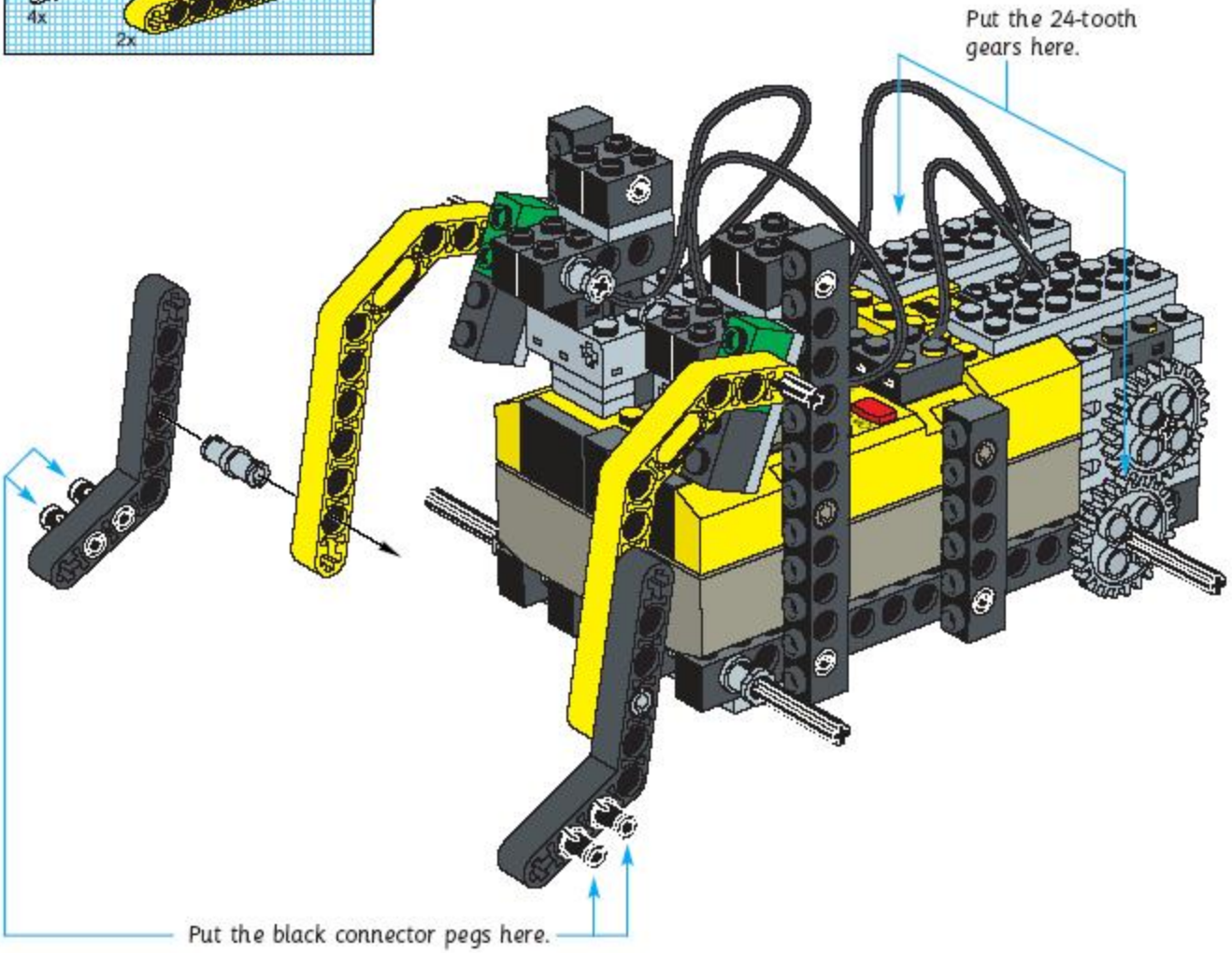




10

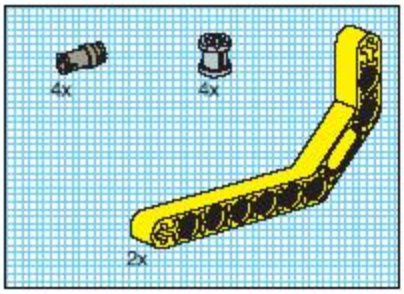
For this step, you need:





11

For this step, you need:

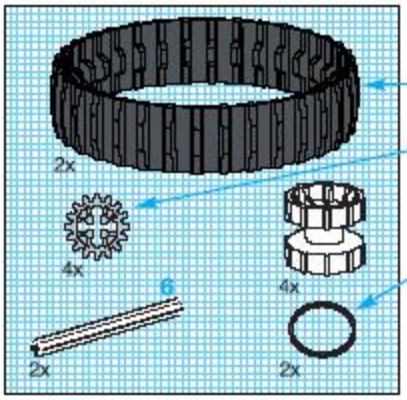


Put another bushing on the axle over here.

Put a bushing here.

12

For this step, you need:



Caterpillar tread

16-tooth gear

Rubber band

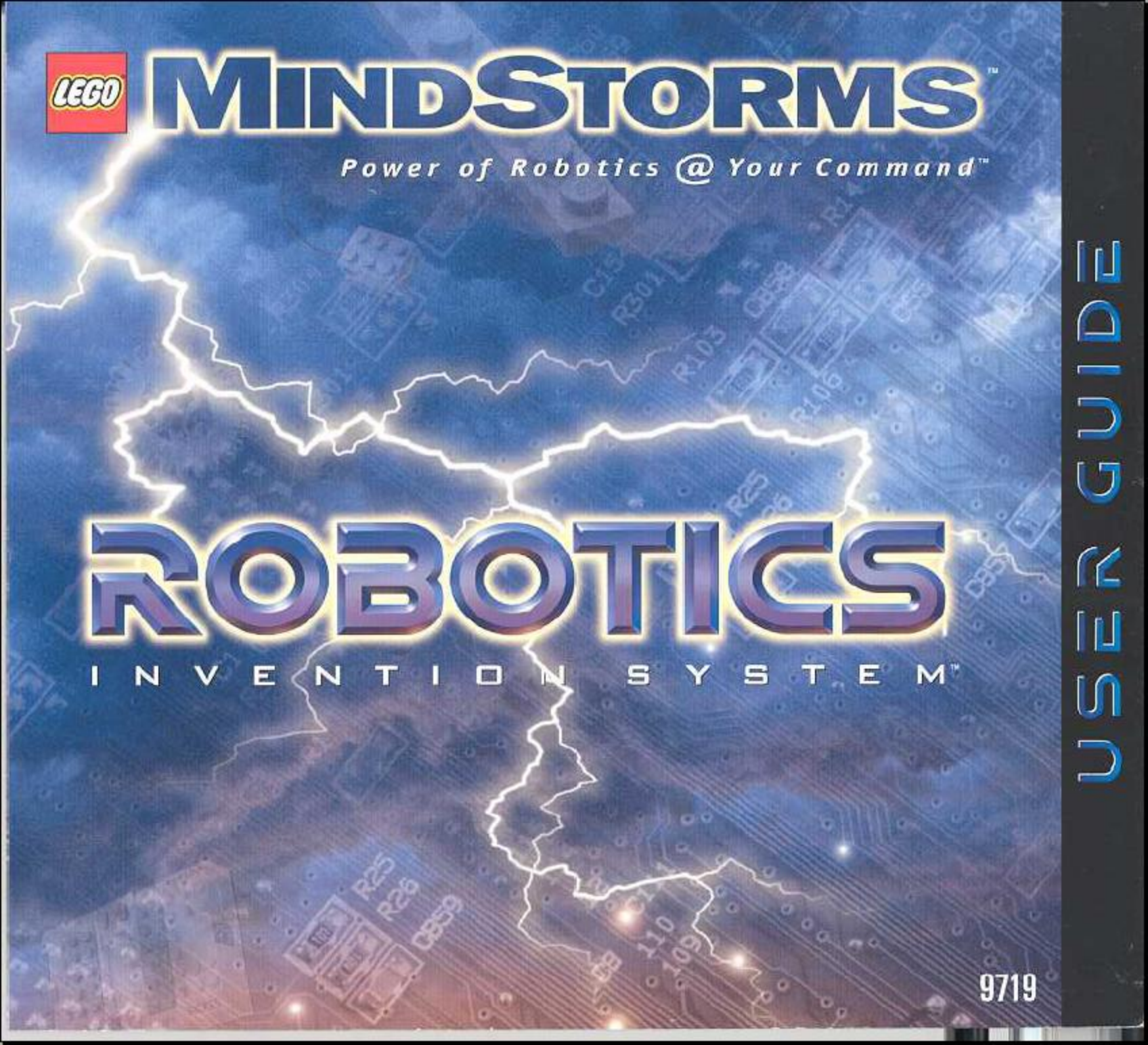
Assemble the caterpillar tread the same way on this side.

Put the rubber bands here.

Put the 16-tooth gear here.

Parts Identification


LEGO MINDSTORMS™
4122118


LEGO
MINDSTORMS™
Power of Robotics @ Your Command™
ROBOTICS
INVENTION SYSTEM™
USER GUIDE
9719

CONTACTING LEGO MINDSTORMS TECHNICAL SUPPORT:

For 24-hour access to updates and answers to frequently asked questions, or to e-mail a technical question to us, please visit our Technical Support Web site at:
http://www.LEGOMINDSTORMS.com/help/

To speak to a Technical Support Representative, you can reach us at the following numbers:

- For toll-free support within the United States, + 1 800 363-2140
  (You may also contact U.S. support directly at + 1 781 830-6865)
- For support within the United Kingdom only, 0 1715 126 090
- For European support outside the United Kingdom, + 31 20 586 4630

Hours of service may vary based on geography and time of year.

This application was produced in cooperation with CITE, Europress, Interactive Factory and SRI International.

ISBN 1-57056-052-8

LEGO® MINDSTORMS™
ROBOTICS INVENTION SYSTEM™
Computer Hardware Specifications

MINIMUM SYSTEM REQUIREMENTS	
Operating System	Windows® 95
CPU	Pentium 90 MHz
RAM	16MB
Available Hard Disk Space	50
Mouse	Windows® 95 Compatible
Available 9-Pin Serial Port For Infrared Transmitter	1
Sound	Sound Blaster 16™ Windows Compatible Sound Device
CD-ROM Speed	CD X 4
Video Display	VGA
Colors	256
Modem (Optional)	28.8 Kbps
Internet Browser (Optional)	Netscape Navigator or Microsoft Internet Explorer

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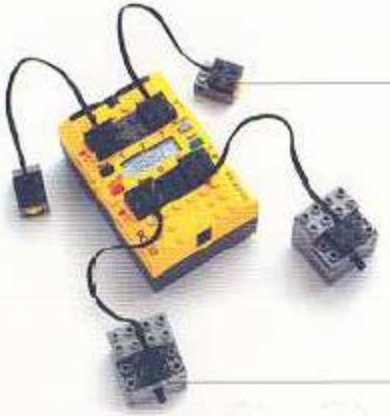
1. Introduction
MindStorms™
Overview of the
LEGO® MINDSTORMS™
Robotics Invention
System™

WHAT IS LEGO® MINDSTORMS™?

Overview of the LEGO® MINDSTORMS™ ROBOTICS INVENTION SYSTEM™

The LEGO® MINDSTORMS™ ROBOTICS INVENTION SYSTEM™ *is the core set in a new line of technology-based products from the LEGO Group. It is the product of a longstanding relationship with the Massachusetts Institute of Technology (MIT). The ROBOTICS INVENTION SYSTEM enables you to design and program real robots that move, act, and think on their own. With the Robotics Invention System, you can create everything from a light-sensitive intruder alarm to a robotic rover that can follow a trail, move around obstacles, and even duck into dark corners.*

The brain of the ROBOTICS INVENTION SYSTEM is the RCX, a LEGO microcomputer that can be programmed using a PC or can be run with its own built-in programs.



The RCX uses sensors to take input from its environment, to process data, and to signal motors to turn on and off.

You first build your robot using the RCX and the LEGO® pieces included in the ROBOTICS INVENTION SYSTEM™ (RIS).

Then create a program for your invention using RCX Code, a simple, powerful programming language. RCX code is part of the software which comes on the RIS CD-ROM. Next, download your program to the RCX using the special Infrared Transmitter. Your creation can now interact with the environment, fully independent from the computer.

LEGO MINDSTORMS™

The ROBOTICS INVENTION SYSTEM™ includes 727 LEGO® pieces, the RCX, Infrared Transmitter and cable, light and touch sensors, motors, gears, a Constructopedia™ building guide, and the ROBOTICS INVENTION SYSTEM software on CD-ROM. The ROBOTICS INVENTION SYSTEM provides you with the guidance to build simple working robots, as well as inspiration for more complex robotic inventions.

The LEGO® Group has a philosophy about how one learns to master technology:

THE BEST WAY TO LEARN IS BY DOING.

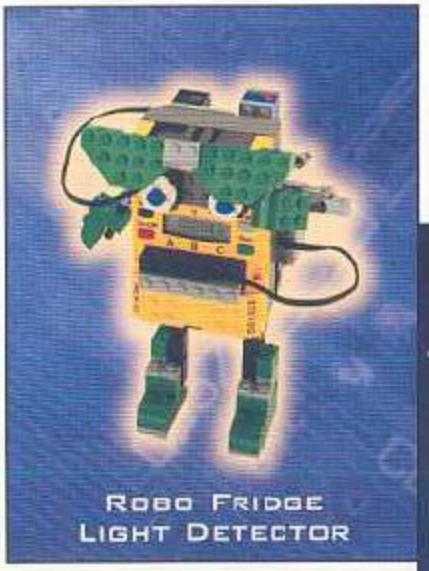
That is why LEGO® MINDSTORMS™ projects provide goals, not solutions.

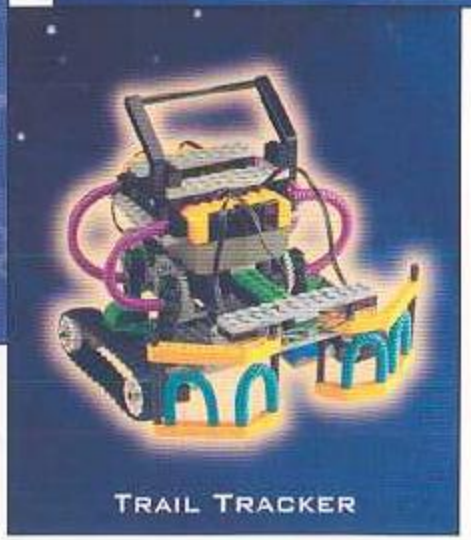
There is no single "right answer" to any given challenge. Everyone develops the solution that he or she feels is best.

"Knowledge is only part of understanding. Genuine understanding comes from hands on experience."

Dr. Seymour Papert
LEGO Professor of Learning Research
MIT Media Lab


ACROFLIP


ROBO FRIDGE
LIGHT DETECTOR


TRAIL TRACKER

2. Hardware

LEGO MINDSTORMS™

- The RCX
- RCX Features
- RCX Display Window
- IR Transmitter

THE RCX

- The RCX comes with five built-in programs. (See more information in *Section 3. Software: Program Vault*.) Selecting and running these programs without a computer is possible by using the Prgm and Run buttons on the RCX control panel. These built-in programs may be overwritten by creating alternate programs on a computer and downloading them to the RCX.

- When changing batteries, make sure you turn off the RCX first. Then replace the batteries within 1 minute or the RCX memory is cleared and the user programs are erased. You will then have to download your programs again into your RCX from your PC.

- The RCX operates using 6 AA batteries housed in the RCX unit or using an AC adapter (not included) connected to the AC port which is located at the opposite end of the RCX from the infrared "eye." When plugged in, the RCX will bypass the batteries to access AC power, conserving the batteries. Alkaline batteries are recommended.

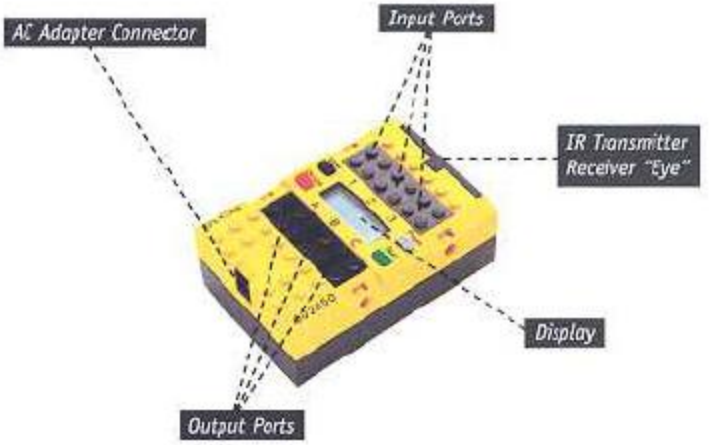
6X AA(LR6) batteries required

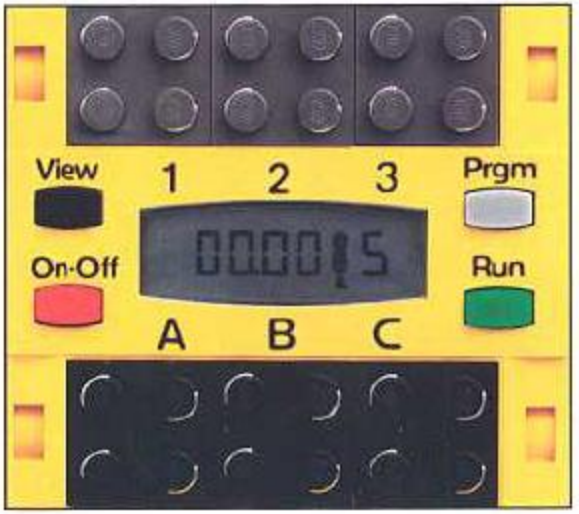
- If left with the batteries installed or connected to a wall outlet with an AC adapter, the RCX automatically powers down. The default "power down" time is set at 15 minutes. However, by using the Set Up Options in Getting Started on the LEGO® MINDSTORMS™ RIS CD-ROM, the setting can be changed to any time between 1 and 99 minutes. There is also an option to set the "power down" time to infinity, which is useful if your RCX will remain connected to a wall outlet with an AC adapter.

- Once the ROBOTICS INVENTION SYSTEM™ is set up on your computer, you can check the RCX battery level status in Getting Started: Set Up Options in the software.

RCX FEATURES

- The RCX has three input ports, three output ports, four control buttons, an LCD display, an AC adapter connector, and an Infrared Transmitter Receiver "eye." It also has LEGO® studs for easy connection of LEGO bricks and beams, as well as holes for inserting LEGO connector pegs.





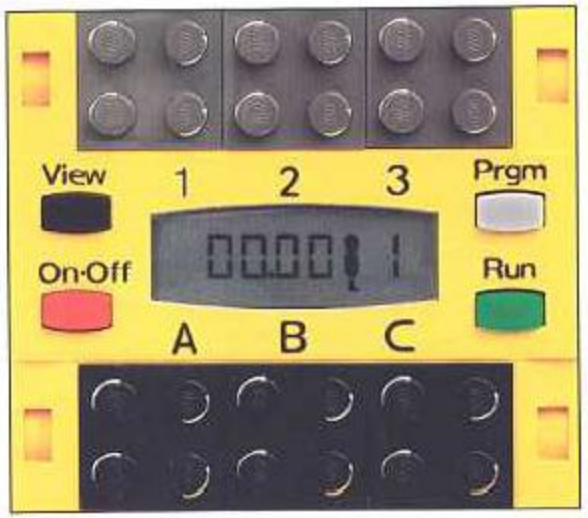
- The three input ports are connection points for sensors (light, touch, temperature, and rotation). The three output ports are connection points for LEGO motors and other LEGO output devices such as lamps.

- The four control buttons are the red On-Off in the bottom left corner, the black View button in the upper left corner, the gray Prgm (or Program) button in the upper right corner, and the green Run button in the lower right corner.

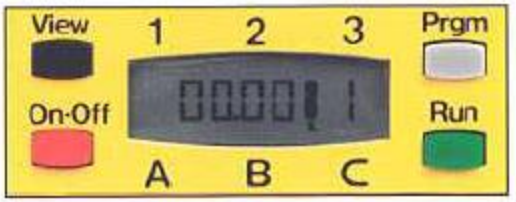
RCX FEATURES

continued

- The **On-Off** button toggles the RCX on or off.
- The **View** button allows the user to select what function is monitored in the display window. For example, you can see the sensor value at input port 1, 2, or 3, or motor speed at output port A, B, or C.
- The **Prgm** or Program button allows the user to select between programs in RCX slots 1 through 5. The number of the program selected appears to the right of the "little person" in the display window.
- The **Run** button starts and stops the downloaded, stored program that has been selected via the Program button. In the "Run" mode, the "little person" will appear to be running in the display window.



RCX Display Window



- The battery-low indicator lights up when battery charge is low. It flashes when the battery charge is very low.

- The infrared communication "cone" lights up to indicate that communication between the Infrared Transmitter and the RCX is taking place.

- Dots light in sequence when a program is downloading from the computer to the RCX.

- An arrow displayed above an output port indicates the output port is active. The direction of the arrow shows the direction of a motor connected to the port.

- An arrow displayed below an input port indicates that the input port is active.

- The "little person" running indicates that the RCX is executing a program. The "little person" starts running when the Run button is pressed.

- The number (1-5) which appears to the right of the "little person" indicates which of 5 downloaded programs will be activated when the Run button is pressed.

- The Software Watch indicates how long the RCX has been on from last setting or resetting. The Watch is only active after the firmware has been downloaded, and can be controlled from Set Up Options in Getting Started. Downloading firmware again or turning the RCX off and on automatically resets the Watch.

RCX DISPLAY WINDOW

continued

Boot Mode: Active without firmware or upon full reset	*Active after Firmware is downloaded*
"Little Person" in display window	"Little Person" in display window
5 built-in programs	5 built-in programs*
Prgm button	Prgm button
Run button	Run button
	View button
	Software Watch
	Number Field
Icons showing input/output	Icons showing input/output
Battery power indicator	Battery power indicator
IR communication icon	IR communication icon

- The first time the RCX is powered, either with new batteries or with an AC adapter, it starts up in a special "Boot Mode" without firmware (running the internal code stored in ROM). Boot Mode offers only those functions indicated on the left side of the table.
- Firmware is special software the RCX needs to communicate with the computer. When firmware is downloaded to the RCX, more display features are available. See the right side of the table.
- The RCX also has a built-in speaker which can produce a series of "beeps."
- The RCX includes an 8-bit microprocessor and internal memory. The memory is used to store firmware, and programs downloaded to the RCX from the PC.

*Note: The Set Up: Part 2 program runs a special sequence and downloads only 2 of the built-in programs plus a test program.

IR TRANSMITTER

- The Infrared Transmitter works by establishing a wireless link between a computer and the RCX when connected to the computer's serial port by the cable. Control programs can be communicated from the computer through the Infrared Transmitter to the RCX. This is called "downloading." These programs can then be executed by the RCX.

- To make the communication between the RCX and Infrared Transmitter work, there must be an uninterrupted field of vision to the "eye" located on the RCX. Two ranges of transmission are available, and can be selected with the Short/Long Infrared Range switch located on the front of the Infrared Transmitter.

- Note: There is a corresponding Short/Long Range setting for the RCX which can be changed in Getting Started: Set Up Options on the RIS CD-ROM. If you have downloaded the firmware using Set Up: Part 2, the RCX is set to Long Range.

IR Transmitter Range Switch

Short Long

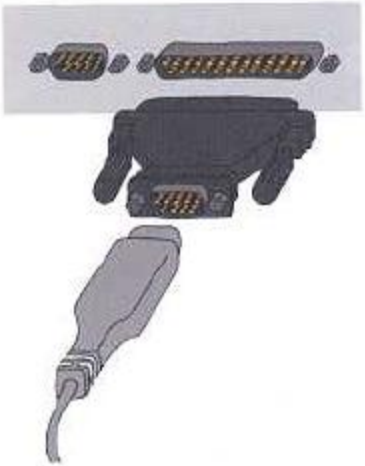
- Even though 4-6 inches between the RCX and IR Transmitter works best for downloading, the RCX can communicate up to 90 feet if unobstructed and set to Long Range.

- Note: If you place the IR Transmitter or the RCX in direct sunlight or under direct Lamp light, you may experience difficulties in downloading. To solve the problem, move the IR Transmitter and RCX out of the sunlight or turn off the lamp.

IR TRANSMITTER

continued

1X 9V battery required

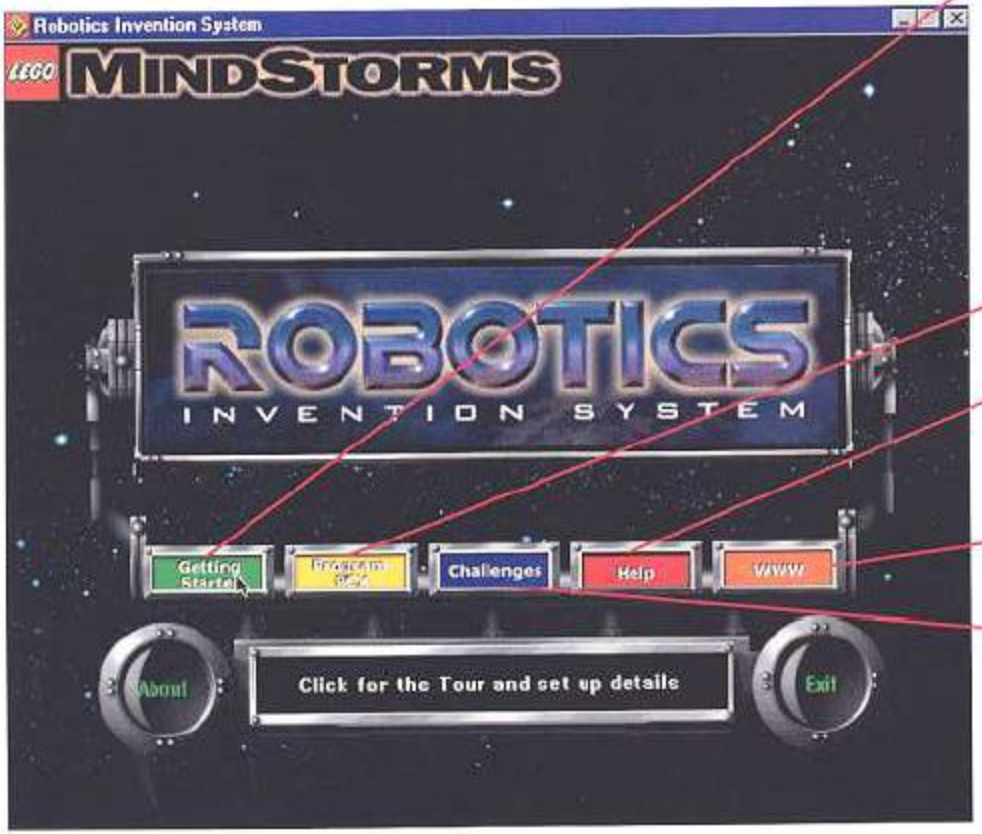


- The Infrared Transmitter requires one 9-volt battery. Alkaline batteries are recommended.
- To connect the Infrared Transmitter to your computer, first make sure that your computer is shut down.
- You need a free serial port. The Infrared Transmitter cable which comes with your LEGO® MINDSTORMS™ ROBOTICS INVENTION SYSTEM™ plugs directly into a 9-pin male serial connector. If your computer has a 25-pin male connector, you will need a 9-pin male to 25-pin female adapter.
- In order to download your own programs through the Infrared Transmitter to the RCX, the LEGO MINDSTORMS ROBOTICS INVENTION SYSTEM "firmware" must be downloaded to the RCX. The firmware is the RCX operating system. Step-by-step instructions for downloading firmware are available in Set Up: Part 2. You can also use Set Up Options. See *Section 3. Software* for more information.
- Once the firmware is downloaded, the RCX can be programmed using the programming language called RCX Code. See *Section 3. Software* for more information.

3. SOFTWARE

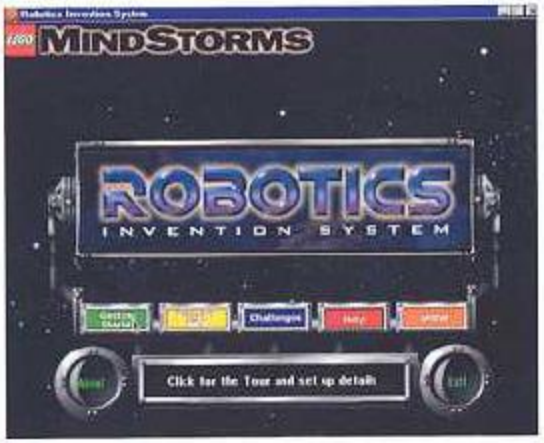

LEGO MINDSTORMS™
MAIN MENU
GETTING STARTED
PROGRAM RCX
CHALLENGES
WWW
HELP

The LEGO® MINDSTORMS™ Robotics Invention System™ CD-ROM Menus



Require purchase of expansion sets.

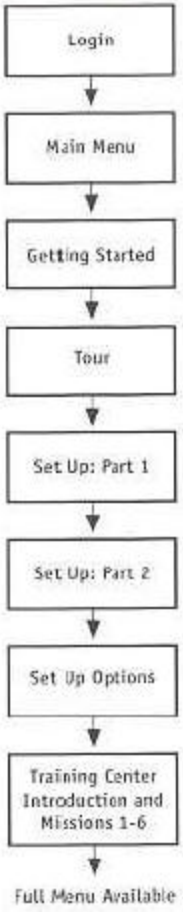
MAIN MENU



- When you login as a new user, or if you have not completed the Training Center Missions, the "Guided Mode" will introduce you to the different sections of the software. The Guided Mode sequence includes the Tour, Set Up: Part 1, Set Up: Part 2, Set Up: Options, the Training Center Introduction and Missions 1-6. If you have already completed the Training Center Missions, you will no longer be in the "Guided Mode" when you login.

- The Main Menu of the ROBOTICS INVENTION SYSTEM™ allows the user to access all features of the software. It includes Getting Started, Program RCX, Challenges, Help, and WWW.

Guided Mode Sequence



- Tip: It is not advised; however, you can bypass Guided Mode and make the full menu active by holding down the Control key and clicking the mouse pointer on the About button in the main menu. To make Guided Mode active again, you will need to login with a different user name.

GETTING STARTED

In the Getting Started section of the software, you will find the Tour movie and set up instructions.

TOUR

The Tour is about a two-minute introduction to the LEGO® MINDSTORMS™ product and its concept of invention. The Tour orients and familiarizes you with the key ideas you will encounter in the ROBOTICS INVENTION SYSTEM™, and introduces the LEGO MINDSTORMS process and terminology.

SET UP: PART 1

In Set Up: Part 1, follow step-by-step instructions that explain how to insert batteries, how to use the buttons, how to turn on motors and read sensors, and how to use some of the built-in programs.

SET UP: PART 2

In Set Up: Part 2, follow step-by-step instructions that explain how to prepare the Infrared Transmitter for use and connect it to the computer, and how to download the firmware so that you can program the RCX yourself.

SET UP OPTIONS

The Set Up Options screen allows you to check or change the way the RCX and IR Transmitter are set up without going back through the Set Up: Parts 1 and 2 programs.

PROGRAM RCX

The Program RCX section of the software includes the Training Center programming instructions, the RCX Code programming environment, and the Program Vault for storing programs.

TRAINING CENTER

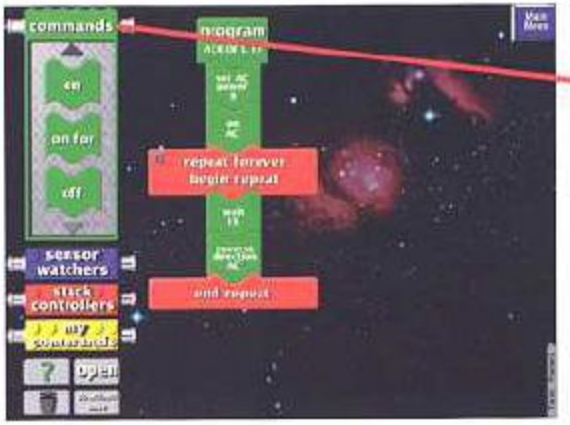
Once you have completed the Tour and Set Up programs, you can enter the Training Center. In the Training Center, you will be guided through the following: an explanation of RCX Code, creating a program in RCX Code, downloading a program to the RCX, saving a program in the Program Vault, and other important functions. Through the Training Missions you will learn the purpose of Commands, Sensor Watchers, Stack Controllers, and My Commands. You will also learn how to select and progress through the ROBOTICS INVENTION SYSTEM™ Challenges. When you have finished the Training Center, you will be familiar with programming RCX robots.

RCX Code

RCX Code is a computer programming environment in which graphics are used to build a program. In RCX Code, each block displayed on the screen represents an instruction. You click, grab, and link graphical blocks on the computer screen. The blocks build (stack) one under another, like pieces in a puzzle, to create a program.

- The aim is to program the RCX to carry out an action or behavior; for example, controlling the movement of two motors in a LEGO robot. Once developed, the program must be downloaded from the computer to the RCX for execution.

- Programming takes place in the RCX Code workspace on the computer screen. The workspace area changes depending on the size of the RCX Code program. If the program is larger than the size of the computer screen, move the pointer to scroll across and down to bring off-screen areas into view.



RCX CODE

continued

- To develop a program, decide what behavior the RCX is to exhibit. For example, if controlling the movement of two motors in a LEGO robot is the behavior chosen, you can create a program by building a stack of sequentially executed RCX Code blocks to do the job.

- The stack may contain any or all the following types of RCX Code blocks:
  - *RCX Code blocks that execute Commands; for example, turn on motor A.*
  - *RCX Code blocks such as Sensor Watchers or Stack Controllers. These Control the stack by selecting and checking sensors, repeating the commands in the stack for a number of times, and/or initiating pauses in the execution of commands.*
  - *RCX Code blocks that contain commands created by you (My Commands).*
- Up to five programs can be stored in the RCX. Each of these programs:
  - *Can consist of up to 9 different stacks which can be executed in parallel (multi-tasking). A stack is either the Program block stack or a Sensor Watcher stack.*
  - *Can enable two RCX units to communicate with one another through infrared transmitters and receivers in the RCX. The first RCX sends the message through its internal infrared transmitter. If the second RCX is within range, it can receive the message through its infrared receiver. The second RCX can then react to this message.*

- Within the RCX, only one program can be active at a time. Programs on the same RCX cannot control one another, nor can they be linked.

- See RCX Code Reference in Help on the LEGO® MINDSTORMS™ ROBOTICS INVENTION SYSTEM™ CD-ROM for more information.

Program Block

The Program Block is the beginning of every RCX Code program. RCX Code blocks attached to the Program Block run from top to bottom when the program is run by the RCX. By right-clicking the pointer on the Program block, you flip it over and can then save, clear, or download the program.

commands

Commands

Command blocks are instructions that tell the RCX what to do. They are found within the green Commands block container.

Some Commands blocks control the output ports. For example, On, Off, On For, Set Power, Set Direction, and Reverse Direction control the output ports to which motors are attached. Many of these blocks flip over when you right-click on them to allow you to change the ports and other values. See RCX Code Reference in Help on the CD-ROM for more details.

The RIS set contains two motors.

On

The On command block turns on ports A, B, or C on the RCX. Motors and lamps can be attached to these ports.

On For

The On For block turns on ports A, B, and C for a certain amount of time. Motors and lamps can be attached to these ports.

Off

The Off block turns off ports A, B, and C. Motors and lamps can be attached to these ports.

Set Power

Adding the Set Power block to your stack allows you to change the power of a selected motor in a range from 1 (minimum) to 8 (maximum).

Set Direction

When a motor port is first turned on, the attached motor turns in a particular direction. This direction on the Set Direction block is indicated by the arrow which points to the right. The arrow to the left indicates the opposite direction. (You can also change the direction of a motor by turning the connector plate of the wire attaching the motor to the RCX 180°.)

Commands *(continued)*

Reverse Direction

The Reverse Direction block allows you to change the direction of motors. Whichever direction a motor is turning, the Reverse Direction block causes it to turn in the opposite direction. (You can also change the direction of a motor by turning the connector plate of the wire attaching the motor to the RCX 180°.)

Wait

The Wait command block in your program tells the RCX to wait a certain amount of time before going on to the next command. Time is in tenths of a second: so, 10 means one second and 15 means one and a half seconds.

Beep

Adding a Beep command block allows you to add one of 6 different beep sounds to your program. The RCX has a built-in speaker for playing the beep sounds.

Tone

The Tone command block tells the RCX to play a tone of a selected pitch for a selected amount of time. You specify the pitch of the note (as a frequency in Hertz). For example, to play middle C, specify the frequency as 523.

	Very Low	Low	Middle	High	Very High
C	131	262	523	1047	2093
C#	139	277	554	1109	2217
D	147	294	587	1175	2349
D#	156	311	622	1245	2489
E	165	330	660	1320	2640
F	175	350	699	1398	2797
F#	185	370	741	1482	2963
G	196	392	785	1570	3140
G#	208	416	832	1663	3326
A	220	440	880	1760	3520
A#	233	466	932	1865	3729
B	247	494	988	1976	3951

Reset Counter

The Counter is an internal sensor in the RCX which can count events such as a condition becoming true (such as, a touch sensor being touched). Add the Reset Counter block to your stack to reset the RCX counter to 0. For example, if you have a Check and Choose Counter or Counter Sensor Watcher in your program which is counting events, the Reset Counter block brings the count back to 0.

Add to Counter

The Counter is an internal sensor in the RCX. It can count events such as a touch sensor being touched. For example, to add 1 to the counter when a touch sensor is pressed, put the "add to counter" block on a Touch Sensor Watcher block.

Reset Rotation

The rotation sensor keeps track of the rotation of an axle which runs through the sensor. The rotation sensor is set at 0 each time the RCX starts to run a program. You can use the Reset Rotation block at another point in your program to set back the rotation sensor setting to 0.

Note: Reset Rotation is not active unless the Rotation sensor is selected on the Advanced page of Set Up Options on the RIS CD- ROM.

Reset Message

The Reset Message block clears out any previously received message number received from another RCX. For example, you may want to use the Reset Message block in Sensor Watchers or Stack Controllers that respond to messages.

Reset Timer

The Timer starts at 0 each time the RCX begins to run a program and counts time as the program runs. You can use the Reset Timer block at another point in your program to set the timer sensor back to 0 to begin the count over again. See also the Timer Sensor Watcher.

Send to RCX

The Send to RCX message block tells the RCX to send out an infrared message to another RCX. The message can be any number from 1 to 255. See also the RCX Sensor Watcher.

Sensor Watchers

Sensor Watchers monitor the sensor readings during your program for the temperature, light, rotation, or touch sensors. There are also Sensor Watchers for the timer, counter, and RCX message; these sensors exist within the RCX itself. Sensor watchers are found in the blue container. The RIS set comes with two touch sensors and one light sensor.

You can choose sensor readings or levels on a Sensor Watcher and add a program stack to a stack connector. When the level chosen on the Sensor Watcher is reached, the attached program stack begins. Once the Sensor Watcher program stack finishes, the RCX goes back to where it left off on the Program Block program stack.

Sensor Watchers have a button in the upper left corner which allows you to resize the block.

The Rotation and Temperature Sensor Watchers are not active by default. To make them active, go to the Advanced page in Set Up Options.

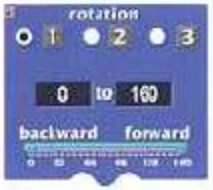
▶ *Touch*

The Touch Sensor Watcher has two states: pressed and released. Use the Touch Sensor Watcher to trigger a program stack when the touch sensor changes state.

▶ *Light*

Use the Light Sensor Watcher to trigger an attached program stack when the first of two consecutive readings falls outside a chosen interval and the second reading falls within a chosen interval; for example, when the sensor sees a "bright" light value of 70% and then a "dark" light value of 30%.

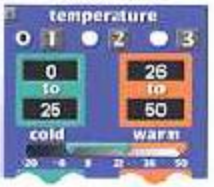
▶ *Rotation*



The Rotation Sensor Watcher keeps track of how many times the axle in the sensor turns, in increments of sixteen counts per rotation. (Not included in the RIS.)

Temperature

Use the Temperature Sensor Watcher to trigger an attached RCX Code stack when the temperature reading of your sensor falls within the chosen interval. For example, when the temperature goes from a "warm" 40°C to a "cold" 25°C. (Not included in the RIS.)



Counter

The Counter Sensor Watcher allows you to trigger a program stack when the count falls within a chosen range of numbers. To set the counter to watch for a specific numbers make the "from" and "to" values the same.

Timer

Use the Timer Sensor Watcher to trigger an attached program stack when the selected amount of time passes. The Timer is within the RCX itself, so you do not need to choose a port.

RCX

The RCX Sensor Watcher allows you to trigger a program stack when the message number received from another RCX using the Send to RCX command block falls within a selected range. To set the RCX to watch for a specific number, make both values the same.

stack controllers

Stack Controllers

Stack Controllers, found in the red container, allow you to choose different ways for parts of your program to run using sensor input, counter, timer, and messages to control RCX Code stacks. Stack Controllers have a button in the upper left corner which allows you to resize the Stack Controller block to save room on the workspace.

Check and Choose

The Check and Choose block tells one of two different program stacks to act, based on the condition you decide; for example, if pressing the touch sensor is true.

Repeat

The Repeat block tells an RCX Code stack to run a chosen number of times.

Repeat Forever

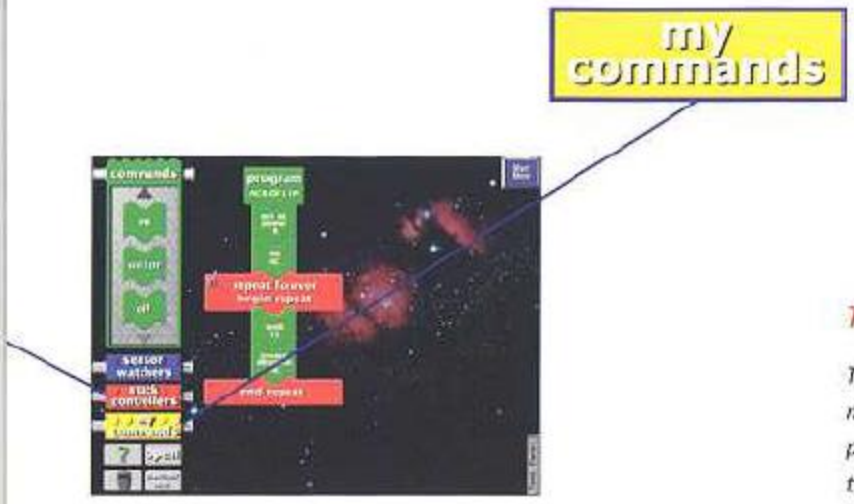
The Repeat Forever block tells an RCX Code stack to run forever.

Repeat While

Repeat While tells a stack to continue running as long as a selected condition is true (such as a touch sensor being pressed.)

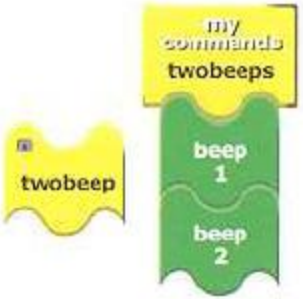
Wait Until

Using a Wait Until stack controller block makes the RCX wait until a chosen sensor condition is true (such as a touch sensor being pressed) before going on to the next command.



My Commands

The yellow My Commands container holds the New My Command block, as well as any My Commands already created by you. My Commands created in RCX Code can be edited or changed. See the Programmopedia in Help on the RIS CD-ROM for instructions on creating My Commands.

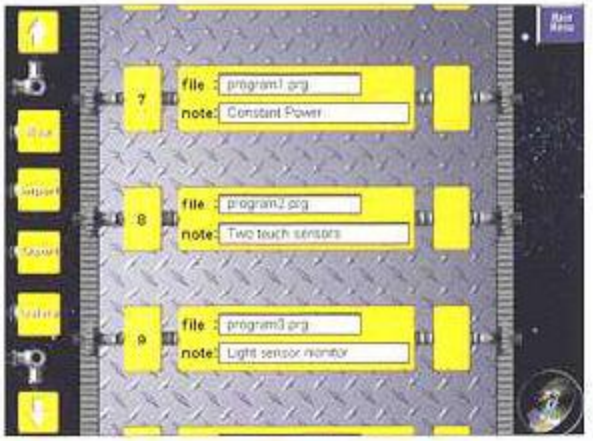


Test Panel

The Test Panel allows you to check the direction and timing of motors and to check the current state of sensors as you are programming in RCX Code. To see the RCX Code Test Panel, click the Test Panel tab. To close it, click the Test Panel tab again. See Training Mission 6 on the RIS CD-ROM for instructions on using the Test Panel.

PROGRAM VAULT

The Program Vault allows users to manage storing their RCX Code programs on their computer's hard disk or floppy drive. Command paddles down the side of the screen are New, Import, Export, and Delete. To the left of center is a "conveyor," operated by the top and bottom arrow at the left of the screen. Each conveyor item represents an RCX Code program (and associated files).



Built-in Programs

Built-in programs 1-5 are included in the RCX. The programs can be seen as RCX Code programs by selecting them from the Program Vault.

Using the Infrared Transmitter connected to a computer, these built-in programs may be overwritten by creating alternate programs on a computer and downloading them to the RCX.

- *Program 1*

Purpose: To provide a constant source of power to two (2) motors connected to ports A and C.

How the Program Functions: Power is supplied when the user activates the RCX, selects "Program 1," and presses "Run." Pressing the Run button again manually stops the program.

- *Program 2*

Purpose: To move a two-motor robot forward and enable it to turn. Assumes motors are connected to ports A and C and touch sensors to ports 1 and 3.

How the Program Functions: Uses two (2) Touch Sensor Watchers to control the two (2) motors. Sensor Watcher #1 (input port 1) monitors touch sensor #1 constantly as it controls Motor A, while Sensor Watcher #2 (input port 3) monitors the second touch sensor which controls Motor C.

Program 3

Purpose: To move a robot forward, then stop it when sensors register a change of light intensity (for example when the robot reaches the dark colored surface). Assumes motors are connected to ports A and C and a light sensor to port 2.

How the Program Functions: Controls power to ports A and C. A Light Sensor Watcher monitors a light sensor and interrupts power when the light sensor detects light intensity in the range 0–40%.

Program 4

Purpose: To provide a two-motor program that repeats five times and then stops. Assumes motors are connected to ports A and C.

How the Program Functions: Provides power to output ports A and C and carries out the following sequence five times:

- *reverses direction on both output ports A and C*
- *pauses for a random time period (between 0 and 3 seconds)*
- *reverses direction to output port A*
- *pauses for a random time period (between 0 and 3 seconds)*
- *reverses direction on port A once more*

Program 5

Purpose: To enable a robot to move forward and change its direction if it encounters an obstacle in its path. Assumes two motors are connected to ports A and C and a touch sensor to port 2.

How the Program Functions: Provides power to output ports A and C. A Touch Sensor Watcher monitors the touch sensor constantly and each time the sensor is pressed, activates the following sequence:

- *reverses direction on both output ports A and C*
- *pauses 1 second, reverses direction on port A*
- *pauses 0.5 second*
- *reverses direction on port C*

Sample Programs

Several RCX Code programs are provided on the RIS CD-ROM. Twelve of the sample programs, one for each of the RIS Challenges, are included. Also included are RCX Code versions of the built-in programs. If you install the expansion sets, you may have additional sample programs added to the Program Vault.

CHALLENGES

Challenges are intriguing invitations to create mechanical, programmable robots and other exciting devices all capable of performing one or another specific tasks. The challenges are open-ended and can be met in various ways, but each task is always clearly described by measurable or observable outcomes.

ROBOTICS INVENTION SYSTEM™

This is the main set of challenges for LEGO® MINDSTORMS™ users. It gives the basic training in robot making and robot programming. There are three main types of robot challenges: Robo, Pathfinder, and Acrobot, each with four levels.

RoboSports™ (Must be purchased separately.)

This add-on is about making robots that can play games with balls or pucks. There are three types of robots: Dunkobots, Puckobots, and Grababots. Each challenge has four levels.

Extreme Creatures™ (Must be purchased separately.)

Extreme Creatures is an add-on about designing, making, and programming twelve creatures of three types: Helptiles, Mutimals, and Big Bugs. Each Challenge has four levels.

Exploration Mars™ (Must be purchased separately.)

This is an add-on about remote exploration of the planet Mars by means of tele-operated landers and rovers. You can build rovers, design Mars surfaces, and operate the rovers on these surfaces by means of images from a camera.

HELP

The Help System is a reference of the features on the LEGO® MINDSTORMS™ ROBOTICS INVENTION SYSTEM™ hardware and software.

The Help System includes:

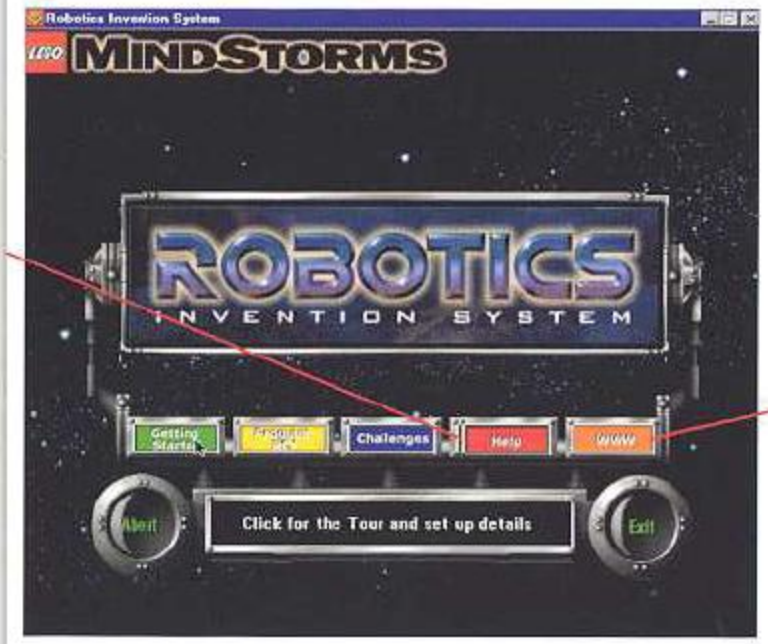
- *the Programmopedia, a guide to solving common programming and robotics problems*

- *RCX Reference, with information about the RCX and related hardware features*

- *RCX Code Reference, with details on the programming language*

WWW

To help you to develop your ideas, the LEGO® MINDSTORMS™ Robotics Network is provided on the Internet at <http://www.LEGOMINDSTORMS.com>.



- Clicking the WWW button launches the web browser for your computer. You must have a browser installed and an Internet connection or clicking the button will have no effect.
- You can create a personal home page where you can upload programs and display pictures of your robotic creations. You can talk to other users, swap strategies, or consult LEGO experts in chat rooms and on message boards. On-line tutorials will help you master programming and building tasks. New challenges are made available for downloading throughout the year.

Your Robotics Network membership card is enclosed in the RIS set. On this card, you will find your exclusive membership number which you will need when you log on for the first time.

Http://www.LEGOMINDSTORMS.com

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