PURDUE UNIVERSITY | Extension - Hendricks County

ROBOTICS 101

Name: _____

Age: _____

Team Name: _____

County: _____

Advisor: _____

4-H 707 Robotics

Author:

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WELCOME

Welcome to Robotics 101, a project designed to introduce you to the world of robotics. Robotics is becoming integrated into many industries and basic robotic knowledge is important in educational and career growth.

The educational goals of this course will help you learn the following:

1. What a robot is and what do they do.
2. How to build a robot using the LEGO® EV3 Mindstorms kit and how it interacts with its environment.
3. How to build a software flow chart.
4. Programming a robot using the LEGO® EV3 Mindstorms diagram software (LabVIEW platform) and using three sensors (Color, Ultrasonic, and Touch).
5. Robot Ethics and Safety.
6. Education, skills, and careers related to robotics.

PROJECT OVERVIEW

Robotics 101, is an entry level robotics project curriculum designed for anyone and any age level from 3rd to 12th grade. No previous knowledge of robots, programming, LEGO® EV3 Mindstorms, or mathematics is required. This guide is designed to be completed by each individual but 4-H members can work on the robot as a small team and should be completed within the 4-H calendar year (roughly 6 meetings).

Robotics 102 is designed for those individuals that would like to pursue programming and take the next step in Robotics. The curriculum is designed for those who have completed Robotics 101 or are in 6th to 12th grades. The curriculum will use the programming language Python to create LEGO® EV3 Mindstorms or VEX robots using a small computer or microcontroller. Additional sensors, non-EV3 sensors, and other motors and actuators can be added to increase robot complexity. This course may require additional personal time to complete within 4-H calendar year (roughly 6 meetings, coming soon).

Robotics 103 is designed for advanced individuals who have completed Robotics 101 and 102 or are in the 9 to 12th grades. The curriculum is designed to utilize different robot sensors and camera vision, with the python programming language and Robot Operating System 2 (ROS2), to launch more advanced robots to complete more advanced tasks. This course may require additional personal time to complete within 4-H calendar year (coming soon).

Each course can be repeated and robot projects can be created based on your comfort level with the topics and skill level.
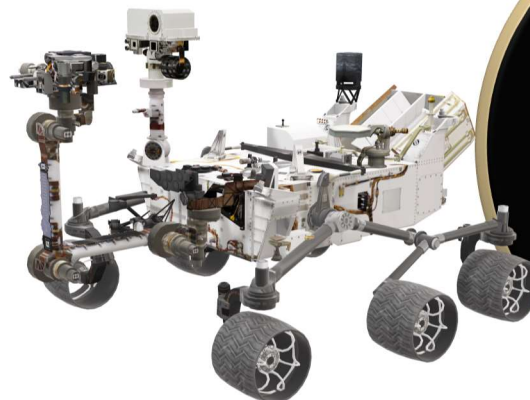
The Robot Curiosity

Curiosity was launched from Cape Canaveral on November 26th, 2011, on the Mars Science Laboratory (MSL) spacecraft. Its destination was Aeolis Palus in the Gale Crater on Mars. Its mission is to investigate the climate and geology on Mars and send the data back to earth for analysis by the MSL team.

Robotics 101

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Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:
1. Build Your Robotics team.
2. Get to know teammates, their names, and their grade level.
3. Familiarize yourself and the team with the LEGO® EV3 Mindstorms kit.
4. Ensure that the computer assigned to your team has the necessary software and recognizes the EV3 Brick from the kit.

Activities: **Complete:**
1. Create a team name. Write down the team's name at the top of every worksheet in the workbook and in the space provided below. _____
2. Write down each team members name and grade level in the space provided below. _____
3. Inventory the LEGO® Mindstorms EV3 kit provided to your team. Use pages 4 through 9 to complete this activity. Make sure each team member gets a chance to inventory part of the kit and familiarize yourself as much as you can with each part of the kit. _____
4. Write the kit number in the space provided above. _____
5. Write the computer name and number from the computer that was provided to your team. _____
6. Power up the computer and log in. Use pages 10 through 12 to complete the computer inspection and ensure that your EV3 brick connects to the computer. _____

Team Members Name: **Grade:**

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

Team Name:

_____

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Piece	Amount	Have It?	Missing Amount?		Piece	Amount	Have It?	Missing Amount?
	54					1		
	4					1		
	2					2		
	2					1		
	1					2		
	1					1		
	1				25 cm / 10 in.*	4		
	1				35 cm / 14 in.*	2		
	1				50 cm / 20 in.*	1		
	1				computer	1		

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Piece	Amount	Have It?	Missing Amount?		Piece	Amount	Have It?	Missing Amount?
	2					4		
	2					4		
	4					2		
	4					8		
	4					4		
	4					6		
	6					8		
	6					2		
	2					4		
	8					4		

Team Name: _____   **Kit Number:** _____   **Computer:** _____

Piece	Amount	Have It?	Missing Amount?		Piece	Amount	Have It?	Missing Amount?
	4				Size 10 – Black	2		
	4				Size 12 – Black	2		
	4				Size 3 – Light Gray	14		
	4				Size 5 – Light Gray	6		
	2				Size 7 – Light Gray	5		
	4				Size 9 – Light Gray	2		
	10					22		
Size 4 – Black	4					4		
Size 6 – Black	4				Size 4 – Dark Gray	2		
Size 8 – Black	2				Size 8 – Dark Gray	2		

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Piece	Amount	Have It?	Missing Amount?		Piece	Amount	Have It?	Missing Amount?
	2					1		
Size 5 – Light Gray	4					6		
Size 7 – Light Gray	4					8		
Size 9 – Light Gray	6					30		
Size 11 – Light Gray	4					20		
Size 13 – Light Gray	6					60		
Size 15 - White	6					10		
	3					10		
	1					10		
	1					6		

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Piece	Amount	Have It?	Missing Amount?		Piece	Amount	Have It?	Missing Amount?
white	6					2		
white	4					2		
white	4					4		
black	4					4		
	4					4		
Light Gray	4					4		
Light Gray	2					2		
	4					2		
	2					4		
	2					2		

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ROBOTS!!!

The term robot was first introduced by the Czech playwright Karel Kapek in his 1920 play, *Rossum's Universal Robots,* with the word **Robota**, being the Czech word for *work*. [1] For the purposes of this course, robotics is defined as the *intersection of math, science, programming, engineering, and technology that produces machines, called robots, that substitute for (or replicate) human actions with little or no human interaction*. Robots must be **programmable**, be **automatic**, **sense its surroundings**, and **perform work safely** according to its programming. A robot can be a **multi-use** machine.

WHAT DO ROBOTS DO

In general, current robots complete tasks around four main areas of concentration. They do **Dangerous** jobs, which are jobs that include bomb diffusion, space missions, below the ocean surface exploration, collapsed buildings to help survivors, and combat situations too risky for military personnel.   They do **Dirty** jobs which includes inspecting sewers, scrubbing ship barnacles, and disposing of nuclear toxic material. They do **Dull** jobs, which includes mowing the lawn, vacuuming the carpet, and separating LEGO® pieces. They also do the **Difficult** jobs in the areas of medical surgery, manufacturing, and safety situations in the construction and mining industries.

SIX TYPES OF ROBOTS

Robots currently are constructed into six different types:

1. **Manipulator Robots** - Robots with joints and a gripper, much like an arm.
2. **Mobile Robots** - Robots with wheels or treads that move on land.
3. **Aerial Robots** - Robots that move in the air, like quad rotors and unmanned aerial vehicles (UAVs).
4. **Aquatic Robots** – Robots that move above or under the water, like robotic submarines or unmanned surface vessels (USVs).
5. **Humanoid Robots** – Robots with legs that move like an animal or a human.
6. **Hybrids** – Robots that are a combination of the other 5 robot types.

ASIMOV'S THREE LAWS OF ROBOTICS

1. A ROBOT MAY NOT INJURE A HUMAN BEING OR, THROUGH INACTION, ALLOW A HUMAN BEING TO COME TO HARM.

2. A ROBOT MUST OBEY ORDERS GIVEN TO IT BY HUMAN BEINGS, EXCEPT WHERE SUCH ORDERS WOULD CONFLICT WITH THE FIRST LAW.

3. A ROBOT MUST PROTECT ITS OWN EXISTENCE AS LONG AS SUCH PROTECTION DOES NOT CONFLICT WITH THE FIRST OR SECOND LAW._
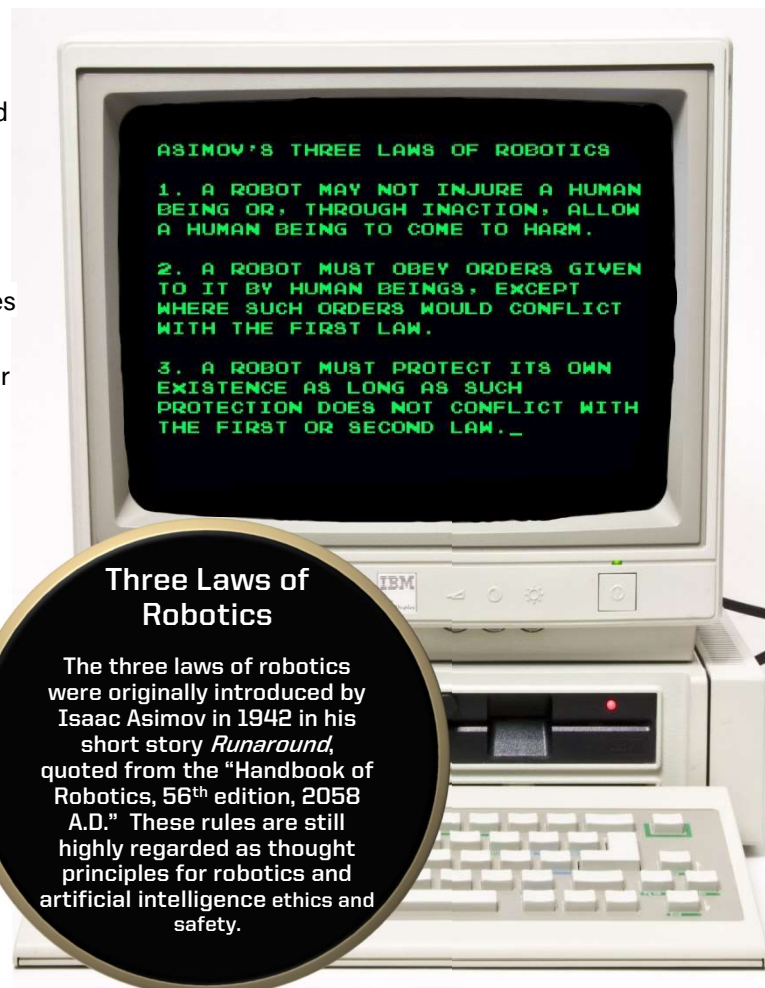
Three Laws of Robotics

The three laws of robotics were originally introduced by Isaac Asimov in 1942 in his short story *Runaround*, quoted from the "Handbook of Robotics, 56th edition, 2058 A.D." These rules are still highly regarded as thought principles for robotics and artificial intelligence ethics and safety.
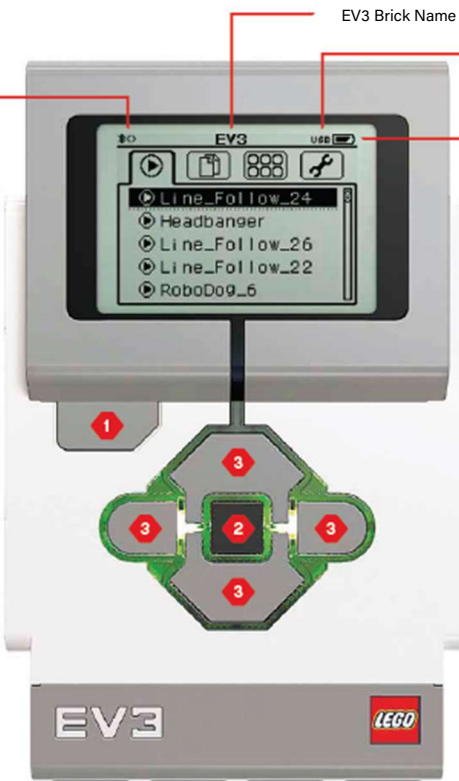
1. Spong et al. *Robot Modeling and Control,* ©2006 Wiley and Sons, Inc. pg.

Robotics 101 PURDUE UNIVERSITY® | Extension - Hendricks County

INTRODUCING THE EV3 INTELLIGENT BRICK

For this course, the EV3 Intelligent Brick serves as the "brain" for your robot. It is a small computer that allows for the robot to interpret information it receives from the sensors (Sense), determine what programmed functions it will execute based on that information (Think), and execute commands to the motors (Act). These robot behaviors continue in a loop once the program is executed until an action terminates the program. Without the intelligent brick, your robot is a fancy paperweight. It is important to test the EV3 Intelligent Brick to ensure robot operation.

Sense

A robot must first sense its surroundings. Electrical signals become data to be interpreted by your program.

Think

A robot must determine what it should do based on the data it receives. This is programmed by you and stored on the Intelligent Brick.

Act

Once the robot has determined a plan, it sends electrical signals back to actuators or motors to execute the planned robot action.

THE LAYOUT OF YOUR EV3 INTELLIGENT BRICK

EV3 Brick Name

USB

Wireless Connection Status

Connection is established with another device

≯

Bluetooth enabled but not connected or visible

≯<

Bluetooth enabled and visible

≯>

Bluetooth is enabled and connected to another device

≯<>

Bluetooth is enabled, visible, and connected to another device

Battery Level

Brick Buttons

Wi-Fi enabled but not connected to a network

1. **Back** – This button is used to reverse actions, to abort a running program, and to shut the brick down.

Wi-Fi enabled and connected to a network

2. **Center** – This button "OK"s various questions, select desired settings, or select blocks.

3. **Left, Right, Up, Down** – Use these buttons to navigate through the EV3 Brick contents.

Ports 1, 2, 3, and 4 are the input ports. The color, touch, gyro, and ultrasonic sensor may be plugged into these ports.

This is the PC port. Connect this port to the computer when loading your program to the EV3 Intelligent Brick.

Ports A, B, C, and D are the output ports. Either the large motors or the medium motor may be plugged into these ports.
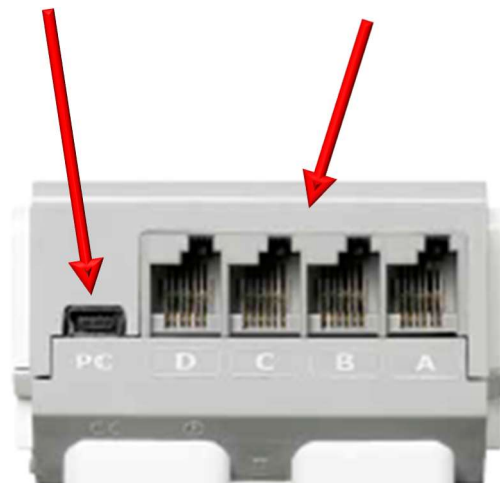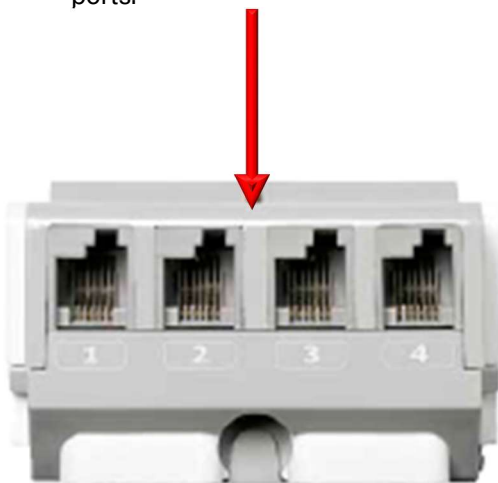
TEST YOUR EV3 INTELLIGENT BRICK

STEP 1: Using your EV3 computer cable, plug the small mini-USB into the PC port on the intelligent brick and the large USB end into a USB port on your computer as shown in the picture. (NOTE: Your computer may need a moment to install drivers from Windows to communicate to your brick.)

STEP 2: Click on the LEGO® Mindstorms Education EV3 icon that is similar to this icon

STEP 3: Click on **File**. Select **New Project** > **Program**. Click the small button labeled **Open**.
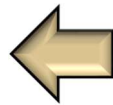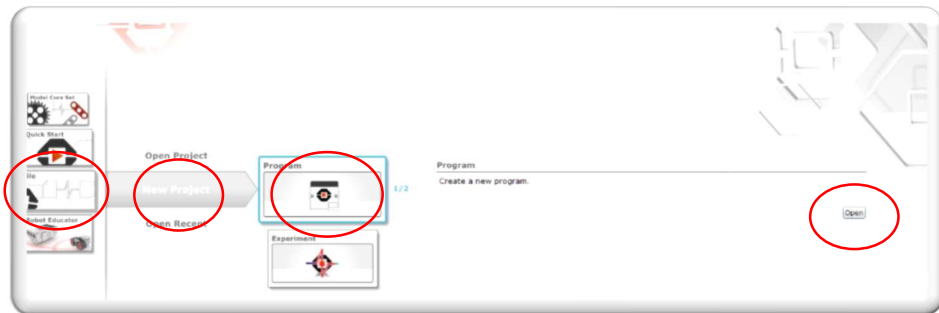
STEP 4: Press button 2, known as the *Center* Button. The lights around the buttons should illuminate red and the screen should say **STARTING**. After a minute or so, the lights should illuminate green and a menu should appear similar to the picture.

STEP 5: In the bottom right corner of the LEGO® Mindstorms Education EV3 software, click on the top tab and verify that your EV3 Intelligent Brick is connected. If it states "No Brick is Connected" or your buttons are still illuminated red, then your course instructor may need to reset or update the EV3 intelligent brick, and use the EV3 software to update the firmware.
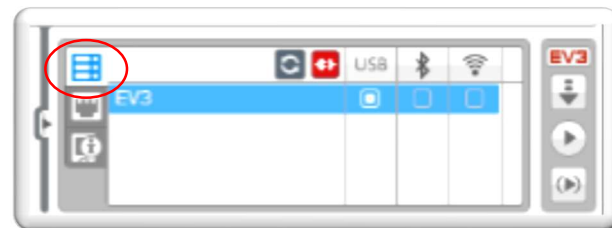
STEP 6: When Step 4 is completed, return to page and mark task 6 complete.

PURDUE UNIVERSITY®

Extension - Hendricks County

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:

1. Build the basic LEGO® educator robot.

Activities: **Complete:**

1. Using the LEGO® Mindstorms EV3 kit and the provided LEGO® Mindstorms education EV3
   instructions packet, build your team's first basic robot.   _____
2. Answer the questions below as a team.   _____

Apply What You Have Learned:

1. Discuss as a group, what types of jobs do robots do?

   _____
   _____
   _____
   _____

2. List one of Isaac Asimov's three laws of robotics? Explain what it means to you.

   _____
   _____
   _____
   _____
   _____
   _____

3. What are the types of robots that can be created?

   _____   _____
   _____   _____
   _____   _____

4. In your team, does anyone have experience or ever used the LEGO® EV3 Mindstorms kit? _____
   If YES, list those team members below:

   _____   _____
   _____   _____
   _____   _____

5. How did inventorying and organizing your kit prior to building the robot help you in your robot construction
   with your team?

   _____
   _____
   _____
   _____

ROBOTS IN ACTION

Robots use motors and actuators to act according to its programming. These motors can be physically attached to wheels, they can be mounted and configured to be similar to arms or legs, or propellers can be mounted to them in order to fly or swim. The EV3 kits also includes gears to translate speed of the motor to better control initial high speed to a lower one without negatively affecting the mechanism or

EV3 LARGE MOTOR

The Large Motor is a powerful "smart" motor. The motor has a built-in rotation encoder that measures precise control up to 1 degree of resolution. The built in sensor allows you to calibrate and align multiple motors to move in straight lines. It is also optimized to drive the base of your robots.
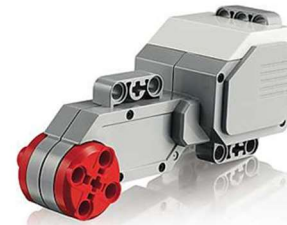
EV3 Large Motor

EV3 MEDIUM MOTOR

The Medium Motor is similar to the Large Motor in that it also has a rotation encoder that measures precise control up to 1 degree of resolution. It is smaller, lighter, and faster than the large motor, but it is less powerful. The Medium motor can be programmed to turn on or off, control its power level, or run for a specified time or rotations.

EV3 Medium Motor

Encoder Disk

Photo Sensor

Digital
Converter
Circuit

LED
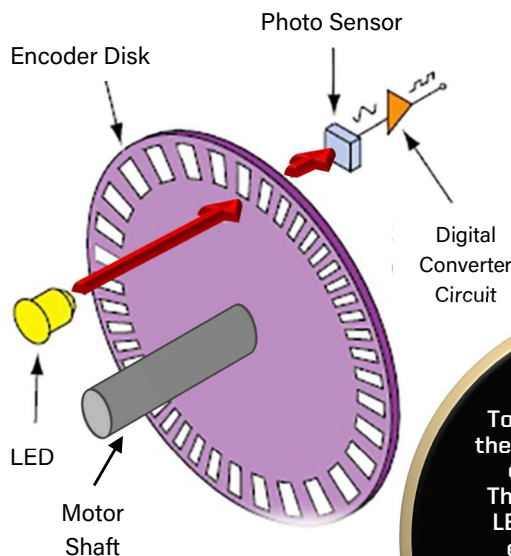
Motor
Shaft

Motor Encoders

To measure the rotations of the motor, the EV3 motors are outfitted with Encoders. These sensors consist of an LED that shines through an encoder disk. The photo sensor picks up the light as is shines through the disk, and a circuit converts the pulses of light to an electrical signal that the EV3 intelligent brick interprets as rotations.

Team Name: _____　**Kit Number:** _____　**Computer:** _____

EV3 SOFTWARE PROGRAMMING

To program your robot, you will be using a programming method called diagraming, which is a graphic representation of an algorithm for your robot. It helps to visualize the flow of how the robot gets data from the sensors, thinks about what to do based on the data, and then set the robot to actions. The code blocks are organized into colored tabs (pallets) to help you organize your robot code with flow diagrams you will develop in a future task. When you are ready to load your program, click the download and run buttons in the bottom right corner to see your robot go!

Actions　Flow Control　Sensors　Math and Data Operations　Advanced Operations　User Created Blocks

Download

Download and Run

Run Selected
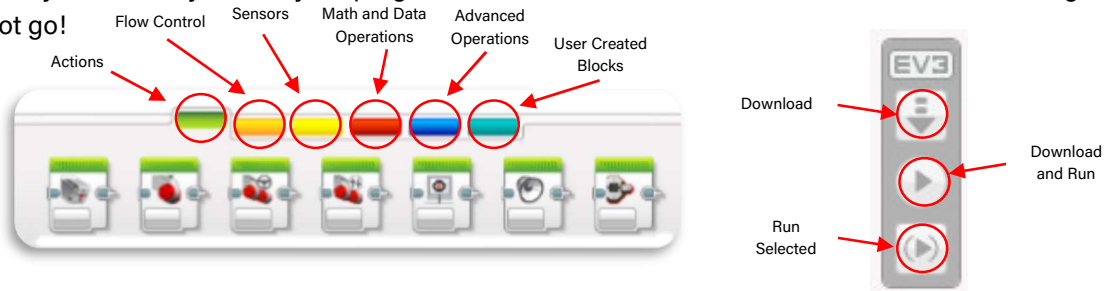
Goal:

1. Move the robot in a **STRAIGHT** line for 10 seconds.

Activities:

Complete:

1. Using the LEGO® Mindstorms EV3 software blocks, move the robot in a **STRAIGHT** line. _____
2. Answer the question below as a team. _____

START A PROGRAM

Start a program with the start button. You **MUST** start every program diagram with this button.

STOP A PROGRAM

You don't need to stop your program always, but it is good practice while you are completing these first tasks to stop your program. You should also use this block if you would like to prevent an action to protect humans or protect the robot.

ROTATE THE MOTOR

This block allows you to rotate a single motor. You can choose the motor, and how the motor rotates. See the parameter settings to the right of the block for programming the robot to complete this task. **HINT:** You need 2 blocks for this task and you may need to calibrate each block to stay straight

Set your output port A, B, C, or D

Set Motor Actions:
1. Motor Off – Does not appear
2. Motor On – Does not appear
3. Motor on only for # of seconds – Set seconds value
4. Motor on only for # of degrees – Set degrees value
5. Motor on only for # of rotations – Set rotations value

Break when done with block.
✓ = True (Yes)
X = False (No)

Set Motor Actions:
1. Turn Motor Off always
2. Turn Motor On always
3. Turn Motor on only for # of seconds
4. Turn Motor on only for # of degrees
5. Turn Motor on only for # of rotations

Motor Power, range from -100 (reverse) to 100 (forward).
HINT: Use this for calibration

Apply What You Have Learned:

1. In order to keep the robot straight, what value did you set the *power parameter*?

MOTOR _____: _____　　　MOTOR _____: _____

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:
1. Use the *Move Tank* Block to move the robot in a **STRAIGHT** line for 10 seconds.
2. Use the *Move Tank* Block to turn in place to the **RIGHT** for 5 seconds.
3. Use the *Move Tank* Block to turn in place to the **LEFT** for 5 seconds.

Activities: **Complete:**
1. Using the LEGO® Mindstorms EV3 software blocks, move the robot in a **STRAIGHT** line.   _____
2. Using the LEGO® Mindstorms EV3 software blocks, turn robot in place **RIGHT**.   _____
3. Using the LEGO® Mindstorms EV3 software blocks, turn robot in place **LEFT**.   _____
4. Answer the questions below as a team.   _____

MOVE TANK BLOCK

This Move Tank block can make a robot drive forward, reverse, turn or stop. This block is ideal for the two large motors that are being used to drive a mobile robot. You can make the two motors move at different speeds and in different directions to turn your robot.

Set your output to the ports connected to the large motors

Set Tank Motor Actions:
1. Motors Off – Does not appear
2. Motors On – Does not appear
3. Motors on only for # of seconds – Set seconds value
4. Motors on only for # of degrees – Set degrees value
5. Motors on only for # of rotations – Set rotations value

Break when done with block.
✓ = True (Yes)
X = False (No)

Set second Motor Power, range from -100 (reverse) to 100 (forward).
HINT: Use this for calibration and for changing direction

Set Tank Actions:
1. Turn both motors off always
2. Turn both motors on always
3. Turn both motors on only for # of seconds
4. Turn both motors on only for # of degrees
5. Turn both motors on only for # of rotations

Set first Motor Power, range from -100 (reverse) to 100 (forward).
HINT: Use this for calibration and for changing direction

Apply What You Have Learned:
1. In order to keep the robot straight, what value did you set the *power parameters* for each motor?
   MOTOR _____: _____   MOTOR _____: _____

2. Did it match the previous parameter values for the individual motor blocks? _____

3. In order to turn the robot **RIGHT** in place, what value did you set the *power parameters* for each motor?
   MOTOR _____: _____   MOTOR _____: _____

4. In order to turn the robot **LEFT** in place, what value did you set the *power parameters* for each motor?
   MOTOR _____: _____   MOTOR _____: _____

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:
1. Use the *Move Steer* Block to move the robot in a **STRAIGHT** line for 10 seconds.
2. Use the *Move Steer* Block to turn in a circle to the **RIGHT** for 5 seconds.
3. Use the *Move Steer* Block to turn in a circle to the **LEFT** for 5 seconds.
4. Use the *Move* steer **Blocks** to move straight for 5 seconds and turn in **RIGHT**.
5. Use the *Move* steer **Blocks** to move straight for 5 seconds and turn in **LEFT**.

Activities: **Complete:**
1. Using the LEGO® Mindstorms EV3 software blocks, turn the robot in a **STRAIGHT** line.   _____
2. Using the LEGO® Mindstorms EV3 software blocks, turn robot in a circle **RIGHT**.   _____
3. Using the LEGO® Mindstorms EV3 software blocks, turn robot in a circle **LEFT**.   _____
4. Using the LEGO® Mindstorms EV3 software blocks, turn **RIGHT**.   _____
5. Using the LEGO® Mindstorms EV3 software blocks, turn **LEFT**.   _____
6. Answer the questions below as a team.   _____

MOVE STEER BLOCK

This Move steer block can also make a robot drive forward, reverse, turn or stop. You can adjust the steering to make your robot go straight, drive in arcs, or make tight turns. The Move Steering block will control both motors at the same time, to drive your vehicle in the direction that you choose.

Set your output to the ports connected to the large motors

Set Speed Motor Actions:
1. Motors Off – Does not appear
2. Motors On – Does not appear
3. Motors on only for # of seconds – Set seconds value
4. Motors on only for # of degrees – Set degrees value
5. Motors on only for # of rotations – Set rotations value

Break when done with block.
√ = True (Yes)
X = False (No)

Set Motors Average Power, range from -100 (reverse) to 100 (forward).

Set Steer Actions:
1. Turn both motors off always
2. Turn both motors on always
3. Turn both motors on only for # of seconds
4. Turn both motors on only for # of degrees
5. Turn both motor on only for # of rotations

Set type of robot steering:
-100 = circle left
-75 = U-turn left
-50 = left turn
-25 = angle left turn
0 = straight
-25 = angle left turn
-50 = left turn
-75 = U-turn left
-100 = circle left

Apply What You Have Learned:
1. Of the 3 motor software blocks, what block does your team think is better for moving the robot straight?
   _____

2. Of the 3 motor software blocks, what block does your team think is better for sharply turning the robot?
   _____

3. Of the 3 motor software blocks, what bloc does your team think is better for doing normal turns?
   _____

SENSING THE WORLD

Robots use sensors to understand and interpret their surrounding environment. Robots use a variety of sensors to try and capture the same variety and quality of your 5 senses (touch, taste, sight, smell, hearing). The following are examples of the LEGO® EV3 Mindstorms that you will be using in your robot.

EV3 COLOR SENSOR

The color sensor detects light intensity and can be programmed to detect color, reflected light intensity, or ambient light intensity.

In **Color Mode**, the sensor can detect 7 colors – black, blue, green, yellow, red, white, and brown. It can also detect no color.

In **Reflected Light Intensity Mode**, the sensor measures the intensity of light reflected back from a red-light emitting lamp.

In **Ambient Light Intensity Mode**, the sensor measure of light from the environment, like a flashlight or sunlight.

EV3 Color Sensor

Color Mode

Reflected Light Intensity Mode

Ambient Light Intensity Mode

EV3 TOUCH SENSOR

The touch sensor is a method for the robot to feel its way through its surrounding environment. For EV3 it is used to detect when the button has been pressed or released. It can be programmed to be used with 3 different action conditions, *pressed*, *released*, or *bumped.*

EV3 Touch Sensor
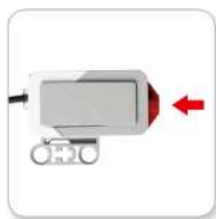
Pressed
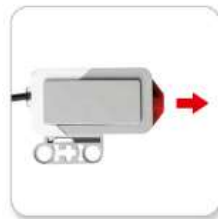
Released
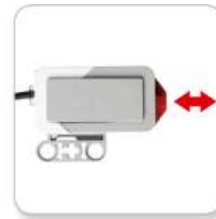
Bumped

EV3 ULTRASONIC SENSOR

The ultrasonic sensor helps a robot measure its distance from a nearby object. Using echolocation, the sensor sends out a sound waves and reads their echoes to detect and measure the distance of objects. This sensor can detect objects up to 100 inches away.

EV3 Ultrasonic Sensor

EV3 GYRO SENSOR

The gyro sensor helps a robot determine its rotational motion and changes in its orientation along one of the axes. Placed flat on top, the robot is able to understand its YAW angle, or angle of rotational turn. Placed in the other positions, and it can tell its ROLL or PITCH angles for balance and changes in orientation, like if the robot has fallen over, or needs to balance.

EV3 Gyro Sensor
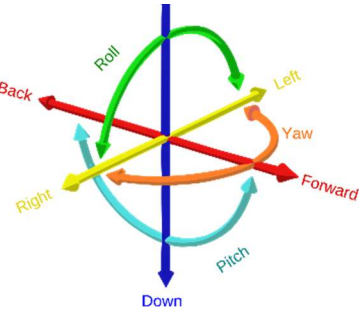
6 Degrees of Freedom

EV3 INFRARED SENSOR

The infrared sensor can also measure distance (slightly different than the ultrasonic sensor) or detect signals that are sent from infrared sources.

In **Proximity Mode**, the sensor estimates the object distance with a value between 0 (very close) to 100 (far away).

In **Beacon Mode**, the sensor estimates the general direction and distance of a matching beacon signal. Direction is measured from -25 to 25, and distance is measure with an value of 0 (very close) to 100 (far away)

In **Remote Mode**, the sensor becomes a switch and can activate or deactivate programmed actions from a matching beacon signal (like a remote).

EV3 Infrared Sensor

Proximity Mode

Beacon Mode

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:

1. Use *a Move, Switch, and Loop* Blocks to move the robot **STRAIGHT**, stopping when a line is detected.
2. Use *a Move, Switch, and Loop* Blocks to move the robot, turn **RIGHT** and stop when a line is detected.
3. Use *a Move, Switch, and Loop* Blocks to move the robot, turn **LEFT**, and stop when a line is detected.
4. Answer the questions on the next page as a team.

Activities: **Complete:**

1. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when a line is detected   _____
   on a **STRAIGHT** path. A board with black tape will be made available for test.
2. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when a line is detected   _____
   upon a **RIGHT** turn. A board with black tape will be made available for test.
3. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when a line is detected   _____
   upon a **LEFT** turn. A board with black tape will be made available for test.
4. Answer the questions on the next page as a team.   _____

LOOP BLOCK

We are now getting into the Sense, Think, and Act of robotics. The Loop block is a container that can hold a sequence of programming blocks. It will make the sequence of blocks inside it repeat. You can choose to repeat the blocks forever, a certain number of times, or until a sensor test or other condition is True. Only the blocks inside the loop will repeat. After the loop ends, the program will continue with the blocks that are after the loop.

Loop Name

Loop mode selector:
1-12. Sensor Conditional Modes
13. Unlimited Mode
14. Number of Counts Mode
15. Logic Conditions Mode
16. Time Mode

For finite loops, how many times you want the loop to be executed

Loop Index Output: How many times has loop executed
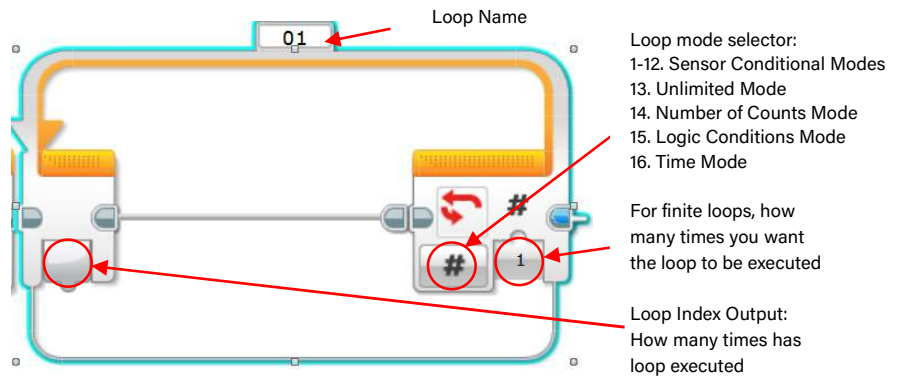
SWITCH BLOCK

The Switch block is a container that can contain 2 or more sequences of programming blocks. Each sequence is called a case. A test (like a sensor comparison) at the beginning of the Switch determines which case the robot will choose to run. Only one case runs each time the switch is executed. **HINT:** For line detection, the light reflectivity comparison may be preferred.

Loop mode selector:
1-12. Sensor Conditional Modes
13. Unlimited Mode
14. Number of Counts Mode
15. Logic Conditions Mode
16. Time Mode

More program blocks

Set the value for the threshold you wish to compare, the output :
✓ = True (Yes)
X = False (No)

Logic Comparison Selector:
0.   =
1.   Not =
2.   >
3.   >=
4.   <
5.   <=
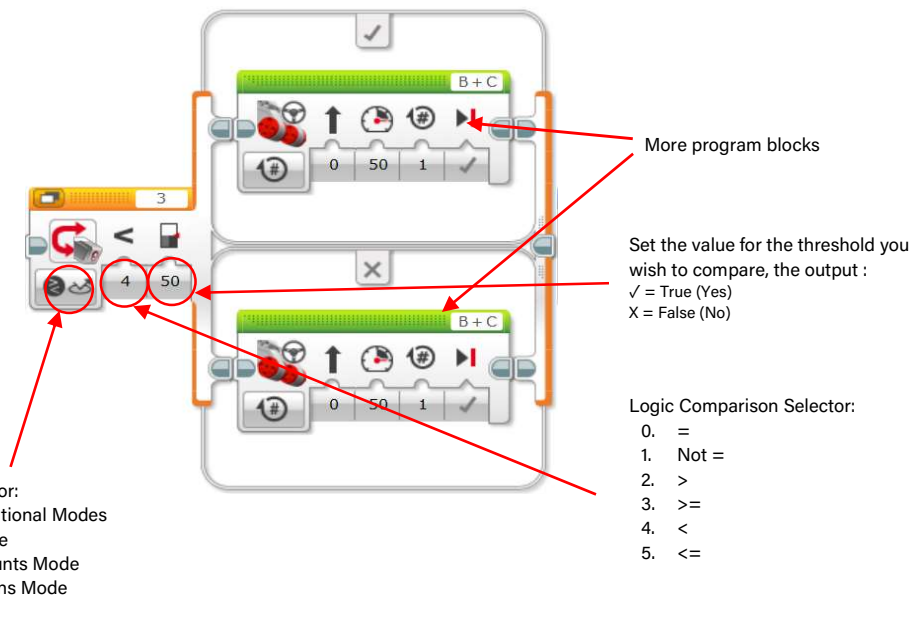
Team Name: _____ **Kit Number:** _____ **Computer:** _____

COLOR SENSOR BLOCK

The Color Sensor block gets data from the Color Sensor. You can measure the color or intensity of light and get a numeric output. You can also compare sensor data to an input value and get a True or False output. Pay attention to the different configuration modes of the block as shown.

Set your sensor input port

Configured to *Measure* mode
1. Color Mode
2. Reflected Light Intensity
3. Ambient Light Intensity

Can connect to Math or Monitor Block

Configured to *Calibrate* Mode
1. Minimum
2. Maximum
3. Reset

Set the values at which you would like your calibrations

Set your sensor input port

Boolean Output:
✓ = True (Yes)
X = False (No)
Information can be sent for other blocks

Configured to *Color* Compare mode

Check for Color:
- 0. No Color
- 1. Black
- 2. Blue
- 3. Green
- 4. Yellow
- 5. Red
- 6. White
- 7. Brown

Set your sensor input port

Boolean Output:
✓ = True (Yes)
X = False (No)
Information can be sent for other blocks

Configured to *Reflective Light Intensity* Compare mode

Logic Comparison Selector:
- 0. =
- 1. Not =
- 2. >
- 3. >=
- 4. <
- 5. <=

Set the value for the threshold you wish to compare, the output is:
✓ = True (Yes)
X = False (No)

Apply What You Have Learned:

1. Why did your team *NOT* use the Color Sensor block?
   _____
   _____
   _____

2. How far across the line did your robot travel while making the right turn (Use your best estimate)?
   _____

3. How far across the line did your robot travel while making the left turn (Use your best estimate)?
   _____

4. Were the distances different? Why?
   _____

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:
1. Use *a Move, Gyro, Switch, and Loop* Blocks to move the robot, turn **RIGHT** and stop when an angle of 115 degrees is detected.
2. Use *a Move, Gyro, Switch, and Loop* Blocks to move the robot, turn **LEFT**, and stop when an angle of 115 degrees is detected.
3. Answer the questions below as a team.

Activities: **Complete:**
1. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when 115 degrees is   _____
   detected upon a **RIGHT** turn.
2. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when 115 degrees is   _____
   detected upon a **LEFT** turn.
3. Answer the questions below as a team.   _____

REVISIT LOOP BLOCK AND SWITCH BLOCK

The next few sections may seem redundant, but they will help you understand the basics of each of the sensors. The blocks for the sensors and their descriptions will be provided for reference, but focus on using the Loop and Switch blocks to complete the tasks. Your final project will depend primarily on these blocks.

GYRO SENSOR BLOCK

The Gyro Sensor Block gets data from an Gyro Sensor. You can measure the rotation rate or rotation angle and get a numeric output. You can also compare the sensor data to a threshold value to get a True or False output. **HINT:** You may need this block to reset your Gyro at the beginning of your program before the loop.

Set your sensor input port

Configured to **Measure** mode
1. Angle
2. Rate
3. Angle and Rate

Can connect to Math or Monitor Block

Set your sensor input port

Configured to **Reset** mode
Set this to reset the value to zero.

Set your sensor input port

Boolean Output:
√ = True (Yes)
X = False (No)
Information can be sent for other blocks

Configured to **Angle** Compare mode

Logic Comparison Selector:
0. =
1. Not =
2. >
3. >=
4. <
5. <=

Set the value for the threshold you wish to compare, the output is:
√ = True (Yes)
X = False (No)

Apply What You Have Learned:
1. How do you know that the robot stopped at 115 degrees?
   _____

2. If you increased the speed of your robot turn, would the robot be closer or further away from 115 degrees when it stopped?
   _____

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:

1. Use *a Move, Switch, and Loop* Blocks to move the robot **STRAIGHT** and stop when the robot is within 5 centimeters of a detected object.
2. Use *a Move, Switch, and Loop* Blocks to move the robot, turn **RIGHT** and stop when the robot is within 5 centimeters of a detected object.
3. Use *a Move, Switch, and Loop* Blocks to move the robot, turn **LEFT**, and stop when the robot is within 5 centimeters of a detected object.
4. Answer the questions below as a team.

Activities: **Complete:**

1. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when an object is   _____
   detected within 5 centimeters going **STRAIGHT.** Setup the robot to get close to the kit box.
2. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when an object is   _____
   detected within 5 centimeters going **RIGHT.** Setup the robot to get close to the kit box.
3. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when an object is   _____
   detected within 5 centimeters going **LEFT.** Setup the robot to get close to the kit box.
4. Answer the questions below as a team.   _____

ULTRASONIC SENSOR BLOCK

The Ultrasonic Sensor block gets data from the Ultrasonic Sensor. You can measure in either inches or centimeters and get a numeric output. You can also compare the distance to a threshold value to get a True or False output. **HINT:** You may not need to use this block for this activity, this section can be used as a reference.

Set your sensor input port

Configured to **Measure** mode
1. Distance (cm)
2. Distance (in.)
3. Presensce

Can connect to Math or Monitor Block

Set your sensor input port

Boolean Output:
√ = True (Yes)
X = False (No)
Information can be sent for other blocks

Logic Comparison Selector:
6. =
7. Not =
8. >
9. >=
10. <
11. <=

Configured to **distance centimeters** Compare mode

Set the value for the threshold you wish to compare, the output is:
√ = True (Yes)
X = False (No)

Apply What You Have Learned:

1. How do you know that the robot stopped within 5 cm?

   _____

2. If you slowed down the speed of your robot, would the robot be closer or further away from 5 cm when it stopped?

   _____

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:
1. Use *a Move, Switch, and Loop* Blocks to move the robot **STRAIGHT** and stop when the robot bumps an object.
2. Use *a Move, Switch, and Loop* Blocks to move the robot, turn **RIGHT** and stop when the robot bumps an object.
3. Use *a Move, Switch, and Loop* Blocks to move the robot, turn **LEFT**, and stop when the robot bumps an object.
4. Answer the questions below as a team.

Activities: **Complete:**
1. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when robot bumps   _____
   object going **STRAIGHT.** Setup the robot to bump the kit box.
2. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when robot bumps   _____
   object going **RIGHT.** Setup the robot to bump the kit box.
3. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when robot bumps   _____
   object going **LEFT.** Setup the robot to bump the kit box.
4. Answer the questions below as a team.   _____

TOUCH SENSOR BLOCK

The Touch Sensor block gets data from the touch Sensor. You can measure whether the touch sensor is pressed, released, or bumped and get a True or False output. **HINT:** You may not need to use this block for this activity, this section can be used as a reference.

Set your sensor input port

Configured to **Measure** mode
4. Distance (cm)
5. Distance (in.)
6. Presensce

Can connect to Math or Monitor Block

Set your sensor input port

Boolean Output:
✓ = True (Yes)
X = False (No)
Information can be sent for other blocks

Logic Comparison Selector:
0. Out
1. In
2. Bump

Configured to **button state** Compare mode
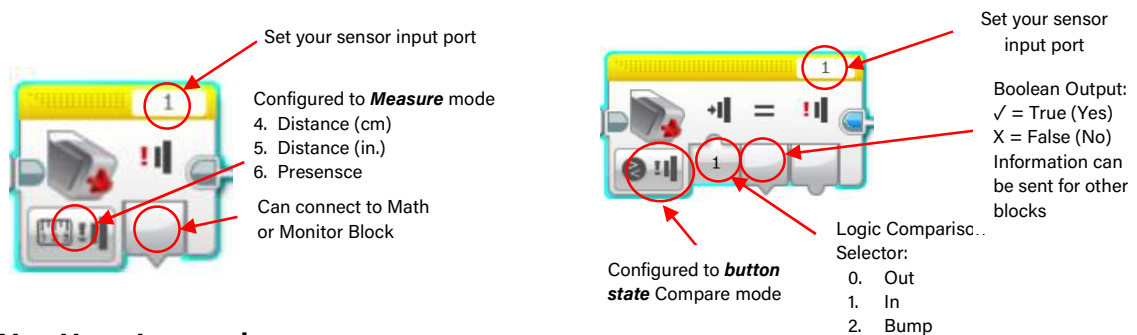
Apply What You Have Learned:
1. What was the difference between the bumper behavior when the robot turned left versus the turn right?

   _____
   _____
   _____

2. Did you try the bumper experiment at different speeds, how did the robot react?

   _____
   _____

3. Why do you think we performed all these STOP tests with the Sensors as our first tasks?

   _____

A ROBOT MAY NOT INJURE A HUMAN BEING

Safety is very important in the area of robotics. Remember, as roboticists, we strive to prevent the injury of others with robot operations. When safety protocols are not followed, today's robots could be very damaging and even fatal to all objects around them.

One solution to safety is safety conditional logic. This is the act of creating software in which the robot is programmed to determine the best course of action based upon the data it receives from the sensors to move to a minimal risk condition. The previous tasks are designed to learn how to stop a robot with sensors. **STOPPING** robot movement in general is a safe *Minimal Risk Condition (MRC)*. In the instance where the robot is still interfering with the human being aided, then moving the robot in a different direction may be the solution.

MINIMAL RISK MANUEVERS

Just like a human, robots have limitations, and can easily break down or wear out if they are operating too much or performing more tasks then required to complete a goal. Now you will be working on creating *Minimal Risk Maneuvers (MRM)*. These are connected software blocks that have the robot perform the multiple and minimal number of tasks to complete a working task *safely*. In future robotics courses, you will be required to document your minimal risk conditions and minimal risk maneuvers as part of your flow diagrams.
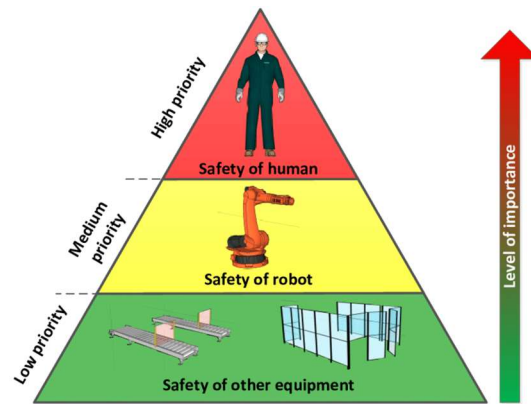
Safety Standards

International Organization of Standardization (ISO) is an example of companies who work towards developing safety standards for robotics in all types of robots and all applications of work activities. These standards include robot task lighting and illumination, recommendations for robot zoning, risk assessment, protective measures, and how to chart MRCs and MRMs. These standards are guidelines to help design safe and robust robots.

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:

1. Use *a Move, Switch, Sound, Loop, and Loop Interrupt* blocks to move the robot **STRAIGHT. S**top the robot when robot bumps object going **STRAIGHT.** After the stops, the robot must **BACKUP** while beeping for 3 seconds, turn **LEFT** in place, and continue **STRAIGHT** for 3 seconds.
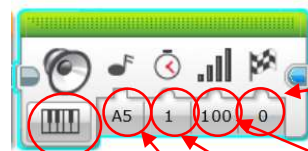2. Answer the questions below as a team.

Activities: **Complete:**

1. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when robot bumps an object going **STRAIGHT.** Setup the robot to bump the kit box. _____
2. Once the kit box is bumped, by the robot, the robot **BACKS UP** while beeping for 3 seconds. _____
3. The robot turns **LEFT** in place. _____
4. After the **LEFT** turn, the robot continues **STRAIGHT** for 3 seconds. _____
5. Answer the questions below as a team. _____

SOUND SENSOR BLOCK

The Sound Block makes sound using the speaker inside the EV3 Brick. You can play pre-recorded sound files or specify a musical note or tone. **HINT:** You may need to use multiple switch blocks for this task.

LOOP INTERRUPT BLOCK

The Loop Interrupt block makes a Loop block end. No more blocks in the loop sequence will execute, and the remaining blocks in the program sequence will continue. You can use the Loop Interrupt block to make the loop exit sooner than it normally would or in response to a condition. You can even specify which loop needs to end from another loop running at the same time using the loop name. **HINT:** Be aware that ending loops in the wrong spot may have unintended consequences.

Configure play mode:
Stop
  0. Play until complete
  1. Play once
  2. Play Repeat

Volume at which the sound will play:
100 = loud
0 = no sound

Pick a tone

Configured to play audio from:
  3. Stop
  4. Play File
  5. Play Tone
  6. Play Note

Value of time in seconds the sound will play

Specify the loop to end

Block is always configured to loop end mode

Apply What You Have Learned:

1. When do you think a robot stopping is **NOT** considered a safety minimal risk condition?
   _____
   _____
   _____

2. Did you experiment with sounds? Is your sound nice or does it sound like a warning?
   _____
   _____

3. How would the robot tell you it is working? (Sounds, Lights, Signs, Colors, Arm Waving, etc.)
   _____

Robotics 101

Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:

1. Use *a Move, Switch, Random, Sound, and Loop* blocks to move the robot ***RANDOMLY. S***top the robot when robot gets close to an object within **3 CM.** After the stops, the robot must ***BACKUP*** while beeping for 3 seconds, turn ***LEFT*** in place, and continue moving ***RANDOMLY***.
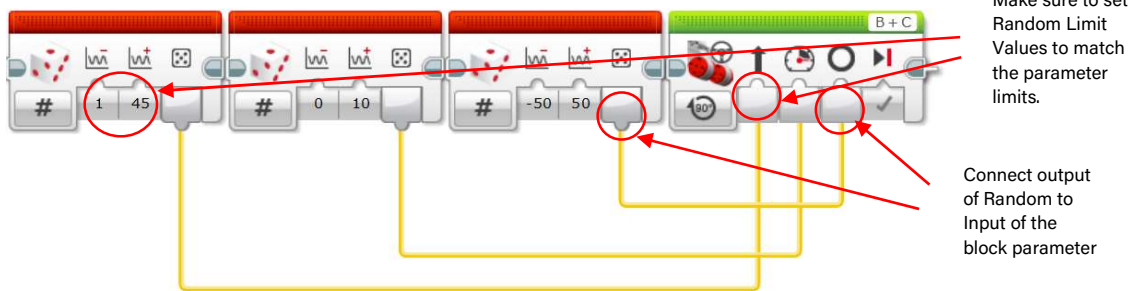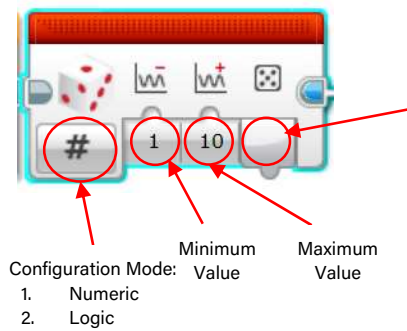2. Answer the questions below as a team.

Activities: **Complete:**

1. Using the LEGO® Mindstorms EV3 software blocks, stop the robot when robot gets close to   _____
   an object within **3 CM** while moving ***RANDOMLY.*** Setup objects to be in the path of the
   robot like a room.
2. Once an object is within **3 CM**, the robot ***BACKS UP*** while beeping for 3 seconds.   _____
3. The robot turns ***LEFT*** in place.   _____
4. After the ***LEFT*** turn, the robot continues moving ***RANDOMLY.***   _____
5. Answer the questions below as a team.   _____

RANDOM BLOCK

The Random Block outputs a random numeric or logic value. Random Numeric values are selected between the low number you select and the high number you select. Radom logic values are either true or false. These values can be outputted to block parameters of subsequent action blocks. **HINT:** You will need a random block for each parameter you choose to set. **HINT 2**: You will be using your previous safety multitasking code for this task. **HINT 3:** You may want to use an Ultrasonic Block comparison.

Output connection to parameter input of other blocks

Configuration Mode:
1. Numeric
2. Logic

Minimum Value   Maximum Value

Make sure to set Random Limit Values to match the parameter limits.

Connect output of Random to Input of the block parameter

Apply What You Have Learned:

1. Describe how random your robot behaved?

   _____
   _____
   _____

2. Did bump into anything?   How many times did your robot bump into items.

   _____
   _____

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Team Name: _____ **Kit Number:** _____ **Computer:** _____

Goal:

1. Use *a Move, Switch, Color, Math, Loop, and Loop Interrupt* blocks to move the robot to follow the line*. Start the robot on the line and have the robot follow the line. At the end of the line, search for a new line by turning the robot in place *LEFT* **90 degrees while looking for the line**. If the robot does not find the line, turn the robot *RIGHT* **180 degrees while looking for the line**. If the robot still does not find the line, turn the robot back to *STRAIGHT* **for 1 rotation while looking for the line**. If the robot does not find a line, **STOP THE PROGRAM.**
2. Answer the questions below as a team.

Activities: **Complete:**

1. Using the LEGO® Mindstorms EV3 software blocks, Place the robot on the line and follow the line.   _____
2. At the end of the line, turn *LEFT* in place looking for line.   _____
3. After the *LEFT* turn, turn all the way *RIGHT* in place looking for the line.   _____
4. After the *LEFT* turn, the robot continues moving *STRAIGHT* for *ONE ROTATION.* _____
5. After **ONE ROTATION**, the robot **STOPS.**
6. Answer the questions below as a team.   _____

MATH BLOCK

The Math Block allows you to make calculations within your program which serve as inputs to other parameters of your program. Math equations will follow the order of operations, so be aware how you inputting your math. **HINT:** You will need a random block for each parameter you choose to set. **HINT 2**: It may be helpful if the robot moves… slower. **HINT 3:** The *C* parameter is useful in the amount of turning your robot does. **HINT 4:** Reflected Light Intensity
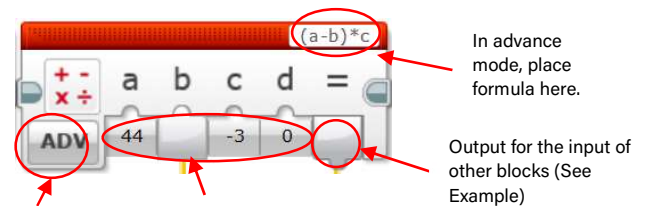
In advance mode, place formula here.

Output for the input of other blocks (See Example)

Input math values, can be constants, or outputs from other blocks (See Example)

Configuration Mode:
1. Add
2. Subtract
3. Multiply
4. Divide
5. Absolute
6. Square Root
7. Exponent
8. Advanced

Get color sensor value and place it in math variable inputs

Watch your formula

Watch your speed

Amount you turn parameter
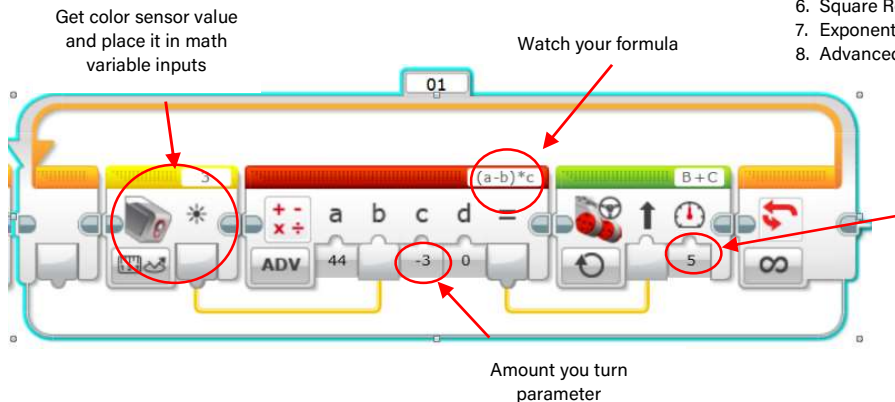
Apply What You Have Learned:

1. What was the value of your motor speed and C parameter? How well did the robot follow the line?

   _____
   _____
   _____

POWER IN ORGANIZATION OF THOUGHT

The design cycle is a process that Engineers and Roboticists use to create new technology, improve on existing technology, and maintain technology that has a long-life cycle or life time. Each organization has their own design cycle process that allows them to develop technology and robots that complies with their policies, best engineering practices, safety, standards, and customer requirements. In general, the design cycle is as follows:

PLANNING: Based on your expertise or experience, it is important to understand and define the problem that the robots need to address. An example of problem definition are the *GOALS* from each of your task you completed. These goals can come from your customer, your company, standards, etc. They also can come from constraints of the project, like environment or financial restrictions. The output of this section of the cycle is usually project design requirements for each expertise of the robot.

DESIGN CYCLE

IMPLEMENTATION: Next, you need to analyze the problem using data, research solutions that may exist, what has been tried, what has worked, what has failed. Once this is complete, you need to brainstorm remaining solutions that will meet the problem definition and work with the various project design requirements and constraints. A widely accepted practice is Test Driven development. The theory is that you write how you will test your robot, before you write the software or build the structure for your robot. It also helps you determine what sensors and how many motors or actuators you will need. Build your solution.

ANALYSIS: TEST, TEST, TEST. An example of evaluation and test is the activities that you marked from each of your tasks. Others should review your tests to verify that requirements have been met for the robot. Your solution may need to be modified based on the test results and feedback that you received from other peer and leadership review.

DISSEMINATION: Once your robot has been created, it will begin its work. This means teaching others how your robot operates, maintenance and care. The reason the design cycle is circular is because your robot will encounter unforeseen issues and new issues when it is in operation. As each issue appears, you will restart at the planning phase to design new solutions as improvements to your robot from new requirements derived from the new found issues.
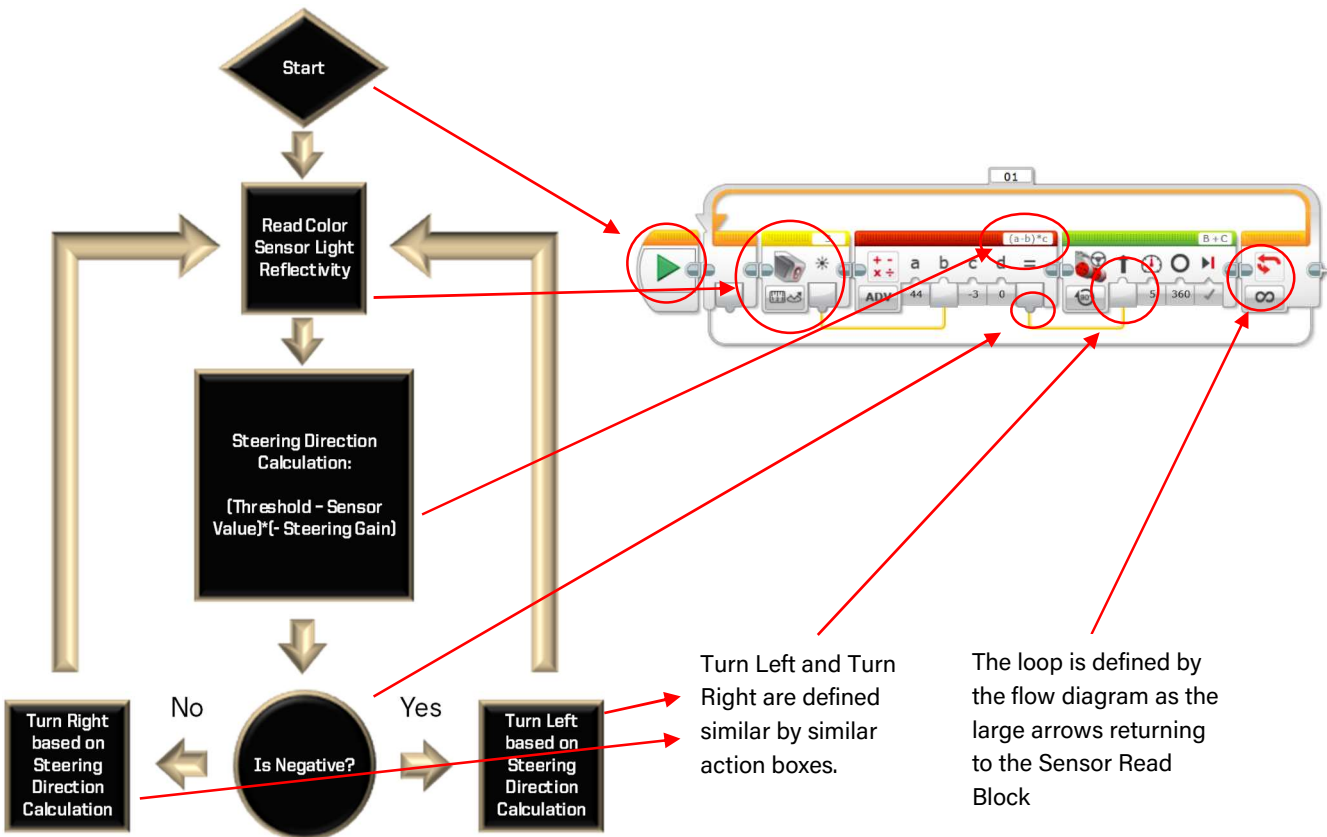
Robotics 101

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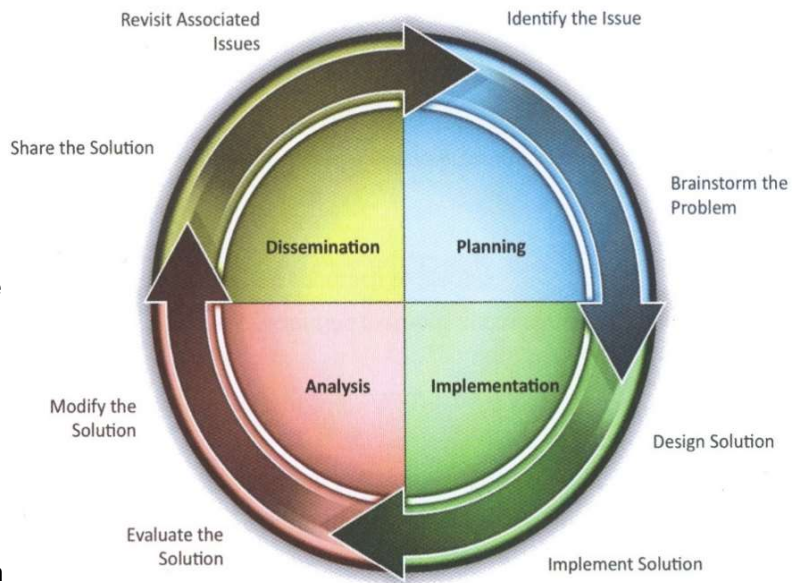
DRAW YOUR SOFTWARE LOGIC

During the design cycle, part of the software development process is to draw out a flow diagram, which is the pseudocode to your software. The benefit of using a flow diagram is that the EV3 Mindstorms diagram programming is easy to translate from your flow diagram. An example of a flow diagram below shows you exactly how they translate. *Each code function type is its own shape.* In this case, *Start and Finish* (not shown) are diamonds, *Actions* are Squares, and *Conditional Logic* is circles. The flow is dictated by the direction arrows. For your 4-H project, you will need to develop a flow diagram and show how it translates to your code. A flow diagram also shows how your software meets your project design requirements.

Start

Read Color Sensor Light Reflectivity

Steering Direction Calculation:

(Threshold – Sensor Value)*(- Steering Gain)

Is Negative?

No — Turn Right based on Steering Direction Calculation

Yes — Turn Left based on Steering Direction Calculation

Turn Left and Turn Right are defined similar by similar action boxes.

The loop is defined by the flow diagram as the large arrows returning to the Sensor Read Block

Dancing Robots?

Boston Dynamics robots have become the industry standard of humanoid robots. Their AI algorithms for non-linear control and innovations in robot joint movement are second to none.
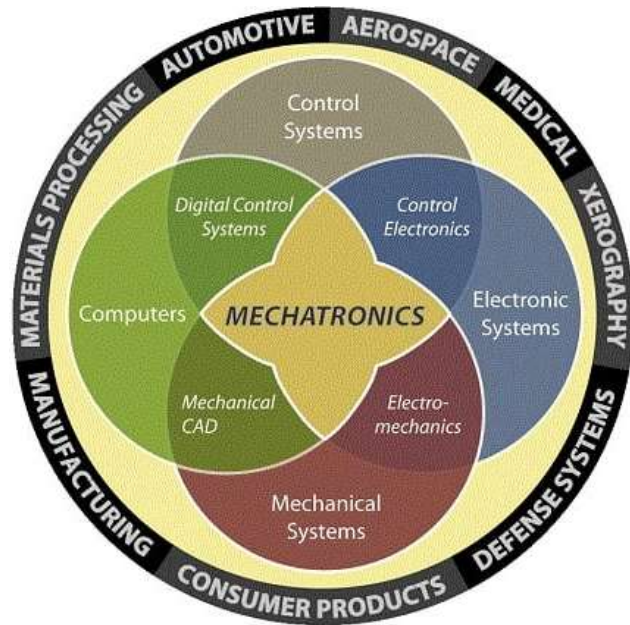

Robotics 101

ROBOTICS CAREERS

The application of robotics extends across many different industries, including manufacturing, agriculture, law enforcement, military, space exploration, medicine, hobbyists, and transportation. This means that a not only is a background in robotics required, but also an understanding of the operational application environment for robots (also known as the Operational Design Domain). Also exciting is that one robotics application may be applied and useful to another robotics application.

HIGHER EDUCATION

Your education for robotics starts now. Programs that offer robot learning opportunities (like 4-H) help you understand the fundamentals on how robots work. Take as many math, physics, programming, computer, electrical, and design classes that you can. Participate in as many clubs in these fields of study any opportunity you can.

People who seek a career in robotics will need a higher education than a high school education. If you wish to become a robotics technician, there are junior college programs with associate degrees that teach how to repair and maintain robots. Designing robots requires an engineering degree. Most people who seek careers in robotics major in mechatronic, computer, mechanical, electrical, structural, biomechanical, or industrial engineering or in computer science. Many individuals have multiple degrees (Bachelor, Masters, PhD) in different engineering disciplines, but it's not required. Universities are now starting to add robotics specific degree programs.

The diagram to the right explains the different engineering disciplines and how they relate to mechatronics, with robotics being a part of mechatronics. The diagram below shows how each core discipline relates to the development of a robot. Based on what you have learned from Robotics 101, see what section interests you and ask questions to any engineer or subject experts in those areas to see what more you can learn.

What Interests you?

There are many areas of robots that need your brain power! All areas of robotics are growing. Pick a field that piqued your interest and learn what you can do to work in that field.
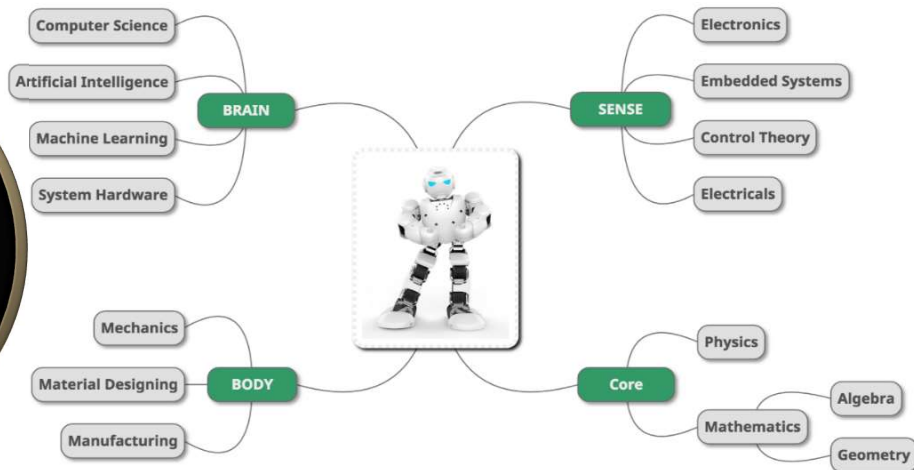
THE GROUP PROJECT FOR COUNTY FAIR EXHIBITION

For Robotics 101, the focus is to design our robots to meet a group challenge before the county fair. That means each team will design a EV3 Mindstorms robot to meet the instructor selected group challenges. Challenges may include but are not limited to:

FOLLOW THE LINE: This challenge requires each team build a robot that follows a line and search for a line if they cannot find one. For every challenge, the path of the line may be different and you are constrained to the parts in your kit.

OBSTACLE COURSE: This challenge requires each team navigate an obstacle course and return without hitting a single object in the course. For every challenge, the obstacle setup can be very different and the start and end goals may be different and you are constrained to the parts in your kit.

MAZE RUNNER: This challenge requires each team to navigate a maze from the start point to the end point and then return to the start point on the outside of the maze. The maze may be configured differently each year you are constrained to the parts in your kit.

ROBOT PARKING: This challenge requires each team to find an open parking spot and park their robot in an open spot. Once some time has passed, the robot leaves the parking spot, drive around the outside of the parking spot, and return to park in a new spot. You are constrained to the parts in your kit.

A DESIGN CHALLENGE AT THE COUNTY FAIR

Having completed robotics 101, each roboticist should have enough knowledge to complete a challenge at the county fair. A day will be designated where we will give each roboticist an opportunity to perform a challenge similar to the challenges above but smaller or a new challenge designed by the robotics team that year that can be completed in less than 2 hours.

INDIVIDUAL EXHIBITION AT THE COUNTY FAIR

All 4-H roboticists are encouraged but not required to have an exhibition at the fair. While robotics 101 is geared towards the group project exhibition at the county fair, robotics 102 and 103 will be developed to build robot prototypes that resolve real world problems in many industries that can be displayed at the county and state fairs. Exhibitions will follow the guidelines outlined in the Purdue Extension Curriculum for the Computers: Robotics Exhibition requirements. See the 4-H handbook for additional information.

EV3 INTELLIGENT BRICK ISSUES

The EV3 Intelligent Brick may run into some issues. The status light codes tell us what the Brick is currently doing and it does this by either pulsing one of the colors or displaying a solid color.

The following list outlines the status codes:
- Red (solid) = Startup, Updating or Shutting Down
- Red (pulsing) = Busy
- Orange (solid) = Alert, Ready
- Orange (pulsing) = Alert, Running
- Green (solid) = Ready
- Green (pulsing) = Running program

If the EV3 Intelligent brick remains in *Forever Starting Mode* then the Brick needs to be reset. Simply remove the battery to depower, replace the battery, and hold down the center and the left button. The robot should turn on the same but now say *Updating* on the screen. Connect the USB cable and open the Mindstorm software on your computer. It will automatically ask you to update firmware. Proceed with the firmware update until your EV3 brick restarts and lights up Green (solid). **HINT:** This will delete all your programs. Make sure you backup your software on the computer.

ROBOT SENSOR ISSUES

Sensors are very delicate, and the EV3 Mindstorms sensors are no different. If your sensor is not working, first try to make sure your sensor software block has the sensor configured to the correct port. Second, make sure that your sensor is plugged in on the number side, and not the Letter side of the EV3 Intelligent Brick. Third, make sure you can see a value on the EV3 software and that the values in the sensor raw value displays in the bottom right corner of the software window are displayed in the correct port assignment.

ROBOT REPEATABILITY ISSUES

Sometimes you will test your robot and get different results. This is expected and sometimes encouraged. The first question that you should ask yourself and your team is **WHY?** From there, maybe check the placement of your robot, maybe check which software version you loaded, and even maybe check to see if part of your chassis or sensor location is staying connected together. If you continue to have any issues, please raise your hand and ask an instructor to help you. Your issue may be added in future revisions of this document.

EV3 Mindstorms Software Block

EV3 Mindstorms Software Block	Block Dictionary Website for Additional Support:
Move Tank Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/MoveTank.html#:~:text=The Move Tank block can,the other the right side.
Move Steer Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/Move.html#:~:text=The Move Steering block makes,of the Move Steering block.
Loop Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/page.html?Path=blocks%2FLEGO%2FLoopCondition.html
Switch Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/page.html?Path=blocks%2FLEGO%2FCaseSelector.html
Color Sensor Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/ColorSensor.html
Gyro Sensor Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/page.html?Path=blocks%2FLEGO%2FGyro.html
Ultrasonic Sensor Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/page.html?Path=blocks%2FLEGO%2FUltrasonicSensor.html
Touch Sensor Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/page.html?Path=blocks%2FLEGO%2FTouchSensor.html
Sound Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/page.html?Path=blocks%2FLEGO%2FSound.html
Loop Interrupt Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/page.html?Path=blocks%2FLEGO%2FInterrupt.html
Random Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/page.html?Path=blocks%2FLEGO%2FRandom.html
Math Block	https://ev3-help-online.api.education.lego.com/Retail/en-us/page.html?Path=blocks%2FLEGO%2FMath.html

artificial intelligence	A branch of computer science concerned with the development of software and algorithms that make computers simulate human intelligence.
automation	The process of repeating the same programmed behavior over and over again.
chassis	The base platform of a robot to that physically mounts all sensors, motors, mobility hardware (wheels, propellers, etc.) and computer controller.
conditional logic	Setting rules or conditions that cause your process to change based on input.
duration	The length of time a process exists or lasts.
encoder	A device that measures motion and converts that measurement to an electrical signal
firmware	Read-only computer code that translates programmed software to the hardware.
hardware	The physical mechanical or physical electrical parts of a robot.
minimal risk condition	Conditional logic state in which a robot is deemed safe.
minimal risk maneuver	Conditional logic operation in which the robot acts safely and with the minimal number of movements.
process	A series of actions or steps taken in order to achieve a particular end.
pseudocode	A simpler description or explanation of algorithms, used in program design.
repeatability	The ability for the robot to behave in the same manner every time the program is run based
resolution	The degree to which a robot sensor measurement is accurate.
revolution	In robotics, a motor turning a shaft one complete circle
robot	A machine capable of replicating human like tasks or work through a series of programmed actions automatically and can be reprogrammed.
robotics	A field of study and science of designing, building, and using robots.
sensor	A device that converts physical real world environmental conditions to electrical signals that a robot can understand.
software	Computer programming that allows a user to control the hardware.

Robot Modeling and Control
Sprong, Hutchinson, and Vidyasagar.
Wiley, 2006

LEGO® Mindstorms EV3 Help.
URL: https://ev3-help-online.api.education.lego.com/Retail/en-us/index.html

Toward a Sustainable Human-Robot Collaborative Production Environment
A. M. A. Alkhdur. Cardiff Metropolitan University, 2017

LEGO® Mindstorms User Guide
LEGO® Group, 2011

Boy Scouts of America Robotics Merit Badge Pamphlet
Boy Scouts of America, 2011 printing