The power of Math in LEGO Robotics

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Goals and Objectives:

I came up with this idea of using mathematical calculation in my LEGO Robotics class a few years ago. One of the first assignments I gave my students was to make their robot travel a certain distance. I noticed right away that my students started guessing the values on the computer instead of measuring and calculating the exact quantity they needed for the program.

Using mathematical calculations and logic before coding the program is an essential skill that each student should master at an early age. The goal of my project was to apply mathematical reasoning to the programming blocks used in Mindstorms EV3.

Florida Standards:

- Mathematics

Domain: RATIOS & PROPORTIONAL RELATIONSHIPS

MAFS.6.RP.1.1: Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.

MAFS.7.RP.1.1: Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units.

MAFS.6.RP.1.3: Use ratio and rate reasoning to solve real-world and mathematical problems.

Domain: THE NUMBER SYSTEM

MAFS.6.NS.3.5: Understand that positive and negative numbers are used together to describe quantities having opposite directions or values.

- Engineering Technology

CTE-TECED.68.ENGTEC.03: Demonstrate understanding and use of measurement tools and systems.

Lessons 1. Moving forward.

Duration/Time Frame: 1 to 3 class periods.

Topics:

- Calculating the circumference of the wheel.
- Understanding the meaning of the circumference of the wheel.
- Using the circumference of the wheel to move forward or backward.

Objectives:

- Calculate the circumference of the wheel.
- Understand the mathematical application of the circumference of the wheel for future calculations.
- Explore different ways to calculate the circumference of the wheel.

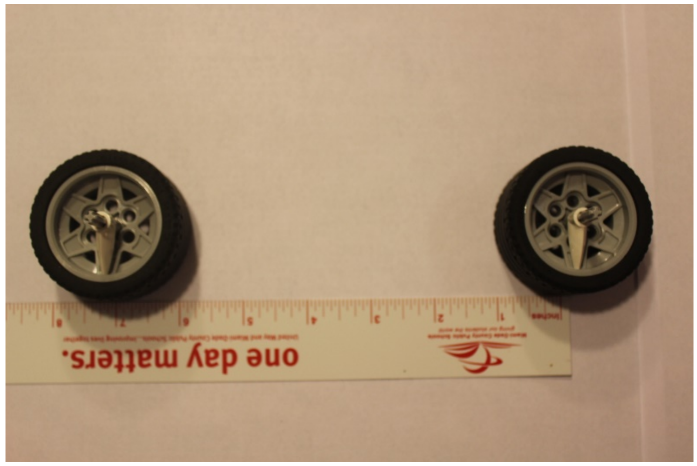
Materials:

- Wheels
- Ruler
- Tape
- Computer
- Lego Robot

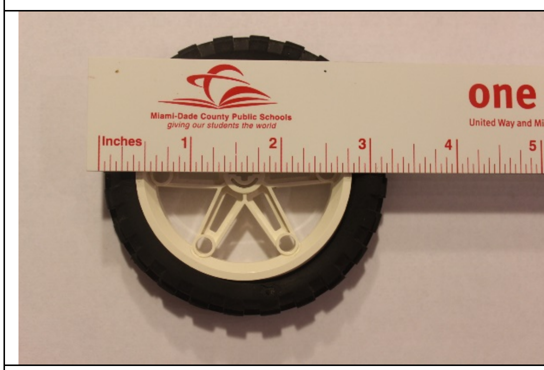
Procedures and Activities:

- As a class activity, discuss with students the reason finding the circumference of the wheel is essential to calculate the number of rotations the robot needs to travel a certain distance. Students must understand through reasoning that the circumference of the wheel is equivalent to the length traveled after one rotation.
- In small groups, have students explore different ways to find the circumference of the wheel(s). For instance, (a) holding a ruler, students can roll a wheel a full rotation, (b) measure the diameter of the wheel and then use the formula $C=d*\pi$, (c) using a piece of thread around the wheel, (d) programming the robot to travel 1 rotation and then measuring the distance traveled, etc.

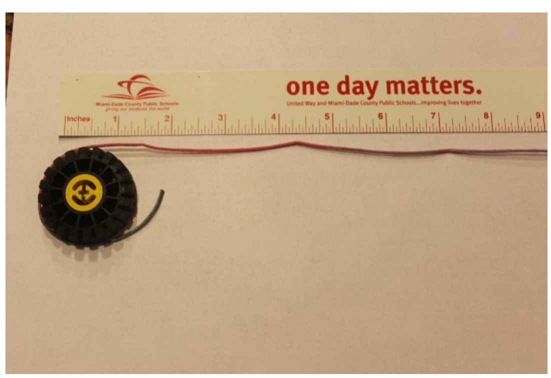
(a) holding a ruler, students can roll a wheel a full rotation



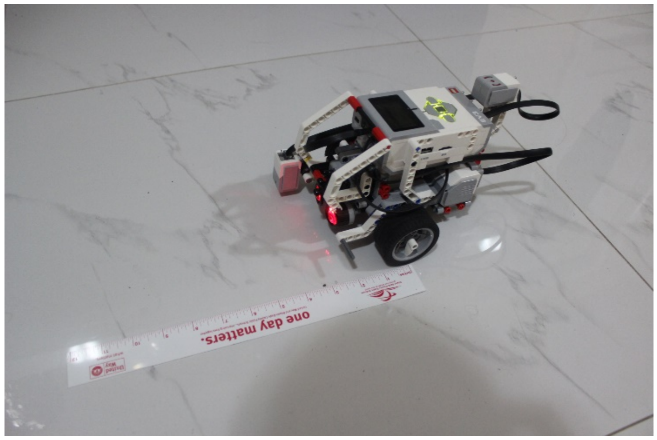
(b) measure the diameter of the wheel and then use the formula C=d*π



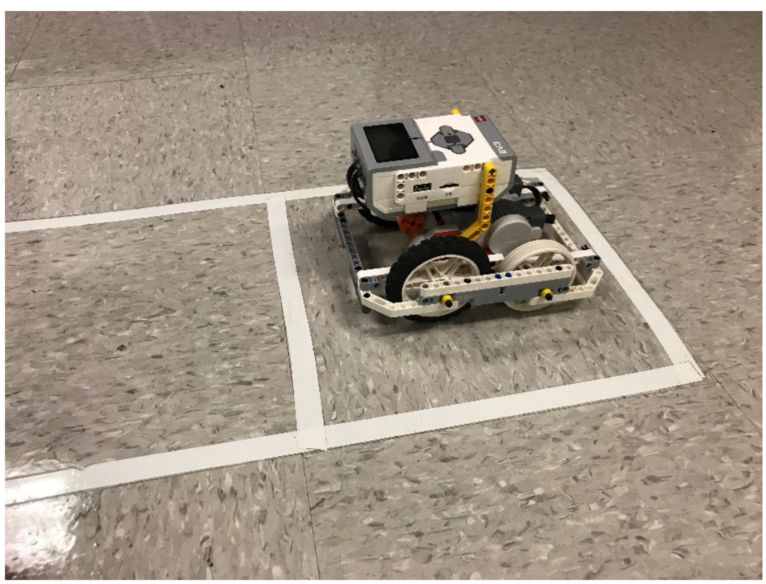
(c) using a piece of thread around the wheel

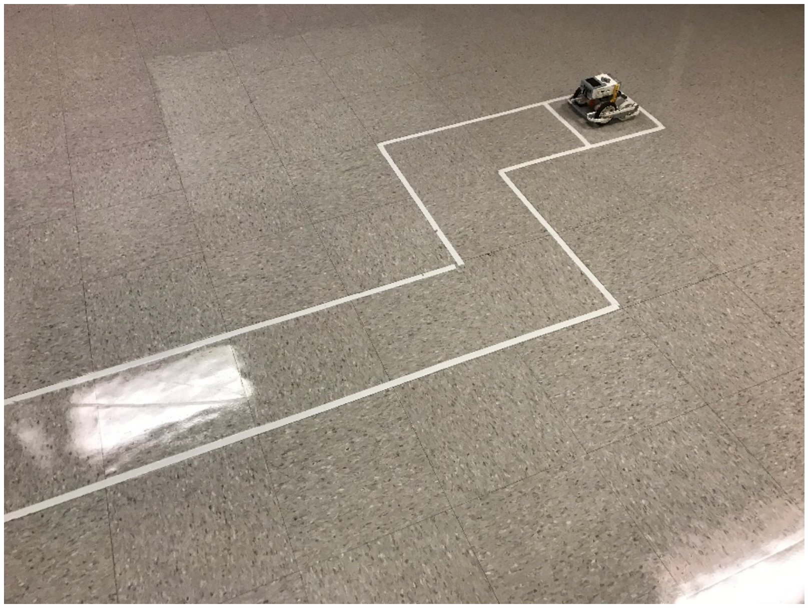


(d) programming the robot to travel one rotation and then measuring the distance traveled



- (Suggested activity) Set up a simple maze on the floor with electrical tape. Once the distance the robot need to travel is set on the floor, have the students measure to figure out how to calculate the number of rotations their wheels need to travel the entire maze. (Note: Students may still not be able to calculate the required rotations to make turns. Have them estimate those measures unless they want to try calculating the actual values)

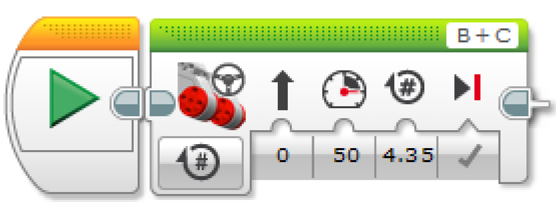




- Examples:

Example 1.
The Circumference of the wheel is 5 in. The distance the robot needs to travel is 30 inches.
Answer: The robot needs to travel 6 rotations

Example 2.
The Circumference of the wheel is 6.9 in. The distance the robot needs to travel is 30 inches.
Answer: The robot needs to travel about 4.35 rotations



Example 3.
The Circumference of the wheel is 8.5 in. The distance the robot needs to travel is 2 inches.
Answer: The robot needs to travel about 0.24 rotations

- Reflection activity. Have students reflect on the applications of using mathematical calculations to program their robots to move forward.
- (Suggested Activity) Formative assessment.

Have students answer the following questions the next day:

1. How many inches will your robot travel after four rotations? (Note: The diameter of the wheels is 3.2 inches)
2. How many rotations will this same robot need to travel 120 inches?

Lesson 2: Making turns.

Duration/Time Frame: 1 to 3 class periods.

Topics:

- Calculating the swing and point turns.
- Understanding the meaning of the distance between the robot's wheel.

Objectives:

- Calculate the swing and point turns.
- Explore the differences between the swing and point turns.
- Apply the mathematical calculations when programming the robot.

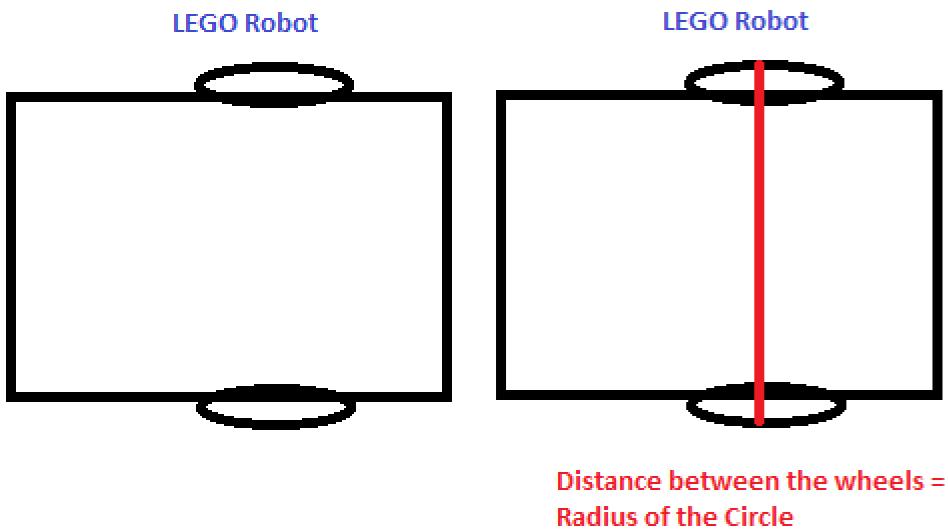
Materials:

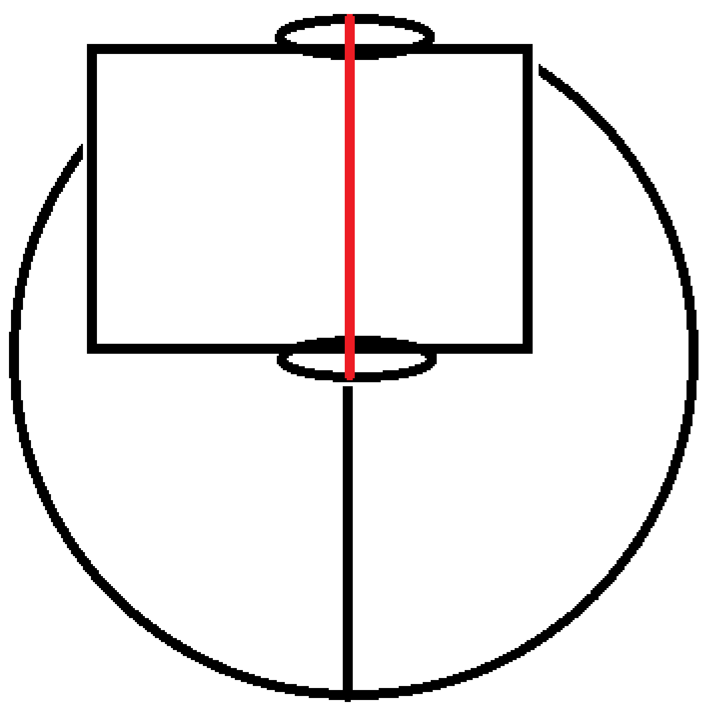
- Wheels
- Ruler
- Tape
- Computer
- Lego Robot

Procedures and Activities:

- As a class, discuss with students the differences between the swing and point turns. (In the swing turn, one of the wheels remains off while the other wheel moves either forward or backward to complete the turn. In the point turn, both wheels move, one moves forward while the other one moves backward)

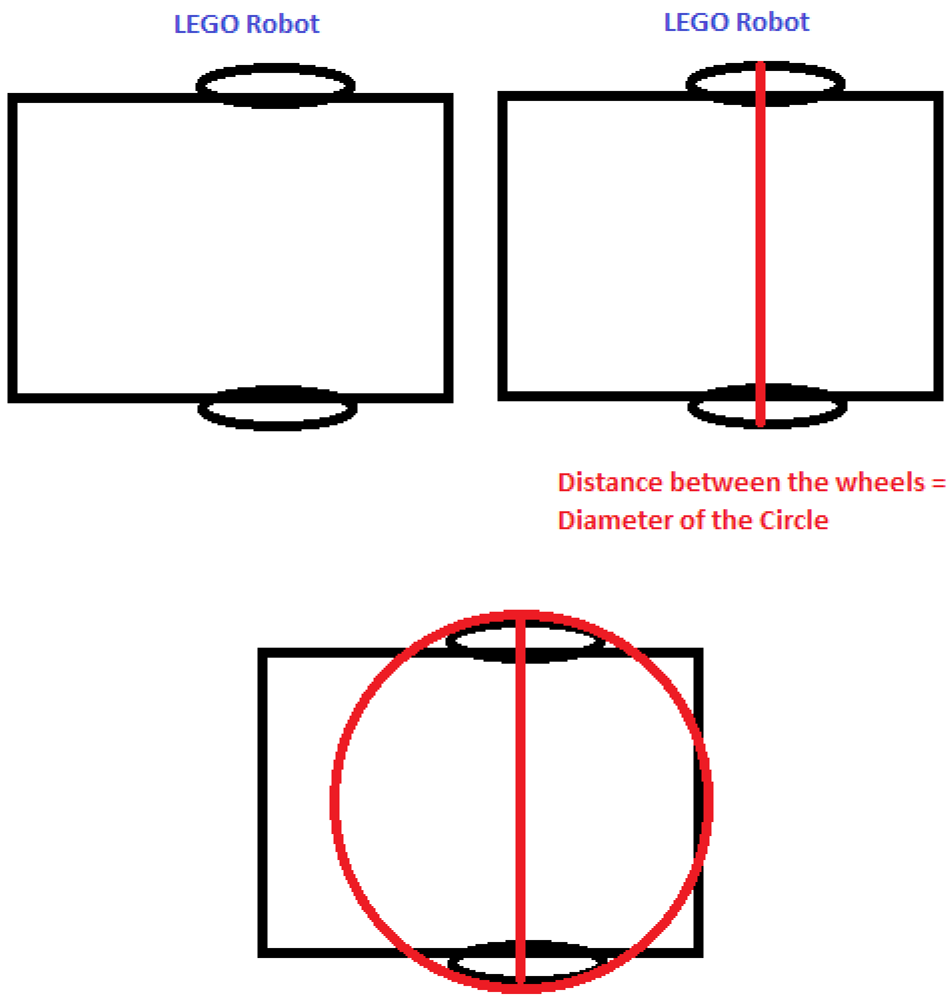
Swing Turn





In the swing turn, one of the wheels remains off while the other wheel moves either forward or backward to complete the turn

Point Turn



In the Point turn, one wheel moves forward while the other one moves backward.

- In a small group, students will calculate both the swing and point - turn having different scenarios of robots and wheel sizes. (see examples)
- Examples 1 and 2 using the swing turn.

Example 1: Use the swing turn

The circumference of the robot's wheels is 8 in
The distance between the wheels is 5 in
Calculate a 90 degree turn of this robot.

Circumference of Circle = π*d
= 3.14*10
= 31.4 inches

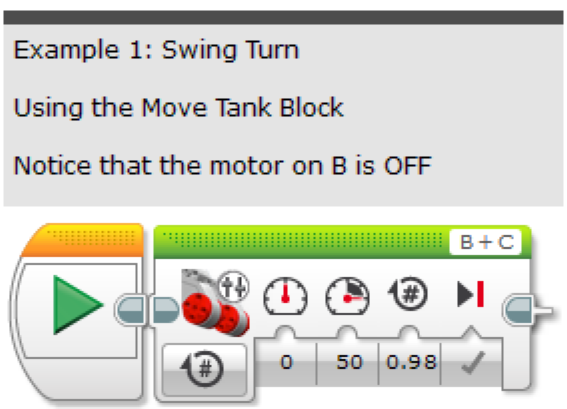
$$\frac{Circumference\ of\ Circle}{Circumference\ of\ the\ wheel} = \frac{31.4}{8} = 3.93 \text{ rotations}$$

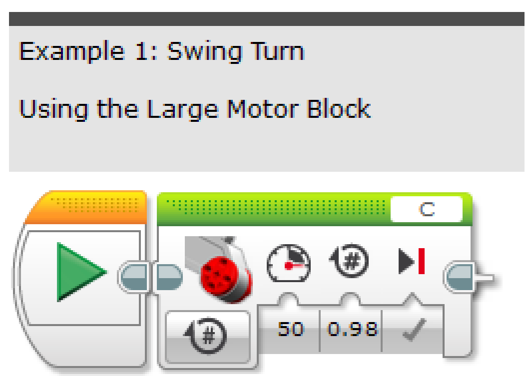
Meaning = The robot will travel a full circle after 3.93 rotations

To calculate the rotations needed for 90 degrees:

$\frac{90}{360} = \frac{1}{4}$ now, $\frac{1}{4}$*3.93 = 0.98 rotations

Answer: The robot will turn 90 degrees with 0.98 rotations





Note: The Swing Turn could be done using the ***<u>Move Tank block</u>*** *or the* ***<u>Large Motor block</u>***.

Example 2: Use the swing turn

The circumference of the robot's wheels is 5.5 in
The distance between the wheels is 4.2 in
Calculate a 30 degree turn of this robot.

Circumference of Circle = π*d
= 3.14*8.4
= 26.4 inches

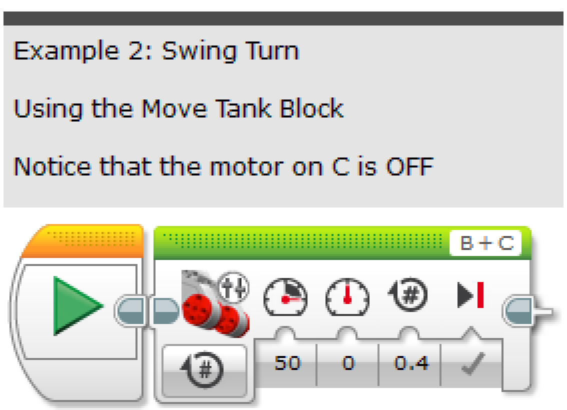
$$\frac{Circumference\ of\ Circle}{Circumference\ of\ the\ wheel} = \frac{26.4}{5.5} = 4.8 \text{ rotations}$$

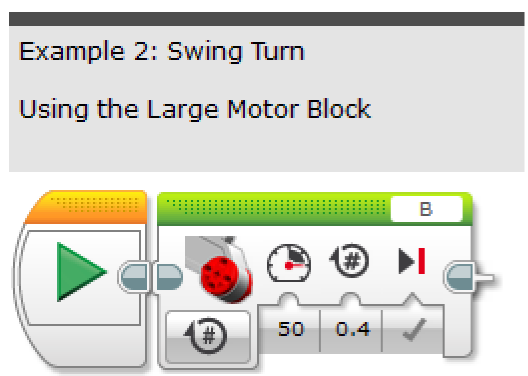
Meaning = The robot will travel a full circle after 4.8 rotations

To calculate the rotations needed for 30 degrees:

$$\frac{30}{360} = \frac{1}{12} \quad \text{now, } \frac{1}{12} * 4.8 = 0.4 \text{ rotations}$$

Answer: The robot will turn 30 degrees with 0.4 rotations





Note: The Swing Turn could be done using the ***<u>Move Tank block</u>*** *or the* ***<u>Large Motor block</u>***.

- Examples 3 and 4 using the point turn

Example 3: Use the point turn

The circumference of the robot's wheels is 7 in
The distance between the wheels is 6.2 in
Calculate a 45 degree turn of this robot.

Circumference of Circle = π*d
= 3.14*6.2
= 19.5 inches

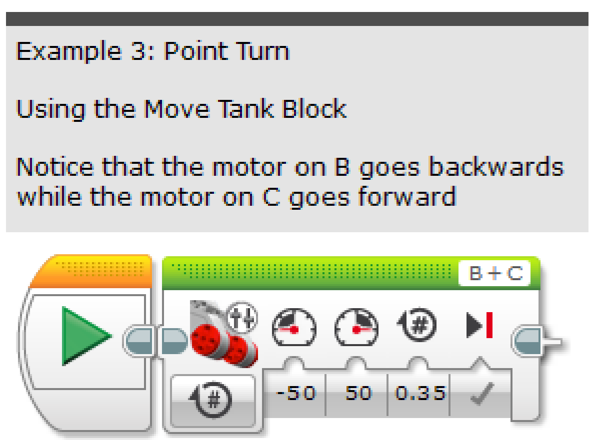
$$\frac{Circumference\ of\ Circle}{Circumference\ of\ the\ wheel} = \frac{19.5}{7} = 2.79 \text{ rotations}$$

Meaning = The robot will travel a full circle after 2.79 rotations

To calculate the rotations needed for 45 degrees:

$\frac{45}{360} = \frac{1}{8}$ now, $\frac{1}{8}$*2.79 = 0.35 rotations

Answer: The robot will turn 45 degrees with 0.35 rotations



Note: The Point Turn must be done using the ***<u>Move Tank block</u>***

Example 4: Use the point turn

The circumference of the robot's wheels is 10 in
The distance between the wheels is 4 in
Calculate a 127 degree turn of this robot.

Circumference of Circle = π*d
= 3.14*4
= 12.56 inches

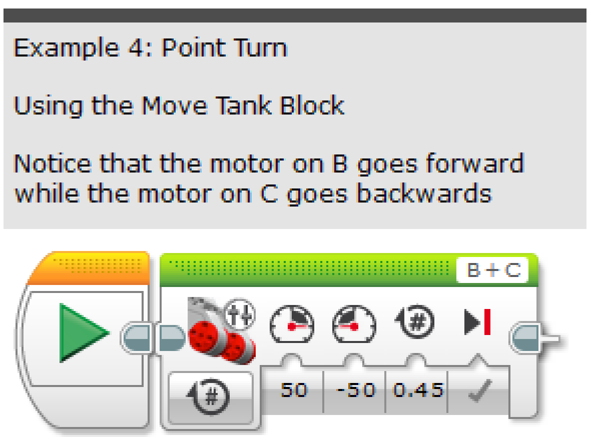
$$\frac{Circumference\ of\ Circle}{Circumference\ of\ the\ wheel} = \frac{12.56}{10} = 1.26 \text{ rotations}$$

Meaning = The robot will travel a full circle after 1.26 rotations

To calculate the rotations needed for 127 degrees:

$\frac{127}{360} = \frac{16}{45}$ now, $\frac{16}{45} * 1.26 = 0.45$ rotations

Answer: The robot will turn 127 degrees with 0.45 rotations



Note: The Point Turn must be done using the ***Move Tank block***

- (Suggested Activity) Formative assessment.
  Have students answer the following questions the next day:

1. James and Tyler are programming their Lego robot. The distance between the wheels of the robot is 4.5 inches. If they are using wheels with a diameter equal to 2.4 inches, calculate the number of rotations they need to make the robot turn 45 degrees? (Note: Solve the problem for both types of turns)

Enrichment. Lesson 3: Motor Rotation Sensor

Lesson 3: Using the Motor Rotation Sensor (Enrichment Lesson)

Duration/Time Frame: 1 to 2 class periods.

Topics:

- Using the Motor Rotation Sensor.
- Programming the Wait block.

Objectives:

- Create simple programs using the Motor Rotation sensor.
- Evaluate different ways to program the robot.

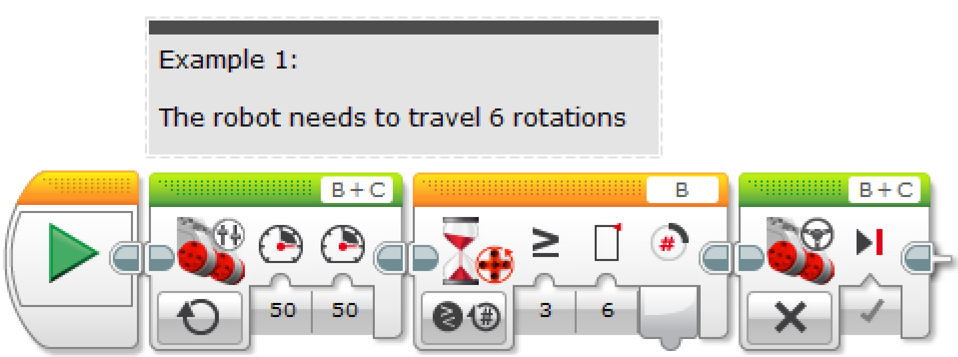
Materials:

- Computer
- Lego Robot

Procedures and Activities:

- Once the Motor Rotation sensor is introduced, students should be challenged to create and evaluate different ways to program the robot to accomplish the same tasks.
- (Suggested Activity). Challenge students to develop and evaluate a program that performs the same task as the ones from Lesson 1, but this time, using the Motor Rotation Sensor (Examples 1, 2, and 3)

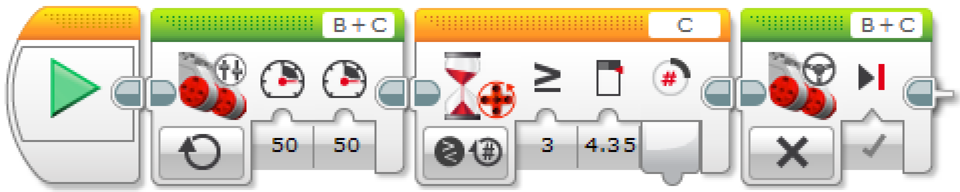
- Answers:



Example 2:

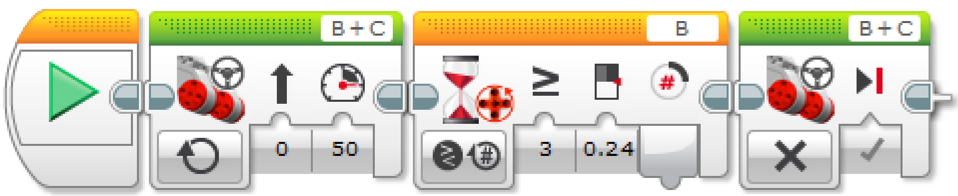
The robot needs to travel 4.35 rotations

Notice that for this example, the Motor Rotation sensor is checking the motor on C.



Example 3:

The robot needs to travel 0.24 rotations



- Reflection: Students should reflect on these other ways to solve the same tasks using the Motor Rotation Sensor.
- Conclusion: Challenge students to find different ways to program the robot to accomplish the same tasks *(Hint: Using other blocks such as the Loop or Switch blocks)*

Resources List

LEGO Mindstorms EV3 Software.

https://education.lego.com/en-us/downloads/mindstorms-ev3/software

Student-ready resources, teacher support, assessment tools, sample programs, and building instructions.

https://education.lego.com/en-us/downloads/mindstorms-ev3/curriculum