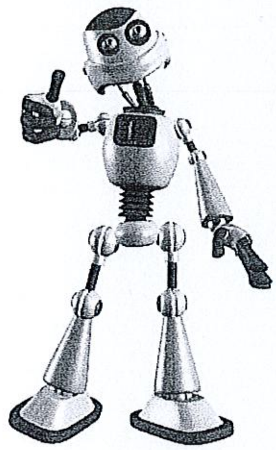
Chapter 1: Introduction



This book is a guide for teachers implementing a robotics unit in the classroom. It is aimed at middle years schooling (ages 9 - 15) but the wide range of activities can be adapted to suit older or younger students. The book is based around a single robot, the RileyRover, which is used in all activities. This approach is valuable in resource limited classrooms, as it allows the teacher to work with a 'standard' robot, rather than using valuable classroom time building and breaking down robots each lesson. The RileyRover design can be found at the back of the book, as well as being freely available online – www.damienkee.com. Please send me an email and let me know if you are using the design!

All activities are based around the 45544 LEGO MINDSTORMS Education EV3 core set. While the activities can be performed with the EV3 brick from Retail or Education, the building instructions have been compiled with the 45544 set in mind.

It is assumed that the teacher has a basic knowledge of how to open the EV3 programming environment and how to download a program to the EV3 unit. Please see the excellent tutorials built into the EV3 software environment for more information.

The book is divided into sections that follow a 10 week plan, although this can be modified to suit the needs of the teacher. The first 6 weeks takes students through a series of activities, progressively exposing them to new aspects of the EV3 programming environment. Following is a set of open ended challenges from which teachers may pick and choose to suit their particular class.

All challenges follow a similar structure:

- Scenario setup + background information. Teachers are free to develop each scenario further as they see fit.
- Equipment list. Aside from the standard EV3 robotics kit, all other required resources are easily sourced within a school environment.
- Teacher notes are provided on common issues that may arise with each challenge and how they are best dealt with.
- Programming examples in the EV3 software environment.
- Student worksheets to fill out (photocopy / print permission is provided).
- Extension activities.

Lesson Plan

The following is a lesson structure for a 10 week unit on robotics. This plan assumes approximately 5 hours of content per week in class, although the ability of the students involved may require slightly more or less time as needed.

Week 1: Organisation and RileyRover Basics

EV3 kits are sorted to ensure all pieces are accounted for. During this week students will also build the RileyRover or another equivalent robot. Students will learn how to use the EV3 programming language to move their robot around the floor using Student worksheet – *RileyRover Basics*. The 'Move Steering' block is the focal point of this week's challenge.

Week 2: History and Flowcharting

Students are introduced to robotics in general. Their use in society and the differences between fictional and real robots are described and the fundamental components of a robot are discussed. Students are asked to prepare a report on robots. Student worksheet – *What is a Robot?* is handed out with the due date left to the teacher's discretion. The concept of flowcharting is presented, and backed up by worksheet - *Flowcharting*. If these activities are finished early, move on to next week's activities.

Week 3: Keeping Track, How Far, How Fast: Data collection

Following on from previous weeks, students will learn to use the Content Editor to document the progress of their robot. Additional activities include the *How Far?* and *How Fast?* worksheets to learn about distance, velocity and data collection.

Week 4: How Many Sides? That Bot has Personality

Students will learn about the 'loop' structure as well as building on their knowledge of geometric shapes. Polygon properties such as internal and external angles are discussed. The Sound, Display and Brick Status Lights are introduced, both as a way to personalise the robot, but also to help debug programs. This is a good time to consolidate the classes' knowledge before moving onto Sensors.

Week 5: Help! I'm Stuck! Let's go Prospecting! Stay away from the Edge!

The concepts of sensors are introduced and the Ultrasonic and Colour Sensors are used to assist the robot with navigation. Students give their robot the intelligence necessary to make decisions for itself.

Week 6: Prospecting and Staying Safe, Going Up and Going Down

These chapters continue the work with sensors, introducing a new programming concept (the Switch Block) as well as a new Sensor (Gyro Sensor).

Week 7: Cargo Deliver, Prepare the Landing Zone

These chapters introduce the use of the Medium Motor as an additional actuator that can be used to manipulate objects. Teachers may choose to do one or both chapters, time permitting.

Week 8: Major Project (Mini- Golf, Dancing Robots, Robot Wave, Robot Butler, Meet your Adoring Public!)

Teachers may choose one or a number of these activities for the students to undertake. They may work in small or large teams, each with a few robots per team. Student may wish to pursue their own project, in consultation with the teacher.

Week 9: Major Project

Students continue working on their major project.

Week 10: As Seen on TV!

Students develop a multimedia marketing presentation with which to 'sell' their robot to consumers. This may take on any number of media formats (website, speech, newsletter article etc.)

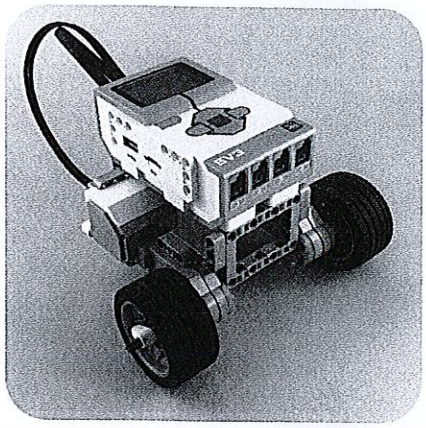
Resources

Extra resources that complement this book can be found on the website

http://www.damienkee.com

Chapter 2: RileyRover Basics

Overview: Build a robot that is capable of driving around an obstacle course.



Project: NASA is in the market for a new planetary rover to explore the recently discover planet Tobor-3. You are required to construct and test a robot that is capable of following a set of commands to explore the planet's surface. Before the robot is deployed, it must be extensively tested to ensure it will perform as expected. You can't fly a technician to Tobor-3 to reboot the robot!

Equipment required

- 1 EV3 robot kit per group
- 1 computer per group
- Masking tape and Tape measure

Teachers' Notes

This section will cover the following topics amongst others

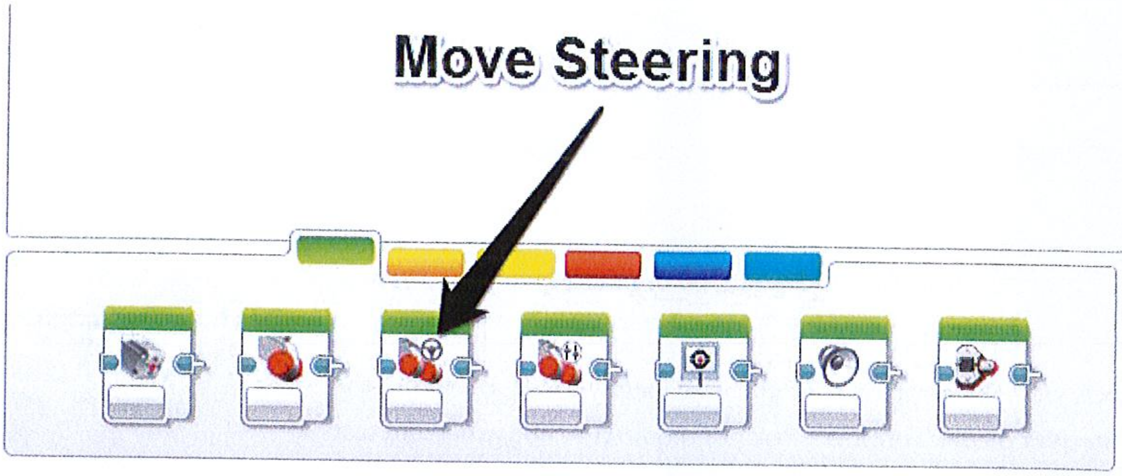
- Basic numeracy
- Decimal and fractional numbers
- Relationship between diameter and circumference
- Conversion between millimetres and inches

Get the students to build RileyRover robot presented in Building Instructions.

Photocopy and hand out Student Worksheet – RileyRover Basics. This worksheet gives the students a range of different activities to follow that progressively increase in difficulty. To make our robot move, we need to send instructions to the motors which in turn drive the wheels. The RileyRover design is often referred to as a wheelchair configuration, as it has a Left and Right motor that allows the robot to drive forwards, backwards and make turns.

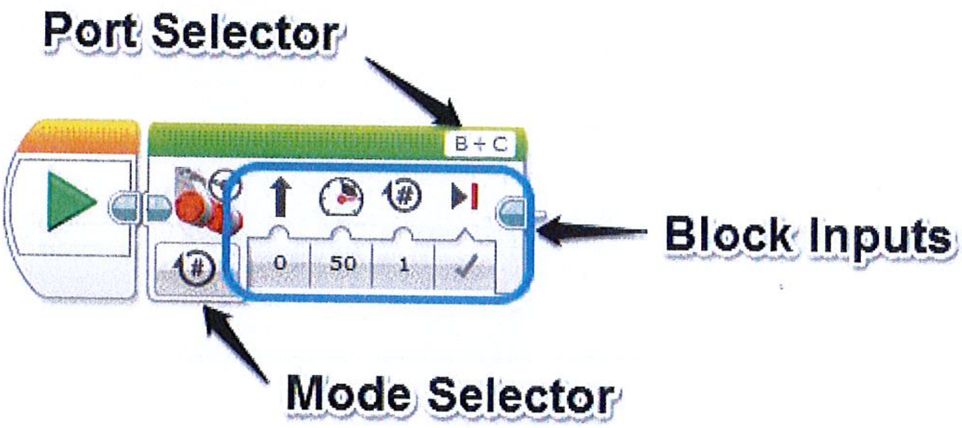
EV3 Software Specific

To perform the programming, we will need to know about the **Move Steering** Block, located in the Action Blocks palette (green). The figure below shows the **Move Steering** Block, highlighting its different block inputs.

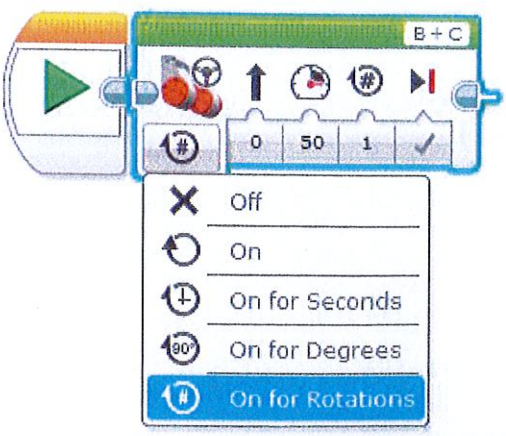


The **Move Steering** Block has several different parts to it as shown below.

The *Port Selector* identifies which Ports the motors are connected to. If you are using the RileyRover design, ensure that you have the left motor connected to Port B and the right motor connected to Port C (cables will crossover). If these are in the wrong spots, then our robot will turn left when we say turn right and vice versa.



The *Mode Selector* selects how you would like to control the duration the wheels will turn; OFF, ON, On for a certain number of seconds, On for a certain number of degrees or On for a certain number of rotations.



Block Inputs

The Block Inputs change depending on which *Mode Selector* has been chosen.

Steering: You can either type in a number, or drag the slider bar. '0' means straight ahead, '-100' means tight turn left and '100' means tight turn right. Numbers in between these limits will give you varying turns, from quite gradual turns through to very tight turns.

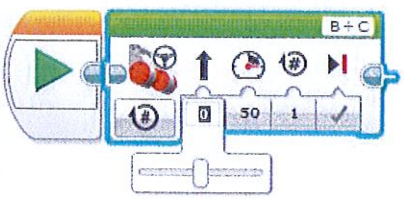
Power: Again you can type in a number or use the slider bar. '100' means 'as fast as possible' forward, '-100' means 'as fast as possible backwards' and '0' means no power (effectively a stop). Numbers in between these limits will make the robot travel at different speeds either forwards or backwards.

Rotations / Degrees / Seconds: This input (visible depending on which *Mode Selectors* was chosen) specifies how far the wheels of the robot will travel, ie. '2' in Rotations mode will make the robot's wheels turn two rotations, '4.5' in Seconds mode will make the robot's wheels turn for four and a half seconds.

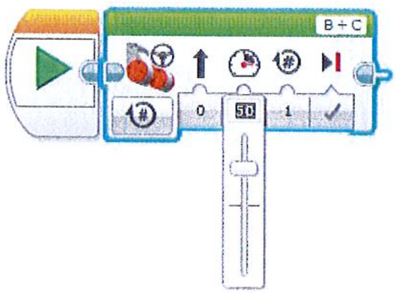
Brake at End: After the robot has completed its movement, the robot can either immediately apply the brakes to the motors (TRUE) or let the motors coast to a stop (FALSE).

Let's choose the *On for Rotations* option for the moment. With this mode selected, we can now set the different Block Inputs to complete the first question on the Student worksheet: Drive Forward 2 Rotations.

Keep the steering on '0' to go straight ahead

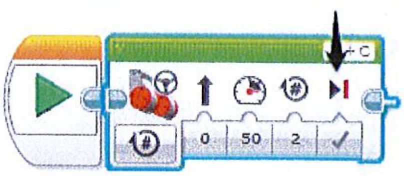


Set the power to 50% forward (-50 would be backwards)

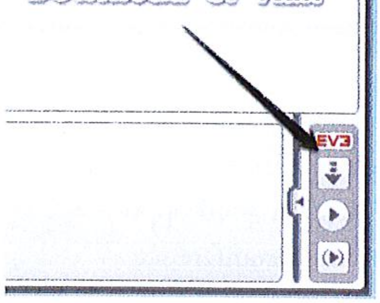


Set the Rotations to '2'

Set 'Brake at end' to TRUE



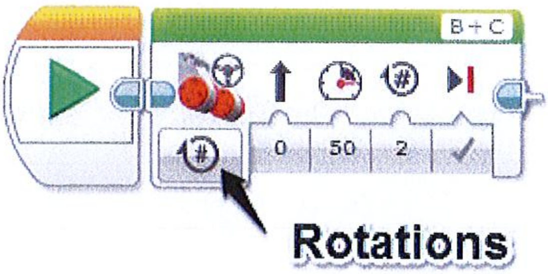
'Download' or 'Run'



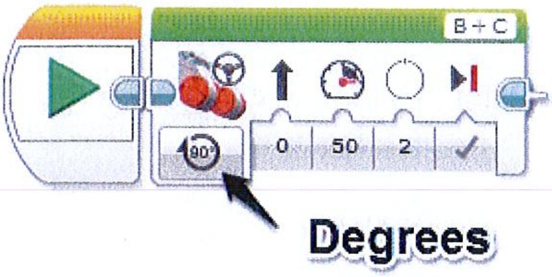
If all goes to plan, the wheels of your robot should drive forward exactly two rotations.

From the worksheet:

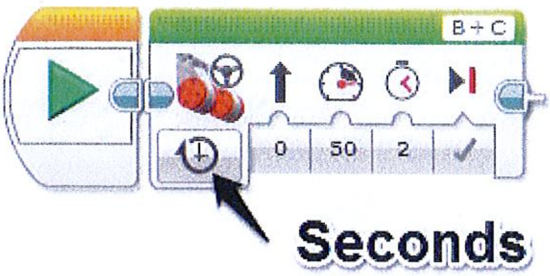
Drive Forward 2 rotations = 352mm or 13.9 inches (if you are using the EV3 wheels provided)



Drive Forward 2 degrees = 1mm. While the robot will barely move, students should see the motors 'jerk' forward a very small amount.



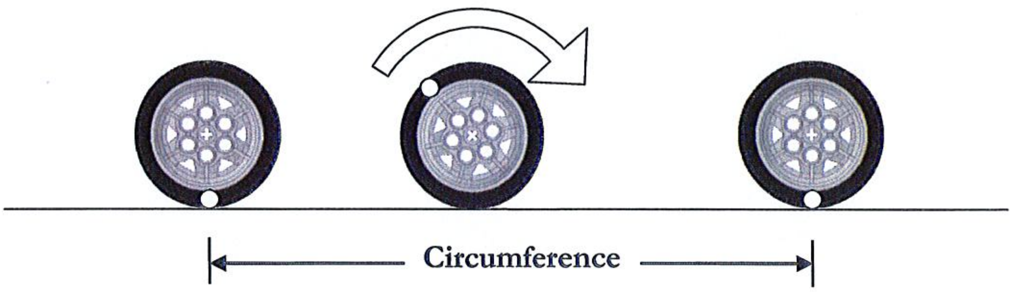
Drive Forward 2 seconds. How far the robot travels will be dependent on the power level chosen. Two seconds forward at 20% power will travel a different distance than two seconds forward at 100% power.



How far will the robot drive if the wheels turn 3 rotations? To figure this out, we need to characterise how the robot performs. This means, take measurements to determine the specifications of the robot's movement. This is a good opportunity to either reinforce or introduce the correlation between the radius of a wheel and its circumference.

Calculating the circumference can be done either mathematically or experimentally depending on the ability of the students.

Experimentally: Take a wheel off the robot and make a mark on the tire with either chalk or masking tape. Create a starting mark on the table and line up our tire mark with it. Now slowly roll the wheel until the tire mark again touches the ground. Make another mark at this point and use a ruler to measure the distance.



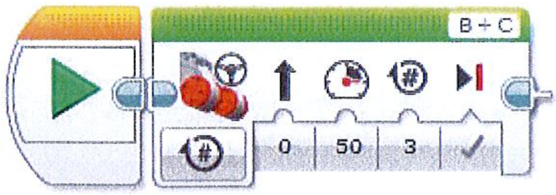
Mathematically: The circumference of a wheel can be calculated using the formulae: $c=\pi\times d$

Where c= circumference, $\pi = 3.14$ (approx) and d is the diameter of the wheel.

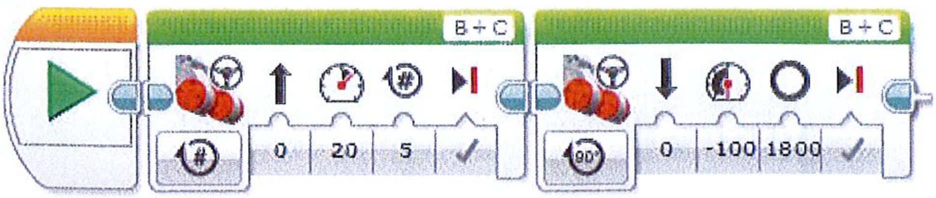
The wheel that comes as part of the standard EV3 set is 56mm (2.2 inch) in diameter which results in a circumference of approximately 176mm (6.9 inch).

What this means, is that for one complete rotation, the robot will travel 176mm (6.9 inches). Given that one complete rotation is 360 degrees, we can calculate that 1 degree of the wheel turning will result in 0.49mm.

For 3 rotations, the robot will travel 528mm (20.8 inches)

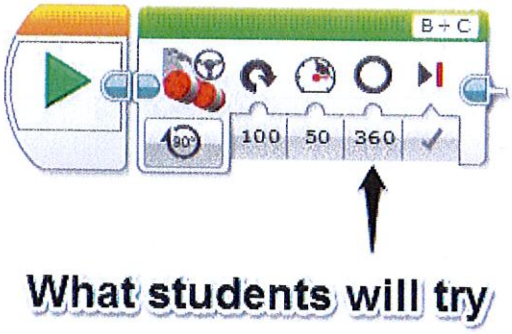


Drive Forward 5 rotations slowly and then backwards 1800 degrees backwards as fast as possible. Encourage students to calculate how far 1800 degrees is (1800 / 360 = 5 rotations). They should find the robot ends up exactly where it starts.



Making your robot turn

For the challenge where students are asked to make their robots turn around in a full circle (360 degrees), they will typically type in 360 degrees and proceed to run the program. When run however, if they are using the RileyRover, they will find that their robot does not actually turn 360 degrees but in fact far less.



This occurs because the **Move Steering** block is designed to control the *wheel* of the robot, not the whole robot. If we observe just the wheel, we will find that it does in fact turn exactly 360 degrees, just as it was told to do. The angle turned by the robot however is dependent on a few different conditions such as the size of the wheels and the distance between the wheels.

Calculating the required duration to make the robot turn 360 degrees is best done experimentally. Every robot design is slightly different, so the number of degrees required to turn a robot completely around may vary significantly, even with robots that look exactly the same.

TIP: The science behind this is that the turning radius of the robot is defined by the point where the wheels touch the ground. Given the EV3 has such wide wheels, it is difficult to determine exactly where the centre of contact with the ground is located. Heavy (or poorly constructed) robots may cause their wheels to splay out slightly, causing the centre of contact to be located slightly closer to the centre.

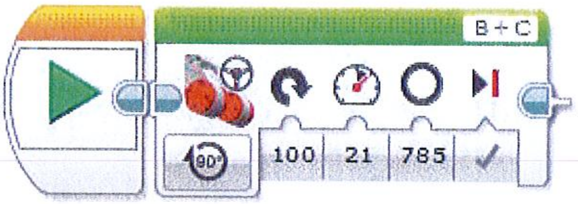
From the Worksheet:

Make your robot turn around a complete circle (360 degrees).

Keep increasing the Degrees parameter of the wheels until the robot does indeed turn 360 degrees. A sharp turn with the Steering Block Input to either the left (-100) or right (100) is required. Students can perform trial and error with different values until an acceptable solution is found.

To test, place a strip of tape on the floor. Start the robot with both wheels on the tape. A perfect 360 degree turn will result in the wheels ending up back on the tape.

For the RileyRover, with fresh batteries, on a smooth surface, an angle of 785 degrees for the wheels on a sharp turn gives an accurate 360 degree turn of the robot. Your robot's number might vary but should be close to this number.



Drive forward 500mm (20 inches), turn around 180 degrees and drive back to the start.

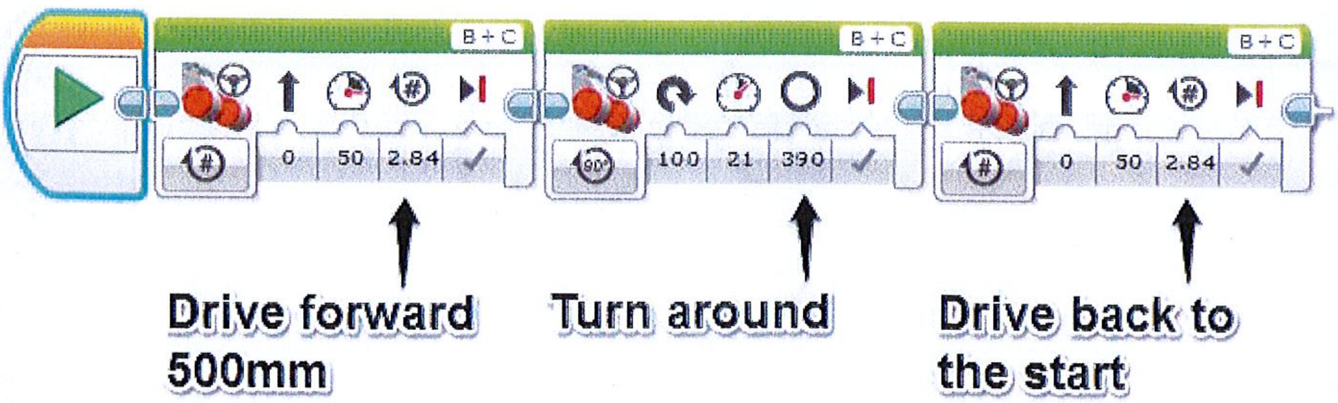
Layout two strips of tape, 500mm apart as our test distance.

The duration required to go 500mm (OR 20 inch) can be calculated by dividing 500mm by the circumference of the wheel (176mm / 6.9 inch).

$$x = \frac{500}{176} \quad \text{OR} \quad \frac{20}{6.9}$$

$$x = 2.84 \text{ rotations} \quad \text{OR} \quad 2.90 \text{ rotations}$$

Using the turning angle discovered above, the students can do a rough calculation of what is necessary to turn 180 degrees. For the RileyRover, on a flat surface the wheels require approximately 390 degrees (785 / 2) to perform an accurate 180 degree turn.



Make your robot drive in a Figure 8 shape:

When running the 'figure of eight' challenge, it can be left open ended or a specific shape can be offered. Encourage the students to draw a picture of the path they are attempting before they start programming. Encourage them to look at each of the individual movements, and relate them back to separate **Move Steering** Blocks. To create a test environment, place 2 markers down, 500mm (20 inch) apart. The robots will need to perform their runs around these markers and are not allowed to hit or move the markers. Robots should ideally make it back to where they start.

If your students are unsure of what a 'figure of eight' looks like, here are a variety of different versions. The digital figure of 8 is the easiest to implement, as the students already know how to drive straight and perform accurate 90 degree turns. If students quickly finish one version, encourage them to try a more complex version.