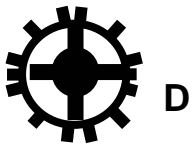


Exact Control – Spin Turns

Using degrees to program an exact turn by the physical robot



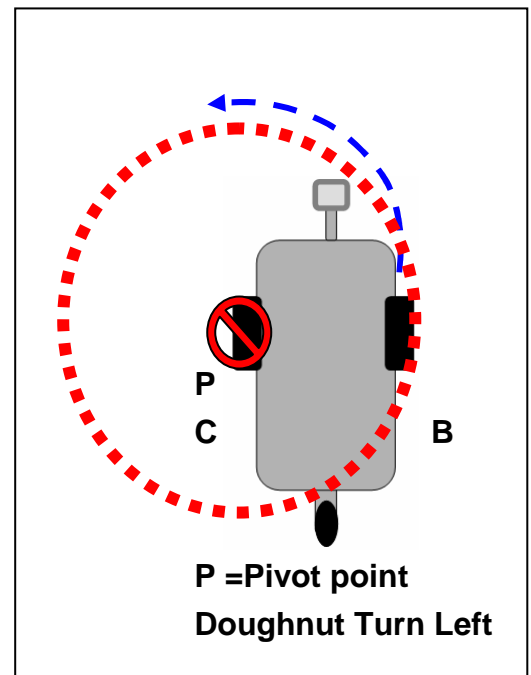
Pre requisite activity – Exact Control – how far in degrees, calculate your robot's 'key'. This worksheet is available on this website.

Calculation Tool - Calculate Degrees .xls , available on this website

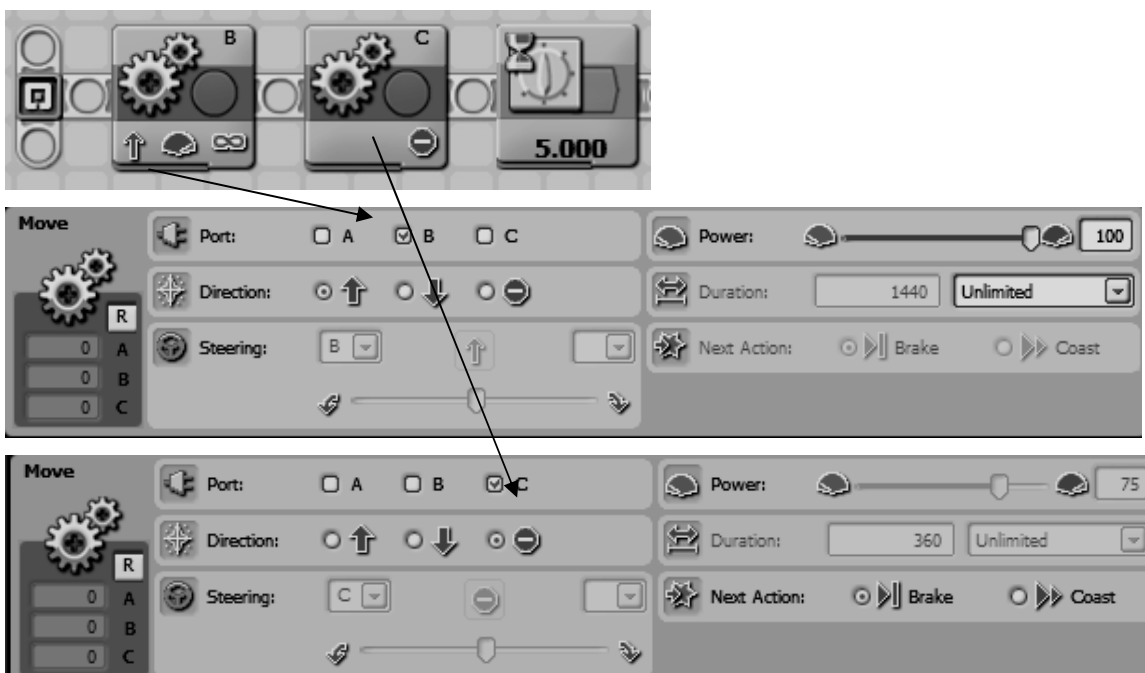
TYPES OF TURNS = CIRCLE SIZE & ARC ACUITY

The NXT robot can execute a number of different types of turns, these are all based on the robot making a circle or arc of a circle of various sizes :

A doughnut turn where one wheel is stopped and the other wheel moves forwards or backwards. The robot takes up more room physically to make this turn and is not the best choice when space is limited. The pivot point for this type of turn is the stopped wheel, furthermore, this turn is influenced by the friction on the stopped wheel. For accuracy, the influence of friction makes exact calculations tricky. Test this – If the robot is permitted to make a full circle with this type of turn, the circle that the wheels make will be larger than the spin turn below.

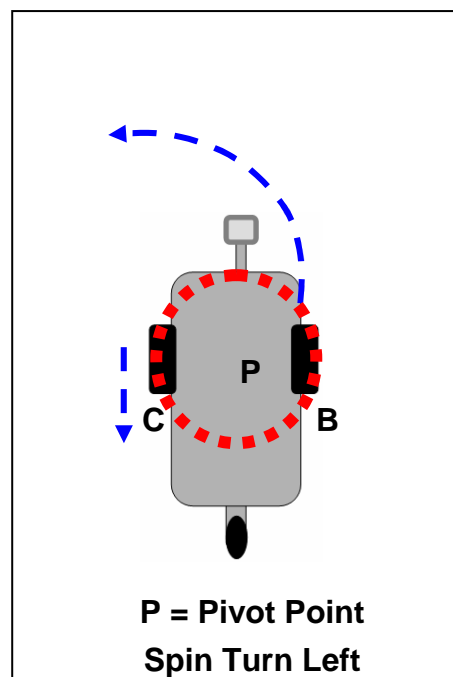
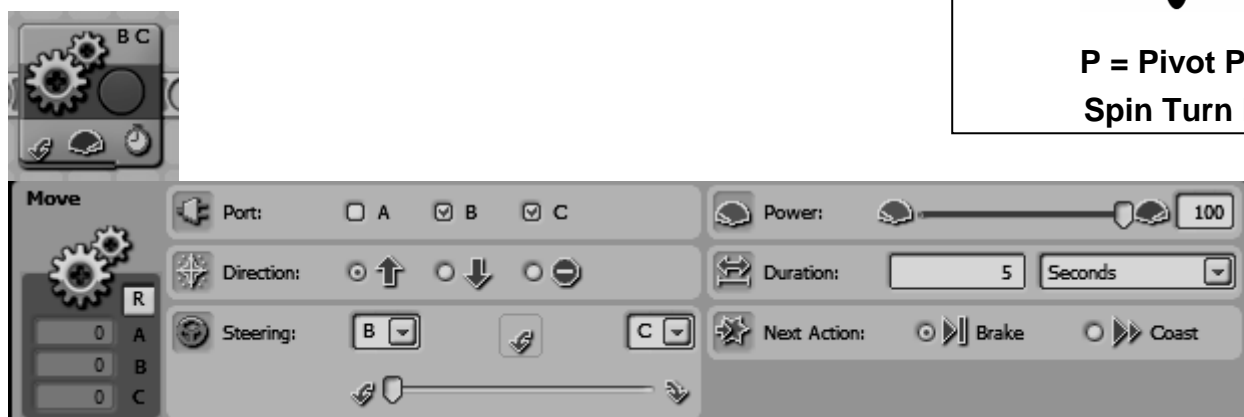


NXTg Common Palette programming doughnut turn for 5 seconds



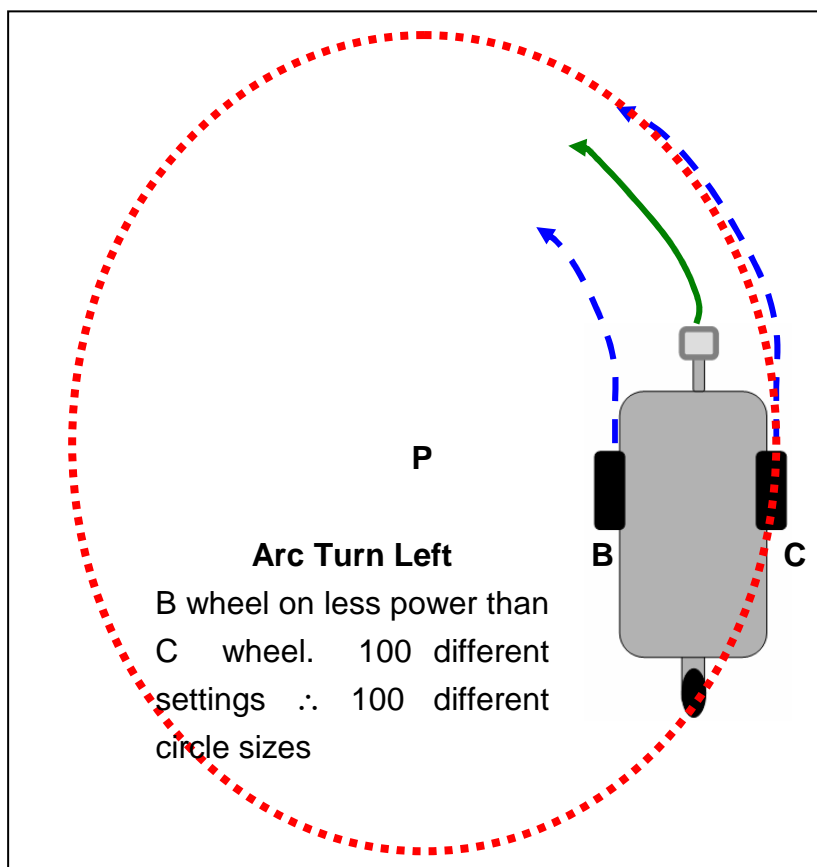
A spin turn where one wheel is moving forward and the other moves backwards. The robot pivots around a centre point situated in the middle of the two wheels. This type of turn takes up the least physical room by the robot and is used when space is limited. As both wheels are moving, the effect of friction is less than the doughnut turn. Test this type of turn on a full circle and observe.

NXT g programming for spin turn- common palette

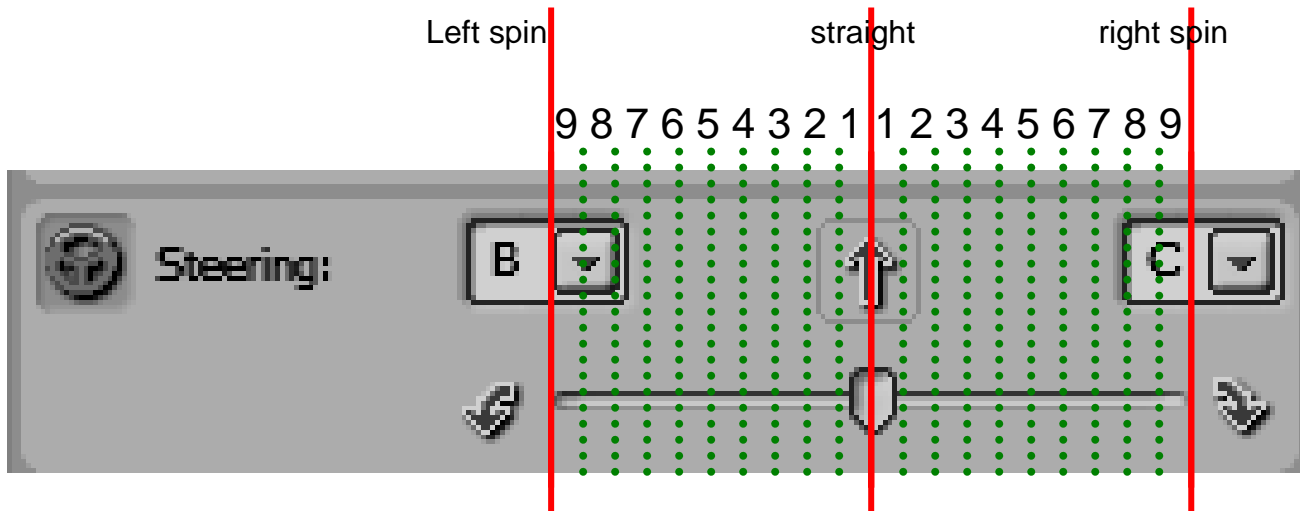


An arc turn where both wheels are moving forward and the power to the wheel on the inside of the circle is reduced so that the robot actually moves forward in an arc (rather than pivoting on the spot).

This type of turn takes up the most room and is the most difficult to calculate accurately because there are so many settings that will influence circle size.



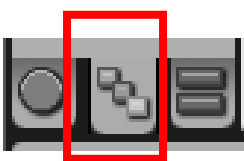
If you program using the COMMON PALETT you can simply use the steering bar on one of the arc settings - there are 9 'notched' settings (The green lines on the illustration following - 9 left, 9 right , but the circle size left or right on the same notch will be the same) , this will exclude the straight setting and the far left /right settings (spin) (the red lines in the lower illustration) .



Common Palette – arc left on the 4th ' steering notch'



Using the steering bar your NXT robot is able to execute 9 different circle sizes/arc lengths.



If you opted for using the complete palette you the NXT robot has 100 power settings that can be used to control individual motors. You would need to check a minimum of 100 power settings and measure the full circle size produced for each combination to begin to program for accuracy.

Complete Palette – Controlling the B and C motors individually and using the 100 power settings



Configuration settings for these motors are on the next page. Note the POWER setting. This controls the size of the circle/act acuity



Basically, the arc type turn produces too many variables and will not be used in this exploration.

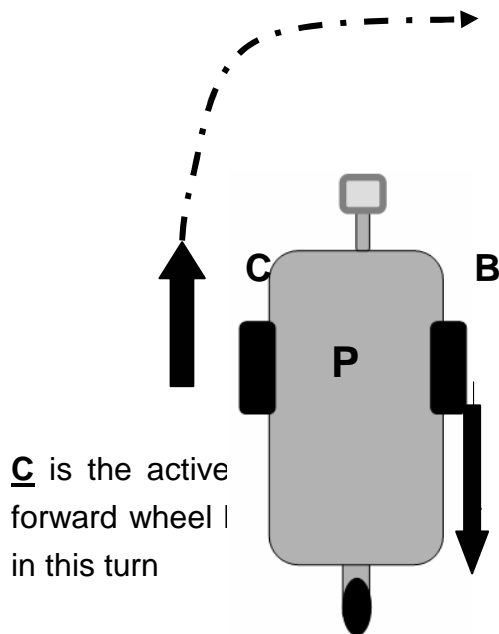
PROGRAMMING ACCURATE SPIN TURNS

In this exploration we will look at the spin turn size, the arc length of that circle formula and then use the arc length we have calculated to program accurate turns by the NXT robot. We will convert the distance the wheel needs to travel for that length circle arc into degrees using your robot's key that you calculated earlier and be able to program exact sized turns.

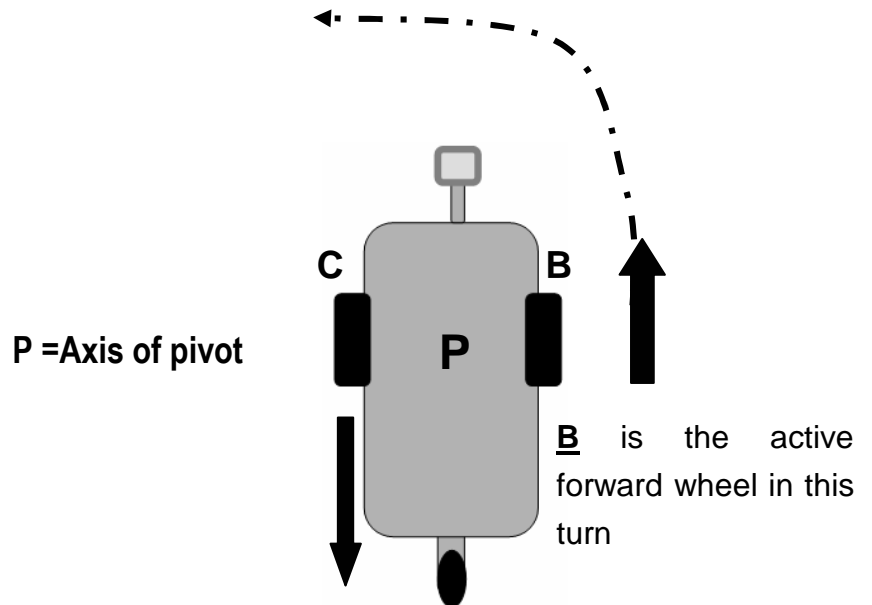
As we now know that the **DEGREES** reading/setting does not mean that your robot can turn a specific degrees turn, the reading refers to the degrees of rotation of the axle which then causes the rotation of the wheel.

By setting the **STEERING** bar completely Left for a LEFT turn or completely right for a RIGHT turn the robot will execute a tight turn pivoting from P (the pivot point)

PIIVOT TURN RIGHT



PIVOT TURN LEFT



To control how far the robot turns you will need to control the degrees setting for the forward wheel

For a right turn this is the C wheel

For a left turn this is the B wheel

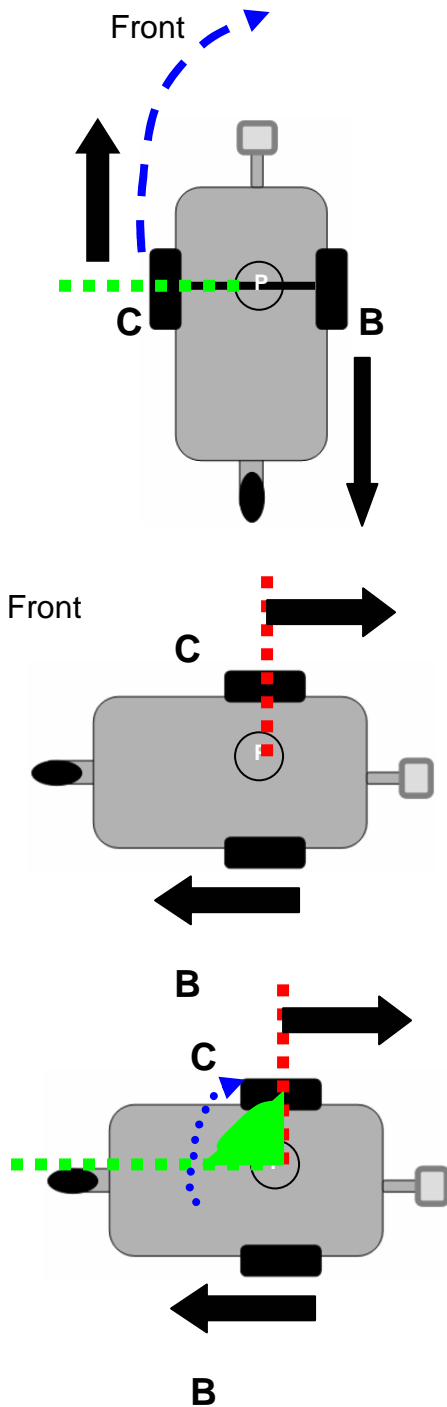
The question is how far does the forward driving wheel have to travel to execute a turn of a certain size.

Then using the NXTg programming environment this distance will be translated into degrees using your robot's 'key' that you calculated earlier..

Though we will calculate the distance traveled by the forward driving wheel (as this wheel determines the circle/arc size/length, the opposite wheel will need to travel exactly the same degrees to execute the pivot turn.

WHAT DEGREES?

Here things may become a little confusing as we are referring to degrees for 2 different attributes that are both using the word 'DEGREES'. So let's define what we mean:



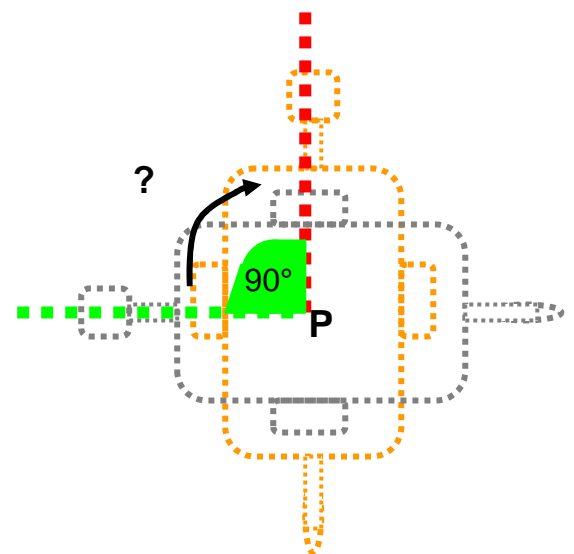
1. **The actual physical robot** will make a spin turn of a certain number degrees. The example at left shows a 90° turn by the robot. *In this document we'll refer to this physical degrees turn as NXT°*

I define the degrees of this turn as the number of degrees measured from the line created by the drive axles start position (lime dotted line at left) and the forward drive axles end position (red dotted line) where they intersect at the pivot point at the centre (circle with P at left) The end point will be the exact centre of the robot from P in a line through the centre of the robot to the front (purple dotted line at left). In the illustration left above I would be executing a right turn of 90°. What I need to know is how far the c wheel has to travel on an arc to execute the turn size I require, in this case it's 90°

The diameter / radius line of the circle will run along the axles with the pivot at it's centre.

The pivot centre is the exact center between the two wheels of the robot. (P). The diameter of

the circle will run along the axles with the pivot at it's centre



The angle of the robots physical turn NXT° is the angle made by the two axle lines (see the lime green angle at left) , the start point and end point, with P at it's centre . We'll use the arc on the circle formula to calculate exactly how far the forward driving wheel need to travel to make this

NXT° degrees

turn. This is the most exact method of controlling the robots turns and is far more accurate than manipulating the robot and using the VIEW DEGREES function on the robot itself to program turns.

Our second reference to degrees is :

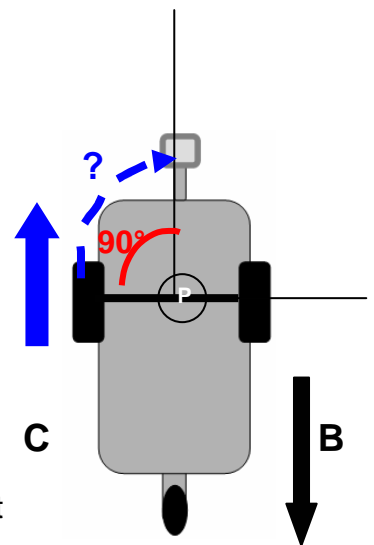
2. **Degrees – degrees rotation of the axle** . This refers to the degrees of rotation of the axle which then causes the rotation of the wheel which then causes the robot to travel a specific distance. This degrees setting is the degrees we use in the programming DURATION to have exact control of distance

CALCULATING EXACT TURNS

To program exact turns we'll need to do 3 additional steps beyond having calculated your robot's 'key' i.e. How far your robot travels per degree

:

- Determine the actual size of the spin turn's diameter and radius and use this in our calculations. We only need to do this investigation once unless you change the robot's physical build, wheel or tyre size.
- Determine the required NXT° turn size (turn of the physical robot) for your particular challenge. E.g. First LEGO League mat missions. Illustration at right is NXT° 90°
- Use a standard mathematical formula to calculate how long the arc for this NXT° turn is. Illustration above right is the length of the blue arc.
- Convert this length into axle turn degrees for the forward driving wheel of the robot using your robot's previously calculated 'key' and use these degrees for DEGREES DURATION in a NXTg program for a spin turn .



We will use a 90° turn as our test turn

a) Determine the actual size of the spin turn's diameter and radius

For this investigation we will need to use/make a few tools , we will use a paint stamp pad to load the robots tyres with paint so that when it executes a full circle spin the tyres will print the circumference of the circle on a large sheet white paper. A large sponge soaked with weak black

paint makes a good stamp pad.

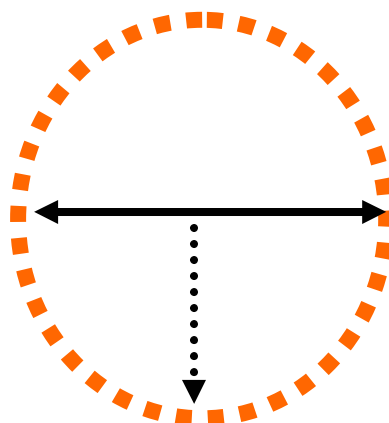
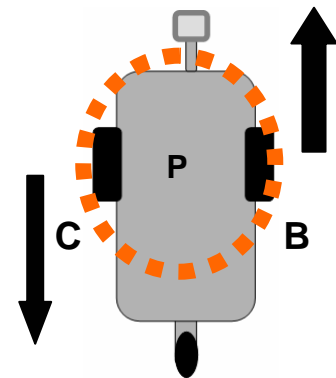
Program the robot to execute a full circle spin. Use a calculated guess for DURATION – degrees. This is unimportant at this point as we just want the robot to make a full spin circle (a little more is ok too) so that we can measure it e.g.



We use the steering set completely to the left or right to standardize the circumference (size) of the circle our robot executes to simplify our calculations, as explained previously this is a spin type turn. .

Download the program, load the robots tyres with paint and run the program with the robot on a large sheet of white sheet of paper.

Measure the diameter of the circle that the robot made (outside of tyre mark to outside of tyre marks) and then calculate the radius .



My circles diameter is :
cm

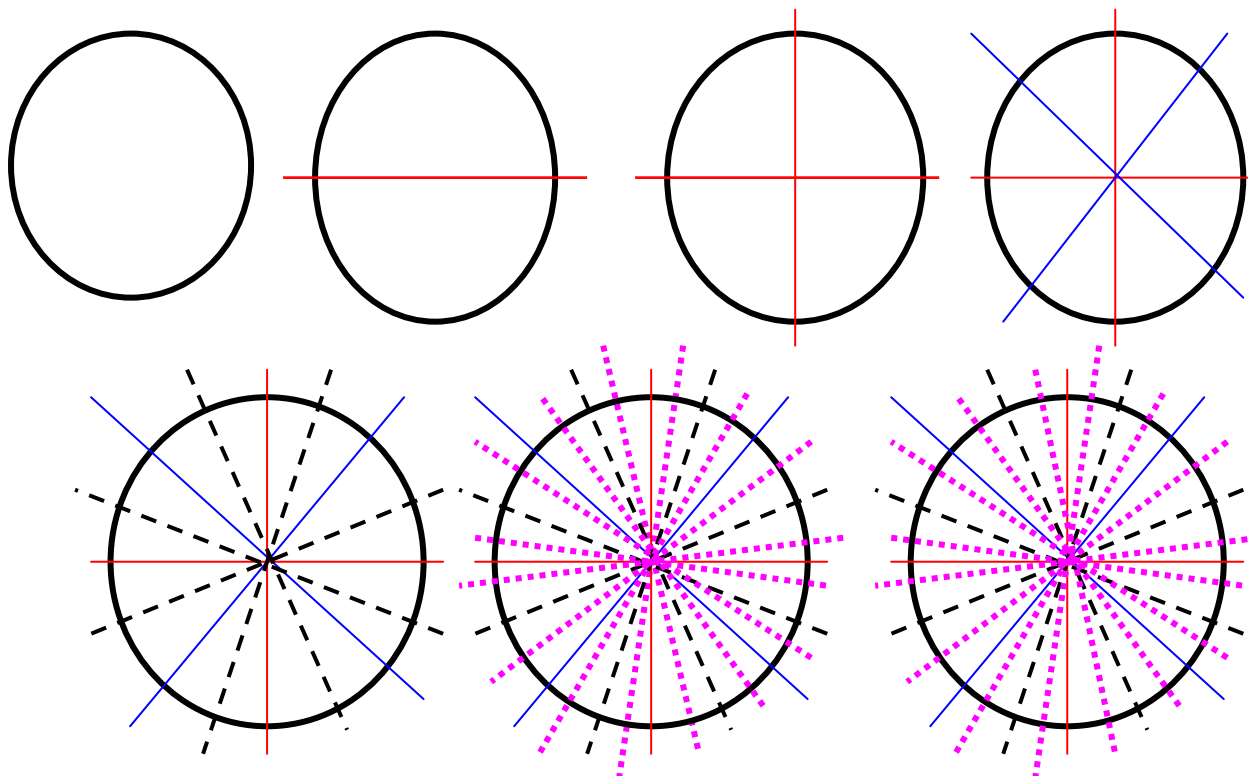
My circles radius is :
cm

b) Determine the required NXT° turn size (turn of the physical robot) for your particular challenge

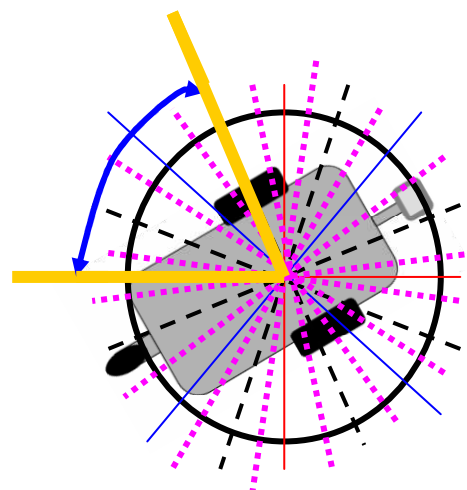
We'll need to make a simple clear protractor large enough for our robot to sit on. Make this out of

clear plastic such as 2 clear sheets of A4 acetate used for comb binding booklet covers, tape them together. You'll need to use a dinner plate as a template to draw a large circle on the plastic with a permanent black marker, then draw a line through the diameter and then the diameter again at right angles. Continue dividing up the protractor circle until you have divided it into 32 equal segments, each segment will be 11.25° . You can either mark in the degrees cumulatively i.e. 11.25, 22.5, 33.75 etc. or simply count the segments to determine how many NXT° your robot needs to turn. The Calculate Degrees Excel worksheet will automatically calculate for you if you enter some initial data.

Protractor



When you need the robot to make specific controlled turn, place the protractor under the robot with the drive wheel axles aligned on one of the lines and the centre of the robot's pivot directly over the centre of your protractor. Manipulate the robot to make the required turn by placing a finger on one drive wheel and another finger on the other drive wheel and gently moving one wheel forwards and the other wheel backwards to manually make a spin type turn. Use the protractor to identify the number of NXT° degrees the forward driving wheel needs to travel (at right, this is between the 2 yellow lines) . You are measuring from the start position of the forward drive axle to the end position of the forward drive axle. Record the degrees (or number of segments x 11.25).



Now we'll calculate the length of the arc that the drive wheel needs to travel.

c) Use a standard mathematical formula to calculate how long the arc for this NXT° turn is.

To use the NXTg programming software to program the robot to execute a specific NXT °angle turn we need to calculate the length of the arc that the drive wheel needs to travel. Then we'll use the "Key" we calculated for our robot to determine exactly how many degrees we need to program for DURATION in a spin type turn for our robot.

Source :

<http://www.mathopenref.com/arclength.html>

"The arc length is the measure of the distance along the curved line making up the arc. It is longer than the straight line distance between its endpoints

The formula the arc measure is:

$$\text{arc length} = 2\pi R \left(\frac{C}{360} \right)$$

where:
C is the central angle of the arc in degrees
R is the radius of the arc
 π is Pi, approximately 3.142

$2\pi R$ is the circumference of the whole circle, so the formula simply reduces this by the ratio of the arc angle to a full angle (360).

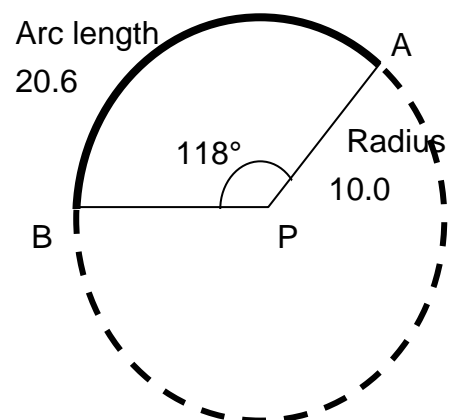
Here's an example of this calculation for the arc on the circle below:

$$\text{Arc length} : 2 \times 3.142 \times 10 \times \frac{118}{360}$$

If you wanted to put this calculation into an excel spreadsheet formula it would be :

$$(((2*3.142)*10)*(118/360))$$

The Calculate degrees spreadsheet provides a number of pre-formatted calculation tools that will automatically calculate once you have entered your basic data



d) Convert this length into axle turn degrees for the forward driving wheel of the robot using your robot's previously calculated 'key' and use these degrees for DEGREES DURATION in a NXTg program for a spin turn .

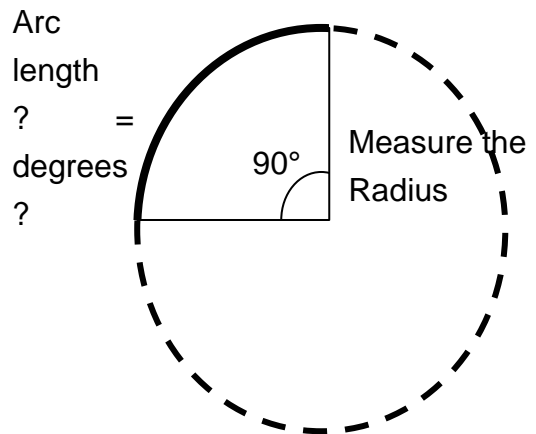


We now know exactly how far the robots forward driving wheel needs to travel to execute our turn.

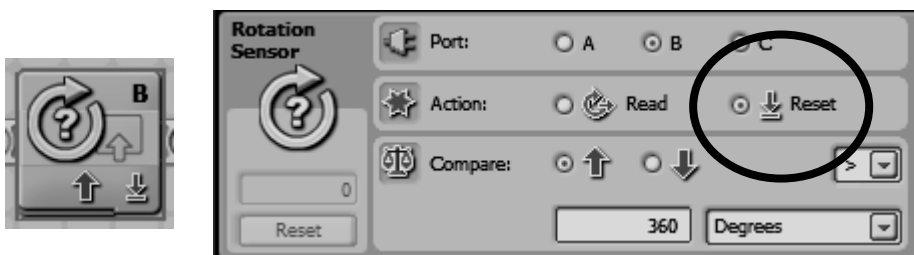
Use the key you calculated for your robot, this tells you how many mm your robot travels per degree.

Example :

How far do you need to travel? 20.6 cm
 Conver this to mm 206mm
 What is your robot's key? 0.0493
 Divide the mm you need to travel by 0.0493
 The robot needs to travel exactly 4179°
 Now program your robot to make a spin turn for DURATION 4179°



Sometimes, within a program it is wise to re-set your degrees sensor to '0', this will improve accuracy. Find this icon in the "Complete Palette – sensor"



The Calculate Degrees.xls spreadsheets will provide you with pre formatted tools to assist you with all your

calculations. Repeat b, c and d for each NXT° turn (use the protractor you made previously though)

Teachers Notes

Programming using degrees and manual methods is only as accurate as the measurements that the students take. It is vital that students recognise the need to measure accurately and note exactly where they are measuring from and to, when using degrees settings the distance should be taken from the centre of the axle of the motor you are using.