

INTRODUCTION TO ROBOTICS LESSON PLAN

USING THE EV3 PROGRAMMING APP

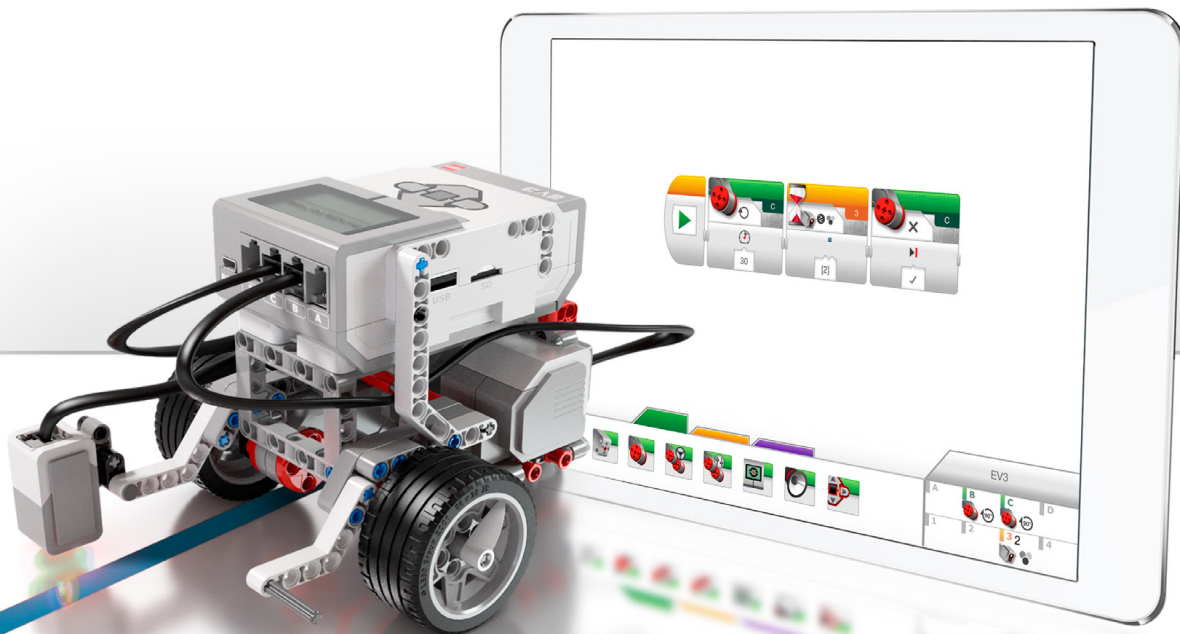
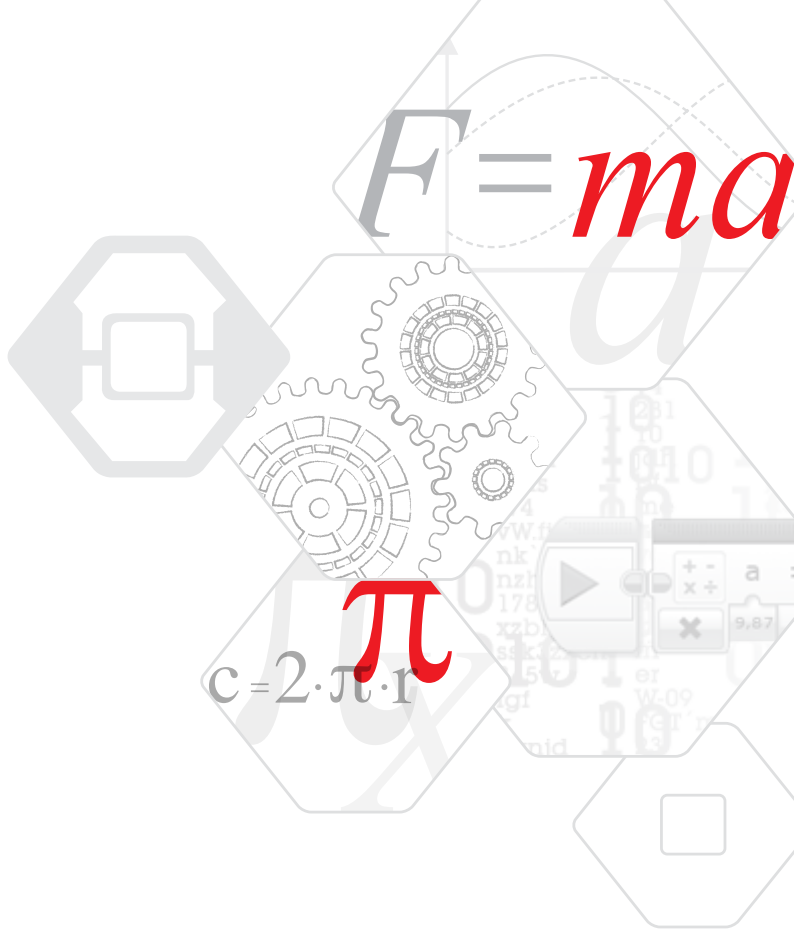


Table of Contents

| | |
|--|----|
| Introduction to Robotics Lesson Plan | 3 |
| Lesson 1 - Building and Setup | 4 |
| Lesson 2 - Curved Move | 6 |
| Lesson 3 - Move Object | 8 |
| Lesson 4 - Stop at Object | 10 |
| Lesson 5 - Stop at Angle | 13 |
| Lesson 6 - Stop at Line | 16 |
| Lesson 7 - Follow a Line | 18 |
| Master Challenge 1 - The Turntable Challenge | 20 |
| Master Challenge 2 - The LEGO® Factory Robot Challenge | 22 |
| Design Brief Challenges | 24 |
| Relevant Standards | 25 |
| Appendix A | 32 |
| Appendix B | 33 |
| Appendix C | 34 |
| Appendix D | 35 |

Introduction to Robotics Lesson Plan

This Lesson Plan provides you as an educator with a step-by-step procedure for how to use the EV3 Programming App with the classroom-based lessons. Each lesson and challenge will give you the help you need to prepare, run, and assess the class. It is up to you to select which and how many of the provided extra tasks and challenges you will use in your Robotics course. In the Design Brief Challenges section, you will find a range of open-ended ideas that encourage a more exploratory approach compared to the tutorials. You can either start your course by focusing on some of the Design Brief Challenges, letting students know in which tutorials and sections of the help text they can find help and inspiration OR you can have students complete them after a more structured start using the tutorials.

Before Starting the First Lesson

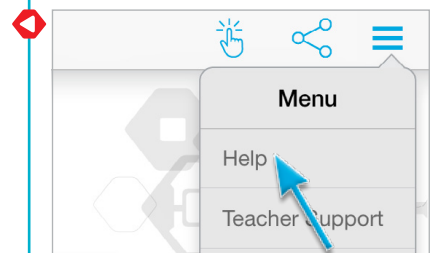
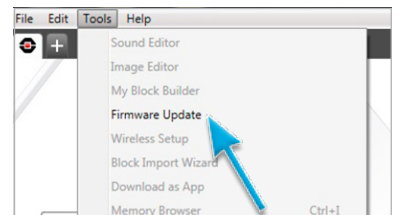
If you have never worked with LEGO® MINDSTORMS® Education EV3 before, you should ensure the following:

1. Each tablet has a pre-installed version of the LEGO MINDSTORMS Education EV3 Programming App.
2. Each EV3 Brick has the latest firmware and is fully charged. To install firmware, you need a desktop version of the EV3 Software. For more instructions, refer to the User Guide, which you can access from the Menu.
3. Before connecting tablets and EV3 Bricks via Bluetooth in the classroom, we recommend renaming each EV3 Brick. This can be done in two ways:
 - a. Update the name via the desktop EV3 Software using a USB cable.
 - b. Update to firmware V1.07E or later and change the name via the EV3 Brick Settings Area (see the User Guide for more help).
4. Check out the Quick Start Video from the Menu.

You may want the students to understand the names and functions of the different elements in the brick set. Discuss the naming and basic functionality of the key hardware components and establish a set of brick management rules. A copy of the 45544 LEGO MINDSTORMS Education EV3 Core Set Elements List is included in the User Guide. The User Guide is your source for everything relating to the LEGO MINDSTORMS EV3 Hardware.



Firmware Update



Lesson 1 – Building and Setup

Objective

After completing this lesson, students will be able to build the Driving Base, connect the tablet to the EV3 Brick, and download and run programs that control the robot's behaviour.

Duration

2 to 3 x 45 mins.

Preparation

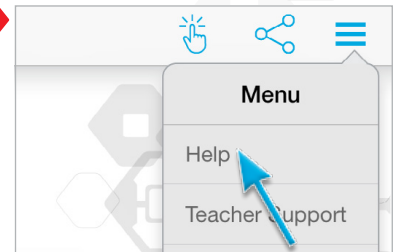
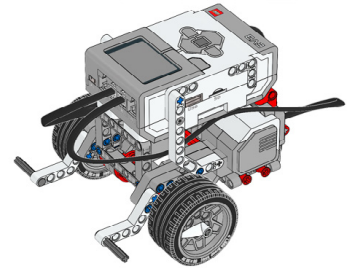
Understand the process of connecting a tablet to the EV3 Brick. Watch the Quick Start Video for guidance. Distribute one EV3 Core Set and one tablet with EV3 Programming App installed per 2-3 students. Optional: cardboard, textiles, and other materials for personalising the robots.

Procedure

1. Students build the Robot Educator Driving Base using the Building Instructions booklet (included with the 45544 Core Set) or the App-integrated Building Instructions available via the buttons on page 2 of each tutorial.

Optional: An effective way of allowing students to take ownership of their robot is to have them personalise it using additional LEGO elements and other material. By doing this, they can turn their robot into a puppy, elephant, or even a fantasy creature.

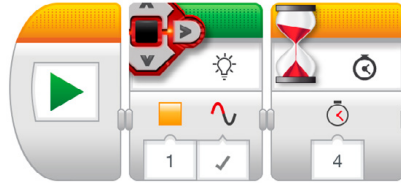
2. As a class, go through the process of connecting the tablet with the EV3 Brick and running the first program OR direct the students to the Quick Start Video, which will help them to connect the devices for themselves.
3. Students use the Programming App to make simple programs that
 - a. make their robot play a sound that is appropriate for their creature;



- b. make their robot display an image or their own text in the EV3 Brick Display;
and



- c. make their robot flash the Brick Status Light.



Assessment

Observe and/or ask questions to determine if the students:

- follow the building instructions to construct the Driving Base successfully;
- connect and download programs;
- manage to create and run simple programs; and
- work cooperatively to solve the tasks.

Lesson 2 – Curved Move

Objective

After completing this lesson, students will be able to navigate their robot through an obstacle course. By selecting the correct programming blocks and setting their parameters, students will know how and when to use point turns, single-motor turns, and curved turns.

Duration

2 to 3 x 45 mins.

Preparation

For task 5b you will need rubber bands to allow students to attach a pen to their Robot. For task 5c you will need to prepare an obstacle course on the floor. You can use a large sheet of paper and markers or place sticky tape on the floor (see illustration below).

Procedure

1. Introduce students to the Lobby of the EV3 Programming App. Students need to know where to find a given Robot Educator tutorial and how to open it. Demonstrate the flow of one tutorial to ensure that students know their way around the tutorials in combination with the Programming Canvas and Hardware Page (see also the Quick Start Video).
2. Students complete the **Curved Move** tutorial, which introduces the Move Steering Block.
3. In the “Test It” phase, the students will open a sample program (this will close the current tutorial). Ensure each group takes the time to describe and explain the robot’s behaviour when running the provided sample program using their own words. This encourages the students to reflect on what they see and how that relates to the programming blocks. They can use the Comment Box provided on the canvas.

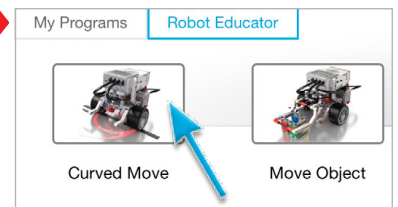
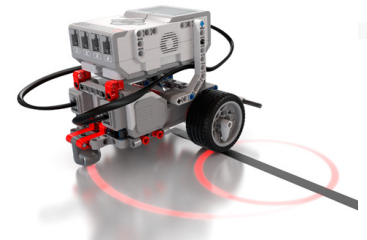
The following sample program is provided for the students:



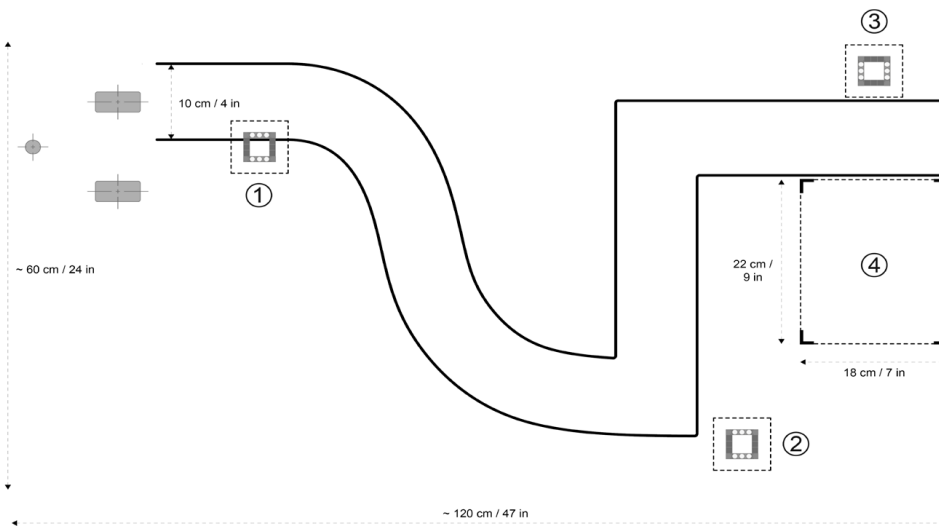
Example of robot behaviour description:

The robot performs a point turn, then a single-motor turn, and finally, a curved turn. Each action is separated by a pause, which allows the robot to settle before executing the next action.

Students can then explain in more detail why the robot behaves in this way, to show their depth of understanding.



4. Students solve the “Modify It” task, which challenges them to add three Move Steering Blocks to their program in order to make the robot drive backwards, following the same path back to the starting position.
5. Lesson Challenge Ideas:
- Program the robot to trace out a figure of eight or the first letter of your name (or some other letter or number).
 - Attach a pen to the robot and program it to draw a cloverleaf, heart, flower, or some other shape.
 - To ensure that students know when to use different kinds of turns (point turn, single-motor turn, or curved turn), make an obstacle course that requires different turning methods (see illustration below and/or Appendix A). The students must write a program that makes the left wheel of the robot follow a path and parks the robot in the parking area.



For this path use curved turns for the first section, followed by single-motor turns for the 90-degree turns, and finally, a point turn before reversing the robot into the parking area.

Assessment

Observe and/or ask questions to determine if the students:

- set the Steering Parameter Value to 50 to perform a single-motor turn;
- set the Steering Parameter Value to 100 or -100 to perform a point turn;
- manage to describe the robot behaviour in relation to the program in as much detail as possible;
- for the Lesson Challenges:
 - are able to trace out the selected shape;
 - are able to attach a pen to their robot and have it draw the correct shape;
 - are able to have the robot follow the path by selecting the correct turn types; and
- work cooperatively to solve the tasks.

Lesson 3 – Move Object

Objective

After completing this lesson, students will be able to program their robot to move and release objects of different shapes and sizes.

Duration

2 to 3 x 45 mins.

Preparation

Find several objects of different shapes and sizes that may or may not fit in the frame of the Medium Motor Module. For the Lesson Challenge you will need to prepare an obstacle course on the floor, if not already done. You can use a large sheet of paper, markers, or sticky tape (see illustration below).

Procedure

1. Students build and attach the Medium Motor Module to the Driving Base.
2. Students build the Cuboid.
3. Students complete the **Move Object** tutorial to understand how they use the Medium Motor Module to grab the Cuboid.
4. In the “Test It” phase, the students will open a sample program (this will close the current tutorial). Ensure each group takes the time to describe and explain the robot’s behaviour when running the provided sample program using their own words. This encourages the students to reflect on what they see and how that relates to the programming blocks. They can use the Comment Box provided on the canvas.

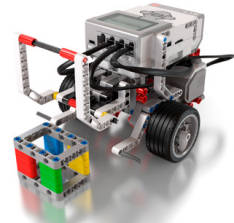
The following sample program is provided for the students:



Example of robot behaviour description:

Using the Medium Motor Module, the robot lowers the frame and grabs the Cuboid. It then reverses before raising the frame to release the Cuboid.

Students can then explain in more detail why the robot behaves in this way, to show their depth of understanding.



Educator

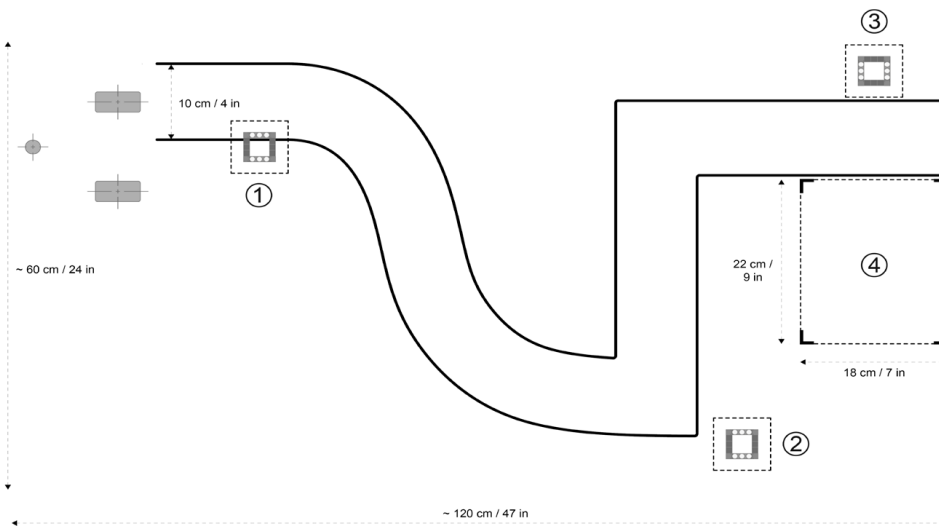


5. Students complete the “Modify It” task. The shape and size of other objects challenges students to modify their program or make changes to the Medium Motor Module that allow the robot to grab the different objects. When modifying the program, students will have to change the number of degrees the Medium Motor turns in order to accommodate the varying dimensions of the objects.

Note: Before modifying the Medium Motor Module, be aware that it is also required in Lesson 4 and Master Challenge 2.

6. Lesson Challenge:

Combine the optional challenge of Lesson 2 with moving the Cuboid (or another object) from predetermined start and end positions (see illustration below and/or Appendix A). For an additional challenge, students can also use the Ultrasonic Sensor to help detect the Cuboid (see Lesson 4 for further details).



Assessment

Observe and/or ask questions to determine if the students:

- successfully grab the Cuboid with the robot;
- manage to describe and explain the robot behaviour in relation to the program in as much detail as possible;
- modify the robot to grab other objects;
- for the Lesson Challenge, grab the Cuboid and place it with some precision in the predetermined end position; and
- work cooperatively to solve the tasks.

Lesson 4 – Stop at Object

Objective

After completing this lesson, students will understand the difference between the Change and Compare Modes of the various EV3 sensors. This particular lesson features the Ultrasonic Sensor.

Duration

2 to 3 x 45 mins.

Preparation

Make sure you understand the difference between Change and Compare Modes. When using Compare Mode, the program waits for a certain distance to be read by the sensor; when using the Change Mode, the program is reading the distance and then waiting for a certain increase or decrease in distance. For the Lesson Challenge, you will need to prepare an obstacle course on the floor, if not already done. You can use a large sheet of paper, markers, or sticky tape (see illustration below).

Procedure

1. Students build the Ultrasonic Sensor Module and attach it to the Driving Base.
2. Students complete the **Stop at Object** tutorial, during which they learn that the Ultrasonic Sensor measures distance to objects. Understanding this allows students to program the robot to react to a detected object.
3. In the “Test It” phase, the students will open a sample program (this will close the current tutorial). Ensure each group takes the time to describe and explain the robot’s behaviour when running the sample program using their own words. This encourages the students to reflect on what they see and how that relates to the programming blocks. They can use the Comment Box provided on the canvas.

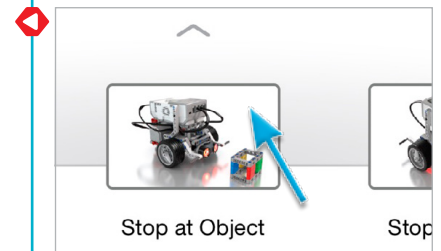
The following sample program is provided for the students:



Example of robot behaviour description:

Measuring distance using the Ultrasonic Sensor, the robot moves forward until it detects a decrease of 11 cm from the Cuboid and stops. The robot then reverses until it detects an increase of 6 cm from the Cuboid.

Students can then explain in more detail why the robot behaves in this way, to show their depth of understanding.



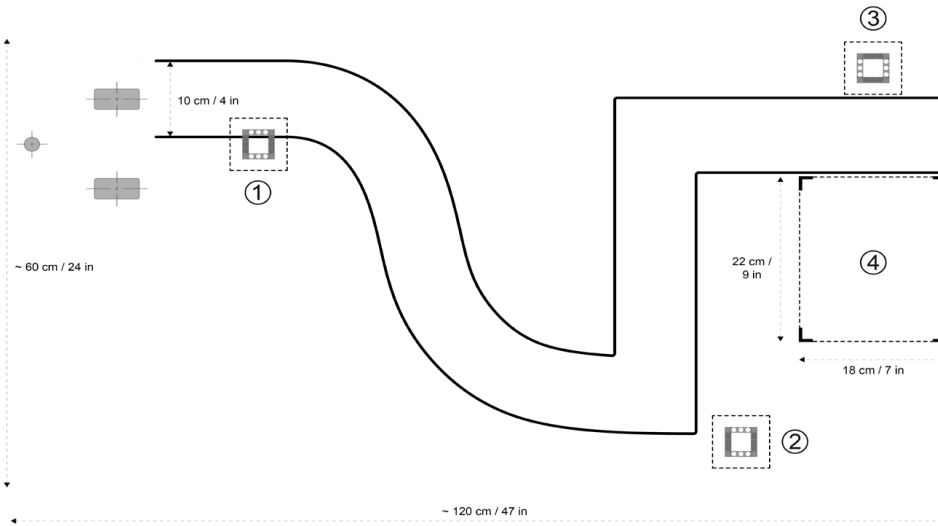
4. Students also complete the “Modify It” task. They should realise that the robot will always move forward 11 cm and then backwards 6 cm, no matter what the start distance to the Cuboid is; this is the essence of the Ultrasonic Sensor’s Change Mode.

5. Lesson Challenge Ideas:

Students attach the Medium Motor Module and grab the Cuboid (see illustration below and/or Appendix A). Remind students to use the Wait Block’s Ultrasonic Sensor – Compare Mode so that the robot moves close enough to the Cuboid.

The following scenarios can be used:

- a. Cuboid in position 1. Robot in start position. Make the robot move the Cuboid to position 2 and return to the start position.
- b. Cuboid in position 1. Robot in start position. Make the robot move the Cuboid to position 3 and then park in position 4.
- c. Cuboid in position 3. Robot starts in position 4. Make the robot move the Cuboid to position 1 following the path.



Change Mode:



Compare Mode:



Assessment

Observe and/or ask questions to determine if the students:

- can use the Ultrasonic Sensor to detect the Cuboid;
- manage to describe and explain the robot behaviour in relation to the program in as much detail as possible;
- in the “Modify It” task, realise that the robot will always move forward 11 cm and then backward 6 cm, regardless of the start distance to the Cuboid;
- for the Lesson Challenges:
 - a. are able to detect and grab the Cuboid from position 1, follow the path before releasing the Cuboid in position 2, and then reverse the robot back to the start position;
 - b. are able to move the Cuboid correctly from position 1 to position 3 and park the robot in position 4;
 - c. are able to move the Cuboid correctly from position 3 to position 1; and
- work cooperatively to solve the tasks.

Lesson 5 – Stop at Angle

Objective

After completing this lesson, students will be able to turn their robot based on input from the Gyro Sensor.

Duration

2 to 3 x 45 mins.

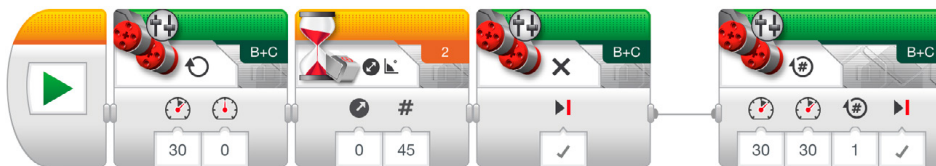
Preparation

Familiarise yourself with the Gyro Sensor to ensure you can detect when it is drifting and how to correct it. The Gyro Sensor chapter in the User Guide will help you familiarise yourself with the sensor. This topic is also covered in Step 4 of the procedure below. By providing sticky tape and protractors, students can create different angles on the floor to validate the turning angle of their robot. For tasks 5a and 5b, you will need to provide rubber bands to allow the students to attach a pen to their robot. For task 5c, you will need to prepare a maze on the floor. You can use a large sheet of paper, objects, markers, or sticky tape (see illustration below).

Procedure

1. The students build the Gyro Sensor Module and attach it to the Driving Base.
2. The students complete the **Stop at Angle** tutorial to make the robot turn 45 degrees based on Gyro Sensor angle readings.
3. In the “Test It” phase, the students will open a sample program (this will close the current tutorial). Ensure each group takes the time to describe and explain the robot’s behaviour when running the sample program using their own words. This encourages the students to reflect on what they see and how that relates to the programming blocks. They can use the Comment Box provided on the canvas.

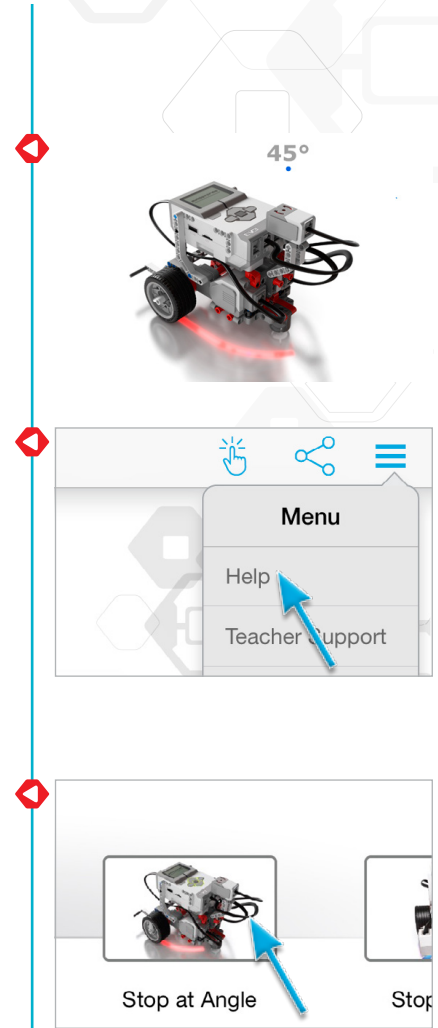
The following sample program is provided for the students:



Example of robot behaviour description:

Measuring rotational angle using the Gyro Sensor, the robot point turns until it detects an angle increase of 45 degrees. The robot then drives forward for one rotation and stops.

Students can then explain in more detail why the robot behaves in this way, to show their depth of understanding.

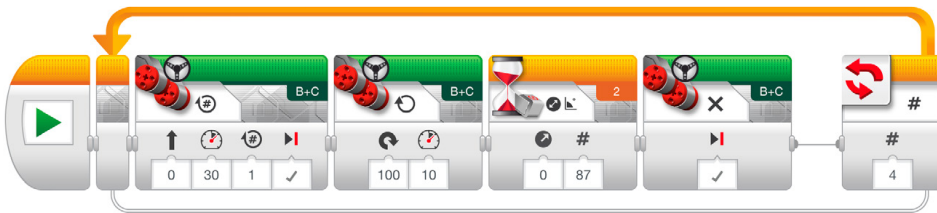


4. Troubleshooting: The troubleshooting notes included in the tutorial will help students understand how to avoid Gyro Sensor drift. Introduce the EV3 Brick Port View App as a method of checking the sensor reading. As the Gyro Sensor has a tolerance of ± 3 degrees, you should expect to have to compensate for that in the programs (e.g. to make a 90-degree turn, you may have to set the "Threshold Value" Parameter of the Wait Block's Gyro Sensor – Change – Angle Mode to 87 degrees).



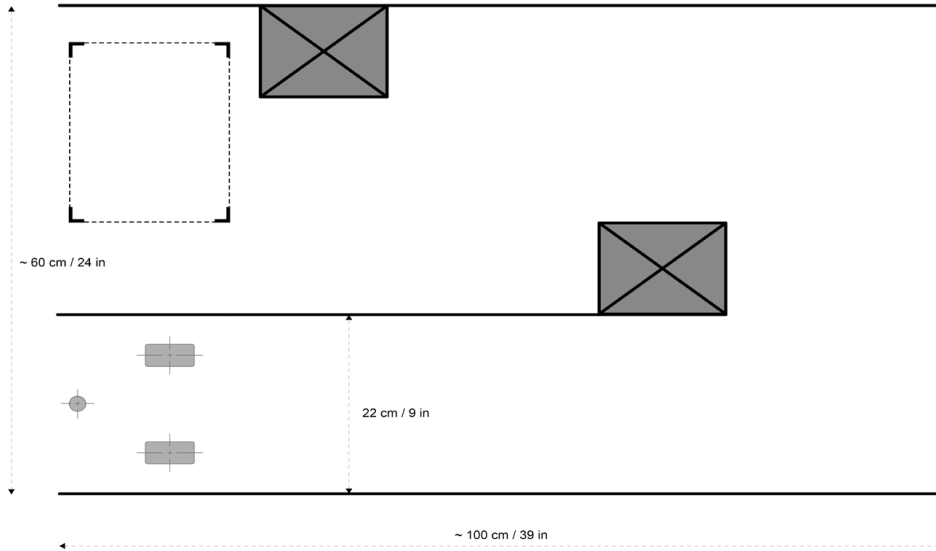
5. In the "Modify It" task, you may want to introduce students to the Loop Block as a way of decreasing the number of blocks needed to drive in a square. However, allow the students sufficient time to work it out for themselves.

Suggested program:



6. Lesson Challenge Ideas:

- Attach a pen to the robot. Use a Gyro Sensor to program your robot to draw the letter "Z."
- Attach a pen to the robot. Use a Gyro Sensor to program your robot to draw a star shape (consisting of five identical angles). Next, try increasing or decreasing the angle. How does the shape change?
- Challenge students to make their robot navigate through a maze using the Gyro Sensor (see illustration below and/or Appendix B).

**Assessment**

Observe and/or ask questions to determine if the students:

- can identify factors that may affect the stopping precision when using the Gyro Sensor (sensor tolerance, motor slack, and rotational momentum);
- manage to describe and explain the robot behaviour in relation to the program in as much detail as possible;
- in the "Modify It" task, can make the robot drive in a square based on Gyro Sensor input;
- for the Lesson Challenges:
 - fully or partially draw the letter "Z";
 - fully or partially draw a star with five identical angles;
 - fully or partially navigate their robot through a maze; and
- work cooperatively to solve the tasks.

Lesson 6 – Stop at Line

Objective

After completing this lesson, students will be able to use the Colour Sensor to stop the robot when a line is detected. Students will also be able to set a Threshold Value for a sensor.

Duration

2 to 3 x 45 mins.

Preparation

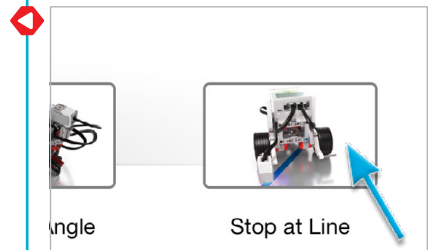
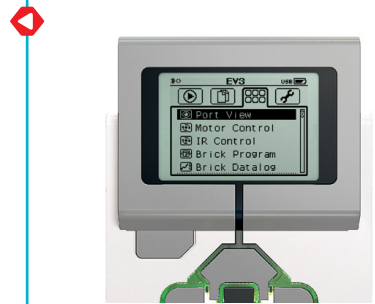
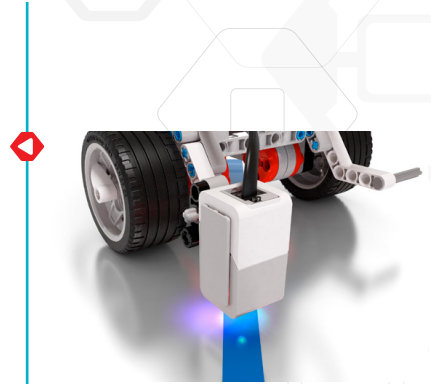
Provide the students with different-coloured paper or sticky tape. Carry out the following to test whether the Colour Sensor can read the selected materials correctly:

1. Turn on the EV3 Brick and connect a Colour Sensor to Port 3.
2. Navigate to the Port View App and open it.
3. Use the Right Button to navigate to Port 3.
4. The value shown is the Reflected Light Intensity (COL-REFLECT). Press the Centre Button to change the mode.
5. Scroll down the displayed list, select Colour Mode (COL-COLOR) and then point the sensor at the coloured material. The value displayed equates to the following colours: 0:No Colour, 1:Black, 2:Blue, 3:Green, 4:Yellow, 5:Red, 6:White, and 7:Brown.
6. If the value does not match the colour of your material, you will need to use another material.

Note: For best accuracy when in Colour Mode or Reflected Light Intensity Mode, the sensor must be held perpendicular and close to - but not touching - the surface being detected.

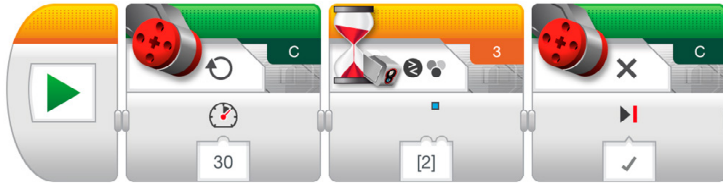
Procedure

1. Students build the Colour Sensor Down Module and attach it to the Driving Base.
2. Students complete the **Stop at Line** tutorial to detect a blue line using the Colour Sensor.
3. Students complete the “Modify It” task, in which the students practise detecting lines of a different colour.



4. In the “Test It” phase, the students will open a sample program (this will close the current tutorial). Ensure each group takes the time to describe and explain the robot’s behaviour when running the sample program using their own words. This encourages the students to reflect on what they see and how that relates to the programming blocks. They can use the Comment Box provided on the canvas.

The following sample program is provided for the students:



Example of robot behaviour description:

Measuring colour using the Colour Sensor, the robot turns until it detects the colour blue and then stops.

Students can then explain in more detail why the robot behaves in this way, to show their depth of understanding.

5. Lesson Challenge:

Ask the students to find out what the “No Colour” Parameter does (it causes the robot to react when the Colour Sensor fails to detect a colour that matches any of the predefined colours).

Assessment

Observe and/or ask questions to determine if the students:

- make the robot stop at different-coloured lines by changing the “Set of Colours” Parameter of the Wait Block’s Colour Sensor – Compare – Colour Mode;
- manage to describe and explain the robot’s behaviour in relation to the program in as much detail as possible;
- for the Lesson Challenge, can explain the “No Colour” functionality; and
- work cooperatively to solve the tasks.

Lesson 7 – Follow a Line

Objective

After completing this lesson, students will be able to use the Switch Block to make dynamic sensor-based decisions in order to make their robot follow a line.

Duration

2 to 3 x 45 mins.

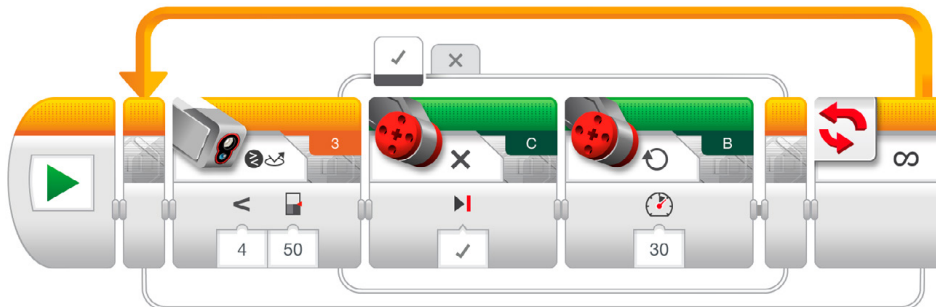
Preparation

Provide students with black and grey sticky tape to make a path for the robot to follow.

Procedure

1. If not already built, students build the Colour Sensor Down Module and attach it to the Driving Base, pointing down.
2. Students complete the **Follow a Line** tutorial. Even though the Wait Block can be used to make a robot follow a line, this tutorial uses the Switch Block in order to introduce the abstract concept of if/then statements to the students.
3. In the “Test It” phase, the students will open a sample program (this will close the current tutorial). Ensure each group takes the time to describe and explain the robot’s behaviour when running the sample program using their own words. This encourages the students to reflect on what they see and how that relates to the programming blocks. They can use the Comment Box provided on the canvas.

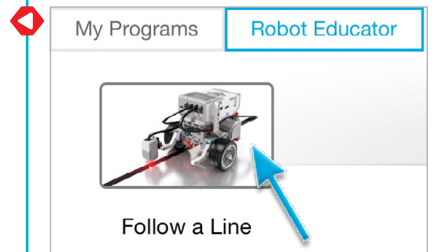
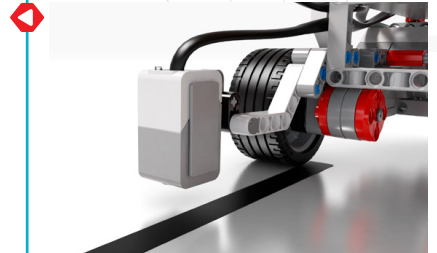
The following sample program is provided for the students:



Example of robot behaviour description:

Moving forward along a line, the robot uses the Colour Sensor to alternately switch each motor on and off when it detects changes in brightness reflected by the dark line and bright surface. This is why the robot “wiggles” forward.

Students can then explain in more detail why the robot behaves in this way, to show their depth of understanding.



4. Students complete the “Modify It” task, which allows them to test their program with a lighter-coloured line. This will challenge them to experiment with the Wait Block’s “Threshold Value” Parameter.
5. Lesson Challenge Ideas:
 - a. Ask the students to test how fast they can make their robot follow a line.
 - b. Make a line-follower program that uses Move Steering Blocks to perform curved turns rather than the sharp single-motor turns used in the tutorial.
 - c. The tutorial sample program uses a Switch Block to create a line follower. Can they produce the same result without using a Switch Block?

Assessment

Observe and/or ask questions to determine if the students:

- are able to make the robot follow the line;
- manage to describe and explain the robot behaviour in relation to the program in as much detail as possible;
- in the “Modify It” task, change the “Threshold Value” Parameter;
- for the Lesson Challenges:
 - a. increase the power in one or both of the Large Motor Blocks;
 - b. fully or partially modify their sample program to include Move Steering Blocks;
 - c. fully or partially create a line-follower program using Wait Blocks; and
- work cooperatively to solve the tasks.

Master Challenge 1 – The Turntable Challenge

Objective

The objective of this Master Challenge is for the students to navigate their robot around a four-bay, turntable-style parking area using a combination of point turns and sensors. After completing this challenge, students will be able to use angles to predict the final position of their robot and compensate for factors that may affect the accuracy of the Gyro and Colour Sensors.

Prerequisites

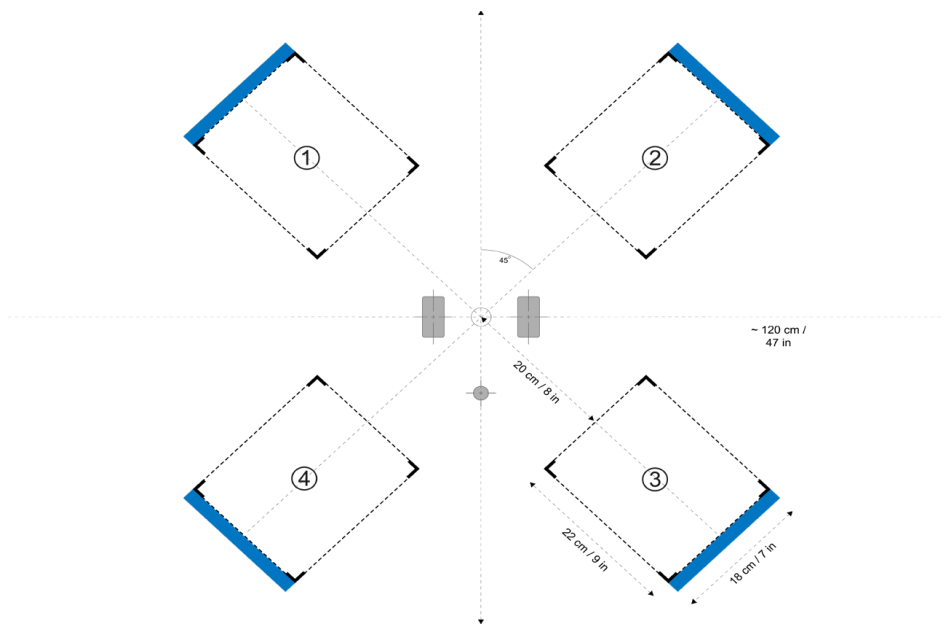
At a minimum, students must be familiar with the Colour Sensor and Gyro Sensor, as featured in the **Stop at Line** and **Stop at Angle** Lessons.

Duration

2 to 4 x 45 mins.

Preparation

To create the challenge mat illustrated below and/or in Appendix C, the students will need blue sticky tape or blue paper, a protractor, a long ruler, a pencil, and a marker pen.



Tasks

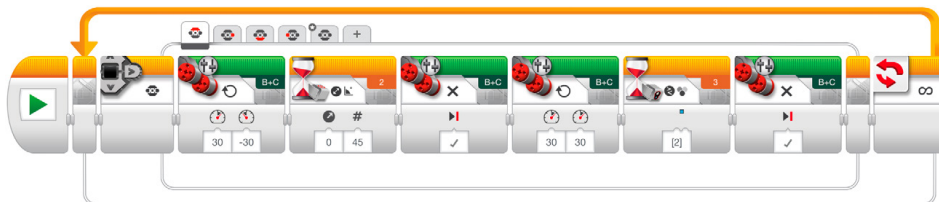
- By using two sensors, students move the robot from the centre to final positions 1, 2, 3, and 4. If using the suggested angles for the Wait Block's Gyro Sensor Mode, students should create their own copy of the chart below and try to predict which of the parking bays their robot will drive into:

| Programmed Angle | Predicted parking bay | Actual parking bay |
|------------------------|-----------------------|--------------------|
| 45 deg. clockwise | | |
| 135 deg. anticlockwise | | |
| 405 deg. anticlockwise | | |
| | | 3 |

Note: There may be several correct answers, as the robot can be rotated both clockwise and anti-clockwise.

- Create a program that uses a Switch Block to allow students to navigate the robot to one of the four parking bays by pressing one of the EV3 Brick Buttons.

Suggested program:

**Assessment**

Observe and/or ask questions to determine if the students:

- use both the Colour and Gyro Sensors;
- correctly predict the angle required to park the robot in each of the parking bays;
- use the blue line to stop forward movement;
- can compensate for the factors that may affect the stopping precision when using the Gyro Sensor (sensor tolerance, motor slack, and rotational momentum); and
- work cooperatively to solve the tasks.

Master Challenge 2 – The LEGO® Factory Robot Challenge

Objective

The purpose of this Master Challenge is to create a simplified representation of one of the real-life robots used by The LEGO Group to automate various tasks at its many production facilities around the world. After completing this challenge, students will be able to combine what they have learned in the previous lessons to master the basics of Robotics.

Prerequisites

It is recommended that students complete all seven lessons before beginning this Master Challenge. However, if you prefer a more project-based, explorative method, you can start out with this challenge and allow students to find help on their own by referring to the lessons.

Duration

2 to 6 x 45 mins.

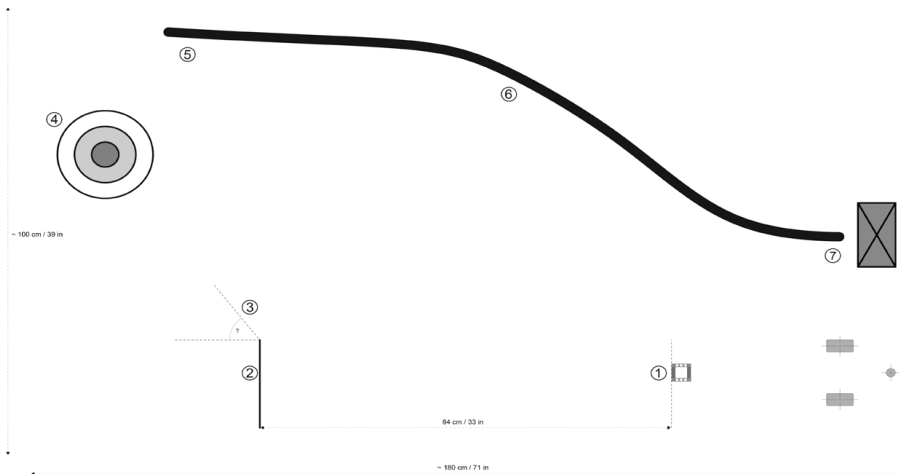
Preparation

To create the path illustrated below and/or in Appendix D, the students will need sticky tape, marker pens, measuring tape, the Cuboid, and a large object at the end of the black line. Students might also need a large protractor for measuring the angle in step three below.

Tasks

1. Detect and grab the Cuboid using the Medium Motor and Ultrasonic Sensor Modules.
2. Drive the robot forward exactly 84 cm.
3. Determine and turn x degrees clockwise using the Gyro Sensor to point the robot towards the target circle.
4. Drive as close as possible to the centre of the target and release the Cuboid.

5. Locate the line using the Colour Sensor. To challenge students, use sticky tape of a different colour than that used in the **Stop at Line** and **Follow a Line** tutorials.
6. Have the robot follow the line towards the large object.
7. Stop right in front of the object. Here, the main challenge for the students is to define for how long the robot should follow the line before stopping. The large object at the end of the line gives the students a chance to escape the line-follower loop using the Ultrasonic Sensor. Time can also be used to solve the challenge.



Assessment

Observe and/or ask questions to determine if the students use their experience from the seven lessons to solve this seven-step challenge, by:

- understanding the difference between Change and Compare Modes. For example, they use the Wait Block's Ultrasonic Sensor – Compare Mode in this challenge to achieve the best results;
- calculating the distance based on wheel circumference or using trial and error to get to the required 84 cm;
- estimating the turn angle by using a protractor and the Gyro Sensor;
- measuring the distance and then calculating the number of motor rotations to get close to the centre of the target;
- programming the robot to stop at the line;
- following the line back;
- stopping in front of the large object; and
- working cooperatively to solve the tasks.

Design Brief Challenges

Not all robots are Driving Bases! These Design Brief Challenges test the students' ability to build and program their own creations based on a brief that allows for a range of outcomes. Students have a chance to choose an approach that, compared to the step-by-step tutorials, is more open-ended. Design Brief Challenges also allow you to assess a student's creative and collaborative skills.

Four design briefs are listed below. For each challenge, you should consider from the outset how many lessons the students will be given in order to complete it. If the students are told that they have four 45-minute lessons and must then be ready to present their unique solution, they have a better chance of managing their time and can adjust their ambitions accordingly.

These Design Brief Challenges can be used as a starting point in your class; students can then use the tutorials and help text as a reference.

Alarm System

Build and program an alarm system using one or more sensors.

Dancing Robot

Build and program a robot with attitude that moves to your favourite music.

Greeting Robot

Build and program a robot that greets you positively when you meet it.

Robotic Sweeper

Build and program a robot that sweeps objects out of its path.

Relevant Standards

The seven lessons, two Master Challenges, and Design Brief Challenges provide a full introduction to robotics and are great examples of how to use robotics within Computing and in a STEM context.

Using the LEGO® MINDSTORMS® Education EV3 concept in the classroom opens up a range of valuable learning outcomes. Skills such as teamwork, creativity, and problem solving are an inherent part of the experience, and students' natural mastery of tablet devices will help them learn the language of programming more rapidly.

Below is a selected overview of national curriculum standards that could be **addressed or partially addressed** when using LEGO MINDSTORMS Education EV3. This list will grow steadily when you expand the use of EV3 in the classroom.

COMPUTING – Key Stage 3

- Design, use and evaluate computational abstractions that model the state and behaviour of real-world problems and physical systems.
- Understand several key algorithms that reflect computational thinking (for example, ones for sorting and searching); use logical reasoning to compare the utility of alternative algorithms for the same problem.
- Use two or more programming languages, at least one of which is textual, to solve a variety of computational problems; make appropriate use of data structures (for example, lists, tables or arrays); design and develop modular programs that use procedures or functions.
- Understand simple Boolean logic [for example, AND, OR and NOT] and some of its uses in circuits and programming; understand how numbers can be represented in binary, and be able to carry out simple operations on binary numbers [for example, binary addition, and conversion between binary and decimal].
- Understand the hardware and software components that make up computer systems and how they communicate with one another and with other systems.
- Undertake creative projects that involve selecting, using and combining multiple applications, preferably across a range of devices to achieve challenging goals, including collecting and analysing data and meeting the needs of known users.

COMPUTING – Key Stage 4

- Develop their capability, creativity and knowledge in computer science, digital media and information technology.
- Develop and apply their analytic, problem-solving, design, and computational thinking skills.

TECHNOLOGY - Key Stage 3*Design:*

- develop and communicate design ideas using annotated sketches, detailed plans, 3-D and mathematical modelling, oral and digital presentations and computer-based tools

Make:

- select from and use specialist tools, techniques, processes, equipment and machinery precisely, including computer-aided manufacture

Evaluate:

- investigate new and emerging technologies
- understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists

Technical knowledge:

- understand and use the properties of materials and the performance of structural elements to achieve functioning solutions
- understand how more advanced mechanical systems used in their products enable changes in movement and force
- understand how more advanced electrical and electronic systems can be powered and used in their products [for example, circuits with heat, light, sound and movement as inputs and outputs]
- apply computing and use electronics to embed intelligence in products that respond to inputs [for example, sensors], and control outputs [for example, actuators], using programmable components [for example, microcontrollers].

SCIENCE - Key Stage 3*Working scientifically**Scientific attitudes*

- pay attention to objectivity and concern for accuracy, precision, repeatability and reproducibility

Experimental skills and investigations

- ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience
- make predictions using scientific knowledge and understanding

Analysis and evaluation

- apply mathematical concepts and calculate results
- present observations and data using appropriate methods, including tables and graphs
- interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions
- present reasoned explanations, including explaining data in relation to predictions and hypotheses
- evaluate data, showing awareness of potential sources of random and systematic error
- identify further questions arising from their results.

Measurement

- use and derive simple equations and carry out appropriate calculations

*Subject Content - Physics**Motion and forces**Describing motion*

- speed and the quantitative relationship between average speed, distance and time (speed = distance ÷ time)
- the representation of a journey on a distance-time graph

Forces

- forces as pushes or pulls, arising from the interaction between 2 objects
- forces: associated with deforming objects; stretching and squashing – springs; with rubbing and friction between surfaces, with pushing things out of the way; resistance to motion of air and water

Forces and motion

- forces being needed to cause objects to stop or start moving, or to change their speed or direction of motion (qualitative only)
- change depending on direction of force and its size

*Waves**Sound waves*

- frequencies of sound waves, measured in hertz (Hz); echoes, reflection and absorption of sound
- sound needs a medium to travel, the speed of sound in air, in water, in solids
- the auditory range of humans and animals

Light Waves

- the transmission of light through materials: absorption, diffuse scattering and specular reflection at a surface
- colours and the different frequencies of light, white light and prisms (qualitative only); differential colour effects in absorption and diffuse reflection

SCIENCE - Key Stage 4*Working scientifically**The development of scientific thinking*

- recognising the importance of peer review of results and of communication of results to a range of audiences.

Experimental skills and strategies

- using scientific theories and explanations to develop hypotheses
- planning experiments to make observations, test hypotheses or explore phenomena
- applying a knowledge of a range of techniques, apparatus, and materials to select those appropriate both for fieldwork and for experiments
- carrying out experiments appropriately, having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations
- making and recording observations and measurements using a range of apparatus and methods
- evaluating methods and suggesting possible improvements and further investigations.

Analysis and evaluation

- carrying out and representing mathematical and statistical analysis
- representing distributions of results and making estimations of uncertainty
- interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions
- presenting reasoned explanations, including relating data to hypotheses
- being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error
- communicating the scientific rationale for investigations, including the methods used, the findings and reasoned conclusions, using paper-based and electronic reports and presentations.

Vocabulary, units, symbols and nomenclature

- recognising the importance of scientific quantities and understanding how they are determined

*Subject Content - Physics**Forces and Motion*

- speed of sound, estimating speeds and accelerations in everyday contexts
- decelerations and braking distances involved on roads

Wave motion

- amplitude, wavelength, frequency, relating velocity to frequency and wavelength

MATHEMATICS - Key Stage 3*Working mathematically**Develop fluency*

- consolidate their numerical and mathematical capability from key stage 2 and extend their understanding of the number system and place value to include decimals, fractions, powers and roots
- select and use appropriate calculation strategies to solve increasingly complex problems
- substitute values in expressions, rearrange and simplify expressions, and solve equations
- use language and properties precisely to analyse numbers, algebraic expressions, 2-D and 3-D shapes, probability and statistics.

Reason mathematically

- begin to reason deductively in geometry, number and algebra, including using geometrical constructions

Solve problems

- develop their mathematical knowledge, in part through solving problems and evaluating the outcomes, including multi-step problems
- select appropriate concepts, methods and techniques to apply to unfamiliar and non-routine problems

*Subject Content**Number*

- understand and use place value for decimals, measures and integers of any size
- order positive and negative integers, decimals and fractions; use the number line as a model for ordering of the real numbers; use the symbols =, ≠, <, >, ≤, ≥
- use the four operations, including formal written methods, applied to integers, decimals, proper and improper fractions, and mixed numbers, all both positive and negative
- recognise and use relationships between operations including inverse operations
- define percentage as 'number of parts per hundred', interpret percentages and percentage changes as a fraction or a decimal, interpret these multiplicatively, express one quantity as a percentage of another, compare two quantities using percentages, and work with percentages greater than 100%
- use standard units of mass, length, time, money and other measures, including with decimal quantities
- round numbers and measures to an appropriate degree of accuracy [for example, to a number of decimal places or significant figures]
- use a calculator and other technologies to calculate results accurately and then interpret them appropriately

Algebra

- substitute numerical values into formulae and expressions, including scientific formulae
- model situations or procedures by translating them into algebraic expressions or formulae and by using graphs
- work with coordinates in all four quadrants

Ratio, proportion and rates of change

- change freely between related standard units [for example time, length, area, volume/capacity, mass]
- use scale factors, scale diagrams and maps
- solve problems involving percentage change, including: percentage increase, decrease and original value problems
- use compound units such as speed, unit pricing and density to solve problems.

Geometry and measures

- calculate and solve problems involving: perimeters of 2-D shapes (including circles), areas of circles and composite shapes
- apply the properties of angles at a point, angles at a point on a straight line, vertically opposite angles
- interpret mathematical relationships both algebraically and geometrically.

Statistics

- construct and interpret appropriate tables, charts, and diagrams

MATHEMATICS - Key Stage 4*Working mathematically**Develop fluency*

- consolidate their numerical and mathematical capability from key stage 3 and extend their understanding of the number system to include powers, roots (and fractional indices)
- select and use appropriate calculation strategies to solve increasingly complex problems, including exact calculations involving multiples of π (and surds), use of standard form and application and interpretation of limits of accuracy
- use mathematical language and properties precisely.

Reason mathematically

- reason deductively in geometry, number and algebra, including using geometrical constructions

Solve problems

- develop their mathematical knowledge, in part through solving problems and evaluating the outcomes, including multi-step problems
- develop their use of formal mathematical knowledge to interpret and solve problems
- make and use connections between different parts of mathematics to solve problems
- model situations mathematically and express the results using a range of formal mathematical representations, reflecting on how their solutions may have been affected by any modelling assumptions
- select appropriate concepts, methods and techniques to apply to unfamiliar and non-routine problems; interpret their solution in the context of the given problem.

*Subject content**Number*

- calculate exactly with fractions, {surds} and multiples of π
- apply and interpret limits of accuracy when rounding or truncating, {including upper and lower bounds}

Algebra

- where appropriate, interpret simple expressions as functions with inputs and outputs; {interpret the reverse process as the 'inverse function'; interpret the succession of two functions as a 'composite function'}
- {calculate or estimate gradients of graphs and areas under graphs (including quadratic and other non-linear graphs), and interpret results in cases such as distance-time graphs, velocity-time graphs and graphs in financial contexts}
- ratio, proportions and rates of change
- compare lengths, areas and volumes using ratio notation and/or scale factors; make links to similarity (including trigonometric ratios)
- convert between related compound units (speed, rates of pay, prices, density, pressure) in numerical and algebraic contexts

Geometry and measures

- {describe the changes and invariance achieved by combinations of rotations, reflections and translations}
- interpret and use bearings

Statistics

- interpret and construct tables

ENGLISH - Key Stage 3*Reading**Understand increasingly challenging texts through:*

- learning new vocabulary, relating it explicitly to known vocabulary and understanding it with the help of context and dictionaries
- making inferences and referring to evidence in the text
- checking their understanding to make sure that what they have read makes sense

*Writing**Write accurately, fluently, effectively and at length for pleasure and information through:*

- writing for a wide range of purposes and audiences
- summarising and organising material, and supporting ideas and arguments with any necessary factual detail.
- applying their growing knowledge of vocabulary, grammar and text structure to their writing and selecting the appropriate form

Plan, draft, edit and proof-read through:

- amending the vocabulary, grammar and structure of their writing to improve its coherence and overall effectiveness.
- paying attention to accurate grammar, punctuation and spelling

*Grammar and vocabulary**Consolidate and build on their knowledge of grammar and vocabulary through:*

- drawing on new vocabulary and grammatical constructions from their reading and listening, and using these consciously in their writing and speech to achieve particular effects.
- using Standard English confidently in their own writing and speech

*Spoken English**Speak confidently and effectively, including through:*

- using Standard English confidently in a range of formal and informal contexts, including classroom discussion.
- giving short speeches and presentations, expressing their own ideas and keeping to the point.
- participating in formal debates and structured discussions, summarising and/or building on what has been said.

ENGLISH - Key Stage 4*Writing**Write accurately, fluently, effectively and at length for pleasure and information through:*

- writing for a wide range of purposes and audiences
- summarising and organising material, and supporting ideas and arguments with any necessary factual detail
- applying their growing knowledge of vocabulary, grammar and text structure to their writing and selecting the appropriate form

Plan, draft, edit and proof-read through:

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