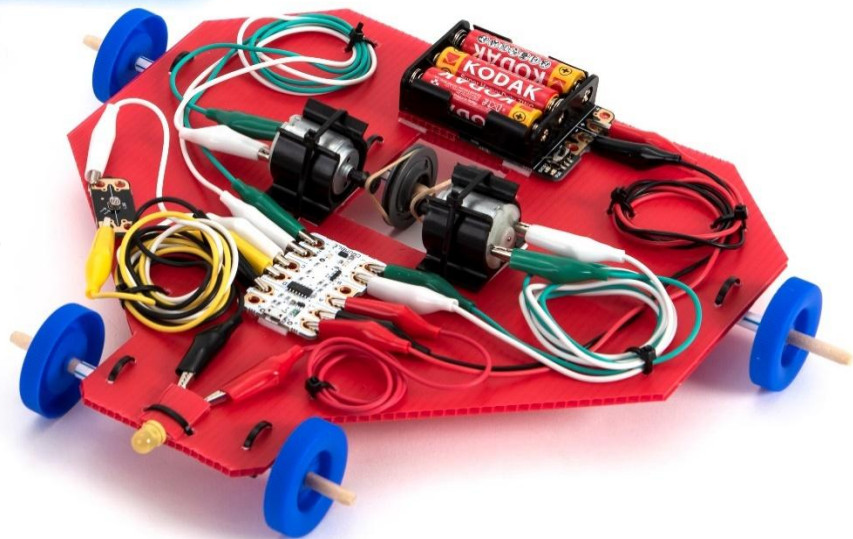


Crumble Robotic Vehicle



Lesson Plan

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Crumble Lesson Plan

- Recommended level – Years 5-6
- Time taken for basic activity – 4-6 hours
- Time taken for extension activities – 4-6 hours
- Pupils to work in groups of 3
- Additional adult help is recommended
- Expectation – to complete a computer controlled robotic vehicle

Skills and Learning

STEM Links

- Science: electrical circuits, forces, materials
- Technology: mechanical systems, electrical systems, computing, design and make process
- Engineering: integrated mechanical, electrical and control systems, troubleshooting
- Mathematics: drawing 2-D shapes, measurement

Curriculum Learning Objectives – it is recommended to cover these topics prior to the exercise so that the pupils are reinforcing their knowledge and understanding, rather than meeting the topics for the first time.

Computing (Key Stage 2)

Pupils should be taught to:

- understand what algorithms are, how they are implemented as programs on digital devices, and that programs execute by following precise and unambiguous instructions
- design, write and debug programs that accomplish specific goals, including controlling or simulating physical systems; solve problems by decomposing them into smaller parts
- use sequence, selection, and repetition in programs; work with variables and various forms of input and output
- use logical reasoning to explain how some simple algorithms work and to detect and correct errors in algorithms and programs

Science: Electricity (Year 6)

Pupils should be taught to:

- compare and give reasons for variations in how components function
- use recognised symbols when representing a simple circuit in a diagram

Pupils should construct simple series circuits to help them to answer questions about what happens when they try different components, for example bulbs and motors. They should learn how to represent a simple circuit in a diagram using recognised symbols.

Science: Forces (Year 5)

Pupils should be taught to:

- identify the effects of friction, that acts between moving surfaces
- recognise that some mechanisms (e.g. pulleys) allow a smaller force to have a greater effect

Pupils should explore the effects of friction on movement and find out how it slows or stops moving objects. Pupils should explore the effects of pulleys and simple machines on movement.

Science: Materials (Year 5)

Pupils should be taught to:

- identify and compare the suitability of a variety of everyday materials for particular uses

Pupils should be encouraged to think about unusual and creative uses for everyday materials.

Design and Technology (Key Stage 2)

Through a variety of creative and practical activities, pupils should be taught the knowledge, understanding and skills needed to engage in an iterative process of designing and making. When designing and making, pupils should be taught to:

Design and Technology: Design

- design innovative, functional, appealing products that are fit for purpose
- generate, develop, model and communicate their ideas

Design and Technology: Make

- select from and use a wide range of tools and equipment to perform practical tasks
- select from and use a wide range of materials and components according to their functional properties and aesthetic qualities

Design and Technology: Evaluate

- evaluate their ideas and products and consider the views of others to improve their work

Design and Technology: Technical knowledge

- understand and use mechanical systems in their products [for example pulleys]
- understand and use electrical systems in their products [for example series circuits incorporating bulbs and motors]
- apply their understanding of computing to program, monitor and control their products

Mathematics: Measurement

Pupils should be taught to:

- measure lengths
- compare duration of events
- measure angles in degrees
- calculate average speed

Curriculum & Assessment Review 2025 Recommendations

Computing:

- Incorporate more real-world practical learning.
- Learn to use AI effectively.

Science:

- Understand how science operates in everyday life.
- Promote cross-curricular links between science and other subjects.

D&T:

- Better support students to think like designers and engineers.
- Incorporate more real-world practical learning.

Associated Resources

Instruction sheets

These are intended for the teacher to run through the activity in advance of the lesson.

- Instructions 1 – Make a Crumble Robotic Vehicle
- Instructions 2 – Crumble Vehicle Extension Activities

Presentations

These are for conducting the actual lesson. Teacher notes for each of the modules providing hints, tips and other useful information to help the class with the activities are provided later in this lesson plan.

- Presentation 1 – Crumble Robotic Vehicle
- Presentation 2 – Crumble Vehicle Extension Activities

Worksheets

These are for pupils to complete after the activity to help capture and record what they have learnt. Suggested answers to each of the worksheets are provided at the end of this lesson plan.

- Worksheet 1 – Crumble Robotic Vehicle
- Worksheet 2 – Crumble Vehicle Extension Activities

Equipment needed

Parts included in class kit:

- 10 Crumble controllers
- 10 micro-USB cables
- 10 Crumble switched battery boxes
- 20 motors
- 20 motor mounts
- 100 crocodile leads
- 60 assorted plastic pulleys (or 20 wooden pulleys)
- 20 motor pulleys
- 100 plastic wheels
- 30 coloured LEDs (light emitting diodes)
- 10 Crumble light sensors (phototransistors)
- 20 wooden rods
- 200 jumbo drinking straws
- 10 sheets of corrugated plastic
- 1 box of rubber bands
- 200 cable ties

Check you have received the correct contents in your class kit. Please let TTS know if there are any problems as soon as possible.

Try pushing the pulleys and the card wheels onto the wooden rod to check they fit tightly. There can be a slight variation in the diameter of the dowel due to the wood's moisture content. If the wheels and pulleys are difficult to fit, sandpaper down the end of the dowel slightly. If they are slightly loose on the dowel, glue them on.

The plastic pulleys may be a very tight fit on the wooden rod – if you have access to a pillar drill you can drill them out to 4.9mm diameter to help them fit more easily onto the rod.

Tools and consumables (not included in class kit):

For all modules

- 10 computers (Windows XP SP3 or newer, or Mac OS X 10.6 (64-bit) and above)
- 30 AA cells (these are often called batteries).
- Rulers
- Marker pens
- Good quality large scissors (not safety scissors)
- Pencil sharpeners
- Sharp pencils
- Blu Tack
- Double-sided foam sticky tape heavy duty 1-2mm thick x 12mm wide – several rolls. Double-side foam sticky pads are also useful, as they are easy to distribute to the pupils.
- 10 sheets of scrap A4 paper (to put the Crumble controllers on during preliminary testing)
- 10 small plastic bowls or food containers to hold small parts
- Secateurs for cutting wooden rod – **only for use by responsible adults**
- If you can get hold of thinner cable ties (2.5mm wide x 200mm long), they are much easier to fit than the ones included in the kit.

For extension activities

- Old mountain bike inner tubes or long balloons or small balloons
- Tape measure
- Masking tape or chalk
- Stopwatch
- Calculator
- Wooden ramp (a sheet of plywood without splinters will also work)
- Protractor
- Cool melt glue guns and glue sticks (several needed, e.g. 3-4, as there could be a queue to use them!).

Note: High melt temperature glue guns should not be used, as they can cause nasty burns.

- Lightweight passengers e.g. plastic figures, bugs or pine cones with googly eyes added (optional)
- Decorations e.g. self-adhesive gems (optional)

Vocabulary list

Axle – a central shaft for rotating wheels.

Battery / cell – this converts chemical energy into electrical energy. It is used to ‘push’ electricity around a circuit. If you connect cells together you get more ‘push’ – a battery consists of two or more cells.

Bearing – this supports the rod, keeping it in position whilst allowing it to rotate.

Drive belt – the belt which connects and transfers movement between the motor and pulley.

LED (light emitting diode) – a diode is a component which has a very high resistance in one direction, so the current can only flow in the other direction. An LED is a kind of diode which glows when electricity passes through it.

Light sensor – this is a component which changes conductivity according to the amount of light falling on it. When more light falls on it, it will conduct more easily.

Pulley – a grooved wheel over which a drive belt can run.

Short circuit – an electric circuit which allows the electricity to flow round it with very little resistance, so the battery will drain quickly and get hot.

Vocabulary related to programming

Algorithm – a list of rules to follow to complete a task (the order is very important).

Sequence – the order in which instructions in the program are carried out.

Selection – making a decision about which instructions to follow based on certain conditions.

Repetition – the repeated execution of a set of instructions until certain conditions are met.

Variable – a storage location used to hold data which the program can use or change.

Input – data that goes into a program.

Output – information that a program produces and sends out.

Risk Assessment

Conduct a risk assessment before undertaking the activity. A sample risk assessment is given below; you can use this as a starting point when writing your own. (L=low, M=medium, H=high)

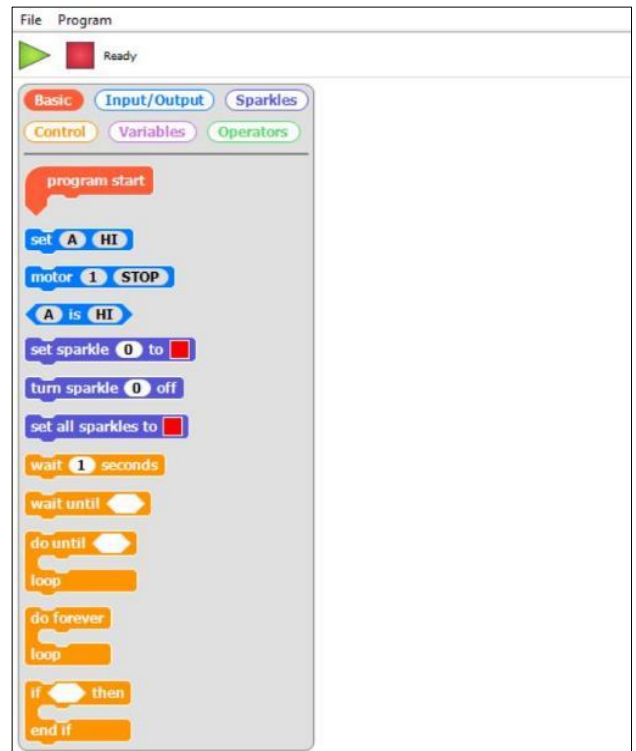
| Activity | Identified Hazard | Initial Risk Rating L/M/H | Control Measures | Controlled Risk Rating L/M/H |
|---------------------------------------|-------------------------|---------------------------|--|------------------------------|
| Use of glue guns | Burns | H | <ul style="list-style-type: none">• Children should be supervised by a responsible adult at all times when using the glue guns.• Explain to children how to use the glue guns.• Warn them that the ends are very hot. Use only low melt temperature glue guns. If burned, hold under running water for ten minutes.• Don't switch on the glue guns until after the safety briefing.• In some schools, children wear safety goggles when using glue guns. | M |
| Accidentally short-circuiting battery | Burns, smoke inhalation | M | <ul style="list-style-type: none">• The battery boxes provided in the Crumble class kit have built in short-circuit protection.• In the event of a short circuit, a re-settable fuse will trip to stop the flow of electricity and a red LED will light up on the battery box.• If this happens, check the circuit and make sure that it is wired correctly. | L |

| | | | | |
|---|--|---|--|---|
| Use of scissors | Injury e.g. to fingers | M | <ul style="list-style-type: none"> • Make the children aware of the dangers. • Do not give out the scissors until after the safety briefing. | L |
| Use of sharp pencils to make holes | Injury e.g. to hands/fingers | M | <ul style="list-style-type: none"> • Explain how to make holes by placing the item on a lump of Blu Tack and then pushing down with the pencil through the item into the Blu Tack. | L |
| Use of secateurs | Severe injury e.g. to fingers | M | <ul style="list-style-type: none"> • Do not allow the children to use the secateurs. They must only be used by responsible adults. | L |
| Use of cable ties | Cable-tying fingers and cutting off blood supply | M | <ul style="list-style-type: none"> • Make the children aware of the dangers. • Cut cable ties off fingers immediately. | L |
| Running extension leads along floor for glue guns | Trip hazard | M | <ul style="list-style-type: none"> • Avoid using extension leads if possible. • Otherwise make sure extension leads are run where they cannot be tripped over. | L |
| Damaged extension leads or glue gun leads | Electrocution hazard | H | <ul style="list-style-type: none"> • Conduct a visual check of all electrical items before session, to ensure the leads are undamaged. • PAT test extension leads and glue guns regularly. | L |

Preparation needed

- Use a craft knife and steel rule to cut some of the corrugated plastic sheets into 25cm x 25cm squares. You can get 4 of these from one sheet. You need 11 squares in a variety of colours, including the one for your sample vehicle.
- Build a sample vehicle to explore any pitfalls, and to demonstrate to the pupils what they will be making and how it works. Instructions are given in 'Instructions 1 - Make a Crumble Robotic Vehicle' and 'Instructions 2 - Crumble Vehicle Extension Activities.' After cutting out your vehicle base from one of the squares of plastic, use it as a template to draw round on the remaining ten squares, making sure the corrugations are in the right orientation. Do this before you start attaching the components to it. Draw round it in fine marker pen so that the size of the copies is similar to the template.
- Use a craft knife and steel rule to cut out the slots in the ten marked out squares. You could use a bradawl to make holes at each corner of the slot – this makes it easier to make the correct sized slot. If you don't have large, good quality scissors for the pupils to use, you could cut out the outline of the base as well.
- Use a pair of secateurs to cut 10 pieces of wooden rod 14cm long for mounting the front wheels. Cut 20 pieces of wooden rod 16cm long for mounting the rear wheels.
- Print out a copy of the worksheet for each pupil.
- Book the school hall for testing the vehicles. On the day set up courses for the vehicles to follow using masking tape or chalk. You could have a simple start and finish line a few metres apart for drag racing, so that you can time the vehicles and calculate the average speed. Also, a straightforward course such as a large square including a start and finish line (it is hard to control the vehicles accurately). You could also set up more complicated courses such as a slalom to challenge the more advanced pupils. You could have a leader board to compare the performance of the vehicles.

- If you don't already have the Crumble software installed on your computers, install it as follows:
 - Set up a destination folder called 'Crumble' on the computer where you want to install the software, e.g. on your Desktop.
 - Download the Crumble software onto the computer from here: <https://redfernelectronics.co.uk/crumble/>.
 - Double-click on the downloaded file and run the set-up wizard.
 - Click 'Next' then when asked where to install the Crumble software click 'Change...' and choose the destination folder you set up earlier.
 - Navigate to the destination folder and double click on 'Crumble'. The window shown on the right should appear:



- As there are only 10 sets of Crumbles and other components you may need to dismantle your vehicle after demonstrating it so that the pupils can re-use the parts for their vehicles.
- When showing the presentations, refer to the teacher notes below for additional information and explanations. If you share this information with the pupils, it should help them to complete their vehicles successfully.

Teacher notes – referring to the relevant numbered slides in the Presentation

Presentation 1 – Crumble robotic vehicle

| | |
|---------|---|
| Slide 3 | <p>Work safely</p> <ul style="list-style-type: none"> • Don't cut yourself with the scissors. • Don't pierce your hands or fingers when making holes in the base with the sharp pencil. • Don't burn yourself with the glue gun. • Don't cable-tie your fingers or you can cut off the blood supply! Cut off any cable ties on fingers immediately. • More information is given in the risk assessment above. |
| Slide 4 | <p>Connect up the Crumble controller</p> <ul style="list-style-type: none"> • The Crumble should be placed on a sheet of paper to avoid placing it on a conductive surface, in case you short circuit and damage it. • The USB connections will only fit one way up. You can see which way up if you look at them closely. Make sure the pupils do not try to fit them upside down as they could damage them. |
| Slide 5 | <p>Run a simple program</p> <ul style="list-style-type: none"> • When the program is stopped, 'motor 1 LED' should switch off. |

Identify these electrical parts

Slide 6

- The parts shown are a battery, a cell, a crocodile lead and a motor.
- Point out that a battery consists of two or more cells. A cell is often called a battery, but this is not technically correct.
- Point out the circuit symbols which represent the battery, cell, motor and crocodile lead.
- Explain that circuit symbols are used on circuit diagrams to represent the electrical components, because they are easier to draw and interpret than trying to draw the actual components.
- Explain that circuit diagrams are used to help design, build and troubleshoot electrical systems.

Collect these parts

Slide 7

- It is recommended to have a small bowl (or plastic food container) available to collect the parts. This helps to prevent items such as the motor pulleys, motors and cells from rolling off the table and getting lost.
- Make sure the pupils do not lose their motor pulleys – they are very small.
- It is best not to have all the same colour of crocodile lead, to avoid mixing them up when connecting up the electrical components.

Mount the pulleys and motors

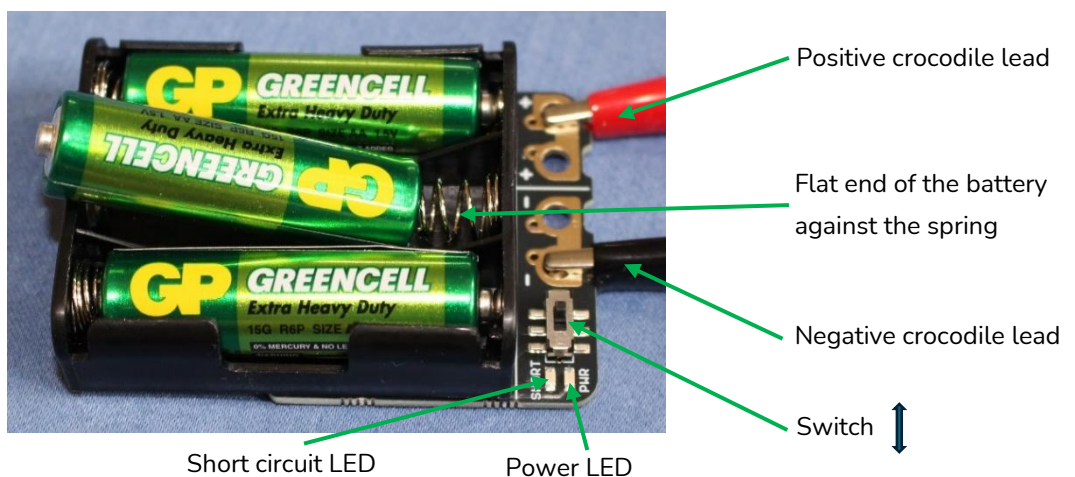
Slide 8

- Make sure the motor pulleys are mounted on the shafts in the direction shown.
- It is recommended to have a small gap of about 1mm between the pulley and the motor housing. If it is pushed up hard against the motor housing, it can create extra friction.
- Make sure the pupils push the motors into the mounts in the direction shown by the longer blue arrow. If you push them in from above you can snap the motor mounts.

Understand your battery box

Slide 9

- Show the pupils where to connect the positive and negative crocodile leads. The colour of the leads is not actually important, but conventionally red is used for positive and black for negative, so that is shown on the picture below.
- Show the pupils how to fit the cells into the battery holder, with the flat end of each cell pushed against the spring.
- Demonstrate how to toggle the on/off switch.



Identify the Crumble terminals

Slide 10

- Either power terminal can be connected to the battery.
- It is important not to connect the battery to any of the other inputs/outputs, as this could damage the Crumble controller.
- The motors can only run off the 'Motor 1' or 'Motor 2' outputs. Terminals A, B, C and D do not produce enough power to run the motor.

Connect up the Crumble circuit

Slide 11

- Make sure the battery box is connected to the 'Power in' terminals before fitting the cells. If it is connected to any of terminals A to D, you can damage the Crumble.
- Pupils have a labelled diagram of the Crumble on their worksheet for reference.
- Check the battery is connected the right way round, i.e. the positive terminal of the battery is connected to the positive 'Power in' terminal on the Crumble.

Try running the motor

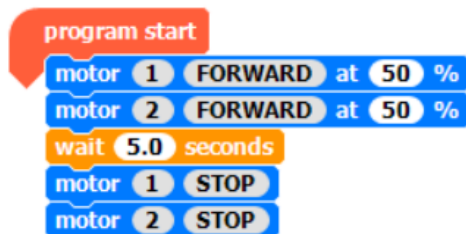
Slide 12

- If the motor doesn't turn when running the program, try to work out why not.
- Does the program specify motor 1, not motor 2?
- Does the motor 1 LED come on when you run the program?
- If so, is the switch on?
- Is the motor connected to 'Motor 1' output?

Run both motors

Slide 13

- This program should run both motors at 50% power for 5 seconds and then stop.



Prepare the base

Slide 14

- It is preferable to mark the lines with marker pen, because felt tip can smudge.
- Check the pupils have marked their lines correctly.

Why we use wheels, axles and bearings

Slide 15

- If the wheels are pushed up hard against the end of the bearings (straws), this will increase the friction and act to slow the vehicle down. Leaving a small gap avoids this problem.

Slide 16

Prepare to fit the front bearing

- It is better if an adult looks after the roll of double-sided tape and dispenses the amount needed. Otherwise, one pupil can accidentally use the entire roll!
- You can demonstrate how pupils can make the holes in the base without damaging either the base or their hands/fingers.
- The holes need to be in between the corrugation lines.

Slide 17

Fit the front bearing

- The straw needs to be cut cleanly across, so that the wheel doesn't catch on the end of the straw as it turns.
- The straw should stick out by roughly the same amount either side of the base.
- Don't squash the straw down onto the foam tape – it needs to be cylindrical to allow the axle to rotate freely.

Slide 18

Fit the front axle

- The rod should only be very slightly sharpened at the end, to help the wheels go on.
- If the wheels are too tight to fit, you can sand the rod down a little.
- If the wheels are loose, you can glue them on.
- It is recommended to help the pupils glue their wheels on, to avoid getting glue in the bearing.
- A small gap between the wheel and the straw end allows the wheel to turn freely.

Slide 19

Restrain the front bearing

- The cable ties should just touch the straw, not crush it onto the axle. If they are too tight, cut them off and fit new ones.
- Make sure the ends of the cable ties are cut off short enough to avoid dragging on the floor.
- You may need to help pupils cut off the ends of the cable ties, as the cable ties are very thick.
- Using large scissors and cutting near the hinge can help. Alternatively, you could use wire cutters or secateurs (not to be used by pupils).

Slide 20

Why we use a pulley system

- The supporting literature includes a file 'pulley.gif'. Click on the gif file to show an animation of the motor pulley rotating at a higher speed and driving the larger pulley, which is rotating at a lower speed. This is to help the pupils understand how the pulley system operates.

Slide 21

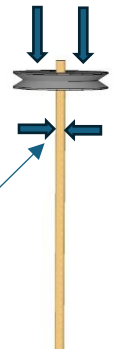
Prepare to fit the rear axles

- The holes can be enlarged from top and bottom in order to fit the cable ties.

Prepare the rear axles

Slide 22

- The rod must not be over-sharpened. The sharpened part of the rod needs to be less than 0.5cm long (i.e. the mark should still be visible after sharpening) or the pulley will be loose.
- The pulley can be a very tight fit. You may need to help the pupils to push them on.
- Support the sides of the rod when pushing on the pulley, to avoid snapping the rod.
- Make sure the pulley sits at right angles to the rod – if it is wonky, the rubber band tends to come off when running.



Assemble the rear axles

Slide 23

- The straw must be cut cleanly across.
- The wheels need to fit tightly. If they are loose, glue them on.
- Make sure there is a small gap between the wheel and the end of the straw to allow the axle to rotate in the straw bearing.

Fit one rear axle

Slide 24

- Make sure the axle is positioned correctly.

Restrain the rear bearing

Slide 25

- Make sure the pupils do not overtighten the cable ties – they are just there to prevent the bearing from moving out of position.
- If the axle no longer rotates easily after fitting the cable ties, they may have been pulled too tight. You could try cutting them off and fitting new ones.

Fit and restrain the second rear axle

Slide 26

- There needs to be a gap between the ends of the two rods so that the axles can be driven independently and do not interfere with one another, enabling the vehicle to turn.

Position the motors on the base

Slide 27

- To prevent the rubber band drive belts falling off when running:
 - You can slide the motors forwards or backwards in their mounts a little to line up the vees of the pulleys.
 - The rubber bands should be slightly stretched. If they are loose, you can reposition the motors forward a little.
 - The motors should be parallel to the rear axles.

Attach the motors and drive belts

Slide 28

- Demonstrate how to measure a rubber band by laying it flat alongside a ruler without stretching it.
- Make sure the base is supported on a large lump of Blu Tack when making holes to avoid damaging it.
- Make sure the Blu Tack is not placed under the straw, as the straw is likely to get squashed.

Prepare the battery box

Slide 29

- The purpose of the plastic shape is to allow the battery box to attach flat to the vehicle. Otherwise, the nut and bolt sticking out of the bottom of the battery box get in the way.

Fit the Crumble and battery box

Slide 30

- Make sure the pupils tape the **underside** of the Crumble – that's the side without the components on it.
- You need a double layer of foam tape on the Crumble to allow space to fit the crocodile clips.
- Remember to remove the plastic film from the foam tape.
- The micro-USB socket on the Crumble should face the front so you can plug in easily.

Re-connect the circuit

Slide 31

- The wires can be positioned to help get the centre of gravity of the vehicle in the right place.
- The optimum position for the centre of gravity is just in front of the rear axles. This helps the rear wheels to grip the floor.
- If the centre of gravity is too far forwards, it is difficult to steer the vehicle. In order to steer, the front wheels need to be able to skid across the floor.
- If the centre of gravity is too far back, the vehicle can tilt over backwards as it sets off!
- You can judge the position of the centre of gravity by balancing the vehicle on your fingertips, or by pressing down on the back of the vehicle and checking it is quite easy to tilt (but not too easy!).

Construct a program

Slide 32

- The language used is similar to Scratch, so most pupils will already be familiar with it.
- Each command needs to attach to the one above it.
- If the rubber bands come off when you run the motors then there could be several reasons:
 - The pulley vees are not in line.
 - The rubber band is loose.
 - The pulleys aren't straight on the axles.
 - The axles or motors aren't at right angles to the rubber band.

Try out the vehicle

Slide 33

- If you start the motors on more than 50% power, they draw too much current and the Crumble cannot boot up.

- The Crumble draws current even when not being used, so you must remember to switch off the battery to avoid draining it when not using the vehicle.

Slide 34

Plenary

- You can reverse the motor direction by either programming it to go the other way or by swapping over the crocodile clips on the motor terminals.
- If there is high friction between the axles and bearings it slows the vehicle down.
- You need high friction between the drive belts and pulleys because otherwise they can slip, so the motion of the motor is not transmitted to the pulley.
- Similarly, the pulley and wheel need to be a tight fit on the axle or they can slip.

Presentation 2 – Crumble Vehicle Extension Activities



Slide 3

Work safely

- Don't cut yourself with the scissors.
- Don't pierce your hands or fingers when making holes in the base with the sharp pencil.
- Don't burn yourself with the glue gun.
- Don't cable-tie your fingers or you can cut off the blood supply! Cut off any cable ties on fingers immediately.
- More information is given in the risk assessment.

Slide 4

How a light emitting diode (LED) works

- Show the pupils an LED. 
- If you have an MES bulb in the school cupboard, you could show them one for comparison purposes. If you light up an MES bulb you can feel it getting warm. 

Slide 5

Fit an LED headlight

- The pupils need to bend the legs gently apart or they can snap them. Luckily, there are plenty of spares!
- If using a roll of double-sided foam sticky tape, it is recommended for an adult to retain the roll and just give out what is needed. Sticky pads could be used as they are easier to distribute.

Slide 6

How to connect the headlight

- If the LED is connected back to front it won't be damaged – it just won't light up.

Slide 7

Connect up the headlight

- You may need to move the Crumble back a little to enable you to plug in the USB lead.

Slide 8

Switch on the headlight

- Terminals A to D only output quite low power, so they will not damage the LED or light sensor.
- Motor 1 and Motor 2 produce a higher output, so they should not be used for delicate components like these.

Slide 9

Algorithms

- You could ask the pupils why there is a wait between each command. It is because if you switch the LED on and then immediately off, you won't even see it come on.

Slide 10

Flowcharts

- Point out the different shaped boxes used for start/stop, inputs/outputs e.g. set A high, and processes e.g. wait 1 second. Arrows are used to indicate the order of flow.

Slide 11

Flash the headlight on and off

- You would expect the headlight to flash on and off twice when you run the program.

Slide 12

Flash the headlight continuously

- You would expect the headlight to flash on and off indefinitely when you run the program.

Slide 13

Run the vehicle with the headlight on

- As the headlight also consumes power, it may be advisable to run the motors on 50% power whenever using the headlight. This is slightly dependent on the state of the battery.

Slide 14

How a phototransistor works

- Show the pupils a light sensor (phototransistor). Make sure they know which is the top, where the component is.

Slide 15

Fit a light sensor (phototransistor)

- Make sure the pupils tape the bottom of the light sensor.
- The double layer of foam tape is to allow space to attach the crocodile clips.

Slide 17

Connect up the light sensor

- Make sure the pupils connect the light sensor the right way round.

Slide 19

Using variables and selection

- On a flowchart, a diamond shape is used to indicate selection.

Slide 20

Make the headlight come on in the dark

- The value of 70 is just based on experience of using the light sensor.
- You can adjust the light level at which it switches by changing the value of 70 to other values, e.g. in the range 10 to 100.

Slide 21

How the program works

- The pupils need to be able to identify the different programming constructs: repetition, input/output, variable and selection.

Slide 23

Other uses for light sensors

- The light sensor is useful because the lights only need to come on when it is dark.

Slide 24

How the vehicle is steered

- In a normal car you turn the front wheels in order to steer, so you need good traction on the front wheels.

Slide 25

Where do we want high or low friction?

- We want low friction for slalom skiing or going down a water slide.
- We want high friction for training shoes, bicycle tyres and brakes to improve grip.

Slide 27

Improve traction on the driving wheels

- The front wheels need low traction so they can skid as the vehicle turns.
- The vehicles may not turn easily on carpet or on tarmac in the playground.
- Explain about centre of gravity, and how you can find roughly where it is by balancing the vehicle on your fingertips to make a pivot.
- If you adjust the centre of gravity backwards towards the rear axles, for example by moving the battery box or coils of wire, this will reduce the weight on the front wheels, and hence the friction. Then you may be able to get the vehicle to turn even on carpet.

Slide 28

Measure your vehicle's performance

- Explain that average (mean) speed is the total distance divided by the total time.
- A likely average speed is around 0.6 m/s.
- Can the pupils suggest any reasons why some of their vehicles perform differently from others?

Slide 29

Try out different courses

- A likely maximum angle up the ramp is around 10°.
- Set up a simple course initially (e.g. large square) and challenge your pupils to program their vehicles to get round the course in the shortest time they can.
- You can ask more advanced pupils to set up a more complicated course, or try out some of the other options suggested on the slide.

Slide 31

Plenary

- An LED is more efficient than a traditional bulb because it wastes less energy as heat.
- A light sensor is used to tell whether it is light or dark.
- On the vehicle, high friction was needed on the driving wheels, and when transmitting power through the pulley system.
- Low friction was needed on the front wheels, in order for them to skid when turning.
- Low friction was also needed between the bearings and the wheels or axles, to enable the axles to turn.
- Bicycles have rubber tyres to improve grip. Rubber is a high friction material.
- The 'do forever' loop demonstrates repetition.
- The 'if else endif' part uses selection.
- The variable is 'u'.

Worksheet 1 – Crumble robotic vehicle - suggested answers

ELECTRICITY

Label the following electrical components: motor, cell, crocodile lead, battery.



crocodile lead



battery

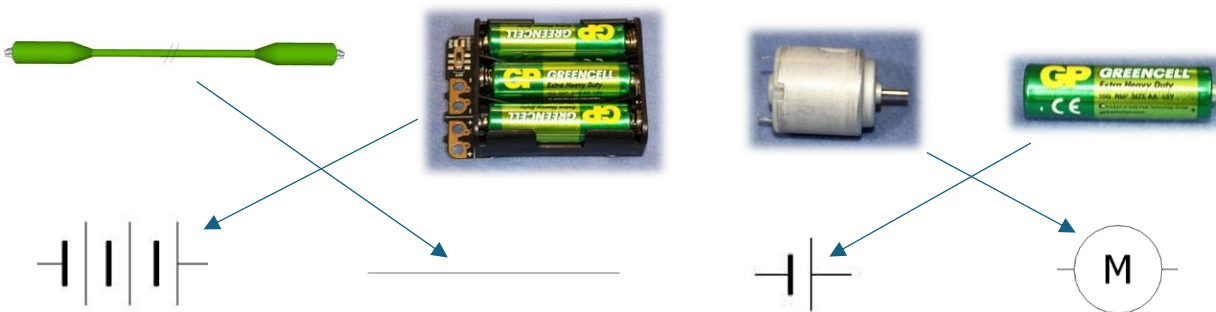


motor

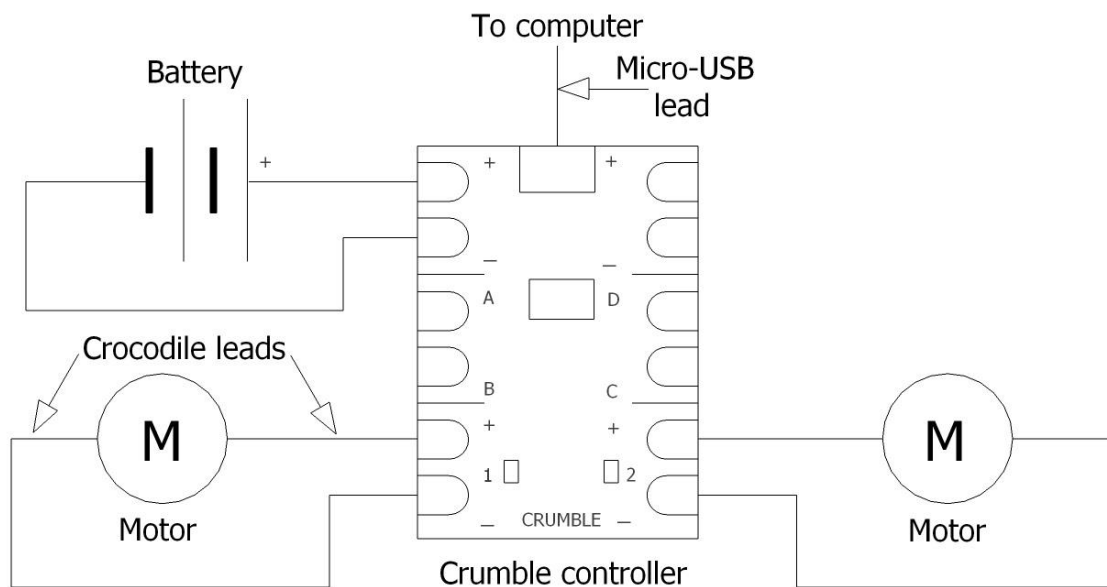


cell

Draw arrows to connect the components to their symbols. The first one has been done for you.



Here is a circuit diagram to show you how to connect the battery and one motor to the Crumble controller. Label the motor, the battery and the crocodile leads.



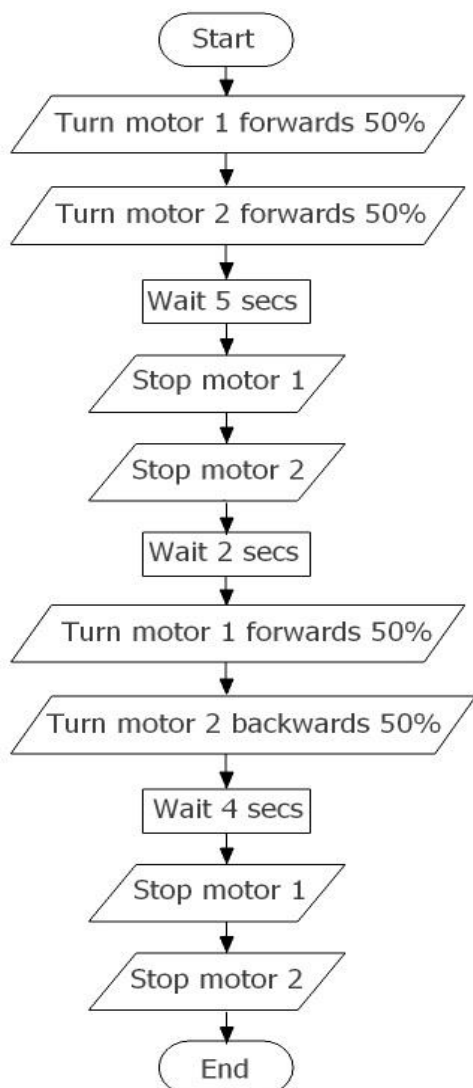
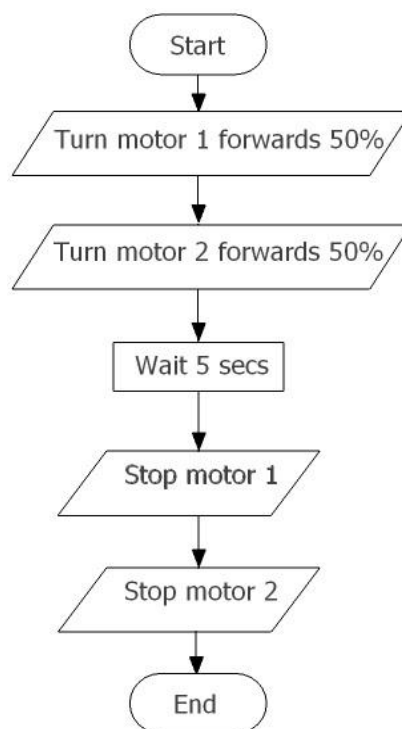
Add a second motor to the diagram and show how it connects to the Crumble controller.

Why are symbols used in a circuit diagram, instead of drawing the actual components?

Symbols are used because they are easier to draw and interpret than drawing the actual components.

PROGRAMMING

- On the right is a flowchart showing the logic for you to program both motors to run at 50% power for 5 seconds and then stop. Construct a program to do this. Run the program and check the motors behave as expected.
- Next, draw a flowchart below to program your motors to run forwards at 50% power for 5 seconds, stop for 2 seconds, run one forwards and one backwards at 50% power for 4 seconds, then stop both motors.

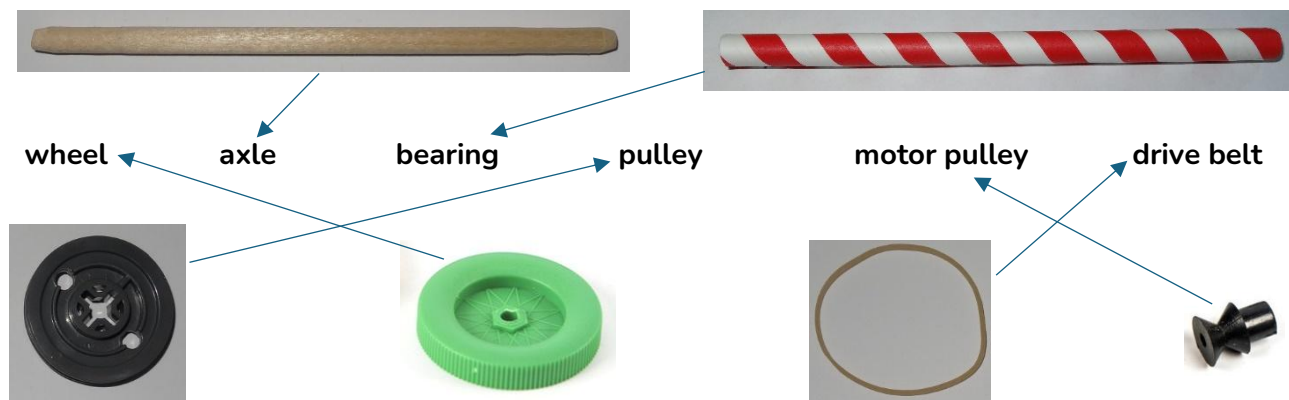


- Below is a program meant to carry out the sequence described in step 2. It has four bugs (errors). Circle the four bugs.



MECHANICAL SYSTEMS

Draw arrows to connect the following mechanical components to their pictures:



What is the purpose of the bearings?

The bearings support the axles, retaining them in position whilst allowing them to rotate.

What would happen if you had high friction between the axles and the bearings?

High friction between the axles and the bearings would act to reduce the speed at which the axles rotate, slowing the vehicle down. If the friction was too high the vehicle wouldn't move at all.

Why do we use a pulley system to drive the vehicle?

The motors cannot drive the wheels directly to make the vehicle move, because the motor shaft rotates too fast and does not produce enough torque. The pulley system reduces the speed and increases the torque enough to drive the vehicle.

Why do the vees of the pulleys need to be in line?

The vees of the pulleys need to be in line, because otherwise the drive belt is likely to come off when the motor starts.

Why do the pulleys and rear wheels need to attach firmly to the rear axles?

If either the pulley or the wheel slips on the axle then the motion is not transmitted, reducing the performance of the vehicle.

EXTENSION QUESTIONS

Why do you need to switch off the battery box when it is not in use?

I need to switch off the battery box when not in use to avoid draining the battery.

Suggest two ways in which you can reverse the direction of rotation of the motor.

I can reverse the direction of rotation of the motor either by programming it to go the other way, or by swapping over the crocodile clips attached to the motor terminals.

| | |
|---|--|
| <p>Why do you need to start the motors on 50% power or less?</p> | <p>I need to start the motors on 50% power or less, because otherwise they draw too much current so that the Crumble controller is not able to boot up.</p> |
| <p>Why do you need to wait for at least two seconds before changing from forwards to reverse?</p> | <p>I need to wait for at least two seconds when changing from forwards to reverse to avoid draining the battery rapidly.</p> |
| <p>What precautions did you take to avoid too much friction between the wheels/axles and the bearings?</p> | <p>To avoid too much friction between the axles and the bearings, I left a small gap between the wheels and bearings, I rounded out the bearings again after trimming them, and I was careful not to pull the cable ties too tight and crush the bearings.</p> |

Worksheet 2 – Crumble vehicle extension activities - suggested answers

| | |
|---|--|
| ELECTRICITY | |
| <p>Why is an LED bulb more efficient than a traditional bulb?</p> | <p>An LED bulb wastes much less power as heat than a traditional bulb.</p> |
| <p>What is a light sensor used for?</p> | <p>A light sensor is used to check whether or not it is dark.</p> |
| <p>Complete this circuit diagram to show how the LED and the light sensor are connected to the Crumble controller.</p> | |

FORCES - FRICTION

Suggest some real-world applications where we want low friction.

Slalom skiing, water slides.....

Suggest some real-world applications where we want high friction.

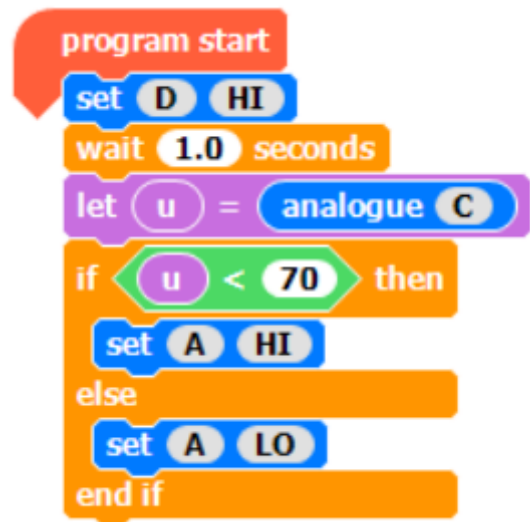
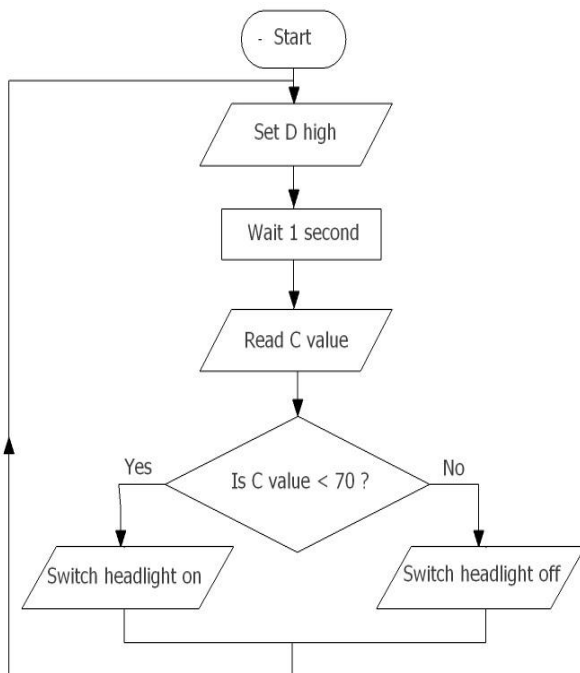
Training shoes, bicycle tyres & brakes.....

PROGRAMMING

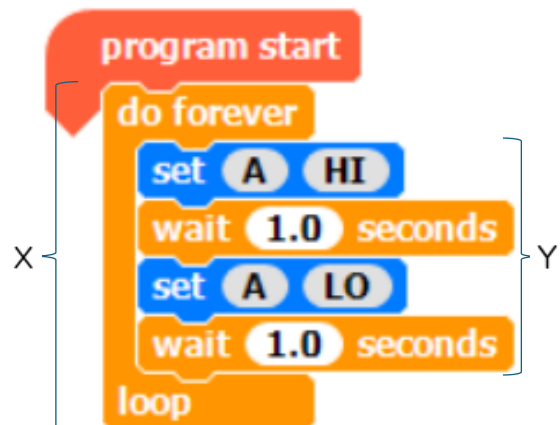
1. On the right is a program used to switch the headlight on if it is dark. Which of the parameters A, C, D and u are being used for the following:

- Input C
- Outputs A, D
- Variable u

2. Complete the flowchart below to show the logic of this program.



3. Below is a program to flash the headlight on and off continuously.



Which part demonstrates sequencing?
Y

Which part demonstrates repetition?
X

| MATERIALS | |
|--|---|
| Is rubber a high friction or a low friction material? | Rubber is a high friction material. |
| Why were rubber tyres added to the rear wheels of the vehicle? | Rubber tyres were added to the rear wheels to improve grip. |
| Why were rubber tyres not added to the front wheels of the vehicle? | Rubber tyres were not added to the front wheels, because they needed low friction to enable them to skid when turning around corners. |
| MATHEMATICS | |
| How did you calculate average speed? | I calculated the average speed by dividing the distance travelled by the time. |