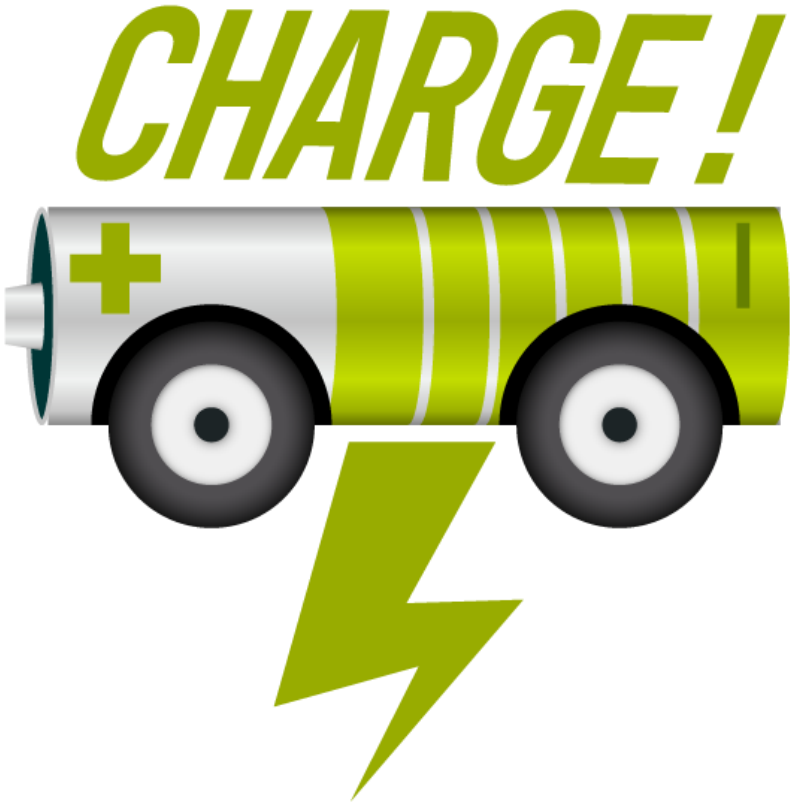
Scottish Council for Development and Industry

Young Engineers & Science Clubs Scotland



Electric Lorry Challenge

Supported by:

SCOTTISHPOWER

Introduction

Following the success of Go Forth, Construct a Crane, Don't Waste a Drop and pH of Scotland, SCDI's Young Engineers and Science Clubs team are delighted to bring you our annual STEM challenge for 2019-20, Charge! thanks to generous support from Scottish Power.

Help!

If you have any problems or questions about the project, please email the Young Engineers and Science Clubs Scotland team at yesc@scdi.org.uk

Feedback

We would love to hear how you're using the project within your school. Please send any feedback, photos or videos to yesc@scdi.org.uk or tweet us @scdiYESC

Health and Safety

Please note that it is teachers' responsibility to ensure activities are carried out safely within the club or class, and to complete a risk assessment in accordance with usual practice before undertaking any practical activities. Please contact us at yesc@scdi.org.uk if you would like a copy of our example risk assessment to help you complete yours.

Background and Careers

The electric vehicle (EV) market is growing but according to the DVLA there are 31.5 million cars on the road in Britain and 31 million of them are still petrol or diesel powered.

Below are some links that discuss how industry and the Government are working towards making EV more accessible, which we hope will be useful starting points for your research poster.

Did you know the world's first electric car was invented by Robert Davidson in Aberdeen way back in 1839! You can read the story in full at The Grampian Transport Museum's, **"It's Electric"** exhibition, which includes a full-sized working replica of Robert Davidson's reluctance motor. This **article** explains how electric cars work, the history behind them and what the future might hold for the industry.

The Energy Saving Trust's **Efficient Driving Tips** might give you some hints and tips of how to modify your design!

ChargePlace Scotland is a network of over 1000 charge points in Scotland and this £7.5 million project will deliver **more electric vehicle charging points**. In Orkney**,** **more than 2% of all car and vans** on the road are electric.

Scottish Power have developed a home charging system called, **Smart EV** and introduced an exclusive Smart Power EV tariff to make **charging more affordable** making the **cost per mile up to ten times less than the cost of petrol.**

Energy suppliers are considering how to meet increasing energy needs while reducing carbon emissions and how the transition to lower-carbon energy will mean enormous change in the products we need. **Shell's Energy Transition Report** discusses their strategy towards the expected changes in the energy system. BP are also working on a **range of solutions** to ensure they can meet the dual challenge of higher energy consumption but lower emissions.

The **Institute of the Motor Industry** has a range of resources and lesson plans to inspire and educate young people on the **diverse range of careers opportunities** within the motor industry, which will evolve as technology progresses.

Car manufacturers are working on their electrification strategy and extensively changing their manufacturing methods. **Jaguar are building a new battery assembly centre and engine manufacturing centre** in the Midlands, to enable them to be able to offer customers electric options for all Jaguar and Land Rover models from 2020.

Developing the Young Workforce is the Scottish Government's Youth Employment strategy to better prepare young people for the world of work, with Regional Groups set up across Scotland connecting employers with education. **Skills Development Scotland** also have resources on how we can prepare for future skills requirements.

The Challenge

You are challenged to build an electric lorry to transport as much cargo as you can across a course in ten minutes.

Charging stations are provided along the way. You must design and load your vehicle for best performance, and choose how often you will stop and recharge. There are penalties if you break down or run out of power between charging stations and have to call in the tow truck.

You are also asked to create a poster about electric vehicles.

There will also be an advanced version of this challenge. If you are interested in programming your vehicle to follow a line and stop at the charging stations automatically, using a micro:bit, Raspberry Pi or similar, please get in touch with us at yesc@scdi.org.uk for more details. You will be able to compete at any of our Regional competitions and there will be prizes awarded at our final competition in Glasgow too. You are welcome to enter the standard challenge as normal too, with the same or a separate vehicle.

Competition Dates

Teams are invited to test their vehicles at our Celebration of STEM events where prizes will be awarded:

- Highlands & Islands Celebration, Eden Court Theatre, Inverness - Thursday 5th March 2020
- Dundee Regional Celebration, Dundee Science Centre - Friday 13th March 2020
- Ayrshire Celebration, Dumfries House, Cumnock - Tuesday 17th March 2020
- North East Celebration, Shell Woodbank House, Aberdeen - Friday 27th March 2018
- South of Scotland Celebration, Borders College STEM HUB - Wednesday 1st April 2020
- National Celebration, Glasgow Science Centre - Friday 5th June 2020

At competitions we can only accept one entry per school, accompanied by up to 6 team members. **Please note** that if you plan to compete for the Regional and/or National Club of the Year Awards and showcase a range of projects at the Celebration events, then the total number of pupils (including any Charge! team members) is 6.

We hope that, like good engineers, you will build more than one design of vehicle and have an internal competition to decide which model will represent your school. If you can't make it along to a competition, we hope you will still have fun constructing and testing your vehicles!

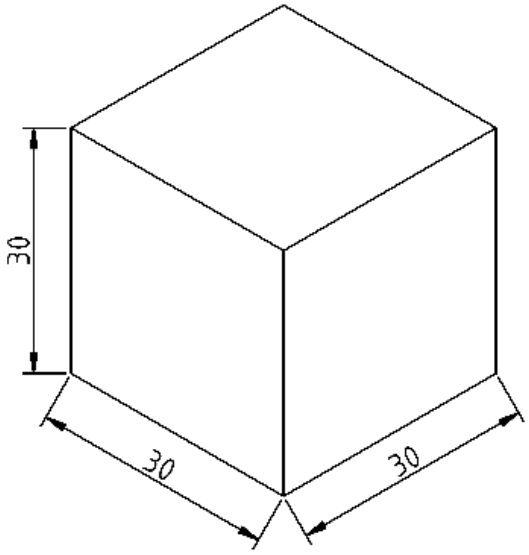
The Vehicle

You are asked to design and build an electric lorry to transport water bottles. A kit of parts is provided to get you started and you are encouraged to use your own materials too. There will be extra points for using recycled materials.

The vehicle shown above is built using only parts from the kit and can carry a single bottle. Instructions are provided to build this vehicle to get you going. You are encouraged to experiment and improve the design. You may also use your own motors, wheels, gears and materials as well as those in the kit.

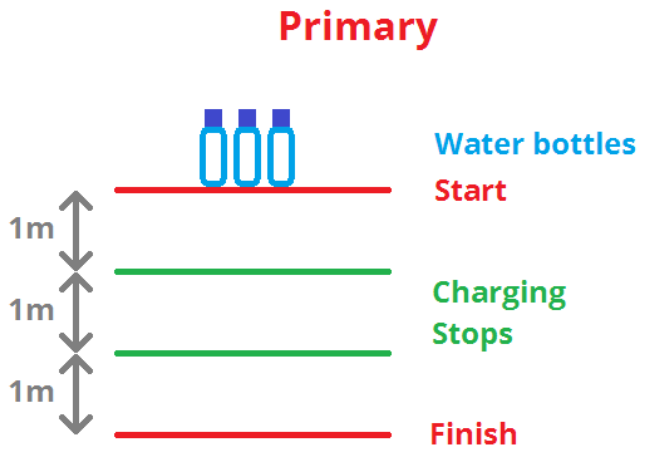
Your vehicle **must** be powered by a single 10F capacitor charged from a 3V supply. Two capacitor modules are supplied in the kit along with chargers. You may also use your own, as long as it is rated 10F and charged to 3V. You will often find capacitors this big referred to as 'supercapacitors'.

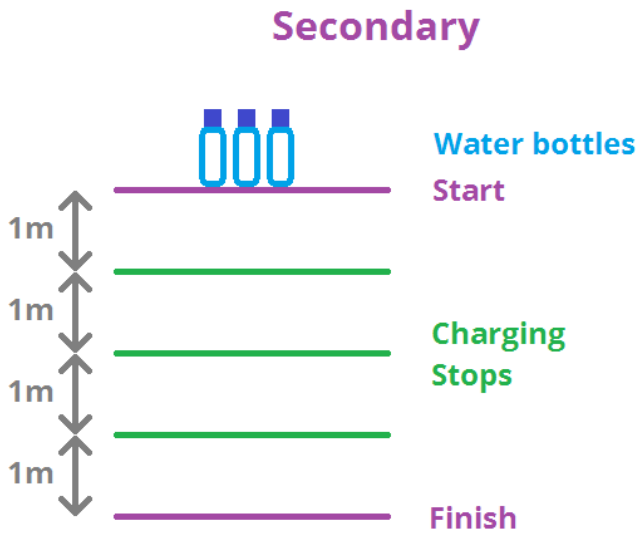
The vehicle when fully assembled, not including cargo, must fit within a cube of size 30cm by 30cm by 30cm.



The Competition

You will be given ten minutes to transport as much cargo as possible across a flat course. The cargo will be standard 500ml full water bottles. For primary schools the course will be 3m long and for secondary schools it will be 4m long.





You can make as many journeys as you like. You must decide how many bottles to load for each journey. You may only load and unload your vehicle at the start and finish point. Any bottles that fall off mid-way will be returned to the start.

A line will be marked across the course every metre to indicate charging stops. You may stop and recharge your vehicle whenever it is over one of the marked charging lines, before setting off on the next section of the journey. You can also charge your vehicle at the start and finish areas.

The car may not move while charging. If you need to lift your car off the ground to charge it to prevent it moving, you must replace it in the same place afterwards.

The competition charger will charge at the same rate as the ones provided in your kit (when fitted with fresh batteries).

The penalty for running out of power between charging stations is severe! Judges will bring a “tow truck” to collect your vehicle and tow it to the nearest charging stop. This will take up valuable competition time and you will also be charged for the service in the form of penalty points.

Your vehicle must return via the course before starting a second journey – you can't just lift it back to the start. If you wish you can change gearing or otherwise reconfigure your vehicle for the return journey. You can make repairs or changes at any charging stop as well as the start and finish area. The course surface will be standard vinyl flooring.

The Poster

As part of the competition you are asked to make a poster about electric vehicles. Some topics you might like to consider are:

- What are the benefits of electric vehicles?
- Why is it important for our society to develop and use alternatives to fossil fuels?
- What types of vehicles are currently powered by electricity?
- What challenges are still to be solved before electric vehicles become more widespread?

Your poster must be interesting, eye-catching, relevant and informative. The poster can be any size. Judges will take a maximum of two minutes to read your poster.

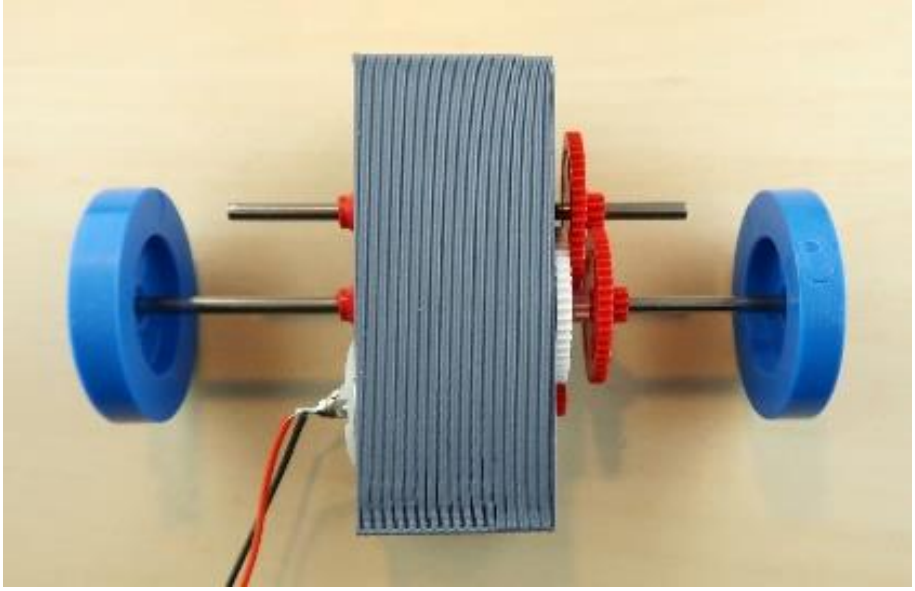
Please Note: In past competitions where scores have been very close, the poster has been the deciding factor for selecting the winner.

Getting Started

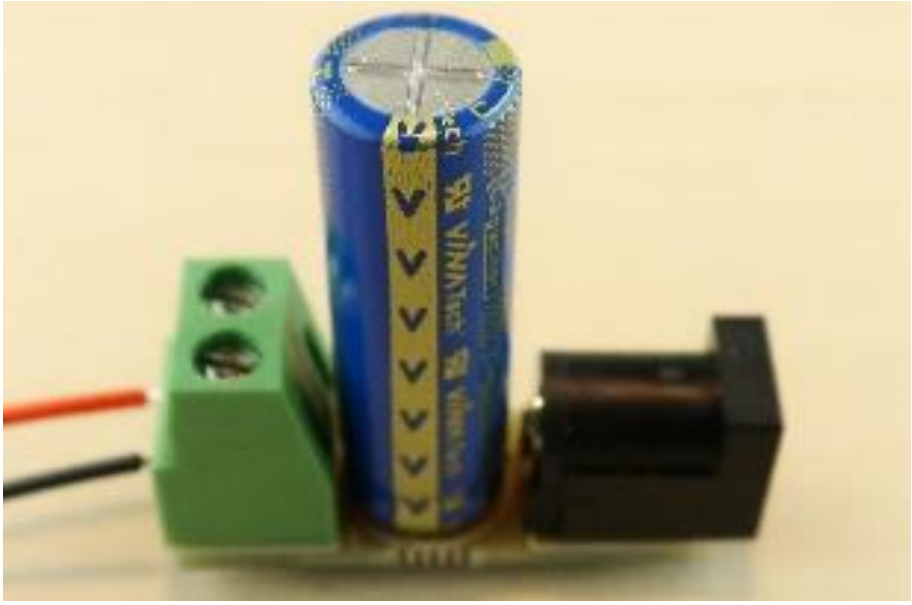
A simple car

Let's build a very simple car that we can then improve upon.

First, take one of the gearboxes supplied in your kit. Push a wheel on to each end of the long shaft.



Take a capacitor module and screw the two wires from the motor into the two screw terminals on the module.



Put some batteries into the charger (the flat ends go against the springs as usual!).

Plug the charger into the capacitor module and turn on the switch on the charger.

Watch as the motor slowly starts to build up speed. Once it seems to have reached top speed (should take about 30 seconds), unplug the charger and put the "car" down on the ground. It should start to move across the room.

You can attach a bottle of water with cable ties if you want to get a feel for how much cargo this basic vehicle can carry.

If your car runs backwards, you can reverse the motor by swapping over the two wires where they attach to the capacitor module.

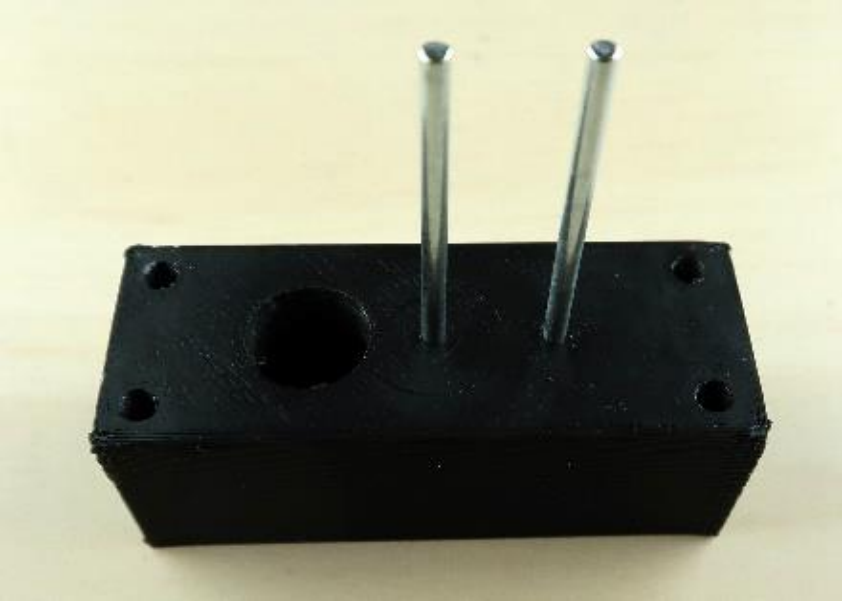
How will you improve upon this basic car? What limitations would this design have in the competition, and how could you make it perform better?

As a starting point, can you add more wheels so the back doesn't drag, and a bigger chassis to hold more bottles?

Investigating gears

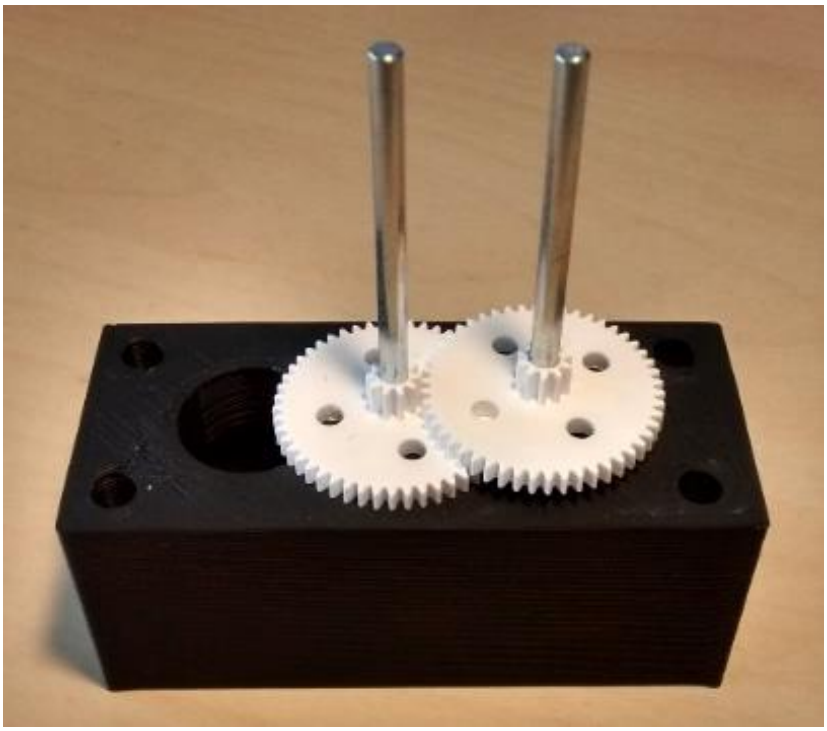
The car we just built runs fairly fast, but it can't move much weight. Here we will investigate how gears work so we can use them to build a car that runs slower but can move much greater weights.

Take the spare gearbox block supplied in your kit and put it on a table with the smoothest side facing upwards. Insert two shafts in the two small holes.



Place a white gear over one of the shafts with the larger side to the bottom.

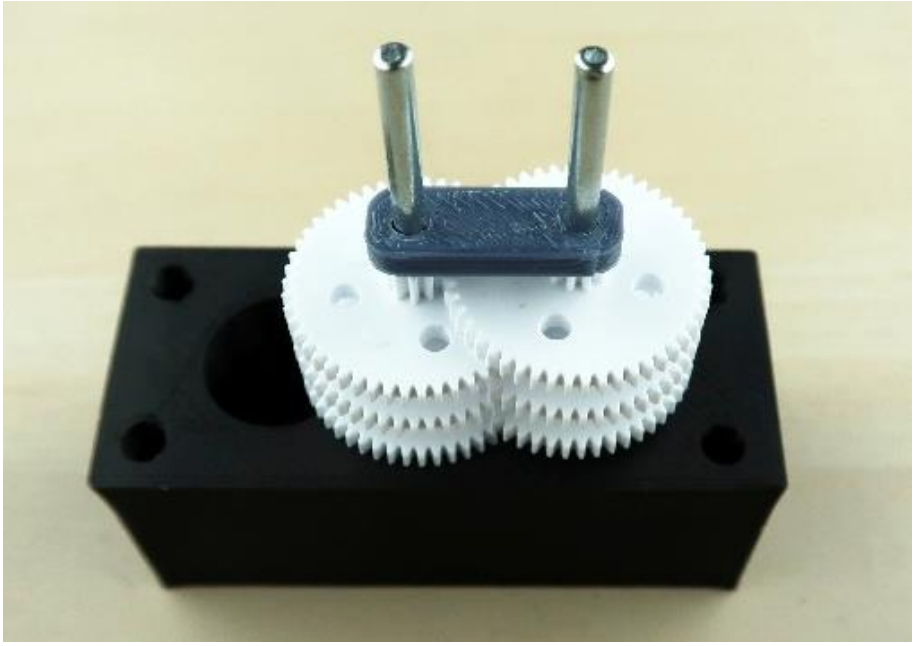
Now place a second white gear over the other shaft, also with the larger side to the bottom. Push it down until it meshes with the small ring of teeth at the centre of the first gear.



Now try turning the first gear and watch what happens to the second gear. Notice the second gear turns much more slowly. You can make a mark on each gear and find out how many times you have to turn the first one to make the second one turn round once. It should be five for these gears. This number is called the "gear ratio".

Importantly, the second gear also turns with five times more strength than the first gear (engineers call this “torque”). We can use this “mechanical advantage” to make our vehicle able to carry more cargo.

You can add even more gears to get an even bigger reduction in speed and a correspondingly bigger increase in strength. Just stack them up, alternating shafts, as shown.



Once you have lots of gears on the shafts, you’ll notice the shafts can move apart enough that the gear teeth don’t mesh properly anymore. Adding the little spacer on top as shown in the picture helps to keep the shafts together and the gears meshed properly.

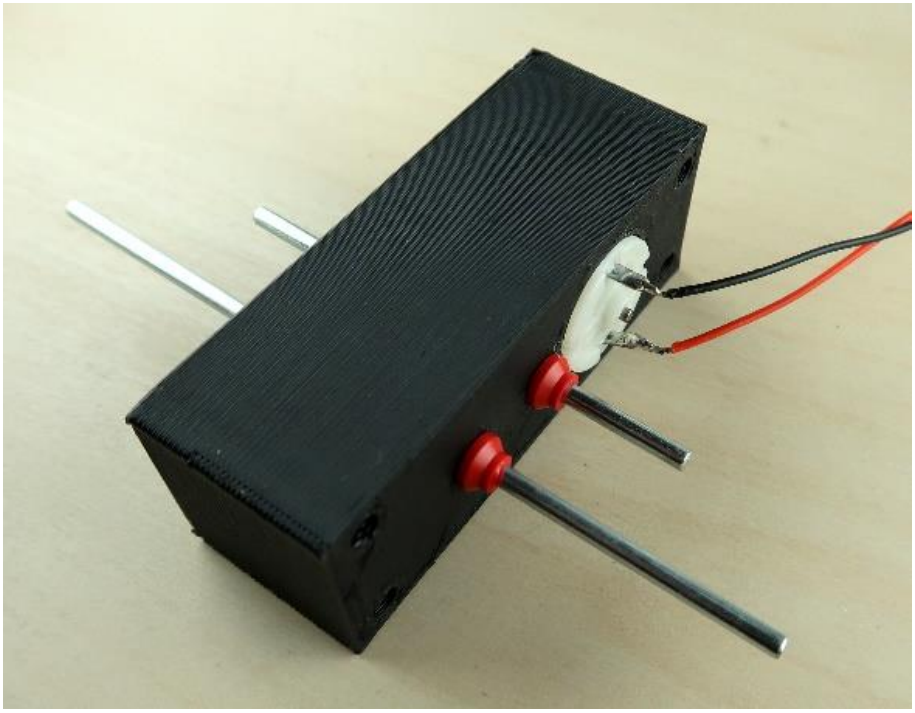
Again, try turning the bottom gear and watch how each gear in the chain turns five times slower than the one below it.

Slowing down the gearbox for extra turning force

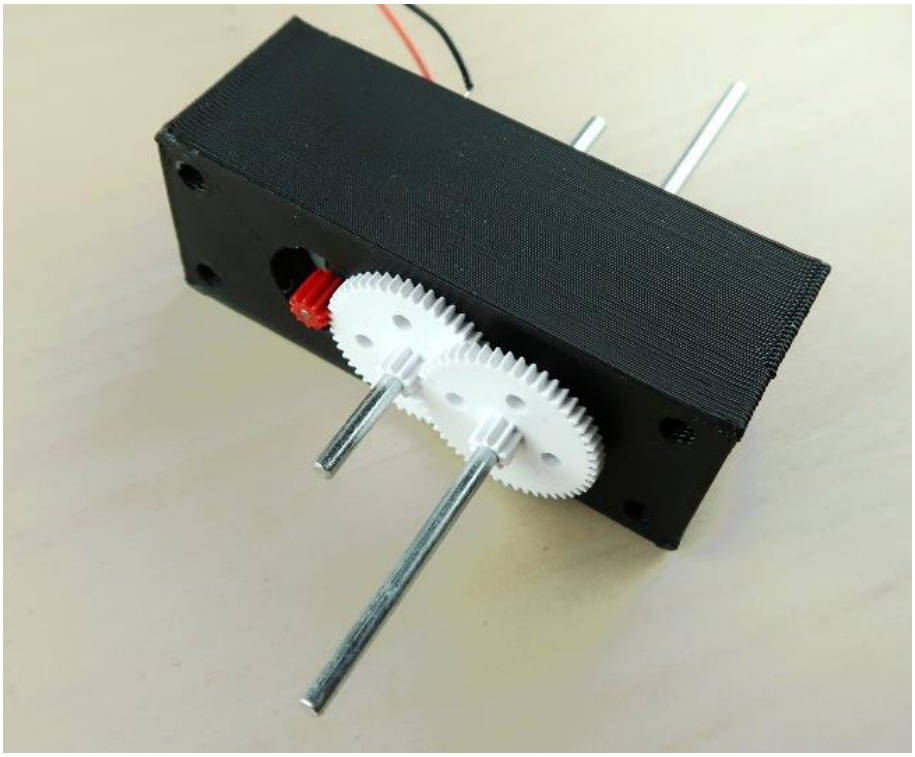
Now we know how gears work, we can reassemble the gearboxes to get some more torque or turning force. They come assembled with three gears which works well for transporting a single bottle fairly quickly. Here we show how to reassemble it with four gears giving extra strength to carry lots of bottles at once. Of course, this comes with the trade-off that it goes at a slower speed.

First remove all the parts from your gearbox except the motor with its wires and little red pinion gear.

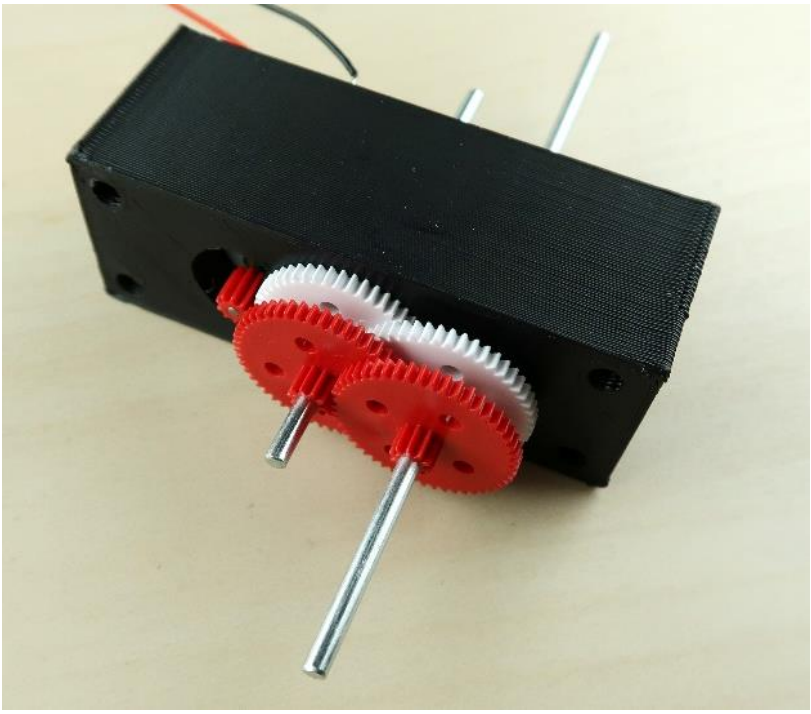
Push an end stop onto each of two shafts and push them up through the holes in the gear block. The short one goes nearer the motor this time and the long one goes further away. Make sure the end stops are on the opposite side of the block from the red pinion gear. Both shafts should be roughly centred in the block.



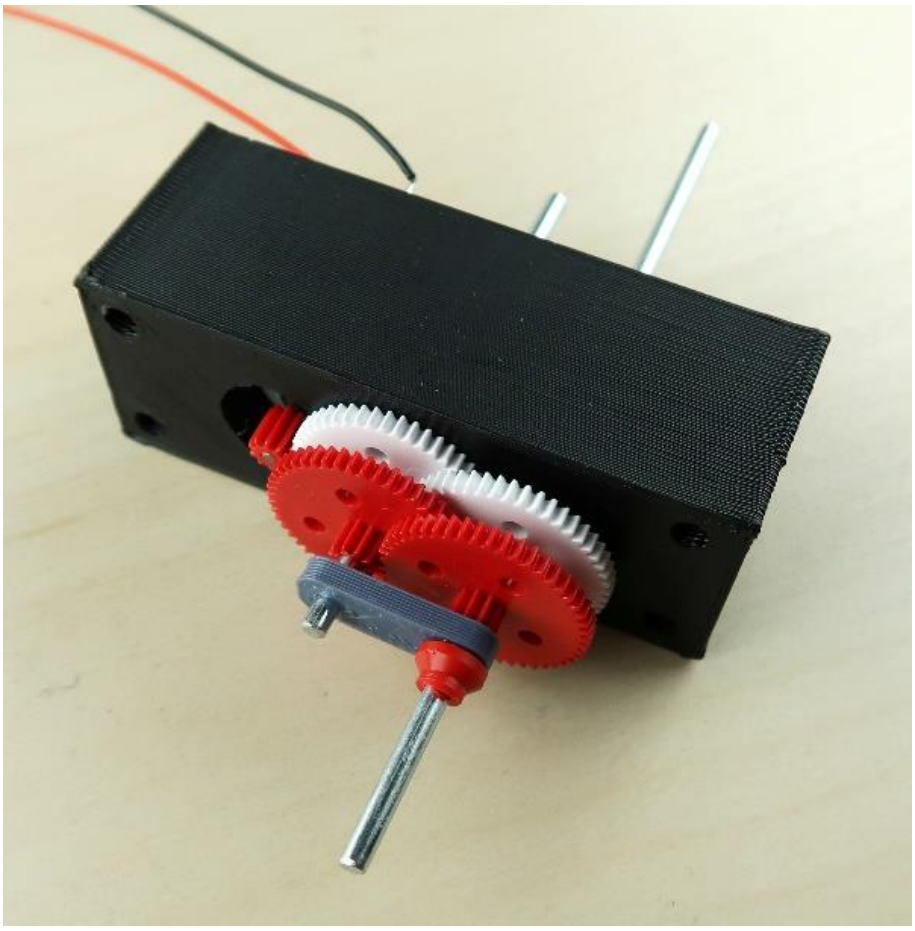
Fit a white gear onto the shaft nearest the motor, big side down, until it meshes with the pinion. Fit a second white gear onto the other shaft.



Push a red gear onto the shaft nearest the motor. Push it almost as far down as it can go but not so tight that the shaft can't turn. It should be loose enough that the shaft can move in and out by about one millimetre. Do the same with the second shaft, again being careful not to overtighten it.

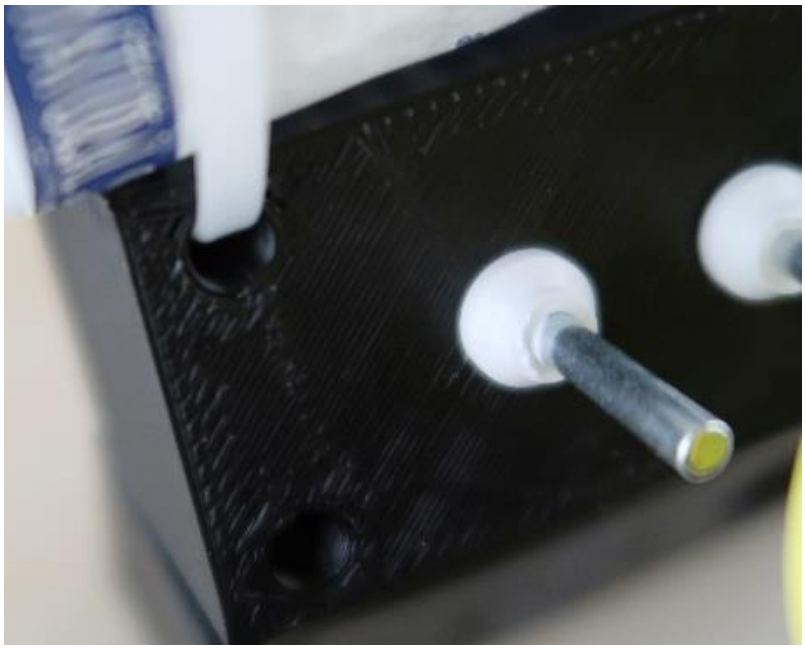


Finally, pop a spacer onto the shafts and hold it in place with an end stop. Once again, make sure you don't push the end stop down so tight that the shaft can't turn.



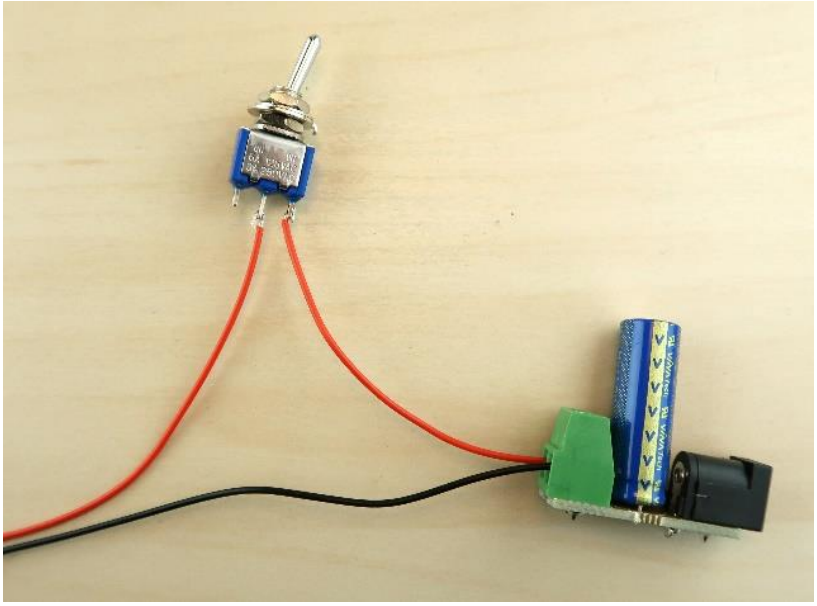
Improving your vehicle

How will you attach a vehicle body to your gearbox so you can hold bottles of water? The holes at each corner of the gearbox are a great place to use cable ties to fix things on. You can also use glue or sticky tape.



How will you make space to hold the cargo so it won't fall out?

When you plug in the charger, it takes about 20-30 seconds for the capacitor to fully charge up. In the competition every second will be precious. Can you speed up charging by fitting a switch between the capacitor and the motor so the motor isn't draining the capacitor at the same time as you're charging it up?



The wheels in the kit aren't very grippy. Can you use rubber bands or cut-up rubber gloves to make them grippier, or swap them for alternative wheels?

You'll notice the gearbox is quite noisy when it runs. To help it run smoothly and reduce wear, rub a little grease (Vaseline) onto each gear. Hopefully it will also reduce friction and so give you a slight performance increase. You might not want to do this until you're sure you've chosen your final gearbox setup so you don't get the parts all sticky while you're still assembling them.

Will you have just one gearbox/motor on your vehicle, or will you have two, one at each side, powering one wheel each? (You can have as many as you want but remember they all have to be powered by a single capacitor module per car).

Some rules to keep things fair

When taking part in the competition, teams will have a few minutes to set up and test their device, followed by a strict 10-minute time slot for the competition. Once the clock starts it will keep running even if you have to make repairs.

Judges will award points for design, inventiveness, the amount of cargo transferred, choice of materials, construction, teamwork and poster design and content.

Judges will favour vehicles you have designed and built yourself over ones with lots of ready-made parts.

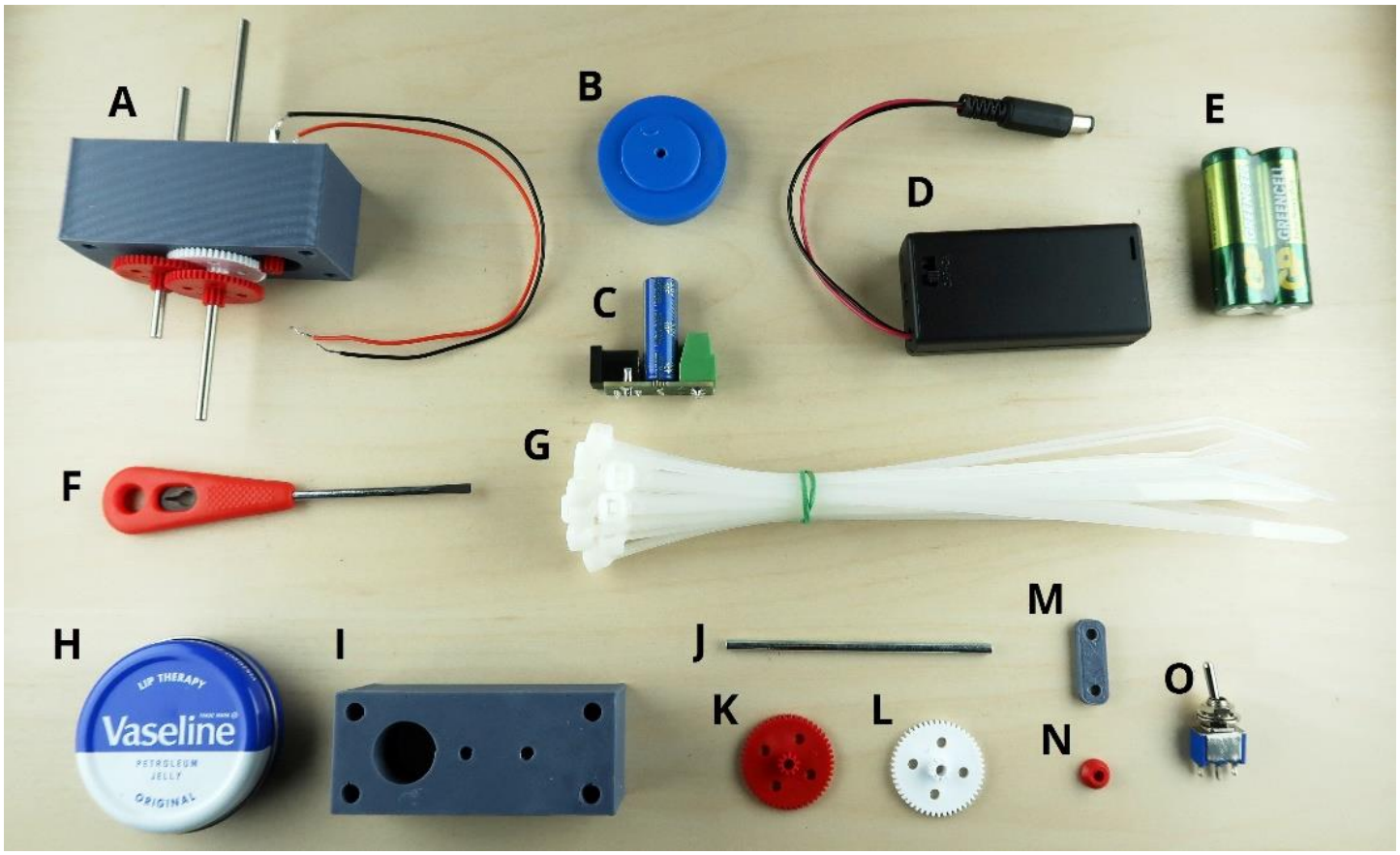
Pupils may only touch the vehicle when it is over a marked charging stop line or at the start or finish point. If it breaks down or runs out of charge between stops, you must wait until the judge brings a “tow truck” to return it to a charging stop.

Teachers are welcome to help with ideas and tricky construction points, but we expect the design and build to be the work of the pupils. Teachers will not be allowed to touch the vehicle during the competition slot and should let the pupils talk about their vehicle with the judges.

If you bring your vehicle to the venue in pieces, remember to assemble it before your competition slot as time is strictly limited!

Please ask us in advance if you are not sure whether something you are planning falls within the spirit of the competition.

Kit contents



Item	Description	Quantity
A	Gearbox	2
B	Wheels	4
C	Capacitor module	2
D	Charger	2
E	AA batteries	8
F	Screwdriver	1
G	Cable ties	20
H	Grease	1
I	Block	1
J	Shaft	2
K	Spare red gear – tight fit	2
L	Spare white gear – loose fit	4
M	Spare spacer	1
N	Spare end stop	2
O	Switch	1

Young Engineers and Science Clubs Scotland

Scottish Council for Development and Industry

1 Cadogan Square, Cadogan Street, Glasgow, G2 7HF

0141 222 9742

yesc@scdi.org.uk

www.scdi.org.uk/yesc

@scdiYESC