STEM ON SCREEN: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## STEM Learning activity resources

**SUBJECT LINKS:**

Design and technology, computing, engineering, physics and maths.

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STEM Learning activity resources

## Introduction

This programme has been created by STEM Learning, the largest provider of STEM education and careers support in the UK. It has been developed in partnership with Club leaders.

## STEM behind the Scenes

STEM plays an important role in the movies, even if you don't always see it on the big screen. Sometimes it's in the special effects that enhance a scene, or even the big ideas behind the story. This programme has students creating their own special effects, building and testing stunt cars and exploring motion capture that could be used to create a spectacular STEM Club promo video. There are also plenty of opportunities for discussion and further exploration.

## Key information

**AGE RANGE:** 14–16

**SUBJECT LINKS:** design and technology, computing, engineering, physics and maths.

**DURATION:** a range of activities from 60 to 90 minutes – at least 6 hours in total.

**FLEXIBILITY:** complete the whole programme over a half term or choose individual activities to suit the needs of your club.

**RESOURCES:** each activity includes a list of the resources required and a comprehensive set of Club leader and student notes.

**IMPACT MEASUREMENT:** each set of resources is designed to help evaluate and assess the progress of Club-based learning on Club members. A useful set of assessment tools are available at www.stem.org.uk/enrichment/stem-clubs

**ACHIEVEMENT:** pupils that successfully complete an entire set of activities can be rewarded with the downloadable STEM Clubs certificate of achievement. Students may be able to use these resources to work towards a CREST Discovery Award.

**APPROPRIATE VENUES:** club leaders can run most activities in general spaces e.g. classrooms, halls, and outdoor areas. Some activities need to be conducted in labs and workshops – these are marked clearly in the Club leader guide and in the table below.

**SAFETY:** each activity includes details about significant health and safety considerations, such as appropriate eye protection, gloves, etc. Club leaders should ensure that all equipment is handled with care, particularly sharp instruments. Advice and guidelines are available from CLEAPPS and SSERC, or see the STEM Clubs handbook (page 20). We recommend that practical activities are risk assessed before commencing and Club leaders must follow their employer or organisations policies.

**OTHER ACTIVITIES:** visit www.stem.org.uk/resources/stem-clubs/ for a wealth of ideas for STEM-related clubs.

**FURTHER SUPPORT:** the STEM Clubs Best Practice handbook includes comprehensive support for leaders of all STEM-related clubs. It can be found at www.stem.org.uk/stem-clubs/getting-started

## Activities

| | | | |
|---|---|---|---|
| 1 | **HOLD IT STEADY:** Students create a super simple camera stabiliser and shoot test footage to see how even a simple system can produce shots that are smooth and controlled. | 60 minutes | |
| 2 | **SPECIAL EFFECTS:** students explore how to make movie special effects. They experiment with fake snow made from sodium polyacrylate and water. Their new-found special effects knowledge could be used in the creation of a STEM Club promotional video. | 60-90 minutes | |
| 3 | **I FEEL THE NEED, THE NEED FOR SPEED!:** students build, program and race their very own cardboard model F1 cars around a small section of track. | 2x 60 minute sessions | |
| 4 | **MOVIE STUNT CAR JUMP:** students recreate their favourite car stunt from a movie by making ramp(s) from different materials and using a remote-control car to test . | 90 minutes | |
| 5 | **WHAT CAN MOVIES TELL US ABOUT THE FUTURE?:** students look at exoskeletons that augment human performance and attempt to produce a functional example of what is possible. | 60 minutes | |
| 6 | **MOTION CAPTURE FOR SPECIAL EFFECTS:** students apply their knowledge of anatomy to plan a motion capture map and capture their motion in slow motion video. | 60 minutes | |

CLUB LEADER GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 1 Hold it steady

## Objective

Students create a super simple camera stabiliser and shoot test footage to see how even a simple system can produce shots that are smooth and controlled.

### TOPIC LINKS

- Design and technology: mechanisms; properties of materials
- Physics: mass, inertia

### TIME

60 minutes

### RESOURCES AND PREPARATION

You may wish to build a test version yourself before delivery.

- saws, screwdrivers, suitable drill bit and drill (optional)
- each small group will need:
- planed timber, 1200mm x 80mm x 15mm
- milk bottle cap
- 3 small washers
- 2 x ~80mm Phillips self-tapping screw
- 9 x ~25mm Phillips self-tapping screw
- 2 x strong ~50mm rubber bands
- slotted masses (that fit over a screw) or large, heavy washers.aeroplanes, pieces of tissue paper, paperclips, salt & pepper

### DELIVERY

1. Introduce the scenario: lots of movies use camera stabilisers, such as Steadicams, to track characters as they move and to add to the feel and drama of a scene. Could students capture similar shots using a phone camera and a few bits of timber?
2. Students form pairs or threes. Discuss what STEM roles might contribute to developing and using camera stabilisers while filming movies and TV, for example: mechanical engineer, electrical engineer, designer, cinematographer, camera operator, camera technician etc.
3. Guide students through the process of making their camera stabilisers. Teams should split the work and find ways to complete steps at the same time where possible. Students can optionally drill pilot holes through the cap and camera holder, as well as through the legs into the top and bottom pieces, to make it easier and faster to tighten these screws. Teams should make sure to insert the long screw through the handle until the head touches the bottom of the handle, so that when it is held, the screw points up.
4. Teams practise using their camera stabilisers without a phone. They should lightly touch or hold one leg to control the motion.
5. Students should only attach their phones to the holder and shoot some test footage if they can do so over a soft surface, such as grass or a gym mat.

**TIP**

**Students can add a little extra mass to the bottom of the screw to increase inertia and stability if required.**

### HEALTH AND SAFETY:

A suitable risk assessment using guidance from CLEAPSS and SERCC should be written and adhered to for this activity.

If the wood is pre-cut, this will reduce risks considerably. If not, please first demonstrate correct and safe use of a saw, then supervise during cutting. Supervise the use of screwdrivers and drills also.

## TIPS

- This may need to be done in the D&T department. Seek specialist help if needed
- Students use their smartphones at their own risk and should move slowly and carefully to avoid damage.
- You can use smaller timber (eg. 12 x 44mm) for the top, legs, bottom and handle of the camera stabiliser, but will need a wider section for the camera holder - about the same width as a phone and thick enough to securely screw into the thin side.
- Students should take care when locating the centre of a face - this is needed for balance. The milk bottle cap is not essential but adds safety if the handle screw jumps out the top screw's head.

## DIFFERENTIATION IDEAS

**Support:** cut the wood to length before the lesson. Make a sample for students to copy. Have a technician or experienced teaching assistants available. .

**Challenge:** ask students to think about how they would improve the design. See links below for suggestions.

## EXTENSION IDEAS

1. Students can research and build a full 3-axis gimbal and use this in a more complex camera stabiliser design using bent aluminium - there are many designs available online.
2. Students can design and 3D print a plastic phone holder for the top of their camera stabiliser, or design and 3D print the parts needed for a 3-axis gimbal, as above.
3. Once they are used to using the system, teams could plan and film a longer tracking shot following a student around the school or some other location, taking great care not to knock the holder assembly off the handle.

## USEFUL LINKS

- This 3-minute clip explains how 3 axis gimbals work
  www.youtube.com/watch?v=VkXyWUcO9hc&feature=youtu.be
- This clip shows an alternative method to construct a camera stabiliser.
  www.youtube.com/watch?v=r_ui5Btmiq4&feature=youtu.be
- A clear photo-led instruction can be found at
  www.instructables.com/id/How-to-make-a-DIY-Steadicam/
- With Access to a 3D printer you can easily print this 3-axis gimbal from thingiverse.
  www.thingiverse.com/thing:2354817/#files

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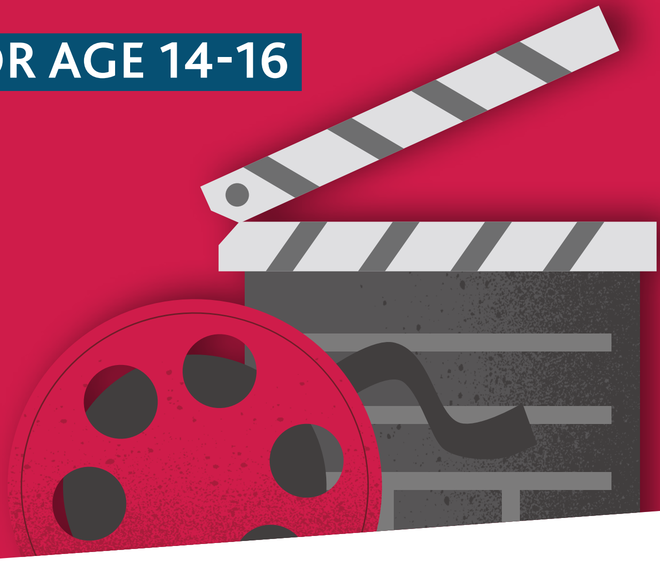
# STEM behind the Scenes

## 1 Hold it steady



### Your challenge

**Camera stabilisers, such as the popular Steadicams, create smooth, dramatic shots. Do you think you could create your own camera stabiliser? It could help to bring your camera footage to life!**

**YOUR TASK Build a super simple camera stabiliser for a camera phone and film some test footage.**

### WHAT YOU NEED TO DO:

1. Cut the six wooden pieces you need from your length of planed timber:

| Piece | Dimensions | Quantity |
|---|---|---|
| Camera holder | 150mm x 80mm | 1 |
| Top / bottom | 120mm x 80mm | 2 |
| Legs | 350mm x 80mm | 2 |
| Handle | 100mm x 80mm | 1 |

2. Draw diagonal lines between opposite corners of the top and bottom pieces to locate the exact centre of their faces. Do the same for the long side of the camera holder.

3. As shown in the diagram: Screw a 25mm screw through the milk bottle cap, the centre of the top face, the 3 washers and into the centre of the camera holder's thin side. Tighten.

**Note:** The milk bottle cap is 'protection' in case the point of the handle pops out of the screw head it is attached to while the camera stabiliser is being used. It should stop the camera holder falling to the ground.

4. Screw one of the 80mm screws into the centre of the bottom piece to create a holder/hook on which additional weights can be placed, as illustrated in the diagram. The additional weights will counterbalance the weight of the camera. Slotted masses will be most convenient to use.

## FUN FACTS

1. Adding mass to the protruding screw on bottom of your camera stabiliser will help to steady the camera by adding to the system's inertia. That is, its resistance to changes in motion.
2. The earliest mention of a gimbal mechanism dates back to the third century BC.
3. Motorised gimbals use inertial sensors to measure changes of direction and servomotors to move the gimbal the opposite way. This provides automatic camera stabilisation for drones and other camera systems.

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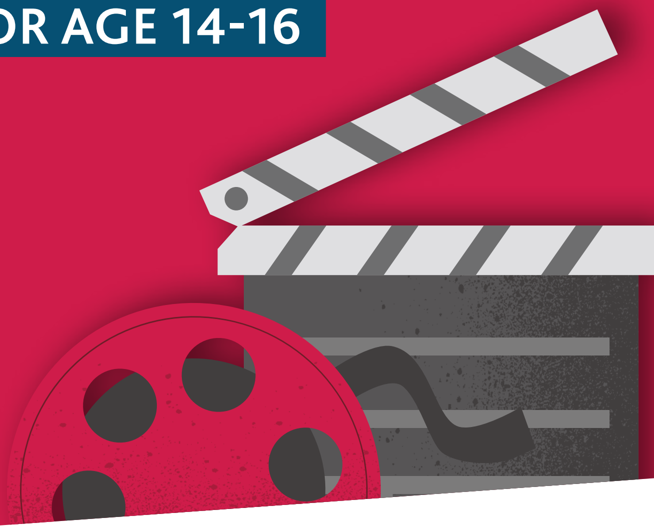
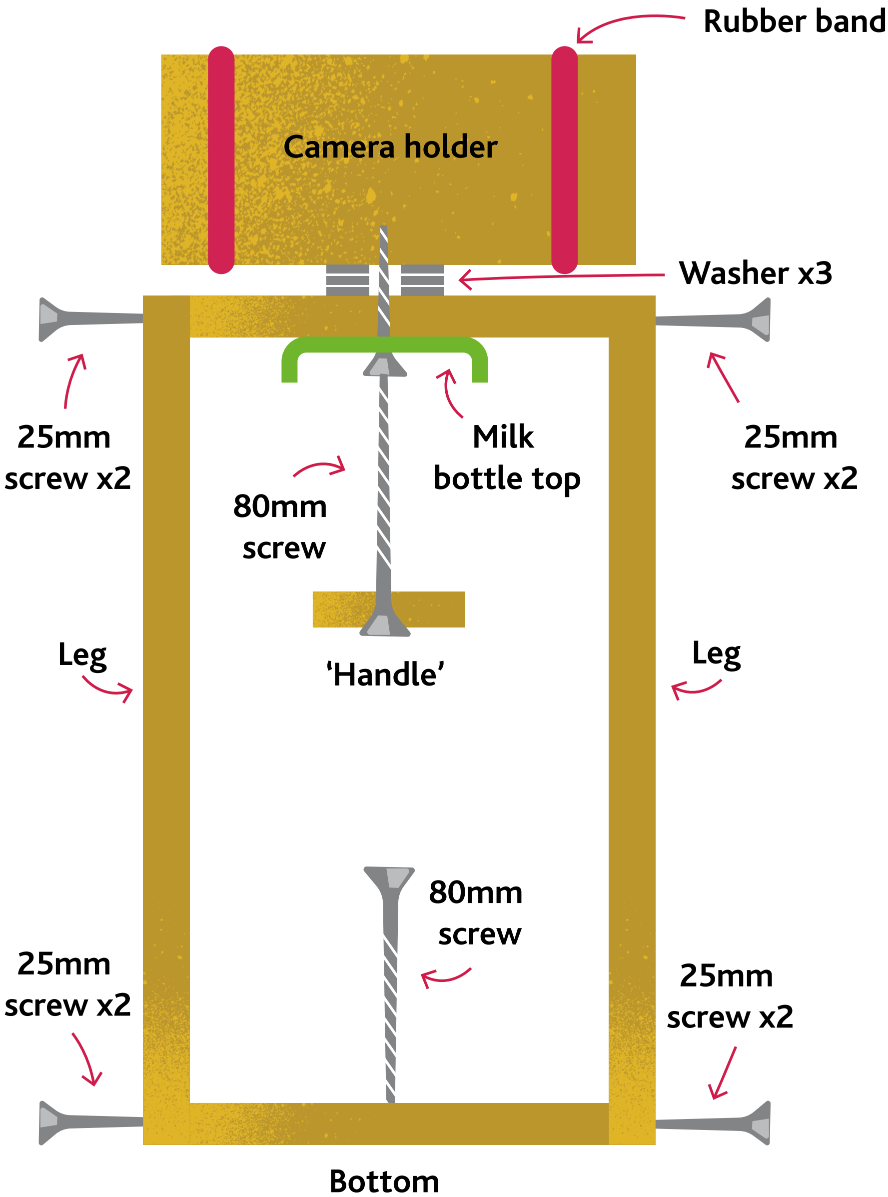
# STEM behind the Scenes

## 1 Hold it steady



5. Screw the legs to the ends of the top and bottom pieces, as shown in the diagram. Use eight 25mm screws to do this.
6. Screw one of the 80mm screws completely through the handle piece, so that the screw head is flush with the wood. Hold the handle so this screw points up.
7. Insert the tip of the handles 80mm screw into the X-shaped screw head of the short screw holding the milk bottle cap to the camera holder, so that it balances on the handle.

   This will create a simple gimbal allowing your camera stabiliser to move freely.
8. Practise walking around with your camera stabiliser. You can lightly touch one leg to control the camera holder's movement.
9. If you wish, use rubber bands to secure a phone to the camera holder. Shoot using the front-facing camera. Shoot over soft ground only. Plan and shoot a brief clip to see how well you can control the camera.
10. Present your camera-stabilised shot to the group!



STEM CLUBS

NUMBER 1 FOR STEM

CLUB LEADER GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 2 Special Effects

## Objective

Students explore how to make movie special effects. They experiment with fake snow made from sodium polyacrylate and water. Their new-found special effects knowledge could be used in the creation of a STEM Club promotional video.

**TOPIC LINKS**

Chemistry

**TIME**

90 minutes

**RESOURCES AND PREPARATION**

- disposable nappies
- polysnow can be purchased here: www.snowsupermarket.co.uk/artificial-snow-c3/magic-snow-c102/instant-snow-polymer-1kg-p18
- top pan balance
- distilled/deionised water

**DELIVERY**

1. Cut open a disposable nappy and add coloured water (preferably yellow to mimic urine!) for a demonstration of the super absorbent polymer sodium polyacrylate (which is found in disposable nappies). Explain that students will now carry out observations on an even more absorbent polymer (PolySnow), which is commonly used on movie sets.
2. The chemistry that allows for PolySnow's amazing absorbent abilities is based around osmosis driven by a greater concentration of sodium ions inside the polymer compared to water. PolySnow will absorb approximately 500–800 times its own weight in de-ionised water, but will only absorb about 300 times its own weight in tap water, due to the high ion concentration of tap water.
3. Show students how to use the top pan balance to measure out 3g of PolySnow, then pour it into a 1000ml graduated beaker. Add 150ml of deionized water to the beaker also and measure the volume of swelling that occurs.
4. There are several possible experiments your students could conduct based around this activity:
   a. How does the swelling rate change with different amounts of polymer? Your students could investigate a range of masses of polymer from 1 to 10g. Does it show a direct correlation between mass and volume increase?
   b. How does the swelling rate change with different amounts of deionized water? Students could measure different volumes of water and record the resulting increase in volume. What correlation does it show?
   c. How does the rate of swelling change when PolySnow is treated with hot water versus cold water? Use a water bath to control water temperature at several different values and measure the resulting volume increase.
   d. Does deionized water produce greater swelling than tap water? A simple comparison with controlled variables should yield very different outcomes in swelling volume. (Up to 800% in distilled/deionised water compared to up to 300% in tap water, due to the fact that sodium ion content is higher in tap water.) Can they explain why this happens?

## HEALTH AND SAFETY:

A suitable risk assessment using guidance from CLEAPSS and SERCC should be written and adhered to for this activity.

PolySnow is nontoxic. However, it is irritating to the eyes and to the nasal membranes if inhaled.

Students MUST wear suitable eye protection.

## SCIENTIFIC UNDERSTANDING

Sodium polyacrylate is the absorbing agent found in disposable nappies. This polymer can absorb up to 800 times its own weight in distilled/deionised water, 300 times in tap water and 60 times in 0.9% NaCl (a standard solution used to mimic urine absorbency). The difference in these three solutions is the electrolyte concentration. This is due to the property of the polymer, which increases osmotic pressure under low electrolyte concentrations, allowing the polymer to swell, and which decreases osmotic pressure under higher electrolyte concentrations, causing the polymer to release water. In distilled/deionised water, water is absorbed by the polymer to lower the [Na+ ] inside the polymer. When salt water is added to the gel, the electrolyte concentration outside of the polymer increases and water exits the polymer to equilibrate [Na+ ]

## TIPS

- **Ask different groups of students to perform different versions of the experiment (a, b, c or d) then swap which experiment each group is performing. Afterwards, the groups can check their results against the results of other groups.**

## DIFFERENTIATION IDEAS

**Support:** only explore the difference between tap water and distilled/deionised water, then give the students the chance to link back their findings to the science. Explain the science to them using their findings if necessary.

**Challenge:** for more able students, you could direct them to the resource on osmosis and ask them to reach the ideal conditions for creating the maximum volume of Polysnow without support. Additionally, using a range of concentrations of NaCl solution, students could investigate the rate of osmosis and how it is affected by ion concentration. This is similar to the osmosis of a potato chip practical that is common at KS4.

## EXTENSION IDEAS

Can they explain how cross linking in the polymers affects how much water the polyacrylate can absorb?

If you add common salt to the fluffy 'snow', the water leaves the snow and forms a wet slurry. Direct students to online resources to use their knowledge of osmosis to explain why.

STUDENT GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 2 Special Effects

### Your challenge

**You have your camera ready and your actors are ready to perform, but to bring your film to life you need some amazing special effects!**

**YOUR TASK** **You are going to re-create a beautiful, snowy landscape – all through your knowledge of chemistry!**

### WHAT YOU NEED TO DO:

First you need to find the perfect conditions for creating your snowy landscape.

1. Measure out 3g of PolySnow using a top pan balance and pour it into a 1000ml graduated beaker. Add 150ml of deionized water to the beaker and measure the volume of swelling that occurs.

1. Conduct experiments to determine the following:
   - a. How does the swelling rate change with different amounts of Polysnow?
   - b. How does the swelling rate change with different amounts of deionized water?
   - c. How does the swelling rate change when PolySnow is treated with hot water versus cold water?
   - d. Does deionized water produce greater swelling than tap water? Can you explain why?

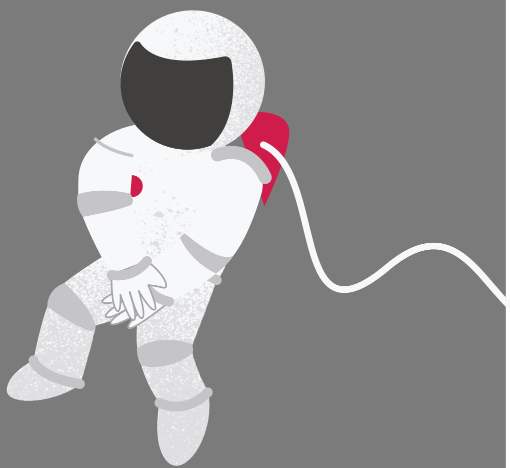
Determine conditions to achieve the greatest amount of swelling. Once you think you have found them, you are ready to create your snow scene!

**Once you have perfected your snow-making method, you will be ready to film your beautiful, snowy movie scene for the STEM Club promo video!**

## FUN FACTS

1. Super-absorbent polymers, such as sodium polyacrylate, were first developed in the late 1960s by the US Department of Agriculture. They were searching for ways to hold moisture in soil more effectively.

2. Super absorbent polymers have since been used in absorbent space suits. This allows busy NASA astronauts to relieve themselves when they are unable to pop to the loo!



STEM CLUBS

NUMBER 1 FOR STEM

CLUB LEADER GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 3 I feel the need, the need for speed!

## Objective

F1 has always been popular in movies, with both “Rush” and “Senna” being recent box office hits.

In this activity, students will build, program and race their very own cardboard model F1 cars around a small section of track. The track could be drawn in chalk/masking tape and modelled on a section of a real-life racetrack like the Circuit de Monaco, Silverstone or Nürburgring.

### TOPIC LINKS

- D&T: Design and prototype of a model F1 car. Program BBC Micro:bits to control servo and motor
- Maths/Physics: Forces on driver and car (centrifugal force, G forces, spoilers to cause downforce on rear wheels), aerodynamics etc. Newtons Laws of Motion.

### TIME

2x 60minute sessions.

### RESOURCES AND PREPARATION

- BBC Micro:bits or Crumble
- computers to program Micro:bits and design/analyse model F1 cars
- motor driver board for BBC Micro:
  www.kitronik.co.uk/pdf/5602_bbc_microbit_motor_driver_v1.0.pdf
- push to make switches
- servo motor
- high rpm motors
- hot glue gun
- craft knife
- cardboard
- plastic wheels and wooden dowel axle
- worksheets on forces relating to F1 – G forces, centrifugal force, downward forces caused by spoilers on the front and rear of the car, etc.Motion Studio or I Can Animate

**TIP**

This may need to be done in the D&T department. Seek specialist help if needed

### HEALTH AND SAFETY:

A suitable risk assessment using guidance from CLEAPSS and SERCC should be written and adhered to for this activity.

Make sure you have a room large enough to facilitate the making of cars.

Take care when using glue guns and craft knives.

Make sure the students wear an apron, gloves and suitable eye protection throughout the D&T sections of the activity.

Testing should also be carried out under teacher supervision.

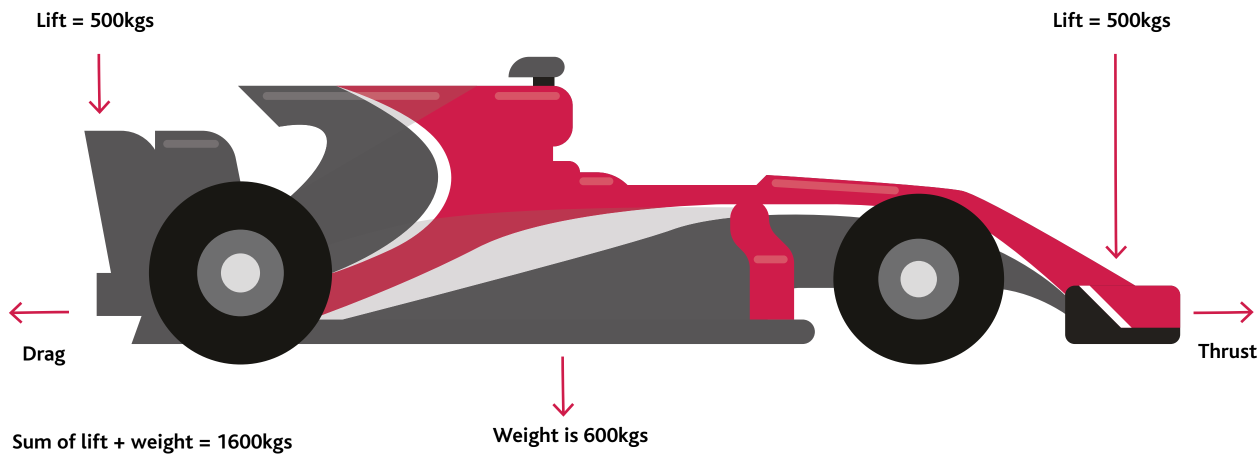
CLUB LEADER GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

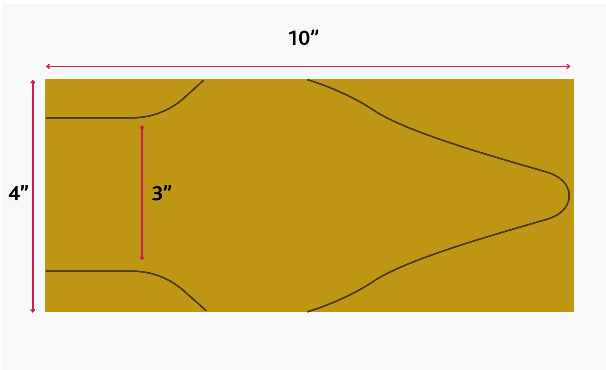
## 3 I feel the need, the need for speed!

### DELIVERY

1. Ask students what forces act on an F1 car.
2. Show diagram below. Downforce is created by the front and rear spoilers to stop the car taking off into the air. They are similar to an aircraft wing upside down.

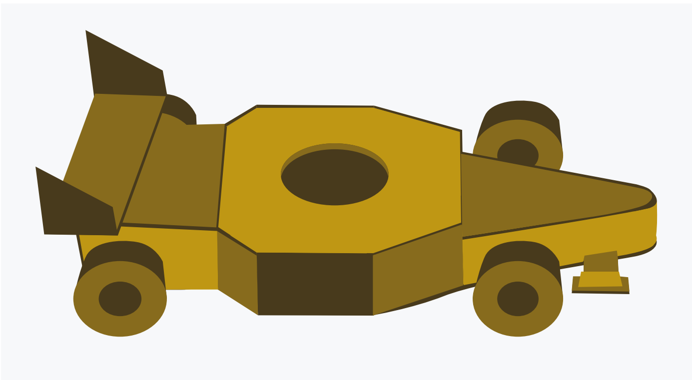



3. Give students time to explore how their car will be controlled using a BBC Micro:bit with following resources that can be printed out and given to students.
   www.kitronik.co.uk/pdf/5602_bbc_microbit_motor_driver_v1.0.pdf
   www.kitronik.co.uk/blog/using-bbc-microbit-control-servo/
4. Break students into groups of 2–3 (or more depending on resources).
5. Students should start to design the body shape of their F1 car. Sections of car i.e. chassis can be drawn onto cardboard and cut out similar to the example below. See Useful links for additional information. Sides can then be cut out and glued on using glue gun.



6 Students push wooden dowel axle through cardboard sides at the front of the car and attach wheels. Back wheels will be powered using motors controlled by micro:bit.

7 Students attach micro:bits, motors and servo to the chassis using a glue gun. Wheels will be supplied and spoilers can also be added if time allows.



8 Programme the micro:bits (refer to resources in section 3).

9 Students can now attempt their first test session on the track. They should take notes about what works well and what they might need to improve.

10 Give students time to discuss and improve their programming of micro:bits to get their F1 car around the track more accurately and quicker.

11 Once they've made their modifications, run the test once more and ask them to take notes on what they observe.

12 Students should discuss feedback with their peers as to how their car performed and what they would improve if doing the challenge again.

## DIFFERENTIATION IDEAS

**Support:** pre-cut the body panels and provide a sample coding flowchart for the micro:bit.

**Challenge:** if students have successfully programmed their car to complete the section of track, set up a more complicated track as an extra challenge

## EXTENSION IDEAS

1 Students could add another micro:bit and two motors to power front wheels to have a 4 wheel drive F1 car.

## USEFUL LINKS

- Example car design with instructions
  www.instructables.com/id/How-to-Make-a-Remote-Control-Car/
- Using a BBC microbit to control a servo motor
  www.kitronik.co.uk/blog/using-bbc-microbit-control-servo/
- Connecting and controlling motors using a BBC Micro:bit
  www.kitronik.co.uk/pdf/5602_bbc_microbit_motor_driver_v1.0.pdf
- Forces on Lewis Hamilton – watch the gauge on the left of the screen, as this shows you the strength and position of the forces acting upon his body.
  https://www.formula1.com/en/latest/features/2017/3/f1-video-2017-vs-2016-g-force-comparison.html

STUDENT GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 3 I feel the need, the need for speed!

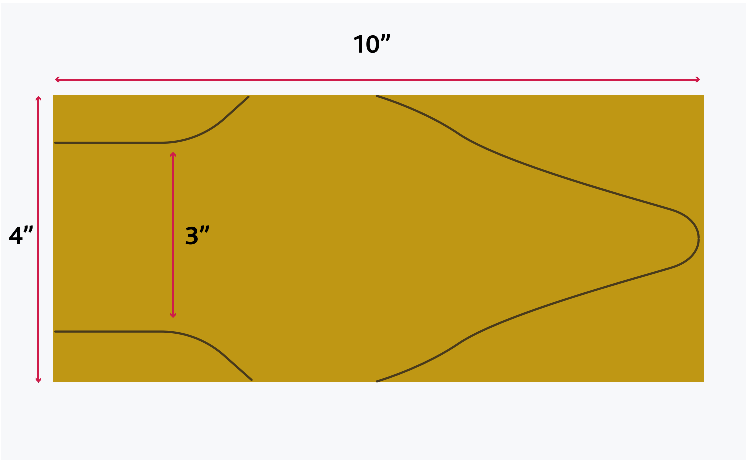
## Your challenge

**Car chases can make any movie more exciting. You will design, build, program and race your very own model F1 car. Can you use it in your own film scene?**

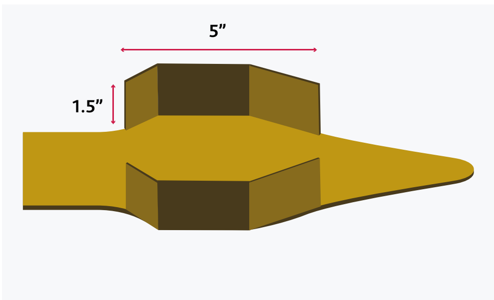
**YOUR TASK Get ready for the race of your lives as you design, build, program and race your very own model F1 car. How fast and far will you go?**

### WHAT YOU NEED TO DO

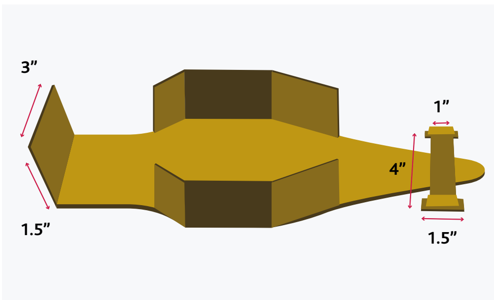
1. Read teacher's handouts on how to use BBC micro:bit to control motors to power your car and a servo to control its steering.
2. Break into groups and design your chassis on cardboard similar to the example below. Cut out your chassis.




1. Design and cut out sides your car on cardboard (5in x 1.5in) and stick them to the chassis using a glue gun.




2. Now add the back section (double layer 1.5in x 3in) and the front spoiler (double layer 4in x 1in, wider (1.5in) at the ends).



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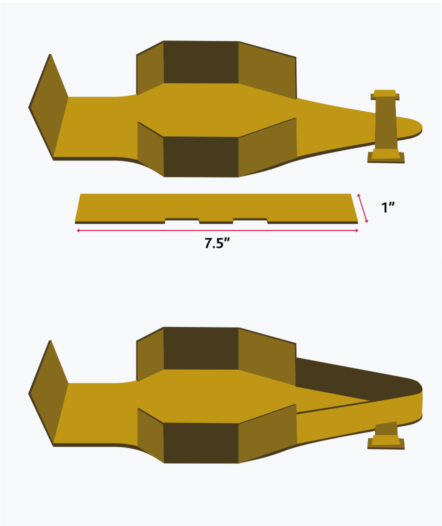
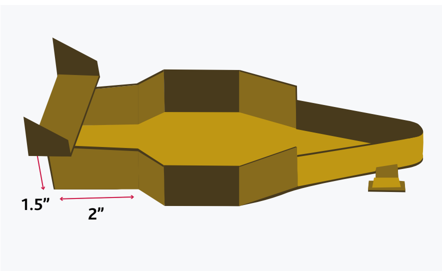
# STEM behind the Scenes

## 3 I feel the need, the need for speed!

3. Cut your front wings (7.5 x 1in) with notches to fit over the front spoiler.



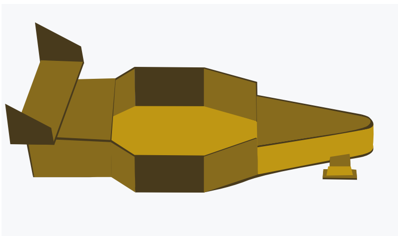

4. Cut your rear wings 2 x 1.5in and attach to the body. You can also add spoilers if you have time.

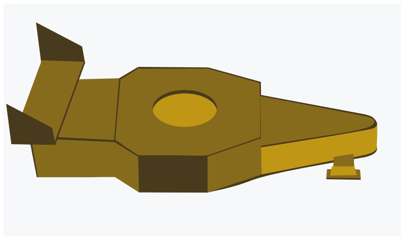



5. Push a wooden dowel axle through the sides at the front and back of the car and attach the wheels. Your rear wheels will be powered using individual motors controlled by the micro:bit.

6. Attach micro:bit, motors and servo to the chassis using a glue gun.

7. Now you'll need to cut top sections to fit over the top. The middle section should have a hole for the driver





8. Program your Micro:bit. Refer to your handouts on using a Micro:bit to program motors and a servo.

9. Test your car on the track. Make notes of what goes well and what needs improvement.

10. Discuss and improve your micro:bit program to get around the track more accurately and quickly. You can also make any modifications to the car itself.

11. Test your car on the track again and record your observations. What effect did your changes have?

12. Compare notes and designs with other groups. Whose car performed particularly well? What would you improve if you tried the challenge again?

## FUN FACTS

1. The very first F1 race was in 1950!
2. F1 drivers are some of the fittest sportspeople in modern sport due to all the forces they have to endure whilst racing at high speed.

STEM CLUBS

NUMBER 1 FOR STEM

CLUB LEADER GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 4 Movie stunt car jump

## Objective

Students are going to recreate their favourite car stunt from a movie by making ramp(s) from different materials and using a remote-control car to test which groups' car can go the longest or highest whilst landing safely.

### TOPIC LINKS

- Design and technology: forces acting on structures – compression, tension, shear etc.
- Maths/physics: angles of ramp, projectiles, velocity/time graph, distance/time graph. Newton's laws of motion

### TIME

90 minutes

Could spend a single lesson afterwards analysing results, plotting more graphs etc

### RESOURCES AND PREPARATION

- 2 x remote control cars (1 to be used as a spare)
- materials to build ramps: thick paper or card, drinking straws or ice lolly sticks, sticky tape and/or glue gun
- cissors or craft knives
- graph paper for plotting of graphs
- A4 blank paper

### HEALTH AND SAFETY:

A suitable risk assessment using guidance from CLEAPSS and SERCC should be written and adhered to for this activity.

Students should take care when using glue gun and craft knives.

Students should stand behind ramps when car is in operation

### DELIVERY

1. Show video clips of 3 different ramp designs (See Useful links below). Discuss with students what different factors will affect the distance/height that the car will jump, e.g. angle of ramp and speed of car.
2. Discuss different forces acting on ramps, with/without car loading. (Use the Student Guide as a starting point.)
3. Students to break into groups of 3/4
4. Students to decide what style ramp they are going to design and construct – ramp to floor, ramp to ramp, or twisted ramp.
5. Students to sketch out to scale possible ramp designs and mark the different forces acting on ramp, with/without the car.
6. Students to work out possible angles, height of ramp, length of ramp, distance of ramps apart, speed of car etc. to make the longest/highest car jump using prior knowledge gained in Science lessons.
7. Once they've found a design they're happy with, students construct their ramps using the supplied materials. You can help students to experiment with paper folding or using other methods to strengthen the ramp platforms.
8. Students now test out their ramps and measure the height and distance they achieve with their designs. They should record their results.
9. Now students evaluate their first jump and decide on changes that could improve their results, e.g. varying the angle or length of ramp. They should repeat their test and record their results again.

10. Repeat this process once more – after making any last tweaks, students can run their test again and record their results.

11. Ask students to draw up graphs plotting velocity/time, and speed/time. They can compare results and discuss in peer groups why some ramps were more successful than others. Discuss Newtons Law of Motion and how this applies to their designs if you have time.

## USEFUL LINKS

**Stunt car jump links:**

- **James Bond twisted bridge:** www.youtube.com/watch?v=I6iksKTURlA
- **Dukes of Hazard ramp to floor:** www.youtube.com/watch?v=rmyEYTc4CPU
- **Subaru ramp to ramp:** www.youtube.com/watch?v=L5N7R9Wbe_E

## TIP

**Teacher can join in and make his/her own ramp(s) and see what group can beat the teacher and perform a longer/higher jump, bragging rights are up for grabs!**

## DIFFERENTIATION IDEAS

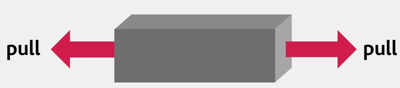
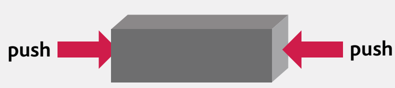
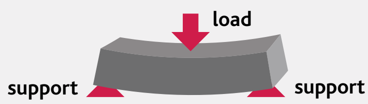
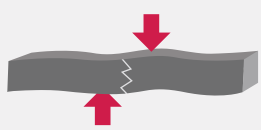
**Support:** more confident/higher level groups can design and make a more complex bridge such as the twisted bridge in the James Bond example. Most groups to jump ramp to ramp so will need to make two ramps.

**Challenge:** Less able groups to construct one ramp and jump from it onto flat surface as Dukes of Hazard clip

## EXTENSION IDEAS

1. Students could draw up ramp design on Google SketchUp
2. Plot more complex graphs showing velocity/time and distance/time

## WORKSHEET ON FORCES:

| | | |
|---|---|---|
| **Traction** | When forces try to stretch the body they act on. These forces opposing. |   |
| **Compression** | When forces try to crush or compress a body. These forces are opposing with the same trajectory. |   |
| **Bending** | When forces try to bend the body they act on. |   |
| **Torsion** | The forces try to bend the body they act on. They try to turn and act in different directions. |   |
| **Shearing or cutting** | When we apply this force, we are using forces that try to divide something. These forces act very near each other, but not opposing (one goes up and the other goes down). |  |

STUDENT GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 4 Movie Stunt Car Jump

### Your challenge

**Have you ever wanted to recreate your favourite movie stunt car jump? You will be designing and making your very own ramps and testing the distance and height you can achieve using a remote control car.**

**YOUR TASK** **Design and make a prototype movie stunt car ramp(s) capable of producing a breath-taking movie scene**

### WHAT YOU NEED TO DO

1. Think about what different factors will affect the distance/height that a car can jump from a ramp.
2. Watch video clips of 3 different ramp designs. Which type are you brave enough to design and build?
3. Discuss what forces act on ramps, with and without car loading. Fill in the gaps in the table provided.
4. With your group, decide what style ramp you are going to design and construct: ramp to floor, ramp to ramp, or twisted ramp.
5. Sketch out to scale possible ramp designs on A4 blank paper and mark the different forces acting on ramp, with and without the car.
6. Work out possible angles, height of ramp, length of ramp, distance of ramps apart, speed of car etc. to make the longest or highest car jump using prior knowledge from Science lessons.
7. Start to make ramps using supplied materials. Experiment with paper folding to strengthen your ramp platforms.
8. Once you have set up your ramp, it's time to test it with one of the remote control cars. Record your results, then repeat the test a few more times. What are the average results? What were the best results?
9. What can you change about your ramp to achieve better results? For example, could you vary the angle or length of the ramp? Modify your ramp and run the test again as in the previous step. Record your results.
10. Identify any final changes you want to make to your design, and run your test one more time.
11. Draw up graphs plotting velocity/time and speed/time for your different designs. Compare your results with other groups. Which designs were most successful, and why?

### FUN FACTS

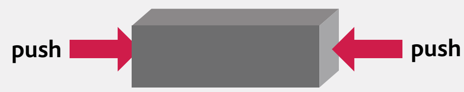
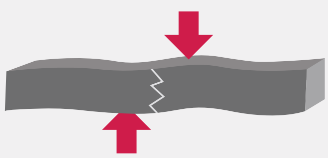
1. The James Bond twisted bridge car jump that you have been shown was done in 1974, over 40 years ago! Until the car actually attempted the jump, no one knew for sure if it would work or not as nothing had ever been done like that before in movie history!

1. Technology, Maths and Physics play a huge role when designing stunts involving jumps or projectiles which are now done with the help of high level computer modelling.!

STUDENT GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 4 Movie Stunt Car Jump

| | | |
|---|---|---|
| | When forces try to stretch the body they act on. These forces opposing. | |
| **Compression** | |  |
| **Bending** | When forces try to bend the body they act on. | |
| **Torsion** | |  |
| | When we apply this force, we are using forces that try to divide something. These forces act very near each other, but not opposing (one goes up and the other goes down). |  |

STEM CLUBS

CLUB LEADER GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 5 What can movies tell us about the future?

## Objective

Hollywood has always idolized superheroes from Wonder Woman to The Black Panther.

The combination of special powers and superhuman strength is appealing on many levels, but in reality we are already starting to augment our natural abilities using technology. We have technology to protect workers carrying out manual tasks. We have technology to minimise the effects of ageing on mobility and movement. We have technology to give soldiers the ability to carry heavy loads, run at speed for miles and even use eye movement to control weapons. All of these technologies are already in various stages of production, so who knows what we might have a few years from now!

Marty McFly's hoverboard and Tony Stark's Iron Man suit may not be on the high street yet, but in the next ten years? Who knows!

In this activity, your students will look at exoskeletons that augment human performance and attempt to produce a functional example of what is possible.

**TOPIC LINKS**

Design and technology: design

**TIME**

60 minutes

(excluding 3D print time. Additional time needed for students to investigate digital manipulation of the 3D print file)

**RESOURCES AND PREPARATION**

- If you do not have access to a 3D printer then many local libraries have them now – find some here www.gov.uk/government/publications/libraries-and-makerspaces/libraries-and-makerspaces
  Also 3D print hubs will print your files (at a cost) and post them to you! www.3dhubs.com/
- The 3D print file is found www.thingiverse.com/thing:2122752/#files and is printed in 3 sections.
- It then needs assembly using 4 x M3 x10 screws with washers and a flexible 'Bic' pen insert

**DELIVERY**

1. Access the STL file for the items beforehand and put it together so you can show a working model to the students. Wait until after they have investigated exoskeletons to show it to them or you may give them preconceptions that will inhibit their designs' creativity.
2. You will need to pre-print the sections to allow students to make immediately or split the session to allow students time to access and adapt the 3D print file.
3. Show students the longer clip then ask them to design on paper an exoskeleton to augment human performance. You could ask them to focus on emergency services to begin with (and avoid military/violent applications if you feel this is an issue)

## TIP

Watch the clips (preferably the long one) before starting the activity – they explain exoskeletons and how they are being developed.

4. Students should consider the biomechanics of the joint/ movement they are augmenting. https://adventure.howstuffworks.com/outdoor-activities/running/training/leg-workouts-for-runners1.htm Eg. Sprinting involves the ankle/ Achilles ligament rebounding as it is pulled by the calf muscles. What materials will they use? What are the properties of the materials? How would they produce the exoskeleton – rapid prototyping allows ergonomics of the user to be quickly accounted for in design. The fastest way currently is 3D printing.
5. If you want to run the 60 minute session at this point you would show the students the assembled finger pen exoskeleton, give them the parts to construct their own and then give them time to play with it and explore it. You could then ask them to think about how they would adapt or improve this design for other uses such as playing the piano or using an X-box controller.
6. If you want to extend this project and allow your students to manipulate the 3D print file, the best way is to use Autodesk Fusion 360. It is the industry standard tool and is free for educators. Found here: www.autodesk.com/products/fusion-360/students-Club leaders-educators
7. Here is how to import the STL file from Thingiverse.com to Fusion 360. It is very intuitive but would be worth you getting to know the program beforehand. https://knowledge.autodesk.com/support/fusion-360/troubleshooting/caas/sfdcarticles/sfdcarticles/How-to-import-or-open-a-file-in-Autodesk-Fusion-360.html
8. The reasons for manipulation would be to ensure the exoskeleton fitted the user perfectly otherwise it would be less effective or injury could occur.

### HEALTH AND SAFETY:

No considerations other than caution when assembling using a screwdriver.

A correctly configured 3D printer does not offer any hazards if used in line with its operating manual.

### DIFFERENTIATION IDEAS

**Support:** have some examples of strong, stiff or flexible materials to support students during the creative design phase. Carbon fibre, other composites, aluminium, rubber etc.

**Challenge:** manipulation of the digital files is a good challenge that students can explore individually or within the session.

### EXTENSION IDEAS

1. Although well beyond the scope of this project there are functioning prosthetics that can easily be built with access to a 3D printer. These are an impressive project that would take 10-15 hours to complete. Example here www.thingiverse.com/thing:2774960

## USEFUL LINKS

**Popular movies that feature exoskeletons:**
https://en.wikipedia.org/wiki/List_of_films_featuring_powered_exoskeletons

**Popular mechanics news article – 13 movies that got the future wrong:**
www.youtube.com/watch?v=NJDo-Fi1278 exoskeletons

**Exoskeleton research – design and improve. 10 minute clip. More in depth:**
www.youtube.com/watch?v=5cvYKWHa2oM

STUDENT GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 5 What can movies tell us about the future?

### Your challenge

**So the special effects are ready to go and your Steadicam is ready to capture this amazing scene. But you also need to think about how humans fit in. How will humans interact with their environment in the future? How can we use exoskeletons to make us stronger, faster or more useful?**

**YOUR TASK In this activity you will look at exoskeletons to augment human performance and produce a functional example of what is possible.**

### WHAT CAN MOVIES TELL US ABOUT THE FUTURE?

Hollywood has always idolized superheroes from Wonder Woman to The Black Panther and Ironman.

The combination of special powers and superhuman strength is appealing on many levels but in reality we are already starting to augment our natural abilities using technology. To protect workers carrying out manual tasks, to minimise the effects of ageing on mobility and movement, to give soldiers the ability to carry heavy loads, run at speed for miles and use eye movement to control weapons – all of these are already in various stages of production!

Marty McFly's hoverboard and Tony Stark's Iron Man suit may not be on the high street yet but in the next ten years? Who knows?

### WHAT YOU NEED TO DO

1. Watch the short clip your Club leader will show you. Whilst watching think about what kind of engineers are involved in this amazing technology. How have they shown creativity? How could it impact on your life? Is there any 'super power' you would like to design?

2. On your design boards, create some sketches of an exoskeleton to augment (improve) human performance. You could start by thinking how this would apply in sports. Don't forget it doesn't have to be a full body suit – it might just be a super strong arm for throwing alien eggs off the surface of a snowy planet!

3. You should consider how the body moves (biomechanics) when you start to design improvements. How does the joint or body movement that you are augmenting actually take place? Where do you need strength? Where do you need flexibility? You can find detailed descriptions online as references, such as
   www.youtube.com/watch?v=XQn929XwSq8Eg
   https://footballkickbiomechanics.wordpress.com/

4. Add details to your exoskeleton design. What materials will you use? What are the properties of the materials? How would you produce the exoskeleton – rapid prototyping allows the unique shape or size (ergonomics) of the user to be quickly accounted for in design. Your Club leader will show you some potential materials you could use.

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# STEM behind the Scenes

## 5 What can movies tell us about the future?

5. Currently, the fastest way to produce a bespoke design like this is 3D printing. Most manufacturers worldwide now use them to make tangible prototypes quickly during the design and testing process.

6. Your Club leader will show you a simple 3D printed exoskeleton finger designed to use only one finger while writing with a pen. Think about how the joints interact.

7. Your Club leader will now give you the parts to construct your own exoskeleton finger.

8. Use the screwdriver to assemble the joints and then explore its movement. How would you adapt or improve this design for other uses such as playing the piano or using an X-box controller?

9. Why would you need to manipulate a design to fit to a human body?

**Design sketches**

## FUN FACTS

1. Multibillionaire Tony Stark's laboratory is full of enviable gadgets, but nothing is more impressive than his computing system and personal assistant, J.A.R.V.I.S.

1. Not only is J.A.R.V.I.S what Siri aspires to be but Space X CEO Elon Musk (who's often called the inspiration for Tony Stark's character), has been working on a way to replicate a virtual workspace like Tony's lab.

1. Suidobashi Heavy Industries in Japan is closer than anyone else to creating the huge mechanised humanoids seen in 'Pacific Rim'. They have already created Kuratas, a 4 metre tall, 5400 kg wearable robot that can be purchased for a cool £1 million.

STEM CLUBS

NUMBER 1 FOR STEM

CLUB LEADER GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 6 Motion Capture for Special Effects

## Objective

In this activity, students apply their knowledge of anatomy to plan a motion capture map of where to apply bright dots on a person, to capture their motion in slow motion video. They then film someone using their dots to compare their accuracy.

### TOPIC LINKS

- Biology: skeleton, anatomy
- Digital skills

### TIME

60 minutes

### RESOURCES AND PREPARATION

- some students will need to wear dark clothing that's closely fitted, like sports skins ideally.
- paper and pens
- glow-in-the-dark spots (about 20 per person) or tape (about 1–1.5m per person), cheaply available from internet sellers
- clear tape
- scissors
- cameras (smartphone cameras work best with a HD slow motion function)
- torches or bright lights (helpful but not essential)
- full sized skeleton model (helpful but not essential)

This activity works best in a room in which you can black out all or most light. If this isn't possible, use white stickers instead of glow-in-the-dark spots.

### DELIVERY

1. Watch the short clip to illustrate motion capture. 2 minutes. www.youtube.com/watch?v=fm-A1lknrxE
2. Discuss how animated characters or non-human characters are brought to life in movies. Examples include Mas Tanaka 'The Force Awakens', Rocket 'Guardians of the Galaxy', Caesar 'Planet of the Apes', Hulk 'Avengers' and even the penguins in 'Happy Feet'. Highlight that in all these cases, the crew captured the motions of real actors and mapped them to the animated bodies of each character to create realistic performances.
3. Students should form small teams. Discuss what STEM roles might help create realistic motion capture: motion capture engineers and technicians, programmers, lighting engineers and designers, camera operators and many more. Students can take on these roles if they wish.
4. What are the crucial parts that create movement in our muscular and skeletal systems? Give students access to the skeleton model.
5. Watch the clip from Harvard University about the biomechanics of throwing. www.youtube.com/watch?v=l_bYlY6AHew
6. Ask students to predict movement of the arm bones during the process of throwing.
7. In their teams, students should discuss and agree where they would place 20 markers on a person in order to capture their movements as accurately as possible. Students must prioritise to select the areas that are most important to common movements. They draw a simple human silhouette and mark 20 spots to create a map. Teams share their maps, justifying them in terms of bones and joint locations and how people move.

**Extension: Some teams may focus in more detail on the process of throwing.**

8. Teams position glow-in-the-dark stickers or pieces of tape on a team member in close-fitting, dark clothes, following their body map.
9. You can use this to support them if necessary. http://mocap.cs.cmu.edu/markerPlacementGuide.pdf
10. Students 'charge' the stickers by shining a bright light on each one for a couple of seconds. Discuss the energy change taking place.
11. Turn out the lights so the room is as dark as possible. The person in each team completes three movements or actions (repeating if necessary), which their team films using the Slow motion function available on most smartphones.
12. Turn the lights on. If possible, share video clips onto a large screen. In turn, teams suggest what their team member did to see which teams could most accurately track movement using their motion capture mapstudents the assembled finger pen exoskeleton, give them the parts to construct their own and then give them time to play with it and explore it. You could then ask them to think about how they would adapt or improve this design for other uses such as playing the piano or using an X-box controller.

## HEALTH AND SAFETY:

No specific risks.

If camera flashes are used then consideration for photosensitive epilepsy needs to be included.

## USEFUL LINKS

**What is motion capture?**

**Where to place 'Mocap' markers:**
http://mocap.cs.cmu.edu/markerPlacementGuide.pdf

## TIPS

- **Position one sticker on each set of toes, six on the outside of joints (ankle, knee, hip, wrist, elbow, shoulder) on each side, one on each hand, two on the head (chin, forehead), and two on the torso (belly, upper sternum under throat). For safety, clear a space for performers.**
- **Performing students should use large, clear, movements to represent common, easy-to-recognise actions. These can be slowed down to as slow as 60fps whilst still maintaining 1080p HD quality imaging.**
- **Warn students in advance that you will be doing this activity and to bring in suitable clothing.**

## DIFFERENTIATION IDEAS

**Support:** choose three actions and let the performer in each team know what these are. Have tape ready-cut into 1–2 cm lengths. Use the tip above to instruct students where to position their stickers. Use more stickers mid-way along each limb (eg. upper and lower arm/leg) and more on the torso.

**Challenge:** Some teams could focus in on the process of throwing and measure the more precise small movements during the throw.

Some teams could place smaller stickers to 'map' a face in detail (ensure performers close their eyes when the team charges their stickers), to capture finer movements or emotions like smiling, laughing, frowning etc.

## EXTENSION IDEAS

1. Give students 50 markers to create a more detailed map and compare the accuracy of the motions this can capture compared to using 20 markers.
2. Students could import their video into editing software and, frame by frame, add lines to join the dots and create an animated stick figure.
3. Using two X box Kinect cameras (around £20 each) and cheaply available mocap software – professional motion capture without the use of markers is very straightforward. www.fastmocap.com/buy.php
4. If students are familiar with open source Blender software they can use the makehuman package (all free) to take motion capture data and turn it directly into animated characters. www.makehuman.org/index.php

STUDENT GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 6 Motion Capture for Special Effects

### Your challenge

**The ability to throw an object with great speed and accuracy is a uniquely human adaptation, one that Harvard researchers say played a key role in our prehistoric survival and evolution.**

**Filmmakers user motion capture to create magnificent digital characters on screen that still move in a way that looks realistic.**

**YOUR TASK How will you capture the motion data needed to send to your animation team? They will use this 'mocap' data to create the hero of your story…so it needs to be perfect!**

### WHAT CAN MOVIES TELL US ABOUT THE FUTURE?

Some of your favourite characters from films are not real people!

In many movies today, the crew capture the motions of real actors and map them to the animated bodies of each character to create realistic performances such as Mas Tanaka 'The Force Awakens', Rocket 'Guardians of the Galaxy', Caesar 'Planet of the Apes', Hulk 'Avengers' and even the penguins in 'Happy Feet'.

Complex mapping processes and digital animations cost millions in Hollywood movies but it's easy to use simple technology to recreate the tricks that conjure up the amazing illusions in our favourite films.

### WHAT YOU NEED TO DO

1. Watch the short Motion Capture video clip your Club leader will show you.
2. In a small team discuss what STEM roles might help create realistic motion capture: motion capture engineers and technicians, programmers, lighting engineers and designers, camera operators and many more. Allocate team roles within your group.
3. Have a look at the skeleton model provided by your Club leader. What are the crucial parts that create movement in our muscular and skeletal systems?
4. Your Club leader will show you a clip from Harvard University about the biomechanics of throwing. Why has throwing been such an important skill for our prehistoric survival and evolution?
5. Using the skeleton to help you, predict the movement of the arm bones during the process of throwing. You can also think about what the muscles might be doing to move these bones.

STUDENT GUIDE: SUITABLE FOR AGE 14-16

# STEM behind the Scenes

## 6 Motion Capture for Special Effects

6. In your teams, discuss and agree where you will place 20 markers on a person in order to capture their movements as accurately as possible. You must prioritise to select the areas that are most important to common movements. Draw a simple human silhouette and mark 20 spots to create a 'map'.

7. Share your maps with the other teams, justifying them in terms of bones and joint locations and how people move.

8. Then position glow-in-the-dark stickers or pieces of tape on a team member in close-fitting, dark clothes, following the body map you designed earlier.

9. Then 'charge' the stickers by shining a bright light on each one for a couple of seconds. Your phone torch will do it. Discuss the energy change taking place.

10. Turn out the lights so the room is as dark as possible. Your 'actor' then completes three movements or actions (repeating if necessary), which your team films using the Slow motion function on your smartphones.

11. Extension: if you can film it simultaneously from different angles, you will have more useful data on the movements of your 'actor'. Professional production use around 16 cameras on each actor.

12. Turn the lights on. If possible, share video clips onto a projected large screen. In turn, teams suggest what their team member did to see which teams could most accurately track movement using their motion capture map.

## FUN FACTS

1. Modern Motion capture in filmmaking was revolutionised with the character of Gollum in the Lord of the Rings and Hobbit films. Gollum is one of the most important fantasy characters of all time, and it's impossible to think of him without recalling Serkis' schizophrenic, frenetic acting. All captured using motion capture!

2. In the biggest selling game of all time FIFA 18 - Motion data capture of Ronaldo's acceleration, run cadence, skills, and shooting technique have informed gameplay elements like fluidity, player responsiveness and explosiveness.

3. The world's largest silicon chip maker, Intel, is investing billions of dollars in combining Virtual Reality and Motion Capture technology to create immersive media and interactive content that might be the future of gaming and cinematic experiences!

STEM CLUBS

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