Exploring Engineering Challenge:

Rollercoaster

ROCHESTER BRIDGE TRUST

About the Rochester Bridge Trust

The first bridge at Rochester was built by the Romans soon after the invasion of Britain in AD43. Once the Romans left, their bridge was maintained by the local people of Kent until the 14th century. In 1381, the River Medway froze solid and, when the thaw came, the ice and floodwater swept away the Roman Bridge.

Two benefactors built a new stone bridge one hundred yards upstream which was opened in September 1391. Their names were Sir John de Cobham and Sir Robert Knolles. Together the benefactors also persuaded their friends and acquaintances to make donations of land and money for the perpetual maintenance of Rochester Bridge. In 1399, King Richard II granted letters patent which allowed the Rochester Bridge Trust to be set up to care for the bridge and its property. Two Wardens were appointed to manage the bridge.

For the next 457 years, the Wardens looked after the medieval bridge. Major improvements were carried out by the civil engineer, Thomas Telford, in 1827. However the increase in road and rail traffic as a result of the industrial revolution meant the stone bridge's days were numbered.

In 1856, the Trust completed a new cast-iron arch bridge on the line of the original Roman Bridge. It was designed by Sir William Cubitt who had been the civil engineer for the Crystal Palace built for the Great Exhibition in 1851. The old medieval bridge was then blown up for the Wardens by the Royal Engineers using gunpowder.

The Victorian Bridge was reconstructed in 1914 as a bowstring truss and is today known as the Old Bridge. A second road bridge, the New Bridge, was opened to traffic in 1970. Between the two road bridges there is the Service Bridge which carries pipes and cables across the river.

The Rochester Bridge Trust is a registered charity and still owns and maintains the two road bridges and the Service Bridge free of charge to the public. The Trust's money is derived from the land and money given by the benefactors in the 14th and 15th centuries. It receives no public money, does not charge tolls and does not raise funds. With any surplus funds, the Trust supports other charitable projects, primarily the preservation of historic buildings and education projects in the field of engineering, particularly civil engineering.

How to use this book

This book includes a copy of all of the resources you will need for running the challenge for your learners. The resources are designed for a class of 30-32 learners.

There are PowerPoints (with explanatory notes) to explain the 'pre tasks', as well as the Challenge itself. The pre tasks are designed to develop the skills and knowledge needed to complete the Challenge. The notes on each slide explain what you would say and the points to draw out of the learners through questioning and hands-on activities.

If you wish to use these as a presentation, they will need to be downloaded as an electronic copy (links are included at relevant points). All downloads are free of charge. Some resources will need to be reproduced for learners to use: you can either photocopy directly from the book, or again, download the PDFs using the links.

This pack includes:

1. a document with guidance on how to structure and deliver the tasks for challenge leader(s);
2. a shopping list of what you need to purchase and some links to companies that provide some of the items;
3. an equipment list for the challenge, listing all the materials and tools you need to run this challenge, allowing you to print one list of everything you need, listed in the order of the sessions;
4. the testing rig instructions for making up the testing station;
5. the pre tasks on PowerPoint (with notes), broken down into two pre tasks to enable them to be used for shorter twilight sessions. Within an hour, it should be possible to complete one of the pre tasks, with sufficient time for the children to clear up and pack away after;
6. Pre task 1 joining materials handout;
7. Pre task 2 test log;
8. 'The Challenge' on PowerPoint (with notes);
9. 'The Challenge' guidance for learners;
10. a sheet of the Rochester Bridge Trust logo for printing, which can be cut up into separate logos;
11. testing notes and a log to help document the results;
12. 'Rollercoaster Challenge' certificate for learners completing the challenge;
13. 'Rollercoaster Challenge' certificate for the winning team;
14. a risk assessment template with suggested risks for the challenge. (Please note, this is not extensive and each Challenge leader should undertake a full risk assessment for their individual setting.)

How to use this book

There are different ways in which you can use this Exploring Engineering Challenge, based on the circumstances in your location. It has been designed to be suitable for 8-11 year olds and could be delivered as:

- a whole day, with one class in a primary school, in a classroom or hall;
- two half days, with one class in a Primary School, in a classroom or hall;
- four twilights, with one class in a Primary School, in a classroom or hall (a twilight would tend to be about an hour, however where possible, negotiate slightly more than an hour to allow for arrivals and packing away e.g. 15.15 – 16.30);
- alternatively, you could scale it up to work with many teams or scale it down for use at home or in a club.

How to use this in your school:

Some schools will recognise the term STEM (Science, Technology, Engineering and Maths) and be keen to have support to enrich their STEM learning. This is a STEM Learning Day and can form part of your enrichment days.

These resources are aimed at children in Key Stage 2 and especially sit within the Year 5 Science Curriculum. You may also want to use it with Year 6 children, after their SATs have been completed.

National Curriculum Mapping:

This Challenge maps to the National Curriculum Programmes of Study as follows:

Design & Technology: the whole concept of the Exploring Engineering Challenge is design process in action. It encourages children to design something, for someone, for a specific purpose.

KS2 (8-11 year olds): Design, Make and Technical Knowledge Criteria.

Maths: KS2 (8-11 year olds): 'Number and Place Value', 'Addition and Subtraction', 'Measurement', 'Geometry – Properties of Shapes'.

Science: KS2 (7-11 year olds): 'Living Things and their Habitats', 'Uses of Everyday Materials', 'Properties and Changes of Materials' and 'Forces'.

Using the Resource in a Club or at Home:

Of course, this material could be used with a local community group/club, e.g., Guides and Scouts, or home education groups, and families. All you need to do is to adapt the quantities of materials you need.

And finally... Enjoy this! It's easy to get started, with just one child or class.

Resources

1. **Leaders' guidance**

   This document provides guidance on how to structure and deliver the tasks. It is an essential guide and contains the same notes included in the digital PowerPoint presentation. As a challenge leader you can use this as a reference document.

2. **Shopping list**

   A list of all you need to purchase and some links to companies that provide some of the items. These links were up to date at time of publishing.

3. **Equipment list**

   This document lists all the materials and tools you need to run this challenge, listed in the order of the sessions, sufficient for one class of 30-32 students, whether structured as a single day, or split into shorter sessions.

4. **Test rig instructions**

   This document includes step by step instructions on how to make the test rig for the final stage of the challenge.

5. **All pre tasks PowerPoint**

   These slides guide your group through the creative pre tasks. These hands-on pre tasks provide them with vital learning to help them make the most of the challenge. The digital version has notes for your guidance for each slide.

   Please adapt the colour of the background to suit your projection equipment so it is not too white.

6. **Pre task 1 joining methods handout**

   A copy of this document is needed for each team so they can log their test results in pre task 1.

6. **Pre Task 2 test log**

   This document provides a simple way for each team to record results from the pre task 2 tests.

7. **The Challenge PowerPoint**

   These slides guide your group through the actual engineering challenge.

8. **The Challenge guidance for learners**

   This guidance for learners can be copied and provided to teams as a reminder of what they need to do and the criteria they are working towards.

9. **Logo samples**

   This document includes multiple copies of the Rochester Bridge Trust logo and can be copied and cut up individually for each team to use in the challenge.

10. **The Challenge testing notes**

    These notes offer guidance on carrying out the testing itself.

11. **The Challenge test log**

    This document provides a simple way for you to record results from the final whole group challenge. There is an Excel spreadsheet version of this log available on our website.

12. **Certificate - individual**

    This is suitable for each participant and can be presented as part of your results ceremony at the end of the challenge.

13. **Certificate – team**

    This is suitable for the overall winning team and can be presented as part of your results ceremony at the end of the challenge.

14. **Risk assessment template**

    A starting point for the challenge leader(s)' own risk assessment for their setting. Please note, this is not extensive and should only be used as guidance.

All of the above documents can be downloaded here: http://www.rochesterbridgetrust.org.uk/exploring-engineering/exploring-engineering-challenges/roller-coasters/

Leaders' guidance

1. Introduction

What is engineering? How do engineers work as a team (including civil engineering roles)?

How engineers design and model things that help balance forces.

2. Pre task 1

Explore how to effectively join materials while considering how to make them stronger, bearing in mind the forces at work around them.

3. Pre task 2

Explore the forces involved in making rollercoaster go and stop, as well as test the incline and surface of the track.

4. Challenge

Apply everything discovered so far to design and model a rollercoaster buggy that protects the passenger, as well as choose a track that helps the buggy travel the furthest distance.

Most of the guidance you need can be found on the notes section under each PowerPoint slide, which can be printed, or used with 'presenter view' when displaying the slideshow.

Introduction to Engineering

What is engineering? Ask learners this question, and whether they know anyone who is an engineer, or if they know any different types of engineer. A very common misconception is that "engineering" refers to fixing things (such as appliances/ electrical devices) and/or mechanic type roles and that it involves getting dirty and using tools!

After watching the video, introduce learners to the challenge: they are going to take part in a real-world engineering problem, they will take on the role of an engineer in designing and testing their own solutions. They will get a chance to see what it is like to take on some of the different engineering roles.

Engineers work in almost every area that affects people:

- biomedical engineering, like new materials for hip replacements or advanced prosthetics;
- making the food we eat and the medicines we take;
- developing new materials like high performance sports fabrics or new electronic displays;
- constructing the world around us including buildings, roads, bridges, schools and hospitals;
- managing our water, gas and electricity supplies and develop new ways to generate electricity such as wind and solar power.

Groups of engineers often work together in a team, as each engineer will have their own role to play. A team of engineers would have to work together to design, test and build a large structure like a rollercoaster. Teamwork is vital if the design is to be successful and the rollercoaster is to work safely. There are lots of things to consider during the design, testing and building processes, and each type of engineer has to focus on one area of the design process.

Whilst designing these large one-off structures, teams of different engineers must work together and this is what learners are going to be doing today. But, what does it mean to work in a team? What different types of engineers might work together as a team to design something like an airport, bridge or rollercoaster? What do you think each type of engineer does within the team?

Civil Engineers - choose the best designs for the job, they call this design 'fit for purpose';

Structural Engineers – work out how the shapes of materials might fit together, to look right and fit together properly;

Materials Engineer – work out what types of materials to use and whether they are strong, flexible, rigid or soft enough; and

Value Engineer - work out how to make the design better value for money. For example, if builders use 1mm less concrete all over a structure, will it save money? But, they also have to make sure if they use less concrete, that the design is still safe.

Civil Engineers have an important job to do to make our lives flow more easily. One of the things they have to think about when designing big things are the forces which will affect their designs. They have to balance the forces and consider the loads that must be supported by the structure. Without doing so, structures could fail and not be fit for purpose.

When designing a structure, the mass of the structure itself is called the 'Dead Load'. Ask students "What could affect the size of this load?" The amount of material in it, the design, the material that it is made from. "What is the impact of having a large Dead Load?" Too many materials = cost, time to build; impacts the remaining amount of load the structure can support.

Leaders' guidance

"What do you think we mean by 'Live Load'?" This is a combination of the users of the structure, for example, vehicles and/or pedestrians crossing a bridge, as well as environmental factors, such as wind, or even snow. "When engineers design large structures, they must think about not just the size of the Live Load, but also the fact that it is moving – what is the impact of the load moving across a bridge?" Encourage students to think about the position of the load and the effect this might have. In a rollercoaster, the loads would be constantly moving, so the civil engineers would have to consider how their design will cope with that.

Two effects of forces which engineers have to think about are tension and compression. Tension is a stretching force and compression results from two forces opposing each other, creating a squashing effect. If the pulling force/tension is greater in one direction than another, the forces aren't balanced and the structure will pull in that direction, which may lead to collapse. To stay up forces need to be equal/balanced. The same for compression, the pushing force on each side needs to be balanced to keep it upright and not fall over. In the presentation, there is a demonstration of tension and compression involving participation from the learners. You could invite learners to try this, just make sure they know they are not trying to make each other fall over, they are trying to balance and also clear the area so they can't knock into anything if they do fall.

Pre task Guidance

Pre task 1 – Learning to join materials

Different materials have unique properties – "properties" means "what something is like or what it can do". The properties that a material has can make it good for a particular function or job.

For example, a toilet roll is quite strong in compression if you hold it vertically and push it from above, but if you lay it horizontally and push from above it squashes really easily. So, it is strong in compression one way, but not another.

String, in comparison, is wobbly and floppy and doesn't have high compressive strength (it can be squashed easily). However, if pulled tight, it has very high 'tensile' strength.

Therefore, the materials which we select for a particular function will depend on the properties we need them to have.

Using the pre-prepared selection of materials with different properties: eg a piece of sponge, a clear plastic bag, a piece of hard plastic/flexible plastic, a piece of elastic, a piece of foil or metal, ask learners to consider the functions they might be useful for, or what you might avoid using them for.

The learners can experiment with joining techniques by using the buggy kit, with the four different adhesive materials. (There is a video that can be shown to demonstrate how to assemble the TechCard buggy.) They need to use the joining methods log to evaluate the relative strengths or weaknesses of each method. The key here is to encourage the learners to use 'trial and error' to find the best solution for the problem.

Do demonstrate how to use double sided tape by joining materials together inside a join rather than around the outside. It is unlikely the learners will have had the opportunity to use double sided tape before.

Pre task 2 – Testing inclines

Show learners the images of 'structures that move quickly'. The aerodynamic shape of these vehicles means that air resistance is reduced. Air resistance is caused by particles in the air creating a force which acts to slow down the moving object. Aerodynamic shapes reduce air resistance so allowing vehicles to travel more quickly. This is something they may need to think about in their design.

There are three demonstrations that can be done to explain how rollercoasters are propelled:

Electromagnets – using 2 bar magnets demonstrate attraction and repulsion. If you stick a magnet to the end of the buggy you can demonstrate that the force of repulsion can be used to push the buggy along. Explain that electromagnets are ones which can be turned on and off using an electric current. The rollercoaster cart can be propelled by using an electromagnet to repel it, by switching the magnet on instantly. Very high speeds can be achieved by using strong magnets.

Hydraulics - use a simple syringe with water in it to demonstrate that when you push the syringe, the liquid squirts. Explain that this can be used to move objects and it is how the brakes in a car work. When you push the brake pedal the liquid pushes on the brake pad to stop the wheels.

Pneumatics – the same demonstration as above, but using syringes full of air. Use a syringe to squirt air and push along a ping pong ball or other light object. Explain that when air is forced out of a cylinder like the syringe, at high pressure, this creates a force which can be used to move objects, like a rollercoaster buggy.

Leaders' guidance

When objects are pulled upwards they gain potential energy. What causes them to then fall back towards the earth? Gravity. The higher the rollercoaster buggy is pulled, the more gravitational potential energy it has. As the buggy descends from the top of the rollercoaster, it gathers speed and the gravitational potential energy is turned into kinetic energy (the energy of moving things. This means the rollercoaster cart is able to move quickly over longer distances.

Friction and air resistance generate heat (thermal energy), which is lost to the surroundings, as is any energy transferred as sound energy. This slows things down. Get learners to rub their hands together. They should feel their hands getting hot, this is due to friction. Ask them what types of surfaces create more friction, which should lead to the conclusion that it is rough surfaces. If this is not well-known/understood, you could use 3 different shoes. such as a trainer, a leather soled shoe and something more "slippy", placed at one end of the ramp and slowly lift it. Learners can make predictions about which one will slide first and why. The shoe with the lowest friction should slide down at the lowest incline.

The focus of this task is to get learners to design their buggy to move as easily as possible, with the aim of going as far as possible. Encourage learners to work methodically: the ramps have 5 different incline settings, with two different surface textures. They should try to limit all other factors that might affect how far the buggy travels: they should avoid pushing it down the slope for example.

It may be worth demonstrating how to make the side holes in the buggy large enough to facilitate the dowel/axle rotating freely, using a pencil as shown in the Pre Task slides. It is useful to mark up the wheels as shown, to demonstrate whether the wheels are rotating (rather than sliding across the table/floor).

Challenge Guidance

The learners have now been given enough information which they can apply to the Challenge.

Introducing the Challenge

1) In the room, you will need to ensure that:

   a) each team has a table or work space in which to complete the challenge

   b) testing areas at the front of the room, accessible for learners to use as a resource during their construction phase, as well as for the testing phase

2) each team should be provided a copy of the Challenge guidance for learners on their tables

3) explain the following Health & Safety rules:

   i. do not run in the room;

   ii. to pick things up off the floor that people might slip on;

   iii. to tie back long hair;

   iv. hold scissors safely and not walk around the room with them.

Using Test Rigs

Each team will be provided a test rig as part of the pre-tasks. They should select the most suitable incline for their buggy design, using the experiences in the pre-tasks to help them.

Questions from Learners

When the learners ask for help, you can prompt them with things they have learned in the pre tasks, or refer to their guidance sheets on their tables.

Structuring the Challenge time

The groups are likely to need a reminder every 10-15 mins what they should be doing to keep them on task. This can include reminding them about:

- comparing ideas and combining the best parts of each person's design into a final design;
- having everyone involved, if you don't have a job to do you can be designing the decoration as points are awarded for this during testing;
- how much time they have left
- remind them how much time they have left;
- give them a last 5 minutes warning at the end;

At the end, tools are to be put down and tidied away into packs, scraps to be put in the bin and, finally, to sit down ready for testing.

Make sure you leave 40 minutes for testing and awarding certificates and prizes.

Leaders' guidance

Extra Materials

As part of this challenge, teams can 'purchase' extra tissue paper, coloured card and recycling. If staffing and space allow, set it up as a "shop", where teams can get the extra materials they require. Each item purchased = 1 point deducted from their final total. Recycled materials are "free".

Context:

You are members of a team of engineers working for Rochester Bridge Trust. You have been asked to design and model part of a rollercoaster buggy which includes selecting the best track incline and surface for a buggy to roll down. Your rollercoaster model needs to be the right size to hold, protect and transport a tomato (instead of a human!).

Brief:

Your challenge is to design, model and test a rollercoaster buggy to hold and protect a tomato (like the humans inside a rollercoaster!). You must also select the most suitable incline and track surface for your buggy to roll down. Your goal is to make the buggy go as far as possible while keeping the tomato safe.

Specification:

1. The buggy must keep the tomato secure so it does not fall out of the rollercoaster during the test.
2. The rollercoaster buggy needs to travel at least 0.5m, but ideally, go as far as possible once it reaches the bottom of the ramp.
3. Your selection of incline and surface needs to enable the tomato to travel safely in the buggy.
4. Your buggy needs to be decorated in a colourful way to make it eye-catching and attractive within a busy theme park.
5. The buggy needs to include a Rochester Bridge Trust logo in a place it can be easily seen.

A simple portfolio must be produced as part of your design and planning and should include:

1. All labelled drawings.
2. Notes on how your team is being organised.
3. Notes/labels on how ideas were thought of and developed.
4. Notes about the challenges you have overcome.
5. Reasons for choosing the final design.

Plenary of the Learning

The beginning and end of the event will be most memorable to learners, so do help them to summarise what they have learnt today.

Two certificates have been included within this book: these are suitable for each participant and can be presented as part of your results ceremony at the end of the challenge. The participants will be very excited by simple prizes like lollies or erasers, or if funding is available YPO sell a pack of moving models as kit which could be a nice prize.https://www.ypo.co.uk/product/detail/510113

Shopping list

Per group of 30-32 learners

Item to be acquired	Ordered	Delivered
Introduction Class set of "Civil Engineers Make My Day" postcards (available from Rochester Bridge Trust, request the quantity you need from: education@rbt.org.uk);		
Pre Task 1 2 packs of 30 Tech Card bases (so you have enough for demos and mistakes too): https://www.ypo.co.uk/product/detail/510128		
1 pack of 180 mixed cardboard wheels with 6mm holes in the middle: https://www.ypo.co.uk/product/detail/510133		
80 axles 6x100mm dowel (this allows spare in case some go missing) - For example 1 pack of this 6mm diameter wooden dowel will do for the axles and for the ramp rung (listed below): https://www.ypo.co.uk/product/detail/533114*		
8 small pots of PVA with spreader (could be small amount in yogurt pot or old vitamin pot with lid and piece of thick card for spreading)		
PVA glue: https://www.ypo.co.uk/product/detail/749125		
Paper clips (min. 32)		
8 reels of easy-peel double sided tape		
8 reels of masking tape		
8 Pritt Sticks		
Pre Task 2 8 5m tape measures		
Magnetic tape/small magnets (could be adhered to the demo buggy) www.amazon.co.uk/Magnets-Assorted-Shapes-Strips-Fridge/dp/B00IJ7DL6Q/ref=sr_1_3?ie=UTF8&qid=1544697410&sr=8-3&keywords=assorted+craft+magnets		
Plastic syringe www.amazon.co.uk/Plastic-Syringe-10ml-5-Pack/dp/B00CX6VVA2/ref=sr_1_3?ie=UTF8&qid=1544697423&sr=8-3&keywords=small+plastic+syringe		
Ping pong ball or light weight ball		
Making all the test rigs 16 pine 26x26x350mm (part A)		
8 pine 20x100x250mm (part B)		
8 wooden dowels 6x300mm (part C) This can be cut with sharp secateurs from the longer lengths listed above from YPO.		

Shopping list

Item to be aquired	Ordered	Deleivered
16 size 4x50mm length countersunk screws (part D) www.diy.com/departments/avf-yellow-zinc-plated-steel-woodscrew-dia-4mm-l-50mm-pack-of-200/255969_BQ.prd		
8 pieces of hardboard 3x185x640mm (Part E). Some hardware stores or small wood merchants will cut this for you from a large sheet of hardboard if you visit in person.		
32 pieces of rectangular section 'Softwood Stripwood' 8x20x300mm (part F). You could request in the shop that this is cut down to 300mm lengths: https://www.diy.com/departments/smooth-stripwood-t-6mm-w-21mm-l-2400mm-pack-of-1/1793523_BQ.prd		
32 pieces of rectangular section 'Softwood Stripwood' 8x20x200mm (part G). You could request in the shop that this is cut down to 200mm lengths: https://www.diy.com/departments/smooth-stripwood-t-6mm-w-21mm-l-2400mm-pack-of-1/1793523_BQ.prd		
96 panel pins 15mm length (part H) www.diy.com/departments/avf-panel-pin-dia-1-25mm-l-15mm-125g-pack-of-731/247178_BQ.prd		
Sandpaper		
Challenge Recycled cardboard materials		
Coloured card approx. 250 micron. For example: https://www.ypo.co.uk/product/detail/136905		
Tissue paper. For example: https://www.ypo.co.uk/product/detail/135727		
String		
Elastic bands. For example: https://www.ypo.co.uk/product/detail/753696		
8 tomatoes roughly the same size, about 50-60mm wide		

Tools you will need to make the ramps and stands:

- Electric drill and 3.5mm, 4.5mm and 7mm drill bits
- Clamps such as G Clamps or sash clamps
- Electric screwdriver to fit the wood screws
- Hammer
- Sandpaper
- Sharp secateurs, a Tennon saw and bench hook or band saw

Equipment list

Listed below is everything you will need for one group of 32. Please adjust the list according to the group you are working with.

For all sessions:

- AV equipment for presentation and presentation on USB stick, extension lead;
- Class set of "Civil Engineers Make My Day" postcards (available from Rochester Bridge Trust, request the quantity you need from: education@rbt.org.uk);
- A large room with tables, chairs etc.;
- Smooth floor if possible and space to let the buggies run up to 2.5 metres. You may want a separate space for this from the working tables;
- A risk assessment for the space and the learners in your setting.

Tool Kit used for the whole day:

Per team	For a group of 32 in 8 teams
Zip lock bag to store:	**8 zip lock bags to store:**
Tape measure/metre ruler	8 Tape measure/metre rulers
1 reel of easy-peel double-sided tape	8 reel of easy-peel double-sided tapes
1 Pritt stick	8 Pritt sticks
1 reel of masking tape	8 reels of masking tapes
4 paper clips	32 paper clips
Separately:	**Separately:**
1 small pot for PVA glue with a spreader	8 small pots for PVA glue with spreaders

Optional: scissors, pens/pencils, coloured pens, paper and rulers.

Pre Task 1: Joining Methods

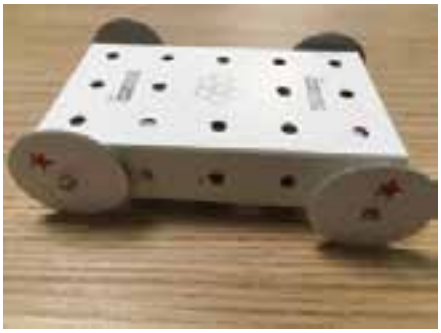
- Ball of string, or a piece of masking tape, and a toilet roll inner;
- One TechCard buggy assembled (as shown);
- Tray of assorted materials to demonstrate the properties of materials/describe them.

Per team	For a class of 30 in 8 teams
Zip lock bag to store:	**8 zip lock bags to store:**
4 TechCard bases	32 TechCard bases
Minimum of 16 assorted card wheels (with 5mm hole)	Minimum of 128 assorted card wheels (with 5mm hole)
8 dowel axels (6mm x 100mm length)	64 dowel axels (6mm x 100mm length)
1 Pre Task 1 joining materials handout	8 Pre Task 1 joining materials handout

Equipment list

Pre Task 2: Ramp incline and ramp surface

- Constructed buggy to show wheels rolling (rather than sliding);
- A ramp;
- A height adjustable ramp;
- Magnets (attach magnetic strip to the front or underside of the buggy);
- A small plastic syringe;
- Small pot containing water;
- Ping pong ball.



Per team	For a class of 30 in 8 teams
1 height-adjustable stand	8 height-adjustable stand
1 ramp with smooth and rough sides	8 ramp with smooth and rough sides
1 cars from pre task 1 (choose the one that is stuck together well, and on which the wheels rotate freely)	8 cars from pre task 1
1 Pre Task 2 Test log	8 Pre Task 2 Test log

Equipment list

The Challenge:

- AV equipment for presentation and presentation on USB stick, extension lead;
- A large room or hall, with tables set up for 8 teams;
- Each team needs the toolkit with tape, glue, paper clips etc. (as listed above).

Per team	For 32 in 8 teams
1 height-adjustable stand	8 height-adjustable stand
1 ramp with smooth and rough sides	8 ramp with smooth and rough sides
1 buggy building kit:	8 buggy building kits:
1 TechCard base	8 TechCard base
2 dowel rods	16 dowel rods
4 card wheels (minimum)	32 card wheels (minimum)
1 tomato	8 tomato
4 squares of coloured tissue paper	32 squares of coloured tissue paper
2 A4 pieces of coloured card	16 A4 pieces of coloured card
recycling (cardboard)/junk	recycling (cardboard)/junk
1 Rochester Bridge Trust logos	8 Rochester Bridge Trust logos
1 The Challenge guidance for learners	8 The Challenge guidance for learners
4 A4 paper for designing	32 A4 paper for designing
	Spare tissue paper, coloured card and recycling – set it up as a "shop", where teams can purchase extra materials. Each item purchased = 1 point deducted from their final total. Recycled card is "free".

Equipment for Testing:

- A testing area, with a smooth floor and space to let the buggies run up to 2.5m;
- masking tape (to mark the start line);
- copy of the challenge test log;
- pen;
- prizes and certificates.

Test rig instructions

Rig Part	Item	Quantity	Detail
Stand	Part A - uprights	2	pine 26 x 26x 350mm
	Part B - base	1	pine 20 x 100 x 250mm
	Part C – horizontal support	1	wooden dowel 6 x 300mm
	Part D - countersunk screws	2	4x50mm
Ramp	Part E – ramp	1	hardboard 3x185x640mm
	Part F – long side batons	4	'Softwood Stripwood' 8x20x-300mm
	Part G – short side batons	4	'Softwood Stripwood' 8x20x-200mm
	Part H – panel pins	12	15mm length

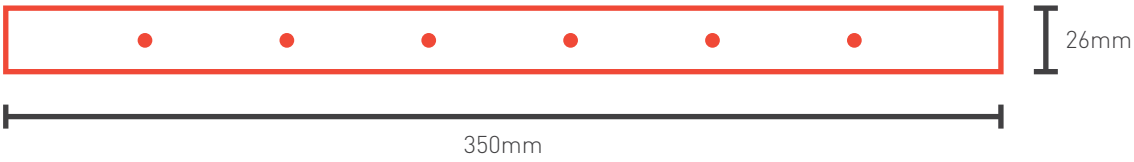
Tools:

- Electric drill with 3.5mm, 4.5mm and 7mm drill bits plus countersinking drill bit
- Electric screwdriver
- Sandpaper
- Hammer
- Sandpaper

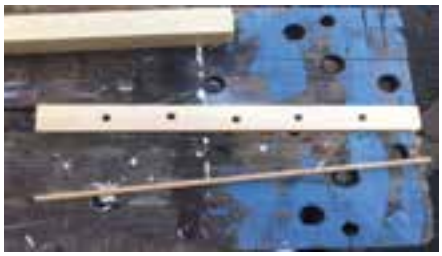
To make the stand:

1. Along each long edge of the uprights (part A) mark the centre line, 13mm from each edge (dotted line -------)

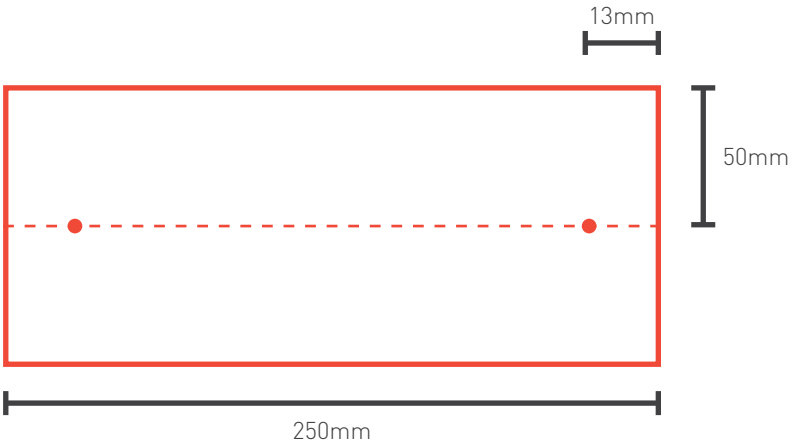
Test rig instructions



2. Mark 6 points along this line at 50mm intervals, which will be the drill holes.
3. Using a 7mm drill bit, drill 6 holes completely through the baton, and check the 6mm dowel rod slides easily through the holes. Do this for both batons so they are identical.



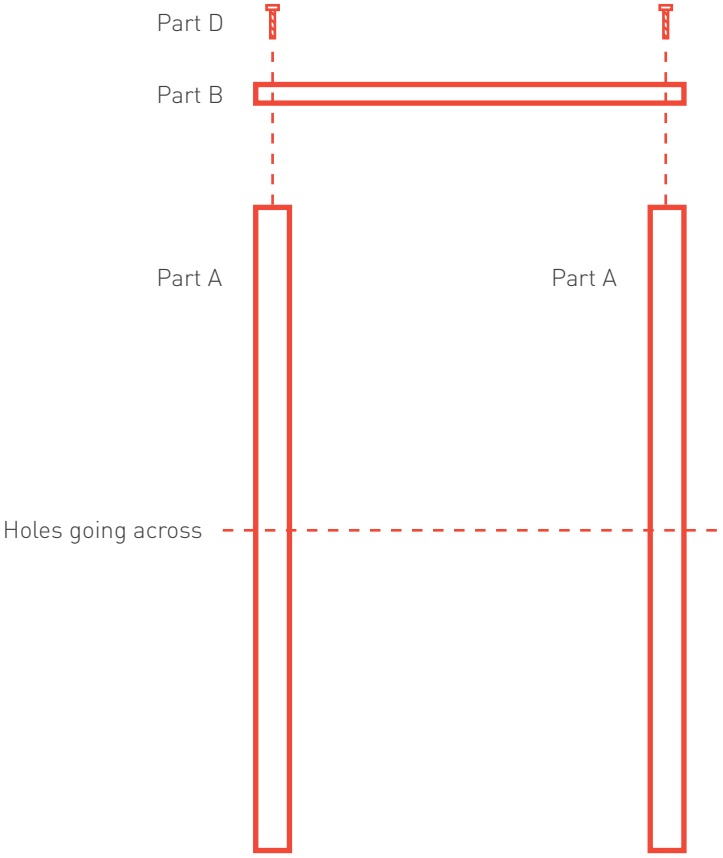
4. In one end of each baton, mark the center point. The easiest way to do this is to draw diagonal lines from one corner to the other through the centre. Where they cross is the centre point.
5. Using a 3.5mm drill bit, pre drill the end of the batons at the center point.
6. Take the base (part B) and mark out a point at each end, 13mm from the short edge and along the center line.



7. Drill a hole through each mark, using a 4.5mm drill bit (so that the screw drops through it easily). Using a countersinking drill bit, drill one side, so that the screw heads sit flush within the wooden base.
8. Sand off rough edges from all wooden parts.

Test rig instructions

9. Using a clamp or workbench to hold the batons, use 2 screws (part D) to affix the base to the wooden uprights, dropping the screw through the predrilled holes in the base (step 7) and using the guide holes in the ends of the batons (step 5). Ensure that the holes in the upright batons (7mm) run across the base (L→R) so that a single dowel can be inserted through both uprights to create a "rung".



The stand should look like this when completed

Test rig instructions

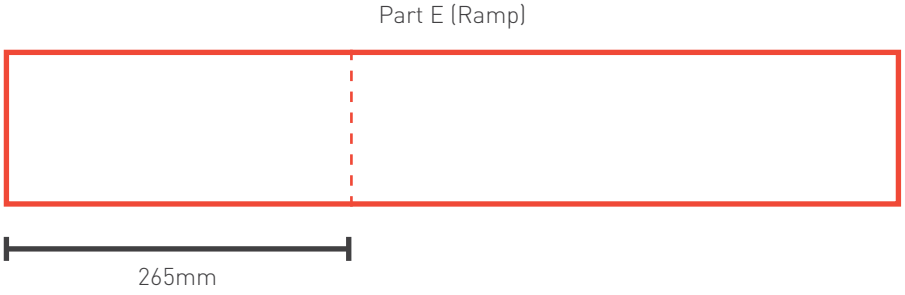
10. Using secateurs or a tenon saw, cut the 6mm diameter dowl rod to a length of 350mm and sand rough edges.

11. The dowel (Part C) should insert across the stand into the holes, at varying heights as shown below.

Test rig instructions

To make the ramp:

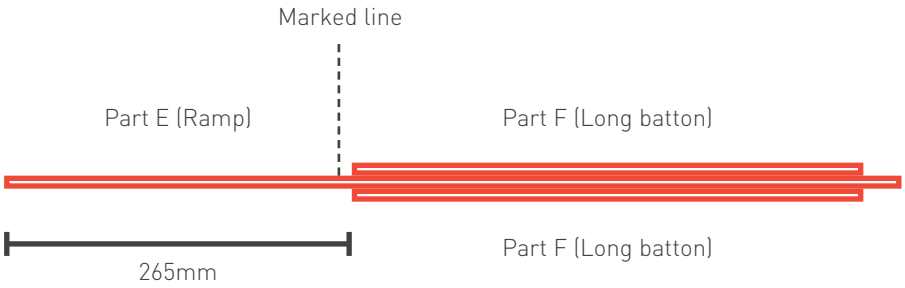
1. Measure a line, 265mm from one end of the ramp. This line will form the centre of a 10mm gap between the long batons and the short batons on each edge and each surface of the ramp.



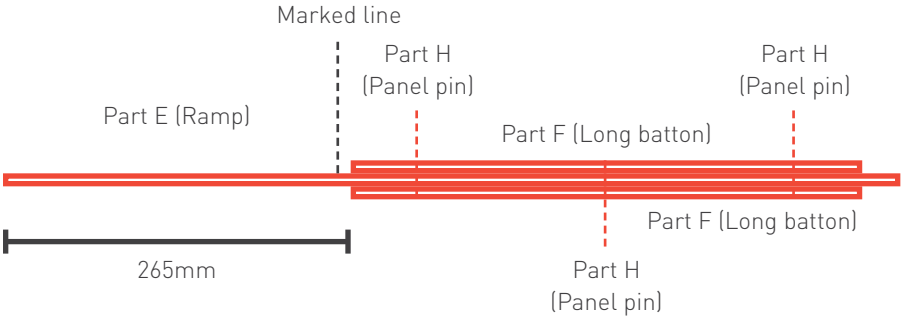
Each ramp will now have a short end and a long end.

Test rig instructions

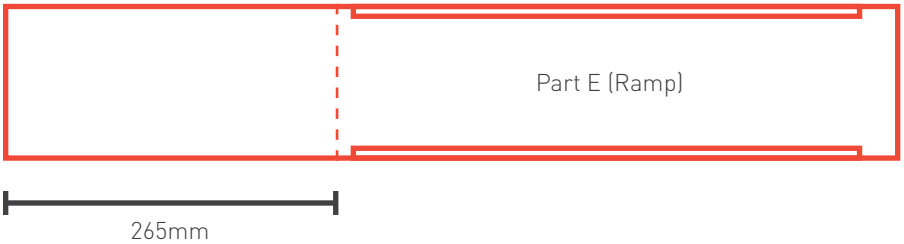
2. On the "long end" lay one long (300mm) baton (part F) underneath the ramp, with its end 5mm from the marked line. Lay another long (300mm) baton on the top surface of the ramp, in line with the other baton. Both baton ends should be 5mm from the marked line. The batons should be 70mm from the end of the ramp.



3. Using 3 panel pins (2 going through from one side and one from the other), secure the batons to the ramp. The panel pins should go through the baton and hardboard and into the baton on the other side, without the end of the pin going all the way through.



4. This should be repeated with the other pair of long batons (Part F), along the opposite edge of the ramp.

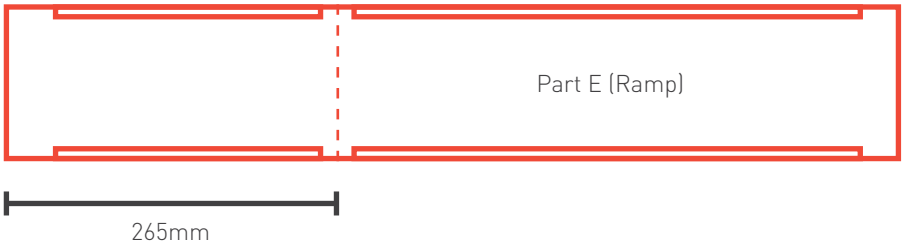


Test rig instructions

5. Repeat steps 2-4 for the short (200mm) batons at the short end of the ramp. This should give a 10mm gap between the long and short batons.

   The short batons should be 60mm from the end of the ramp.

6. Once all batons are attached to the ramp, both surfaces should have 2 long and 2 short batons on them as shown below.



The final ramp and stand should look like this. The short end goes at the top of the ramp, so that it doesn't tip backwards.

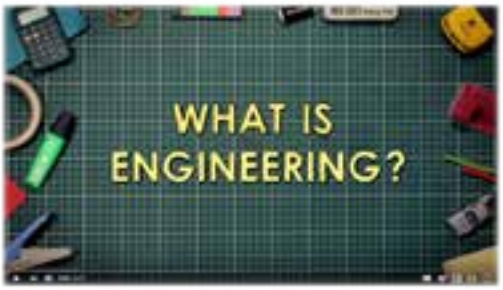
Rollercoaster pre task slides

Exploring Engineering Challenge

Today you are going to be Engineers!

ROCHESTER BRIDGE TRUST

What do engineers do?



UON FEBE – What is Engineering?

https://www.youtube.com/watch?v=bipTWWHya8A

Rollercoaster pre task slides

What do engineers do?

- Design and improve things
- Use creativity to design solutions to real world problems
- Shape the future
- Affect all areas of our lives – food, health, transport, homes, power, sports, leisure……EVERYTHING!

Working as a team

Rollercoaster pre task slides

Team Roles for Engineers

Science, design, maths, teamwork, creativity, geography and problem-solving, working together:

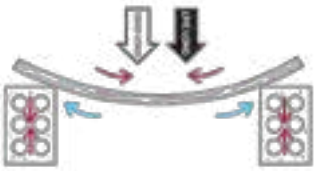
Architect – how the new design will look
Structural Engineer – how it will be made
Materials Engineer – what it will be made from
Value Engineer – which design is best value, based on criteria

Civil Engineers – Make My Day!

Civil Engineers design:	But not these:
Stations	Trains, signals or tracks
Roads, tunnels and bridges	Cars, lorries or bikes
Airports	Planes
Water treatment plants	Taps/toilets
Harbours	Boats
Flats and large structures	Houses

Rollercoaster pre task slides

Issues for Engineers - Forces and Loads



Forces in a beam bridge

Image: BalfourBeatty/Connect Plus

ROCHESTER BRIDGE TRUST

Tension and Compression

Tension
Stretching Force

Compression
Squashing Force

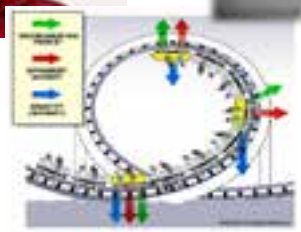
ROCHESTER BRIDGE TRUST

Rollercoaster pre task slides

Materials Engineers

How forces affect materials

(G Force Face – Virgin Media/ http:// www.hashtag.co.uk/ virgin-high-speed



ROCHESTER BRIDGE TRUST

Pre Task 1:

Material Engineers, are you ready?

ROCHESTER BRIDGE TRUST

Rollercoaster pre task slides

Test, like Material Engineers

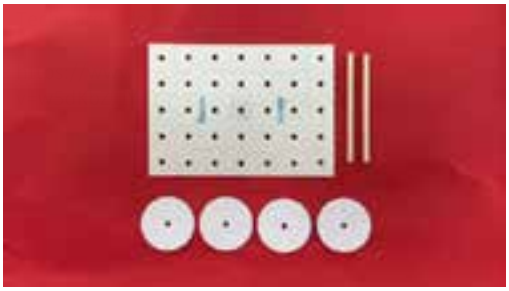
Might Select Materials to be:

- strong under compression/tension
- easy to cut and shape (malleable)
- rigid
- waterproof
- durable (long lasting)

Or perhaps the opposite of these properties.

Pre Task 1:

Joining materials



TechCard – TechCard Simple Vehicle

https://youtu.be/w5dKbZ_iY-0

Rollercoaster pre task slides

Pre Task 1:

Material Engineers

How might we join these materials together?

How well did this joining method work?

How could we make the material stronger?

Use the joining materials to make some small buggies.

Material Engineers…Go!

ROCHESTER BRIDGE TRUST

Pre Task 1:

Joining materials

Number your team members 1-4, number:

1. Assemble your buggy with PVA glue and paper clips
2. Assemble your buggy with double sided tape
3. Assemble your buggy with sticky tape
4. Assemble your buggy with a glue stick

ROCHESTER BRIDGE TRUST

Rollercoaster pre task slides

How to ensure the axles turn




ROCHESTER BRIDGE TRUST

Evaluate, like Engineers

	Advantages (Good)	Disadvantages (Bad)	Which would you want to use and why? (Conclusion)
PVA Glue			
Double Sided Tape			
Sellotape			
Hot Glue			

ROCHESTER BRIDGE TRUST

Rollercoaster pre task slides

Evaluate, like Engineers

What worked well and not so well?

What have you learnt that you are going to use to make the buggy stick and stay together?

ROCHESTER BRIDGE TRUST

Structures which move quickly

ROCHESTER BRIDGE TRUST

Rollercoaster pre task slides

Civil Engineers design theme parks

Roller coasters move using:

- **Electro magnets** – magnets turn on and propel the cart
- **Hydraulics** – the cart is pushed out by liquids in a tube creating pressure
- **Pneumatics** – the cart is pushed out by compressed air inside a tube
- **Motors** – the cart is pulled to a great height using a motor/chain

Rollercoaster pre task slides

Simplest roller coaster

Coaster Bot – Chain Lift Hills: Explained

https://www.youtube.com/watch?v=06jLTR6NVrM

The cart is given potential energy

Where is the cart travelling most quickly?

What happens at the end of the track?

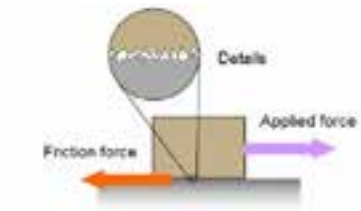
https://www.abss.k12.nc.us/site/handlers/filedownload.ashx?moduleinstanceid=60214&dataid=107545&FileName=43.%20Unit%2012%20Energy%20Study%20Guide%20-%20answers.pdf

Rollercoaster pre task slides

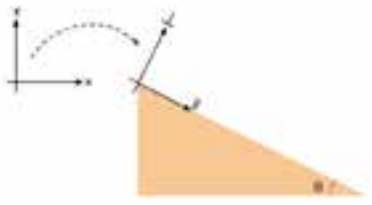
Test, like Engineers

Keywords:

- **Friction**: the force that resists the movement when 2 surfaces try to slide over each other
- **Incline**: the slope of a surface



https://elearnstation.com/scenari/statics2/res/image_06.png



https://www.khanacademy.org/science/ap-physics-1/ap-forces-newtons-laws/inclined-planes-ap/a/inclined-planes-ap1

Rolling vs sliding

- For the rollercoaster buggy to remain in control, it must roll down the incline and not slide
- Therefore some friction is needed on the slope to keep the wheels rotating:

https://www.youtube.com/watch?v=lHUzgDSrwtw

David Castaneda– Rolling vs Sliding

Rollercoaster pre task slides

Pre Task 2:

Material and Structural Engineering?

You have a track test rig with 5 settings of incline.

The track also has two different types of surface – one smooth and one rough.

ROCHESTER BRIDGE TRUST

Pre Task 2:

Material and Structural Engineering?

Investigate which is best:

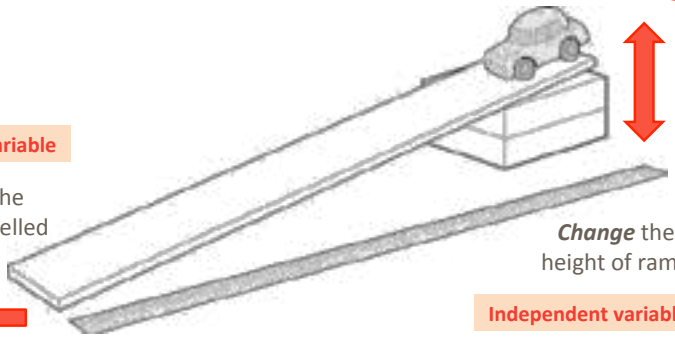
- Which angle of incline?
- Which track surface (smooth or rough)?

Which combination works best to get the buggy to **roll** the furthest?

ROCHESTER BRIDGE TRUST

Rollercoaster pre task slides

Change the angle of incline



Dependent variable

Measure the distance travelled

Change the height of ramp

Independent variable

https://www.sciwebhop.net/sci_web/science/ks3/worksheets/word/default.asp?topic=9K
Pearson Education Limited 2002

Think, like Engineers - Prediction

1. What do you think will happen?
2. Test and see what happens.
3. Was your prediction right?

Rollercoaster pre task slides

Pre Task 2:
Top tips

- Add a dot to the wheels of your cart so you can ensure they are rolling during your investigation.
- Select one side of the track to test at a time.
- Test the buggy at different incline settings 5-30 cm height.
- If you have time, repeat this for the other ramp surface.
- Use the table to record your findings and evaluate which is best and why.

ROCHESTER BRIDGE TRUST

Evaluate, like Engineers

ROCHESTER BRIDGE TRUST

Rollercoaster pre task slides

Work together, like Engineers

Get together with another team and compare findings

ROCHESTER BRIDGE TRUST

Pre Task 2:

Feedback

Which combination(s) worked best for making your buggy roll the furthest?

Can you think of anything else that might have affected how far the buggy travels?

In real life, what factors might affect the motion of the rollercoaster buggy on the track?

ROCHESTER BRIDGE TRUST

Joining methods

	Advantages (Good)	Disadvantages (Bad)	Which would you want to use and why? (Conclusion)
PVA Glue			
Double Sided Tape			
Sellotape			
Pritt Stick			

Make a buggy each. Each of you needs to choose a different joining method so you can test all four methods. Make a note of your results so you can feedback to others.

Pre Task 2: Incline and track test log

Ramp height (cm)	Smooth Track (Distance in m and cm)	Rough Track (Distance in m and cm)	Which would you want to use for the furthest distance and safest rolling? Why?
5			
10			
15			
20			
25			
30			

Start with either the smooth or rough track and test each incline one by one.
Start the buggy in the same place each time and measure how far the buggy runs at the end of the track with a tape measure.

Record your results above so you can decide which incline and track surface will be best.

Rollercoaster Challenge slides

Rollercoaster Exploring Engineering Challenge

Are you ready?

ROCHESTER BRIDGE TRUST

Structures which move quickly

ROCHESTER BRIDGE TRUST

Rollercoaster challenge slides

Context

You are members of a team of **engineers** working for Rochester Bridge Trust.

You have been asked to **design and model** part of a rollercoaster buggy which includes selecting the best track incline and surface for a buggy to roll down.

Your rollercoaster model needs to be the right size to hold, protect and transport a tomato (instead of a human!).

ROCHESTER BRIDGE TRUST

Brief

Your challenge is to design, model and test a rollercoaster buggy to hold and protect a tomato (like the humans inside a rollercoaster!).

You must also select the most suitable incline and track surface for your buggy to roll down. Your goal is to make the buggy go as far as possible while keeping the tomato safe.

ROCHESTER BRIDGE TRUST

Rollercoaster challenge slides

Specification

1. The buggy must keep the tomato secure so it does not fall out of the rollercoaster during the test.
2. The rollercoaster buggy needs to travel at least 0.5m, but ideally, go as far as possible once it reaches the bottom of the ramp.
3. Your selection of incline and surface needs to enable the tomato to travel safely in the buggy (ie it must roll not slide)
4. Your buggy needs to be decorated in a colourful way to make it eye catching and attractive within a busy theme park.
5. The buggy needs to include a Rochester Bridge Trust logo in a place it can be easily seen.

ROCHESTER BRIDGE TRUST

Test Rig

This is the same ramp test rig that you used in the experiment in the last session. You must use the results from your other investigations to choose the best incline and ramp surface to make your buggy travel the furthest. Each group has the same ramp to make the competition fair.

ROCHESTER BRIDGE TRUST

Rollercoaster challenge slides

Materials

- You have a pack of materials for making your buggy
- Do not use any other materials.
- You do not need to use all the materials supplied.
- You can "buy" extra materials but it will cost you points

ROCHESTER BRIDGE TRUST

Tools

- You are only allowed to use the tools provided.
- All cutting must be done safely.
- Use the results from your joining experiment, to decide on the best method to stick your buggy together.

ROCHESTER BRIDGE TRUST

Rollercoaster challenge slides

Materials and Tools

MATERIALS	TOOLS
1 copy of 'The tournament instructions.doc' 1 TechCard buggy template 4 wheels (various sizes) 2 dowel rods (axles) 4 sheet coloured tissue paper 2 sheet coloured card 1 A4 sheet brown stiff card (recycling) 1 logo	Pencils Rulers Small scissors Felt tip pens, various colours Glue stick PVA glue Masking tape Double sided Sellotape Ramp and stand Tomato

ROCHESTER BRIDGE TRUST

Your portfolio must include:

All labelled drawings.

Notes on how your team is being organised.

Notes/labels on how ideas were thought of and developed.

Notes about the challenges you have overcome.

Reasons for choosing the final design.

ROCHESTER BRIDGE TRUST

Rollercoaster challenge slides

Timings for this session

- **15 mins** Introduction to the task and testing criteria
- **15 mins** Planning and drawing/labelling a design for your team
- **40 mins** Modelling
- **10 mins** Testing model/evaluating model
- **10 mins** Final changes to model buggy
- **20 mins** Testing and scoring
- **15 mins** Tidying up!

ROCHESTER BRIDGE TRUST

The Challenge is designed to be fun!

Enjoy the challenge,
enjoy the team work!

ROCHESTER BRIDGE TRUST

Rollercoaster challenge slides

5 MINUTES LEFT!

ROCHESTER BRIDGE TRUST

TOOLS DOWN!

Time to pack away

- All scrap and rubbish in the bin.
- Clear away rubbish on the floor, too.
- Spare materials and tools go into your packs in the middle of your table.
- Sit down ready for testing.

ROCHESTER BRIDGE TRUST

Rollercoaster challenge slides

Testing (0,1 or 2 points for each criteria)

1. The buggy keeps the tomato secure, it does not fall out of the rollercoaster during the test.
2. The rollercoaster buggy travels at least 0.5m across the floor.
3. The selected incline and surface is suitable and ensures the tomato is safe.
4. The buggy is decorated in a colourful way. It is eye catching and attractive.
5. The buggy includes a Rochester Bridge Trust logo on a place it can be easily seen.

ROCHESTER BRIDGE TRUST

ROCHESTER BRIDGE TRUST

Rollercoaster Exploring Engineering Challenge

THE RESULTS!

Are you ready?

Rollercoaster challenge slides

Rollercoaster Exploring Engineering Challenge

Today you were Engineers!

Keep asking questions like why, how, what and you can be like Engineers everyday!

Guidance for learners

Remember the pre tasks at the start of this Challenge, and you can look back at these notes to remind you.

Materials

- You will be able to select materials for making your buggy from a list.
- Do not use any other materials.
- You do not need to use all the materials supplied.
- You may "buy" extra materials but it will cost you points.
- You are only allowed to use the tools provided.
- All cutting must be done with care to keep you safe.

Challenge Materials/Tools List for All Teams

Please check that you have the following materials on your table and report any shortages to your challenge leader.

Tools

Materials	Quantity
TechCard buggy template	1
Wheels (various sizes)	4
Dowel rods (axles)	2
Coloured tissue paper*	4 sheets
Coloured card*	2 sheets
Recycling**	1 item
Rochester Bridge Trust logo	1
Tomato	1

* You can "buy" extras of these for 1 point per purchase. The points will be deducted from your total at the end.

**You can have extra recycling – free!

Tool List

- Pencils
- Rulers
- Small scissors
- Felt tip pens, various colours
- Glue stick
- PVA glue
- Masking tape
- Double sided tape
- Paper clips
- Height adjustable stand
- Ramp
- Measuring tape/metre rule

Guidance for learners

Context

You are members of a team of engineers working for Rochester Bridge Trust.

You have been asked to design and model part of a rollercoaster buggy which includes selecting the best track incline and surface for a buggy to roll down.

Your rollercoaster model needs to be the right size to hold, protect and transport a tomato (instead of a human!).

Brief

Your challenge is to design, model and test a rollercoaster buggy to hold and protect a tomato (like the humans inside a rollercoaster!). You must also select the most suitable incline and track surface for your buggy to roll down. Your goal is to make the buggy go as far as possible while keeping the tomato safe.

Specification

1. The buggy must keep the tomato secure so it does not fall out of the rollercoaster during the test.
2. The rollercoaster buggy needs to travel at least 0.5m, but ideally, go as far as possible once it reaches the bottom of the ramp.
3. Your selection of incline and surface needs to enable the tomato to travel safely in the buggy.
4. Your buggy needs to be decorated in a colourful way to make it eye-catching and attractive within a busy theme park.
5. The buggy needs to include a Rochester Bridge Trust logo in a place it can be easily seen.

A simple portfolio must be produced as part of your design and planning and should include:

a) all labelled drawings;

b) notes on how your team is being organised;

c) notes/labels on how ideas were thought of and developed;

d) notes about the challenges you have overcome; and

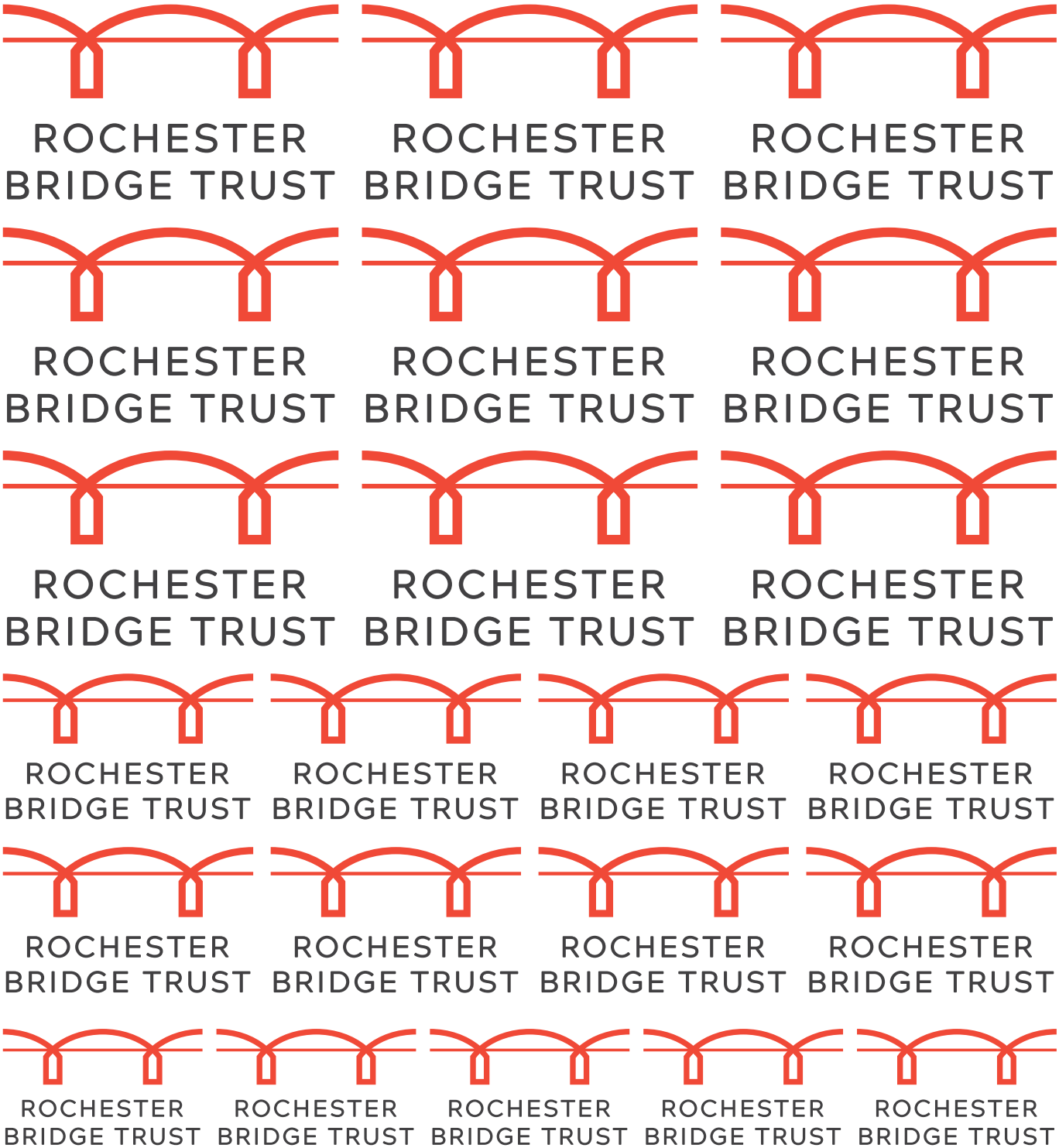
e) reasons for choosing the final design.

Inspiration from Existing Products:

Structures which move quickly

This is designed to be fun! Enjoy the challenge and the teamwork.

Rochester Bridge Trust logo samples



Testing notes

The test log provides you with the six tests and space to log results for each team, as well as note whether extra materials were purchased in exchange for points.

For the final testing stage, you will need to mark out the start line using masking tape (where the end of the ramp meets the floor and the 0.5m distance that the buggies must travel).

Each test is worth 0, 1 or 2 points:
0 = doesn't do this
1 = does this somewhat or just about
2 = yes, does this.

NB: for most of the tests, it will be obvious if the criterion has been met. We are trying to give points to the teams rather than trying to penalise them during each test.

Most tests are visual tests against the criteria: is the tomato secure within the buggy at the end of the test, is the selected incline and surface suitable, and does the design include the logo?

The fourth specification requires the buggy to be decorated in a colourful way: this will be down to the judges' discretion.

A key test of the buggy will be to measure the travelling distance: has it travelled at least 0.5m, and then sufficiently further to offset any 'purchases' made?

Testing Criteria:

1. The buggy keeps the tomato secure, it does not fall out of the rollercoaster during the test.
2. The rollercoaster buggy travels at least 0.5m across the floor.
3. The selected incline and surface is suitable and ensures the tomato is safe.
4. The buggy is decorated in a colourful way. It is eye catching and attractive.
5. The buggy includes a Rochester Bridge Trust logo on a place it can be easily seen.
6. **BONUS:** 1 point for every 10cm beyond 0.5m, the buggy travels
7. **SHOPPING:** subtract 1 point for every item "bought"

Test log for whole group

No = 0 Somewhat = 1 Yes = 2 points

Team names:								
1. The buggy keeps the tomato secure, it does not fall out of the rollercoaster during the test.								
2. The rollercoaster buggy travels at least 0.5m across the floor.								
3. The selected incline and surface are suitable and ensure the buggy roles safely.								
4. The buggy is decorated in a colourful way. It is eye catching and attractive.								
5. The buggy includes a Rochester Bridge Trust logo on a place it can be easily seen.								
BONUS: 1 point for every 10cm beyond 0.5m, the buggy travels								
SHOPPING: subtract 1 point for every item "bought"								
Total								

Certificate

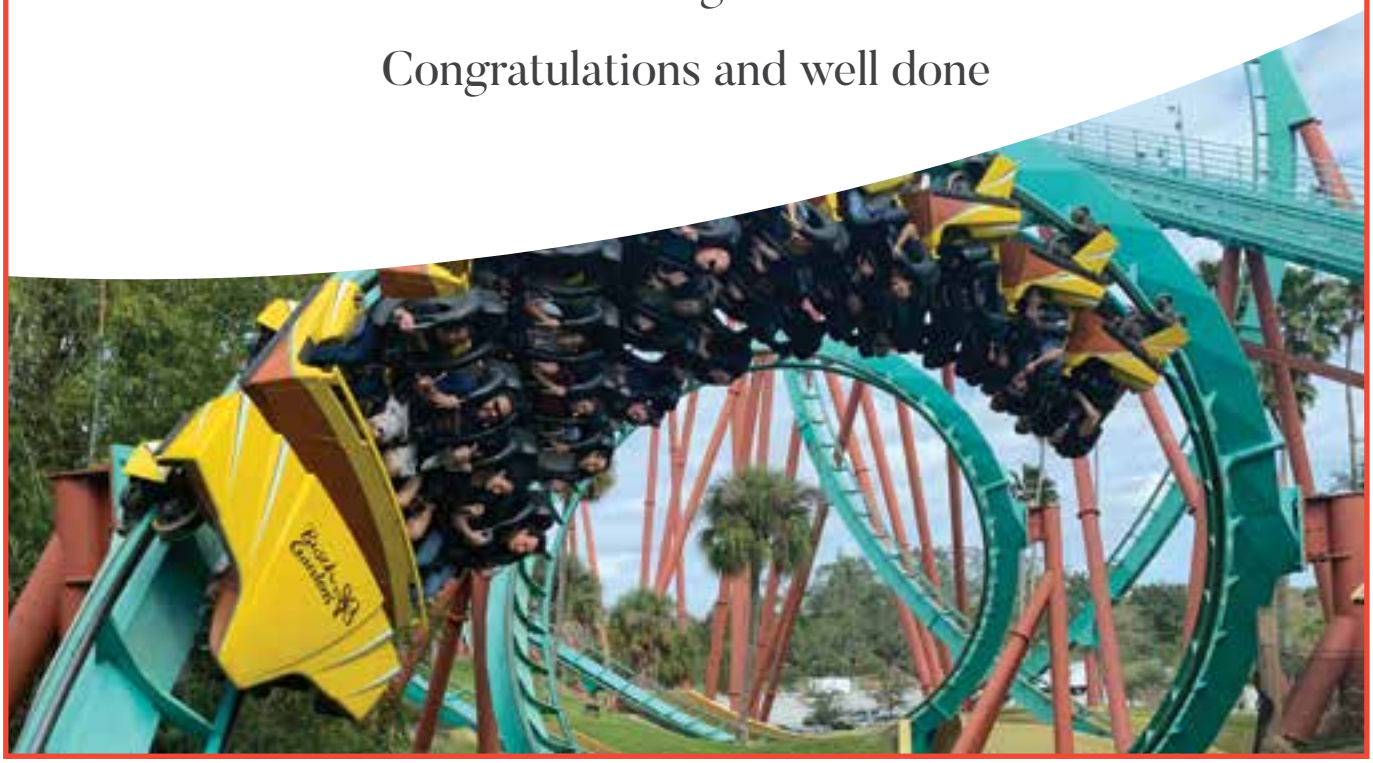
CERTIFICATE

ROCHESTER
BRIDGE TRUST

This is to certify that _____

worked hard taking the first steps to become a Civil Engineer

Congratulations and well done



Certificate

CERTIFICATE

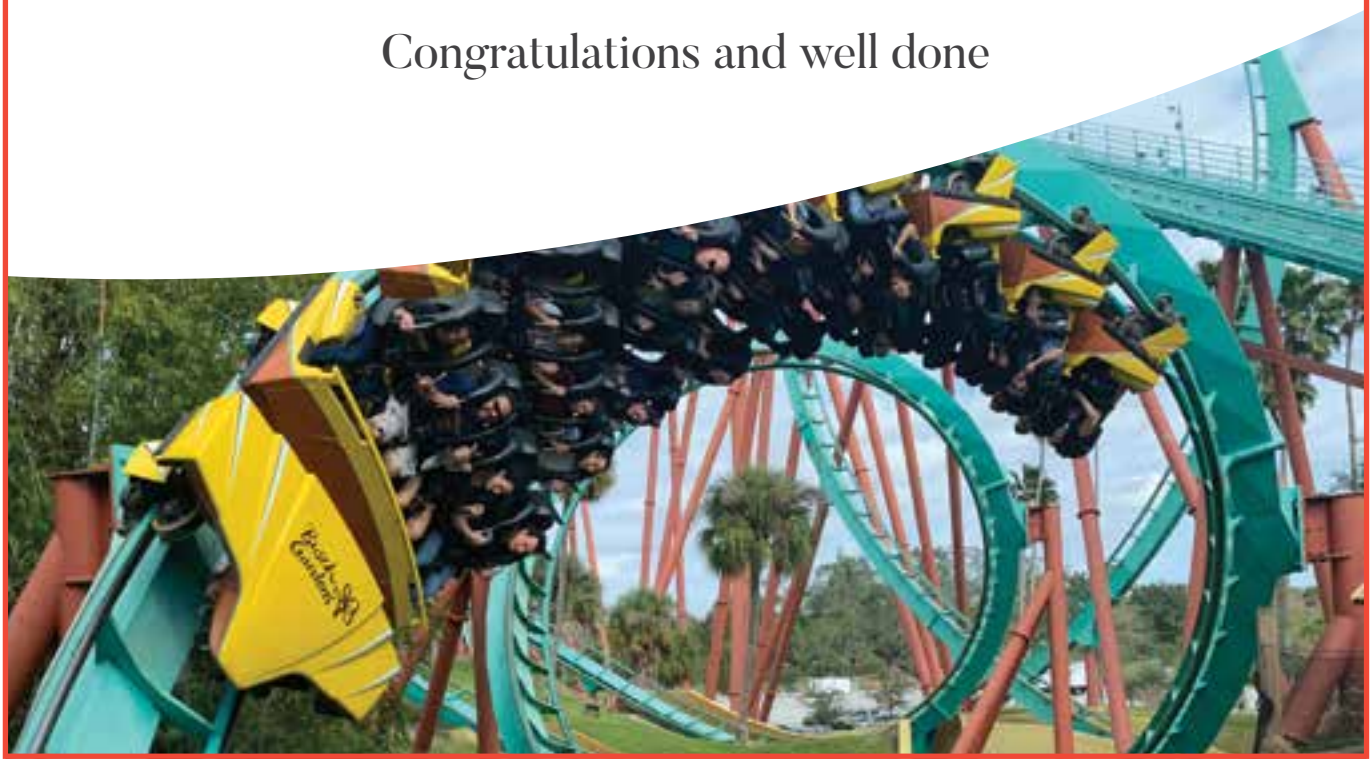
ROCHESTER
BRIDGE TRUST

This is to certify that _____

of _____

designed and built the winning rollercoaster buggy!

Congratulations and well done



Risk assessment

Activity: Exploring Engineering Challenge – Rollercoaster **Date written:** September 2019

Brief overview of activity: Designing and Construction of rollercoaster buggy using small craft materials and tools – FOR INFORMATION ONLY

Potential hazards?	Who might be harmed and how?	Level of risk (low/ medium/ high)	What will be done to manage this risk?	Action by whom?	Action by when?	New risk	Action plan for untoward occurences
Physical activities	Individuals – falls during pushing / pulling activity	Medium	Choose individuals of equal size. Clear demonstration area so no sharp edges. Clear safety instructions to individuals involved.			Low	Administer first-aid / call for emergency medical assistance as required
Craft activities	Learners – splinters & cuts from broken wood; cuts from using sharp implements.	Medium	Safety instructions and supervision. n.b. no carrying sharp implements around the room Adequate supervision.			Low	Administer first-aid / call for emergency medical assistance as required
Movement around space	Falls, slips, trips.	Medium	Safety instructions – walk don't run; pick up anything which falls on the floor; no carrying sharp implements around the room. Tuck chairs & bags under tables during making activities. Clear items which have fallen onto the floor asap. Provide dustpan and brush for this purpose.			Low	Administer first-aid / call for emergency medical assistance as required

Please note: this risk assessment sample is to be used as information only. You must ensure that you carry out your own full risk assessment for your particular setting and participants.

ROCHESTER
BRIDGE TRUST

Supporting engineering education

www.rochesterbridgetrust.org.uk