STEM TOOLKIT

Institution of MECHANICAL ENGINEERS

Improving the world through engineering

imeche.org

CONTENTS

TIME TO GET HANDS ON

These engineering challenges are designed to stretch budding engineers and show them the principles needed to solve problems in the real world.

HOW TO USE THIS KIT

This booklet accompanies the STEM toolkit, which is full of all the craft materials needed for a class of 30 to complete a series of engineering challenges.

Each challenge will work on its own, or can be paired with another, depending on how much time you have for your workshop.

To get started, we suggest picking a challenge and giving it a go yourself.

For each project, there are sections in blue which are specifically for you, the Ambassador, outlining the project methods and objectives. The white sections contain the main activity instructions, which can be shared with the students.

You can download useful materials to help run each activity at imeche.org/stemtoolkit.

OUR PREFERRED APPROACH

Constructivism is the theory that people learn best through making, and it's an excellent way to teach mechanical engineering.

When setting the challenges, give the students the building blocks they need to get started and then encourage them to start experimenting.

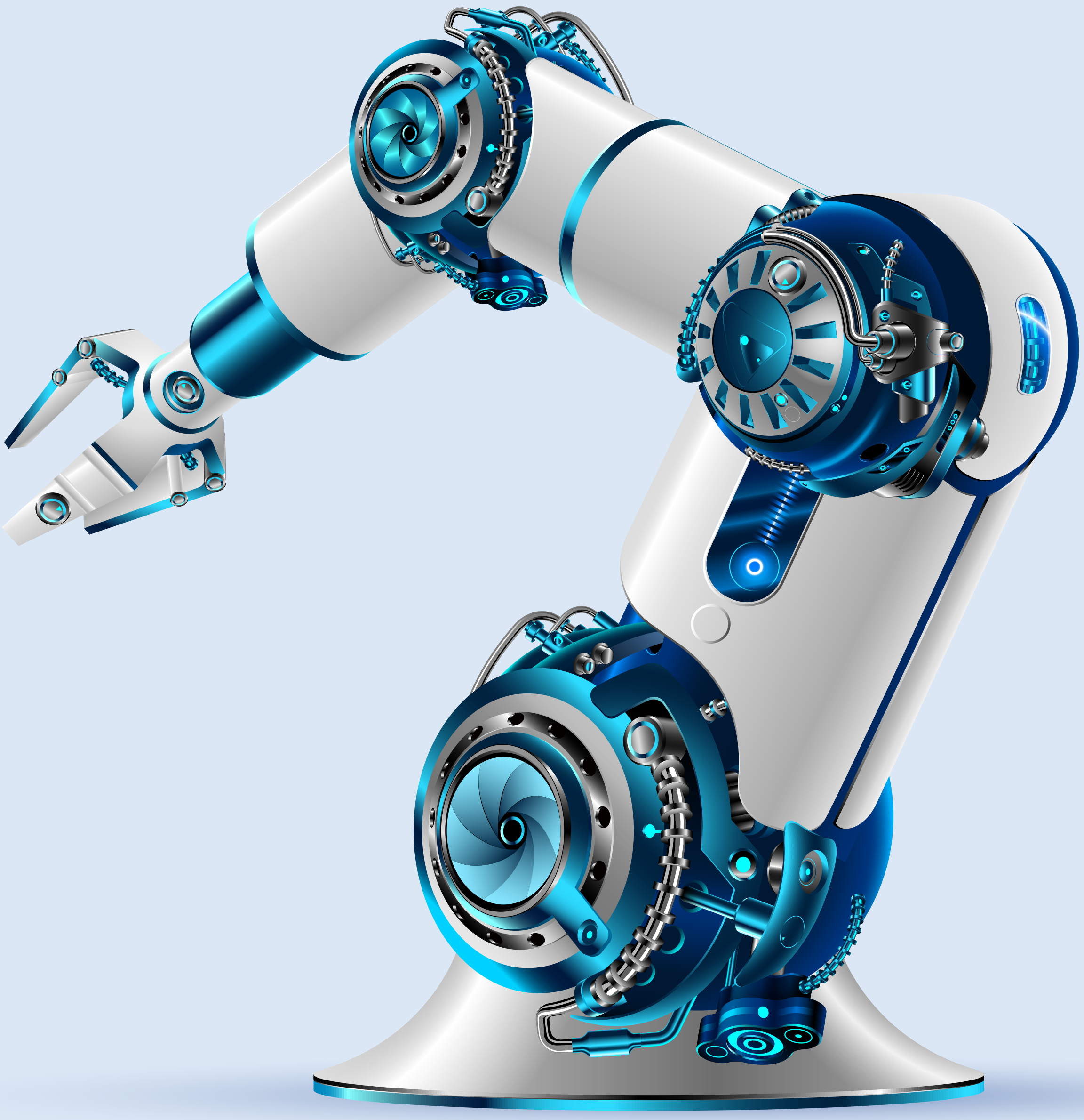
We encourage moving between the groups asking the right questions. This allows students to come up with their own solutions as far as possible. You may need to explain any relevant physics or maths where necessary.

SET THE SCENE AND PROVIDE AN INCENTIVE

Children retain more knowledge when they care about the subject matter. Use the warm-up activities and your own real world knowledge to bring the challenges to life and engage with the students.

Each challenge has a competition element to it, where the outcome can be measured, e.g. which is the strongest bridge.

We have provided a printable certificate that you can award either to the winning team, or for behaviour you would like to encourage, such as good teamwork. This can be found along with other useful materials at imeche.org/stemtoolkit.



HELP & SUPPORT

Where can I find the student worksheets and resources?

You can download and print the student worksheets from imeche.org/stemtoolkit

Does the content cover school learning outcomes?

Yes, the content in this brochure covers multiple national curriculum points. These can be found in the Teaching Notes section of each session.

How many students can the STEM toolkit be used for?

The STEM toolkit can be used for sessions with up to 32 children. We suggest no more than 4 students in each team.

Do students have to be in teams?

Students don't have to work in teams, but we recommend they do. A big part of being an engineer is being able to work successfully in a team.

How long is each session?

The timings for each session range between 1-2 hours. There are plenty of extension activities available in each session if you finish early.

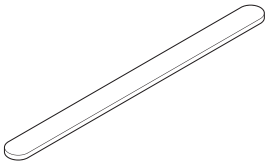
How can we make sure students have learnt the content?

At the end of each session there is a short quiz for students to take. There are also discussion points that you can use to wrap up at the end of the session.

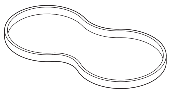
WE'D LOVE TO SEE THE CREATIONS YOUR STUDENTS COME UP WITH, SO GET INVOLVED ONLINE!

@imecheuk @imecheuk @imecheuk

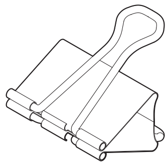
WHAT'S IN THE TOOLKIT?



Lollipop Stick
240



Elastic Band
160



Bulldog Clip
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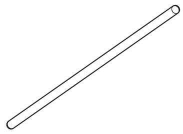
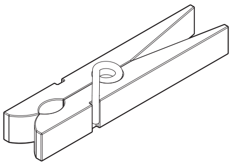
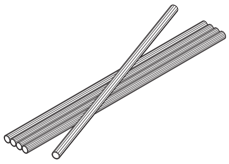


Wooden Dowel
112



Clothes Peg
80



Paper Straw
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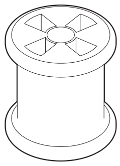

Cotton Reel
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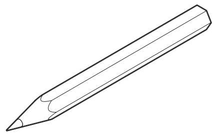

Pencil Pack
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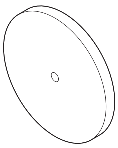

Wheel
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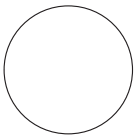
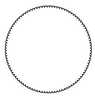
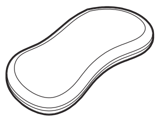


Ping-Pong Ball
8



Pom-Pom
8

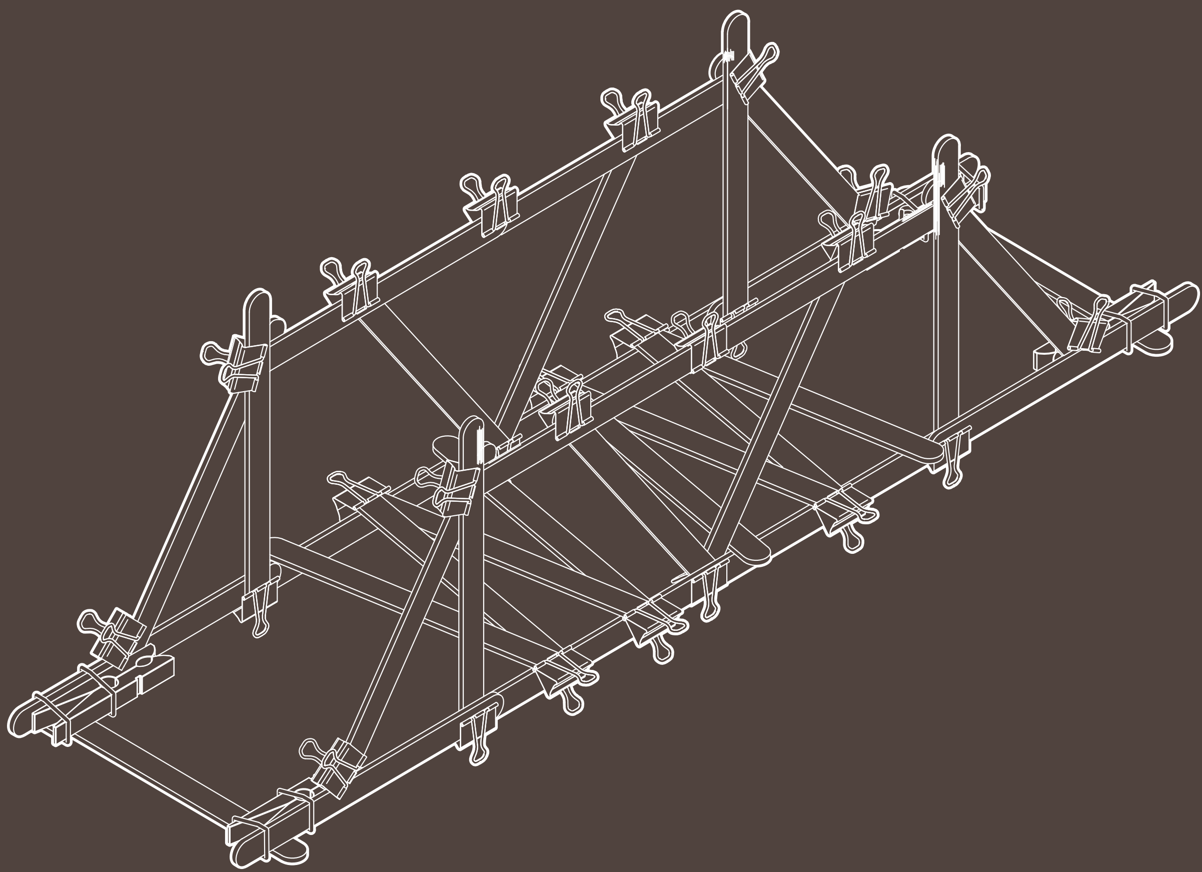


White Tac
4

CHALLENGE 1

BRIDGE BONANZA

In this challenge, teams will work together to create the strongest bridge they can to span a gap, using everyday materials.



TEACHING NOTES

SUMMARY

Students will work in teams to design and build a bridge out of a few simple materials. Bridges must span at least 45cm and hold as much weight as possible for 10 seconds.

Teams are encouraged to be frugal and use the fewest number of lollipop sticks, whilst still achieving their team goals.

They will then evaluate their own work during a class discussion.

LESSON PLAN

ACTIVITY	DESCRIPTION	TIMING
Introduction	Introduce the goal of the session and hand out the student resource sheet. Divide students into teams of 4 students, providing a set of materials to each.	5-10m
Warm-up Activity A	Introduce the bridge idea exercise and ensure students have the required materials to complete it.	5-10m
Warm-up Activity B	Introduce the bridge prototyping exercise and ensure students have the required materials to complete it.	10-15m
Main Challenge	Explain to students that their bridge must span at least 45cm and require no more materials than those provided. Each bridge must be able to hold as much weight as possible for 10 seconds.	30-40m
Measuring Up	When the teams have finished building, they need to test the bridges' durability and weight capacity.	10-15m
Extension Activities	If any of your teams finish their build early, get them to try one of the extension activities.	5-15m
Extra Content	Additional educational content for those with enquiring minds.	10-15m
Quiz	Ask your students to complete this quick quiz to test their knowledge.	10-15m
Wrapping Up	Cover the discussion points with the students to close the session.	10-15m

LEARNING OUTCOMES

Students will learn:

- How to apply scientific principles to bridge building
- The physics of bridge-building
- Planning and construction
- The importance of loads and stresses on their structure
- About teamwork, time management and working with limited resources

CURRICULUM

KS1 Design and Technology

- Evaluate their ideas and products against design criteria
- Build structures, exploring how they can be made stronger, stiffer and more stable

KS2 Design and Technology

- Use research and develop design criteria to inform the design of innovative, functional and appealing products that are fit for purpose, aimed at particular individuals or groups
- Understand how key events and individuals in design and technology have helped shape the world
- Apply their understanding of how to strengthen, stiffen and reinforce more complex structures

TOP TIP

For more mature students, increase the distance and weight requirements for the bridge.

DOWNLOAD

Download and print student worksheets from imeche.org/stemtoolkit

WRAPPING UP

MEASURING UP

10-15m

The winning team will be the one that builds the strongest bridge. To be able to test the bridges at the end of the session, make sure you have some weights that you can slowly increase until they collapse.

Good weights include books, stones or marbles in a cup.

EXTENSION ACTIVITIES

There are plenty of extra considerations that architects need to take into account when designing bridges. If students finish early, here are a few ideas for extension activities.

A

5-10m

Increase the width of the gap to 60cm.

B

10-15m

Reduce the materials used. Imagine there is a global shortage of lollipop sticks - can the teams still create a successful design?

DISCUSSION POINTS

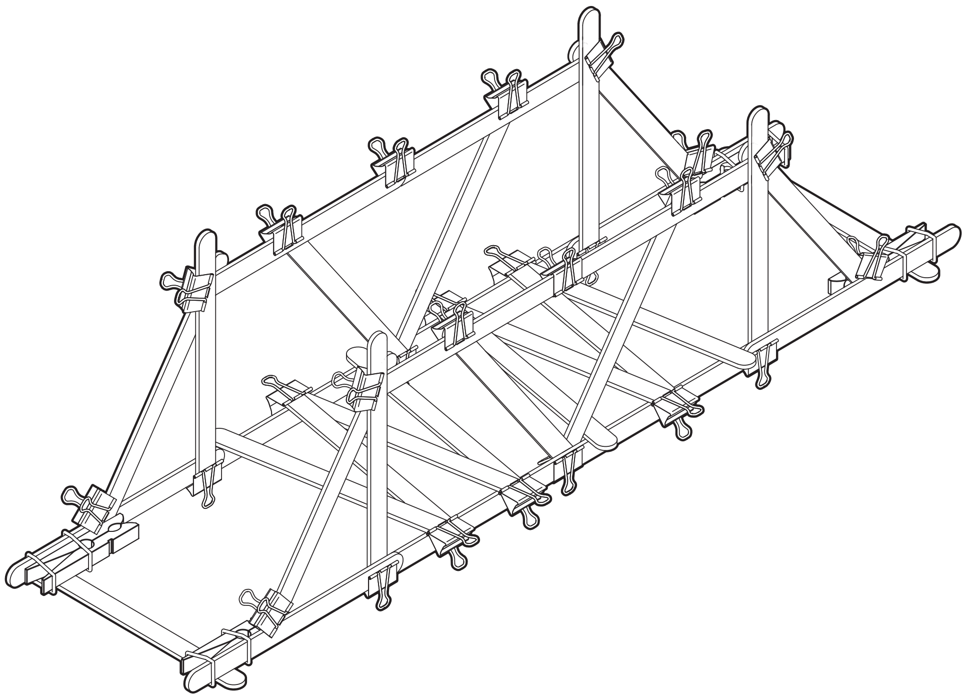
10-15m

To close the session, hold a class discussion and cover the following points:

- Was there a successful design amongst the teams? If not, why?
- Could the teams have used fewer materials?
- Did the teams have to deviate from their original designs?
- What do the students like about designs from other teams?
- Do the teams think it would have been easier to work alone? Why?
- What would the teams change if they were to attempt the task again?

REMEMBER

Provide a recap or short summary to the class highlighting the key engineering skills and what has been learnt during this activity.



BRIDGE BONANZA WORKSHEET

GETTING STARTED

5-10m

This bridge building STEM activity will get you thinking about the foundations of bridge building and what creates a strong structure.

This build requires you to work well as a team and challenges you to carefully consider the most effective use of materials available to you.

It's up to you and your team to create the strongest bridge you can. Are you ready to build?

VOCABULARY

Strut - A rod or bar designed to increase strength. Lollipop sticks make excellent struts.

Load - The weight or forces that are put on a bridge. On large bridges, this may be the number of cars; for this challenge, we will use any weights available, such as pens or books.

Truss Bridge - A bridge made primarily of triangles to give them strength.

Beam Bridge - Horizontal beams supported at each end by piers.

Arch Bridge - These are arch-shaped and have abutments, structures to support the arches, at each end.

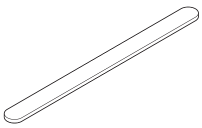
Cantilever Bridge - Built using cantilevers, which are horizontal beams that are supported on only one end.

Suspension Bridge - Bridges that are suspended from cables.

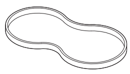
Cable-stayed Bridge - Similar to suspension bridges, as they are held by cables. However, the difference is that less cable is required and the towers holding the cables are proportionately shorter.

Polygon - Any two-dimensional shape with straight lines. The name tells you how many sides the shape has. For example, a triangle has 3 sides.

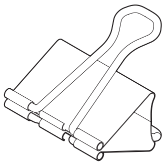
EACH TEAM WILL NEED



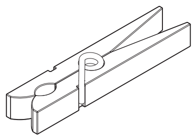
Lollipop Stick
30



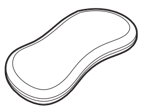
Elastic Band
20



Bulldog Clip
16



Clothes Peg
10



White Tac

WARM-UP ACTIVITIES

A

5-10m

Draw a picture of some bridges that you have seen or been across, either on foot or in a car. Have a think why they may be particularly strong?

B

10-15m

Using paper and cardboard, pick one bridge to make a prototype of the bridge designs that you and your teammates drew in warm-up activity **A**.

MAIN CHALLENGE

30-40m

The challenge is to work together as a team to build a strong bridge across the gap in front of you using the materials provided.

Great engineers always create designs of what their final masterpiece will look like. Sketch out different options and experiment with different approaches.

The bridges must span at least 45cm and hold each weight for at least 10 seconds.

Don't forget to think about the design principles you can find in the six main bridge types and remember, if you can make the bridge symmetrical, you're less likely to have weak points.

Once completed and tested, there will be a class discussion about your findings.

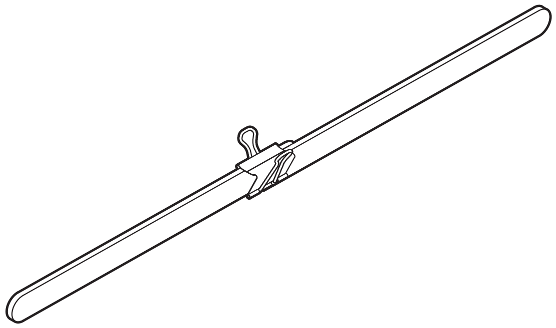
BUILDING YOUR BRIDGE

There are many ways to build a bridge using the materials provided. Use your creativity to form innovative, load bearing structures!

TECHNIQUES TO TRY

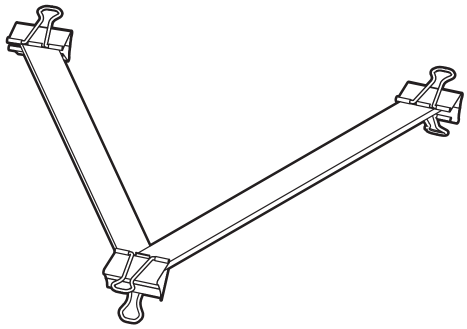
STRAIGHT JOINT

Join two lollipop sticks together in a line using a bulldog clip. Be sure there is an overlap between both lollipop sticks to ensure a strong joint.



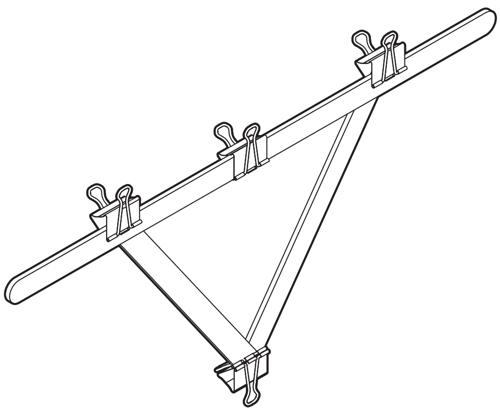
ANGLED JOINT

Angled sections can be joined together as shown below:



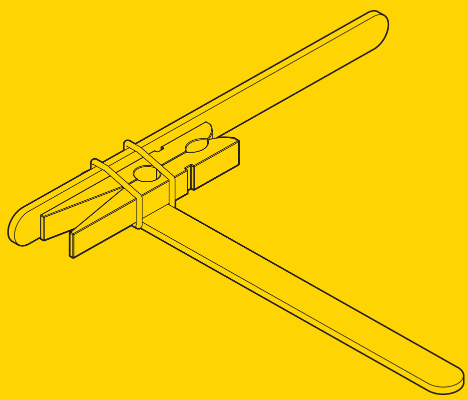
TRUSS

By combining these techniques, you're able to create a truss. Trusses are excellent at distributing the load applied to your bridge. Several trusses can be joined together using the provided materials to create strong, stable structures. Use these techniques to get building!



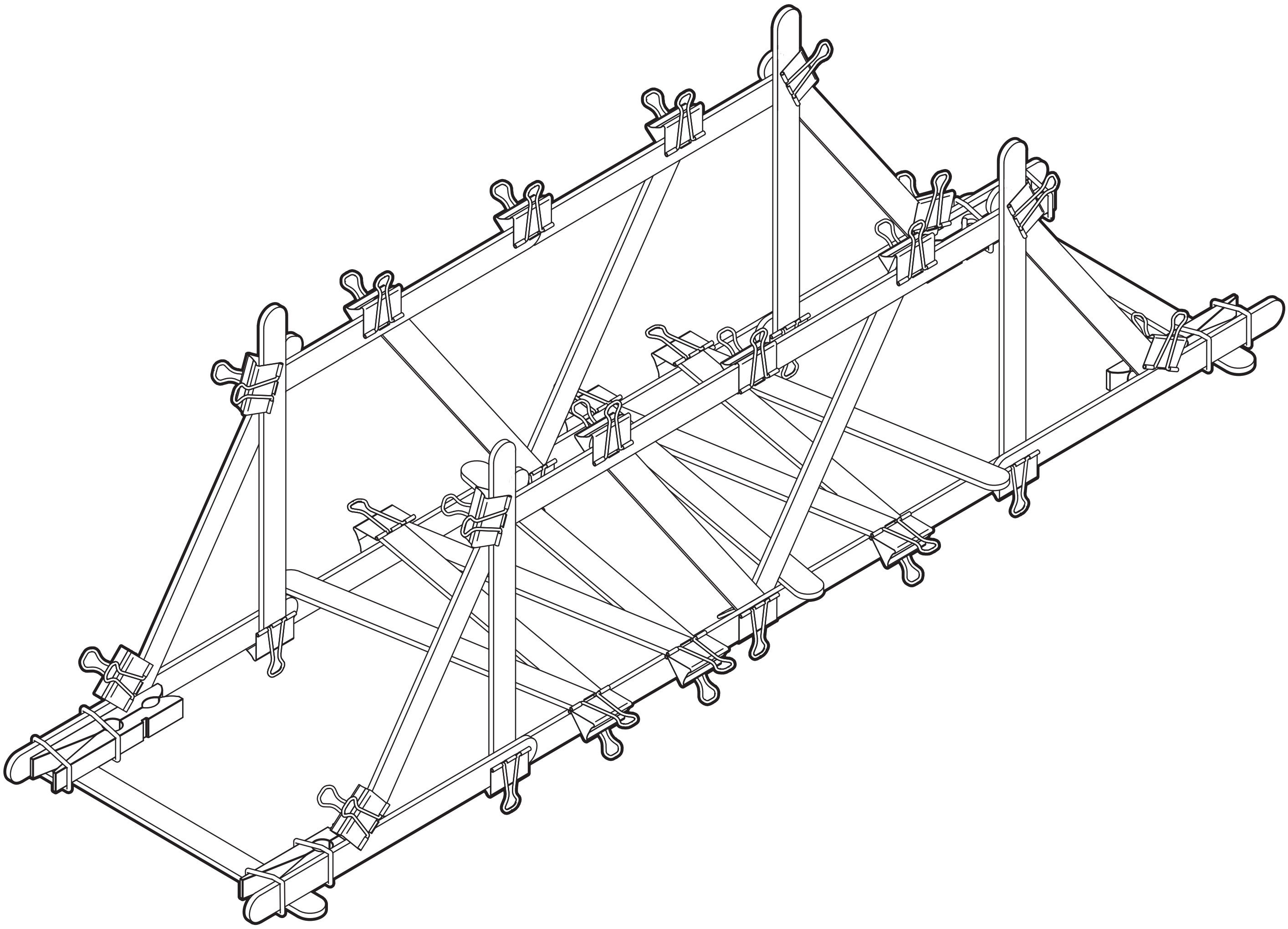
ADVANCED TECHNIQUE

Perpendicular faces can be created by fixing two lollipop sticks to a clothes peg using a rubber band, as shown here. This can be particularly useful when constructing the sides of the bridge.



EXAMPLE BRIDGE

We created a bridge using only these techniques.
Think about where you want the load to be applied on your bridge.
Be as creative as you can!



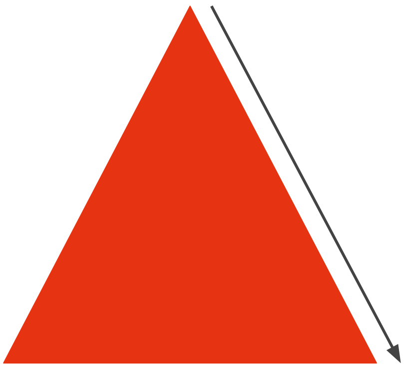
BRIDGE BONANZA

STRENGTH OF TRIANGLES

10-15m

KS1/2 PROOF OF CONCEPT

Let's look at some different shapes, and image they are hollow frames. Looking at the square in the image to the right, if you were to push hard enough on one corner, it would collapse into a rhombus shape and could even fall flat. Not ideal for bridge building!



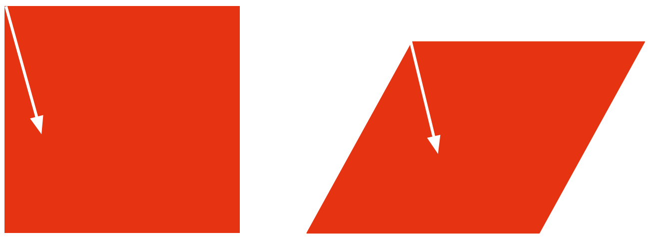
However, if you push on one corner of a triangle, the force travels down the edges and keeps the shape rigid. This is why triangles are considered the strongest shape.

Got your heart set on a bridge that uses squares? Not to worry, you can use triangles to create a more stable square. Have a look at the ideas below to give you some inspiration.

KS3/4 DEEPER LEARNING

All polygons are not created equal - and they certainly aren't all as strong as triangles. But why?

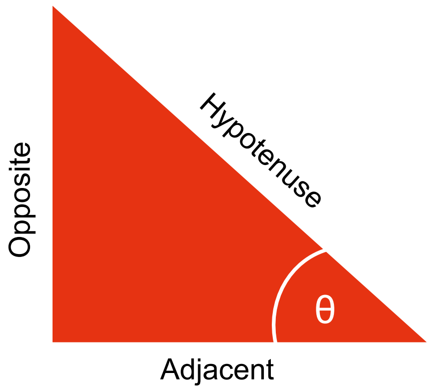
The points where outer edges of a polygon meet (the corners) are called vertices, and a single corner is called a vertex. In most shapes you can change the angles at the vertices without changing the lengths of the edges, as with the collapsing square below.



But triangles are different because the vertex angles are dependent on the lengths of the sides. You can't reduce any of the interal angles without squashing the opposite edge.

Because of these relationships, if we apply a force on the triangle, the opposing edges are always applying a reaction force in order to maintain the shape. This is why triangles are so stable.

The geometric dependancies of triangles are described by trigometry.



$$\sin\theta = \frac{opp}{hyp} \qquad \cos\theta = \frac{adj}{hyp} \qquad \tan\theta = \frac{opp}{adj}$$

Think about how trigonometry might be used when designing a real bridge.
Have you made sure to use triangles in your bridge?

QUIZ

15-20m

What shape is a truss bridge primarily made up of?

....

....

Why is symmetry important in bridge design?

....

....

What do engineers do before starting construction?

....

....

Why are triangles often found in bridge designs?

....

....

How important are the materials we use when building a bridge?

....

....

QUIZ

What is the difference between a cable-stayed bridge and a suspension bridge?

....

....

Can you name a famous suspension bridge - or draw what one would look like?

....

....

If you could choose other materials to build your bridge from, what would you choose and why?

....

....

If you had to build your bridge to cover a wider gap, other than making your bridge longer, what else would you need to think about changing?

....

....

How does the weight of a bridge impact the final design?

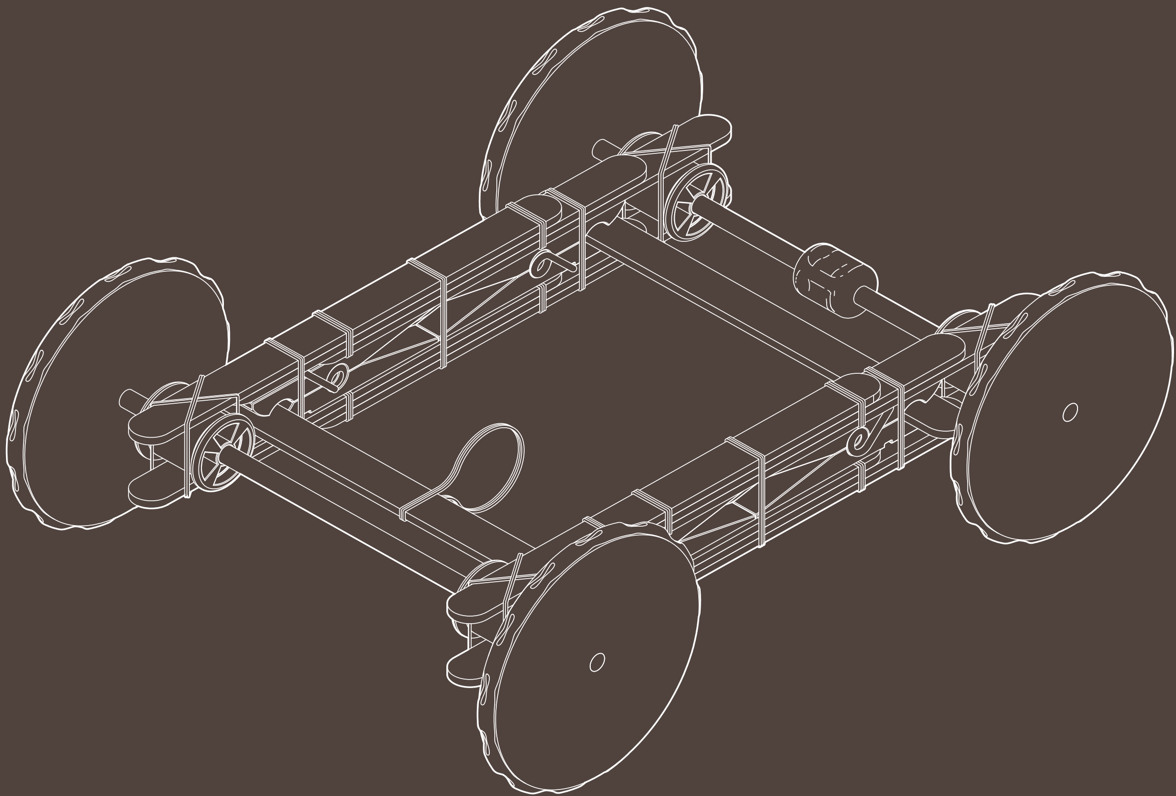
....

....

CHALLENGE 2

LUNAR ROVER

In this challenge, teams will work together to create a speedy Lunar Rover. First to cross the finish line wins!



TEACHING NOTES

SUMMARY

The Lunar Rover session challenges students to build a functioning rubber band car. They have the option to follow the build template provided, or if they're feeling adventurous they can design and build their very own.

In teams, students will use the craft materials provided to construct their creations, which they will showcase at the end of the session. The rover that travels the furthest distance wins!

Students will learn about potential and kinetic energy in this session, whilst also considering the relationship between mass, force and torque, and the effect they will have on their final design.

LESSON PLAN

ACTIVITY	DESCRIPTION	TIMING
Introduction	Introduce the goal of the session and hand out the student resource sheet. Divide students into teams of 4, providing a set of materials and worksheet to each.	5-10m
Warm-up Activity A	Introduce the warm-up activity and ensure that students have the required materials to complete it.	10-15m
Main Challenge	Explain to the students that their Lunar Rover has to travel as far as possible, whilst staying intact. They don't have to use all the materials provided and can design their own if they choose to.	30-40m
Measuring Up	When the teams have finished constructing, they will need to test their designs by measuring how far their Lunar Rovers can travel.	10-15m
Extension Activities	If any of your teams finish their build early, get them to try one of the extension activities.	5-15m
Extra Content	Additional educational content for those with enquiring minds.	10-15m
Quiz	Ask your students to complete this quick quiz to test their knowledge.	10-15m
Wrapping up	Cover the discussion points with the students to close the session.	10-15m

LEARNING OUTCOMES

Students will learn:

- How to identify the effects of friction that act between two moving surfaces
- How to test and refine their designs
- How to communicate their design process and results
- Newton’s 1st, 2nd and 3rd Laws
- About small group work and teamwork, time management and working with limited resources

CURRICULUM

KS1 Design and Technology

- Evaluate their ideas and products against design criteria
- Build structures, exploring how they can be made stronger, stiffer and more stable

KS2 Design and Technology

- Use research and develop design criteria to inform the design of innovative, functional, appealing products that are fit for purpose, aimed at particular individuals or groups
- Understand how key events and individuals in design and technology have helped shape the world
- Apply their understanding of how to strengthen, stiffen and reinforce more complex structures
- Evaluate their ideas and products against their own design criteria and consider the views of others to improve their work

TOP TIP

Set up a designated testing area for teams before the session, so that everyone has the opportunity to test their makes throughout the build.

DOWNLOAD

Download and print student worksheets from imeche.org/stemtoolkit

WRAPPING UP

MEASURING UP

10-15m

This challenge culminates in each team testing their makes and recording their best distance out of three attempts. When teams finish their Lunar Rover, all they need to do is wind them up, and let them roll!

The team with the build that travels the furthest is the champion!

If a team has successfully completed their build ahead of time, why not get them to try one of the extension activities below.

EXTENSION ACTIVITIES

A

5-10m

Ask teams to alter their designs to increase the distance that their Lunar Rover will travel. Get them to think about the amount of potential energy they currently have and the weight of their build. They can refer to the additional education resource at the end of their worksheets if they need a helping hand.

B

10-15m

If you have two or more teams that have successfully completed their build, why not set up a race challenge. The fastest Lunar Rover wins!

DISCUSSION POINTS

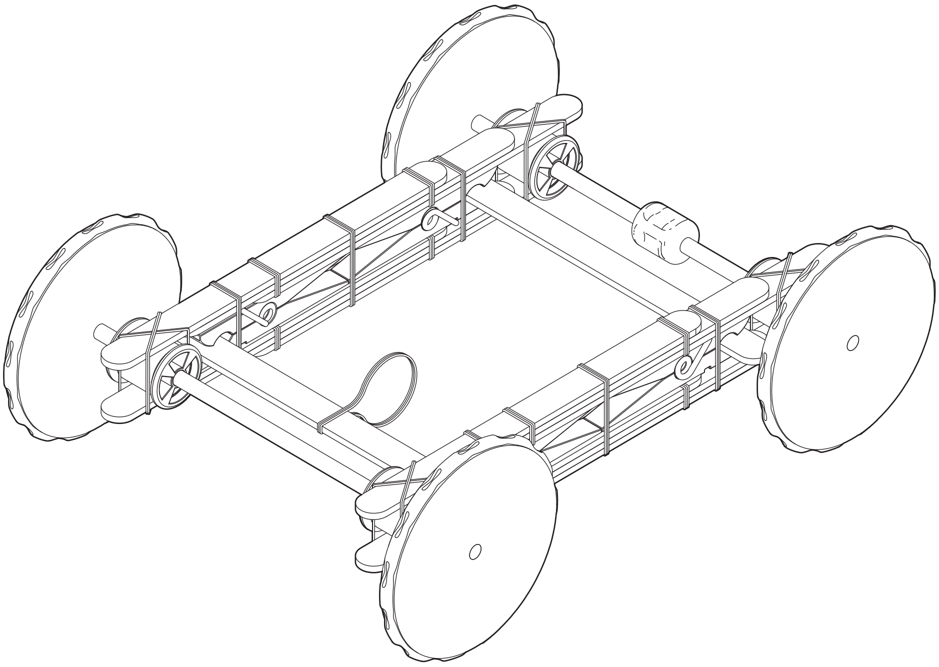
10-15m

To close the session, hold a class discussion and cover the following points:

- Was there a successful design amongst the teams?
- If not, why?
- Could the teams have used fewer materials?
- Did the teams have to deviate from their original designs?
- What do the teams like about their rivals' designs?
- Do the teams think it would have been easier to work alone?
- What would the teams change if they were to attempt the task again?

REMEMBER

Provide a recap or short summary to the class, highlighting the key engineering skills and what has been learnt during this activity.



LUNAR ROVER WORKSHEET

GETTING STARTED

5-10m

The Lunar Rover is a classic STEM based build that incorporates the science behind potential energy and kinetic energy, whilst having to think creatively and solve problems.

This build will require determination and perseverance, whilst simultaneously testing your ability to problem solve.

As a team, you'll need to build a working Lunar Rover that will remain intact and can travel unaided to the required distance.

VOCABULARY

Energy - The ability to do work.

Kinetic Energy - The energy of motion.

Potential Energy - Energy that is stored in an object either by lifting it up or, if the object is elastic, due to it being stretched or compressed.

Energy Conversion/Energy Transformation - The process of changing one form of energy to another.

Inertia - The resistance of any physical object to any change in its velocity.

Momentum - The tendency of a moving object to keep moving. This is calculated by mass x velocity.

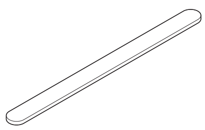
Friction - The resistance that one surface or object encounters when moving over another.

Precision - How close two or more measurements are to each other.

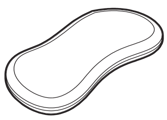
Accuracy - How close the result comes to the known true value.

Torque - A measure of the force acting to cause rotation about an axis.

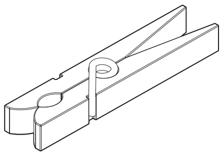
EACH TEAM WILL NEED



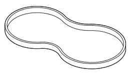
Lollipop Stick
30



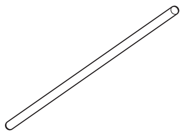
White Tac
1



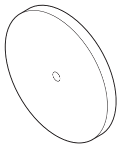
Clothes Peg
4



Elastic Band
20



Wooden Dowel
2



Wheel
4

WARM-UP ACTIVITIES

A

10-15m

Within your team, discuss the following principles. Read the description of each one carefully and consider what each means. Can you and your teammates think of any examples of each principle?

Newton's Laws of Motion

- Newton's First Law - An object either remains at rest, or continues to move at a constant velocity, unless acted upon by an external force.
- Newton's Second Law - Force = mass x acceleration (F=ma). This means the acceleration of an object is proportional to the overall force, and inversely proportional to it's mass. In other words, you can increase the acceleration of a vehicle by increasing the driving force, or by reducing it's mass.
- Newton's Third Law - For every action, there is an equal and opposite reaction. For example, if you push against a tree (action), and the tree doesn't move, it will be pushing you back with the exact same force (reaction).

MAIN CHALLENGE

30-40m

In teams, you're going to build your very own Lunar Rover. You can follow the build instructions provided, or if you're feeling adventurous you can design and build your own unique rover.

As a team, we suggest you discuss and agree on your design before you start to build. This will give you the best chance of success.

Using the materials provided, your Lunar Rover must be stable enough to travel unaided and travel as far as possible. The team with the furthest recorded distance after three attempts wins!

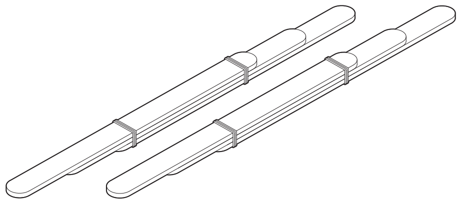
Remember to work closely as a team, and listen to everyone's ideas.

Once you've completed the challenge, there will be a quick quiz followed by a class discussion.

BUILDING YOUR LUNAR ROVER

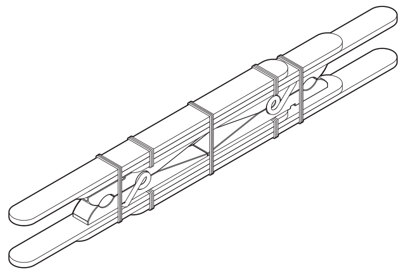
A

Lay three lollipop sticks on top of each other, with the top and bottom sticks slightly off centre. Use elastic bands to secure these in place. Now repeat this so you have two.



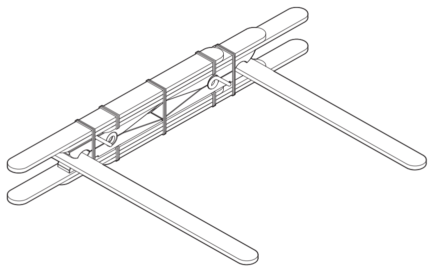
B

Next using the lollipop stick structures and two pegs, secure the pegs between the two structures using elastic bands. You can use white tac in addition here for added stability.



C

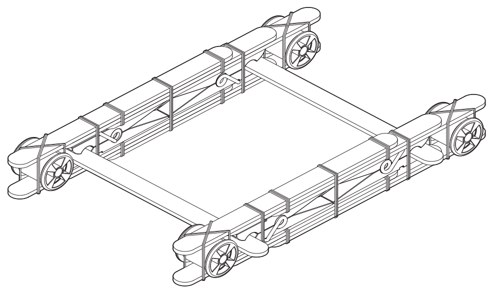
Take an additional lollipop stick and secure this between each peg.



D

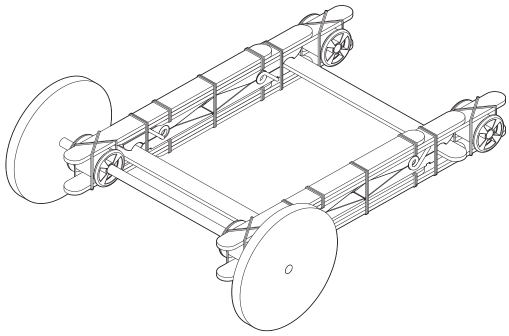
Take two cotton reels and secure them in place as shown below, using white tac and elastic bands.

Repeat steps **A** and **B** and secure the two structures together with the lollipop sticks added in step **C**.



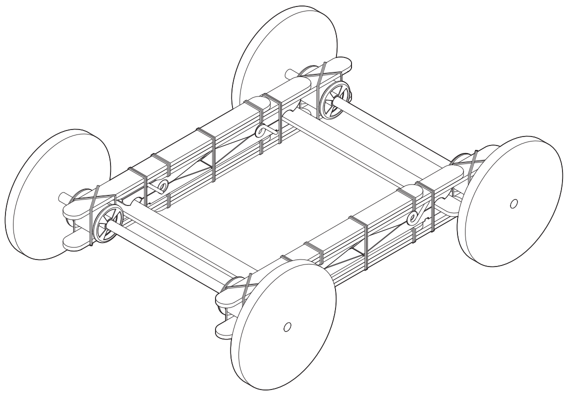
E

Next insert a wooden dowel through the cotton reel on both structures, so they are now connected. Attach a wheel to each end of the dowel, and secure with white tac or tape if the wheel isn't secure.



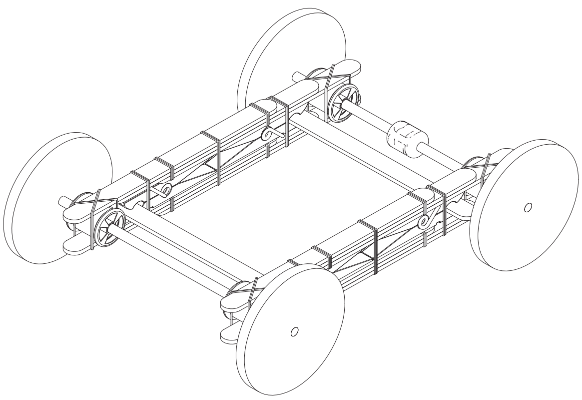
F

Repeat this with the other end so you have something that matches the image below.



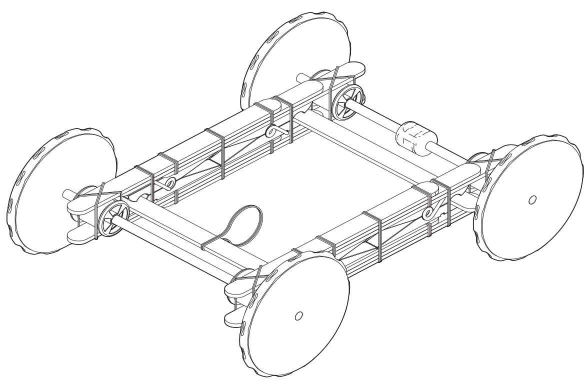
G

Take some white tac and attach this to the middle of the dowel at the rear of your Lunar Rover. You can choose which end you would like to be the front and back, but make sure it's central.



H

Tie an elastic band to the front dowel of your Lunar Rover, making sure it lines up with the white tac on the rear of the rover. To add friction you can add white tac to the rims of the wheels. Now you're ready to get going!



LUNAR ROVER

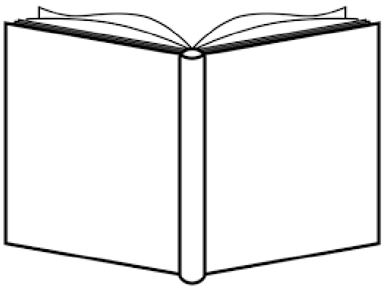
10-15m

MASS FORCE AND TORQUE

KS1/2 PROOF OF CONCEPT

Imagine there's a feather on the table in front of you, and you're trying to push it across the table with just one finger. Should be pretty easy, right?

Now imagine it's a book that you're trying to push across the table. That's going to be much harder! This is because the book is heavier than the feather, and the heavier an object is, the more force (or harder push) is required to move it.



How might this help explain why some of the Lunar Rovers are moving faster and easier than others?

KS3/4 DEEPER LEARNING

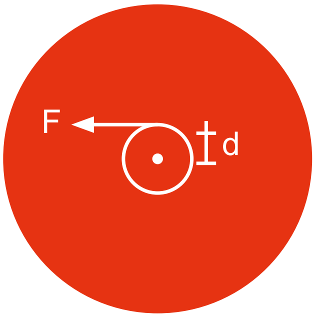
The force required to move different objects can be further explained using Newton's Second Law, of Motion which shows that the greater the mass, the more force that's required to reach a given amount of acceleration.

$F = ma$ where F is the Force, m is the mass, and a is the acceleration.

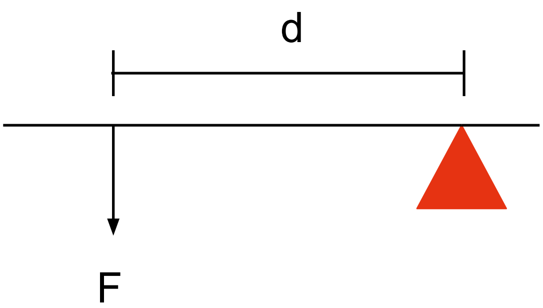
So for a given acceleration $F \propto m$ ...Force is directly proportional to mass.

Another thing to consider is **torque**, which is a measure of the turning force on an object.

$\tau = Fd$ τ is the Torque, F is the force acting on the axle and d is the distance



The wheels of the Lunar Rover are subject to torque. If the torque is too high, and there isn't enough weight on the car to balance it, you might find that your car flips over instead of remaining stable. Where might be the best place to add mass in order to counteract this torque? For this you'll want to consider **moments**, which are similar to torque, but don't act on a rotating object.



$M = Fd$ M is the moment, F is the force and d is the distance between the force and a pivot point.

You can counteract excess torque by producing a given moment. In this diagram, imagine the fulcrum, or pivot point, is your wheel axle. If you add weight, or increase the distance between the weight and the fulcrum, then you will increase the moment.

How could you reduce the mass of your Lunar Rover, whilst still counteracting the high torque required to make your vehicle move faster?

QUIZ

10-15m

What is force?

....

....

Is more or less force required to move a heavier object?

....

....

What is Newton's Second Law?

....

....

What is friction?

....

....

How could you increase friction between your Lunar Rover and the surface it is racing on?

....

....

QUIZ

What is torque?

....

....

What could happen if you generate too much torque on your driving axle?

....

....

How could you counteract excess torque?

....

....

What is energy conversion and why is it an important factor in your Lunar Rover designs?

....

....

What is the difference between precision and accuracy?

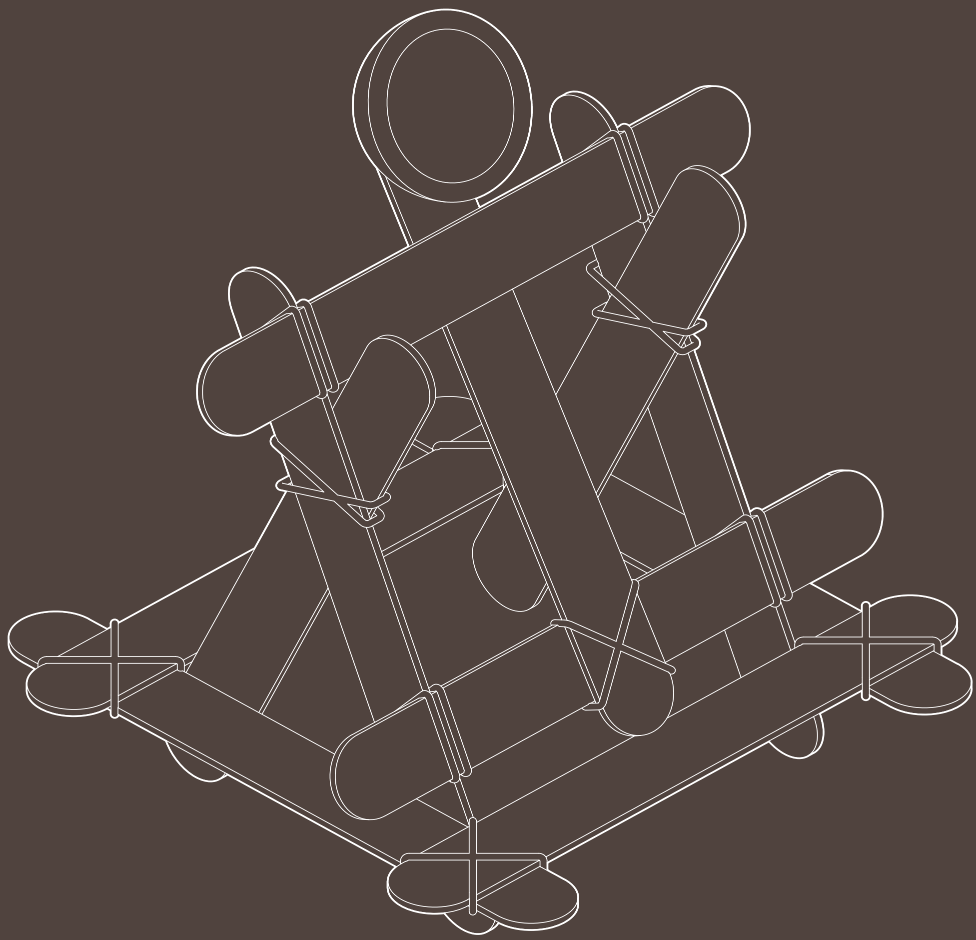
....

....

CHALLENGE 3

CATAPULT

In this challenge, teams will work together to create a catapult powered only by elastic bands.



TEACHING NOTES

SUMMARY

The Catapult session challenges students to design and build a catapult, which uses a lever and fulcrum to launch a pom-pom or ping-pong ball across the room.

Students will work in teams using lollipop sticks, elastic bands, pegs, bulldog clips and white tac to create their own medieval catapults, which will be put to the test in a final showdown.

The students will learn about force, accuracy, precision and angles. The catapults will be assessed by both accuracy and distance, with a winner for each category.

LESSON PLAN

ACTIVITY	DESCRIPTION	TIMING
Introduction	Introduce the goal of the session and hand out the student resource sheet. Divide students into teams of 4 students, providing a set of materials to each.	5-10m
Warm-up Activity A	Introduce the catapult energy exercise and ensure students have the required materials to complete it.	5-10m
Warm-up Activity B	Introduce the catapult vocabulary exercise and ensure students have the required materials to complete it. Provide feedback to the students after the activity.	10-15m
Main Challenge	Explain to students that their catapult must be stable enough to fire at least six projectiles; three will be measured on accuracy and three on distance.	30-40m
Measuring Up	When the teams are finished building, they need to test their catapult's capabilities. Accuracy and distance are the two key measurements.	10-15m
Extension Activities	If any of your teams finish their build early, get them to try one of the extension activities.	5-15m
Extra Content	Additional educational content for those with enquiring minds.	10-15m
Quiz	Ask your students to complete this quick quiz to test their knowledge.	10-15m
Wrapping Up	Cover the discussion points with the students to close the session.	10-15m

LEARNING OUTCOMES

Students will learn:

- How force affects the motion of a projectile
- Optimum angles for launching a projectile the farthest
- The importance of accuracy and precision in the design phase
- The effects of potential and kinetic energy on the final design

CURRICULUM

KS1 Design and Technology

- Design purposeful, functional, appealing products for themselves and other users based on design criteria
- Evaluate their ideas and products against design criteria
- Build structures, exploring how they can be made stronger, stiffer and more stable
- Explore and use mechanisms [for example, levers, sliders, wheels and axles], in their products

KS2 Design and Technology

- Use research and develop design criteria to inform the design of innovative, functional, appealing products that are fit for purpose, aimed at particular individuals or groups
- Understand how key events and individuals in design and technology have helped shape the world
- Apply their understanding of how to strengthen, stiffen and reinforce more complex structures
- Understand and use mechanical systems in their products (for example, gears, pulleys, cams, levers and linkages)
- Evaluate their ideas and products against their own design criteria and consider the views of others to improve their work

TOP TIP

Set up a designated testing zone for students with enough room for at least two teams to test at a time.

You can also give each team an allotted time to test their catapults.

DOWNLOAD

Download and print student worksheets from imeche.org/stemtoolkit

WRAPPING UP

MEASURING UP

10-15m

In this challenge there will be two winning titles to work towards: The team who manage to launch their projectile the farthest and the team with the most accurate landing. To test the catapults, pull back on the pivot arm, load the basket with the projectile and release. It may be possible for one team to win both titles with an inventive and well-built design.

You have the option of using pom-poms or ping-pong balls as your projectiles. Experiment which would be better for distance and which, for accuracy?

EXTENSION ACTIVITIES

There are plenty of extra considerations that engineers need to take into account when designing a catapult. Here are a couple of ideas for extension activities if a team finishes early:

A

10-15m

Ask students to alter their design to increase the amount of kinetic energy released.

B

5-10m

Ask the students to make a target from a piece of paper and practice trying to aim for it in preparation for the measuring up process.

DISCUSSION POINTS

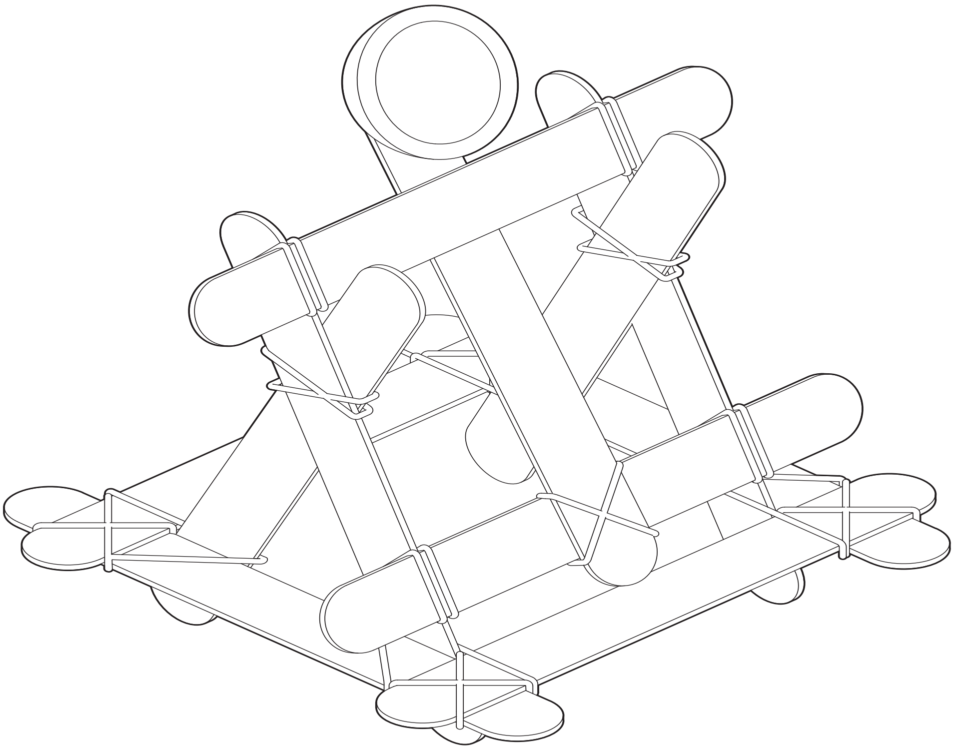
10-15m

To close the session, hold a class discussion and cover the following points:

- Did the teams succeed in creating a stable catapult that was able to launch a projectile?
- If not, why did it fail?
- Was each team's catapult accurate and how far did their projectiles go?
- What do the students like about designs from other teams?
- Do the teams think it would have been easier to work alone? Why?
- What would the teams change if they were to attempt the task again?
- What additional materials would the teams need to improve their design?

REMEMBER

Provide a recap or short summary to the class highlighting the key engineering skills and what has been learnt during this activity.



CATAPULT WORKSHEET

GETTING STARTED

5-10m

Have you ever thrown a ball and wondered how to make it go further?

Now it's time to put your skills to the test; with this catapult build you get to design and prototype your very own catapult using your engineering skills.

By the end of this session you will have considered some key principles related to projectiles and built a catapult that puts these concepts into practice.

VOCABULARY

Basket - The part of the catapult where the ball (or load) rests.

Pivot Arm - Part of the catapult that moves the load/ball forward. This is also known as a lever.

Fulcrum - The point about which the pivot arm moves.

Stop Block - The part of the catapult that stops the arm after it launches.

Base - The part of the catapult that supports the catapult.

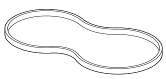
Potential Energy - Energy that is stored in an object either by lifting it up or, if the object is elastic, due to it being stretched or compressed.

Ballista - Missile weapon that launches large projectiles, similar to the crossbow.

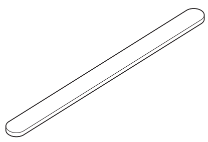
Mangonel/Catapult - This is the most iconic catapult type, with bucket to hold the missile/load.

Trebuchet - Designed for maximum power and distance, and utilises a fulcrum and counterbalance.

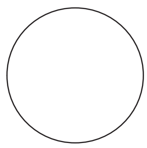
EACH TEAM WILL NEED



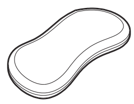
Elastic Band
20



Lollipop Stick
10



Pom-Pom or Ping-Pong
Ball
1



White Tac

WARM-UP ACTIVITIES

A

5-10m

Using an elastic band to help you, answer the following questions:

- What happens when you stretch the rubber band? Is this potential or kinetic energy?
- What happens when you release the rubber band? Is this potential or kinetic energy?
- What other objects have potential and kinetic energy?

B

10-15m

Describe the functions of these catapult components, the ambassador will provide answers at the end of the activity.

- Basket
- Pivot arm (lever)
- Fulcrum
- Base
- Potential energy
- Bonus Question: How is potential energy being stored?

MAIN CHALLENGE

30-40m

As a team, you are going to work together to build structurally stable catapults.

Using the materials and instructions provided, you should build a catapult that is stable enough to launch six projectiles. The success of this will be measured in two categories: accuracy and distance.

After completing the instructions, you can try to alter your design to increase accuracy and distance.

Once completed and tested, there will be a class discussion about your findings.

DID YOU KNOW?

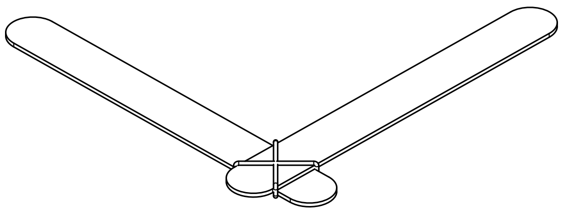
Catapults were originally designed and used as weapons during battles. Today they are used for a variety of different reasons ranging from toys, to launching jets from aircraft carriers that have limited runway space.

BUILDING THE CATAPULT

A

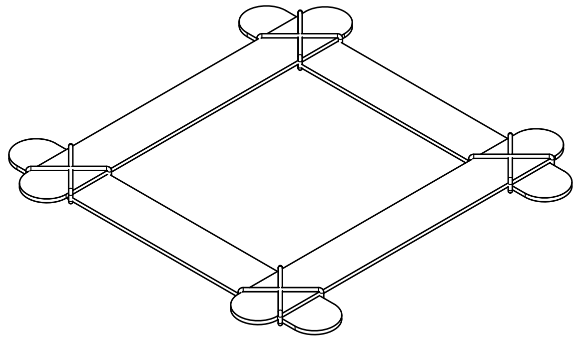
Connect two lollipop sticks to form a right angle. The sticks can be held in place by using an elastic band.

It may be necessary to wrap the band around the joint several times if the joint isn't secure enough. You can also add extra elastic bands if one isn't creating enough stability.



B

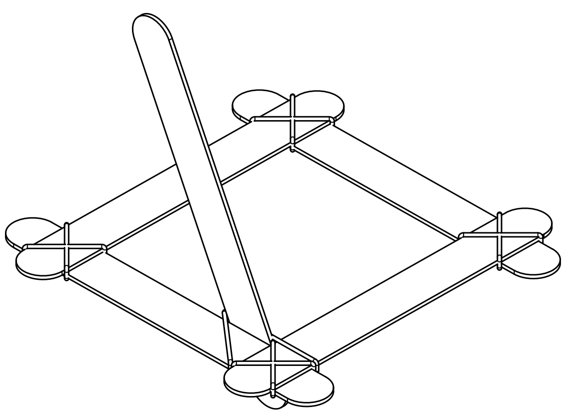
Repeat step **A** until four lollipop sticks have been connected to form a square structure. This will form the base of your catapult.



C

Join a lollipop stick to the inside of your base using an elastic band so that it is vertical, or perpendicular to the base.

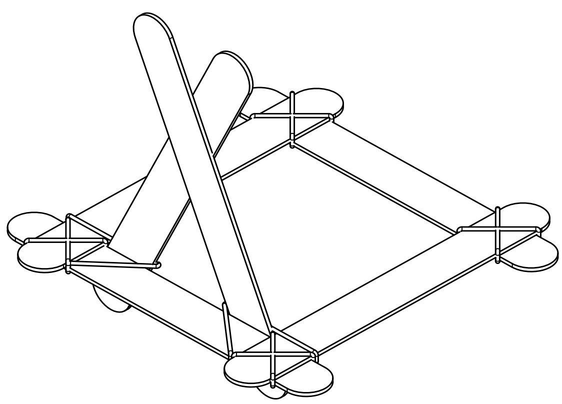
Again, you may need to wrap the band around the joint several times if the joint is not secure enough.



D

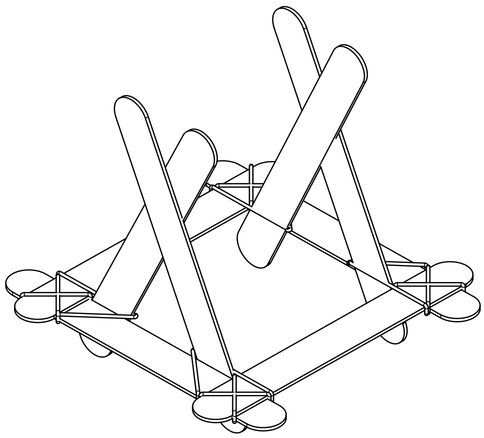
Repeat step **C**, joining another lollipop stick vertically to the base so that it is in line with the one that was fixed in place in step C.

These two uprights should be able to cross over each other to make an A-frame, as shown below.



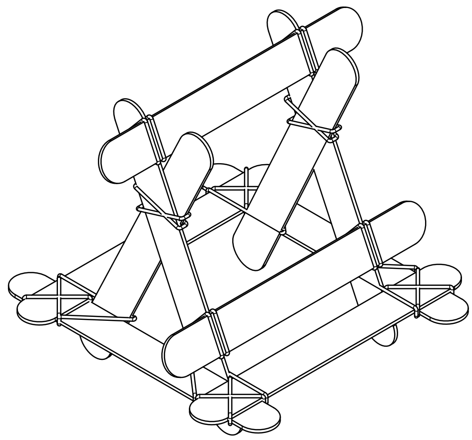
E

Repeat steps **C** and **D** for the other side and fix each side in the A-frame shape using an elastic band as shown below. The location at which you choose to cross the lollipop sticks will dictate the angle the projectile is released from the basket.



F

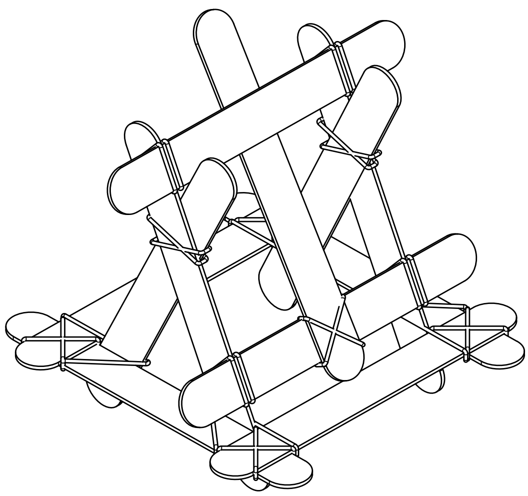
Pick which side will be the front of your catapult and, using elastic bands, fix two lollipop sticks horizontally to the front edges of the two swept back angled lollipop sticks. One lollipop stick should be joined near the bottom, close to the base and one should be added at the top, above the point where the sticks cross.



G

Thread a final lollipop stick vertically between the two sticks added in step **F** as shown below. The bottom should be in front of the lower horizontal lollipop stick and the top should be behind the upper horizontal lollipop stick.

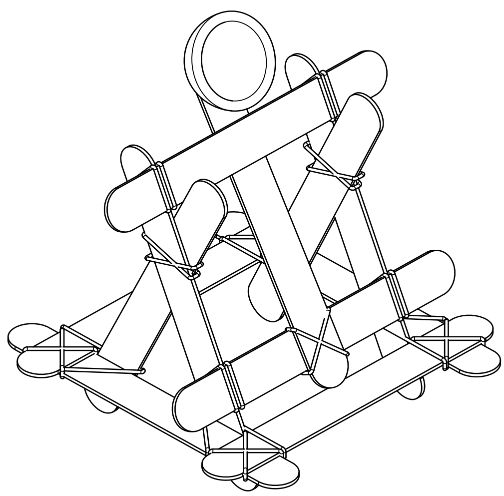
Try to position it centrally and fix the bottom of the stick to the lower horizontal lollipop stick using an elastic band. This will be your catapult's fulcrum.



H

Use your hands to form a basket out of white tac that is large enough to hold the projectile. Stick it to the very top of the vertical lollipop stick added in step **G** to complete your catapult.

When firing your projectile, be sure not to stick it to your basket, but to balance it. This will allow you to launch your projectile successfully.



CATAPULT

10-15m

ELASTIC POTENTIAL ENERGY

KS1/2 PROOF OF CONCEPT

Thinking back to your testing, did you notice any of your bands snapping? If you did, that is because there is a limit to how much you can stretch an elastic band. If you stretch it too far, your band will snap or stretch permanently, leaving you with a catapult that just won't work.

By adding more elastic bands, you can strengthen your catapult's stability and power. The more elastic bands you use, the more elastic potential energy is stored when you pull back the catapult's arm, which results in a higher force pushing your projectile away. Simply put, if you want your catapult to be more powerful - try putting more bands on!

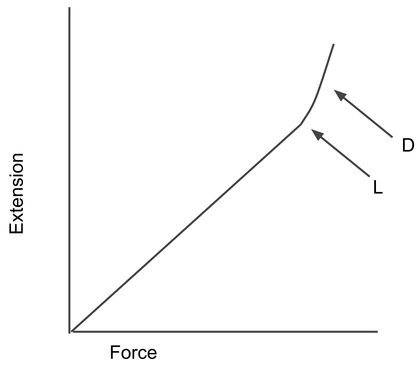
KS3/4 DEEPER LEARNING

To explain this, we will take a look at an equation commonly referred to as Hooke's Law.

$F = ke$ *Where F is the force, k is the spring constant and e is the extension.*

The spring constant is dependent on the spring/ elastic object that you use. The stiffer the spring, the higher the spring constant, so when you add more elastic bands, the spring constant increases. This results in needing a higher force in order to extend it by the same amount.

This equation also tells you that when you extend a spring, or elastic band, the amount of force required is proportional to the distance that you are stretching it, so the further you stretch the band, the more force you need to apply.



Take a look at the graph above, which illustrates Hooke's Law. If you stretch an elastic band beyond a certain point, the relationship in Hooke's Law is no longer observed. This point is labelled L on the graph, and is called the Limit of Proportionality.

Past this point, there is a sharp increase in extension compared to the force applied. When the band then reaches point 'D' - the elastic limit - the band will no longer return to its original length and will be permanently deformed. (You may see this happen where white patches occur on the band).

How could this help develop your Catapult designs?

QUIZ

10-15m

What function does the pivot arm have?

....

....

What happens when you add more elastic bands to the catapult?

....

....

What was the catapult's original purpose?

....

....

What is a projectile?

....

....

What is potential energy?

....

....

QUIZ

10-15m

At what point is the potential energy transformed into kinetic energy?

....

....

What two things dictate how much force is exerted by the bands?

....

....

What does it mean when white patches appear on your elastic band?

....

....

What is a fulcrum?

....

....

What were catapults originally designed for?

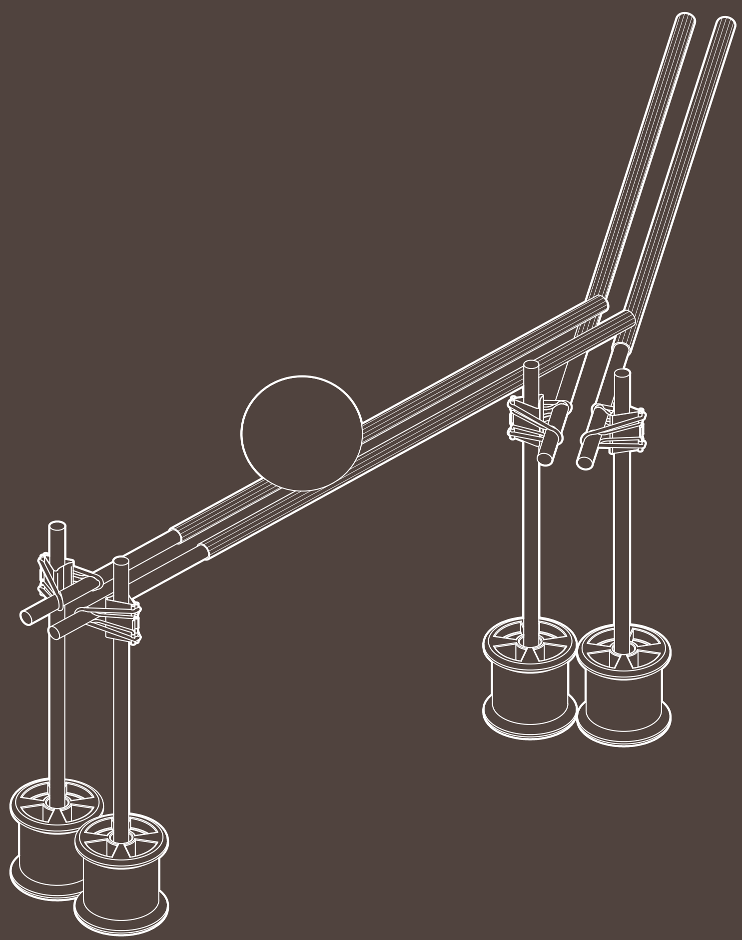
....

....

CHALLENGE 4

BALL RUN

In this challenge, teams will work together to create a track for a ping-pong ball to roll along.



TEACHING NOTES

SUMMARY

This resource provides you with everything you need to successfully run a ball run workshop with your students.

The ball run activity places focus on the “make, try and refine” segments of the innovation process. By viewing their ball runs as a prototype, students will be able to spend time refining and changing their creations.

Using simple crafting materials, students will be required to design and build their very own ball run that will need to keep the ball off the floor for the longest time, whilst constantly staying in motion.

This may seem like an easy ask, but this make will require creativity, teamwork and most importantly perseverance!

LESSON PLAN

ACTIVITY	DESCRIPTION	TIMING
Introduction	Introduce the goal of the session and hand out the student resource sheet. Divide students into teams of 4 students, providing a set of materials to each.	5-10m
Warm-up Activity A	Introduce the movement mechanisms exercise and ensure students have the required materials to complete it.	10-15m
Main Challenge	Explain to the students that their structures must ensure that the ball will remain off the ground for as long as possible, whilst in constant motion.	30-40m
Measuring Up	When the teams have finished building, they will need to test their ball run. The aim is for the ball to be moving on the track for the longest amount of time.	10-15m
Extension Activities	If any of your teams finish their build early, have them try one of the extension activities.	10-20m
Extra Content	Additional educational content for those with enquiring minds.	10-15m
Quiz	Ask your students to complete this quick quiz to test their knowledge.	10-15m
Wrapping Up	Cover the discussion points with the students to close the session.	10-15m

LEARNING OUTCOMES

Students will learn:

- To observe, discuss, compare and contrast results
- To make predictions and hypothesise
- How to make changes to an experiment in order to achieve desired results
- How to work through adversity to help build and achieve a problem solving mindset
- The varied properties of materials and their impact on forces and motion

CURRICULUM

KS1 Design and Technology

- Design purposeful, functional, appealing products for themselves and other users based on design criteria
- Evaluate their ideas and products against design criteria
- Build structures, exploring how they can be made stronger, stiffer and more stable

KS2 Design and Technology

- Use research and develop design criteria to inform the design of innovative, functional, appealing products that are fit for purpose, aimed at particular individuals or groups
- Apply their understanding of how to strengthen, stiffen and reinforce more complex structures
- Evaluate their ideas and products against their own design criteria and consider the views of others to improve their work

TOP TIP

Ensure each team has enough room to work, without the risk of disrupting other teams. They'll need plenty of space to test their run throughout the building process.

Help teams who are having difficulty by working with them to brainstorm solutions. Encourage them to come up with the answer as a team.

DOWNLOAD

Download and print student worksheets from imeche.org/stemtoolkit

WRAPPING UP

MEASURING UP

10-15m

The winning team will be the team who manage to keep their ball moving throughout their ball run for the longest time. This should be measured using a stopwatch by a designated time keeper. If the ball becomes stationary or falls from the run, the timer is stopped.

EXTENSION ACTIVITIES

Engineers are constantly editing and testing their designs to ensure that their structures do exactly what they want it to do. If a team has successfully built and tested their ball run, ask them to try the following:

A

10-15m

Do you like the look of a different team's ball run? Pair up with them and try to combine the two runs to extend the amount of time that your ball stays off the ground.

B

15-20m

Using your materials, design a run that mimics a ski jump. The challenge is to launch the ball off the end of the jump and catch it in a container.

DISCUSSION POINTS

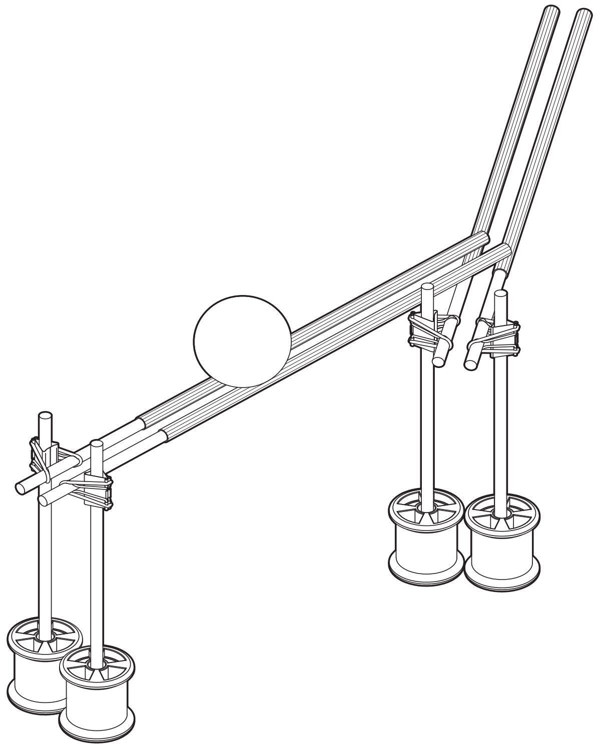
10-15m

To close the session, hold a class discussion and cover the following points:

- What did teams find the most challenging throughout the design process?
- Did the teams find testing to be important during the design phase?
- If the teams had more materials, what would they do differently?
- What structures worked best for rolling their ball slowly?
- If teams were to build this full scale, what materials would they use and why?

REMEMBER

Provide a recap or short summary to the class highlighting the key engineering skills and what has been learnt during this activity.



BALL RUN WORKSHEET

GETTING STARTED

5-10m

The ball run is an intricate STEM build that teaches you planning, construction, teamwork and most importantly how to persevere when faced with not succeeding during your first attempt.

Perseverance and planning are key when completing this activity. Don't forget to test your materials before you start your design phase.

Be sure to share your ideas with your team members, as collaboration is an important part of being an engineer.

VOCABULARY

Acceleration - The rate of increase in speed or velocity.

Prediction - Declaration of what will happen based on reason and knowledge.

Impediment - A hindrance or obstruction. Something that makes things more difficult.

Slope - An incline or slant, such as a hill or ramp.

Force - A push or pull that acts on an object.

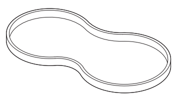
Gravitational Potential Energy - The energy stored in an object when it is elevated. This energy is converted to kinetic energy when the object falls back down.

Kinetic Energy - The energy of motion.

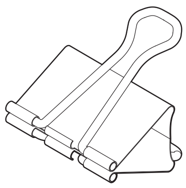
Momentum - The force or speed of an object in motion.

Friction - The resistance that one surface or object encounters when moving over another.

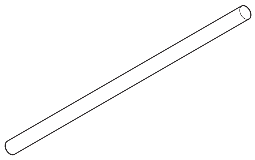
EACH TEAM WILL NEED



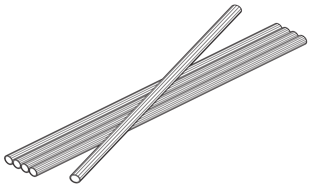
Elastic Band
20



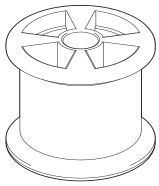
Bulldog Clip
16



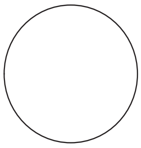
Wooden Dowel
14



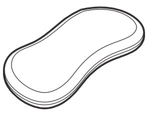
Paper Straw
10



Cotton Reels
6



Ping-Pong Ball
1



White Tac

WARM-UP ACTIVITY

A

10-15m

Everybody is in a rush to get from A to B. Moving things as efficiently as possible has been a challenge that engineers have been trying to solve for thousands of years. Their creativity and perseverance has allowed cities to thrive and has even put humans on the moon!

Consider and discuss the following:

- What systems have been created throughout history to help move things along a specific course? (Aqueduct, power lines, underground etc.).
- Where does the water in your home come from?
- Where does the water in your home go?
- What problems could arise with this system?

Thinking about the mechanisms that allow water to run through pipes will help you design and prototype your ball run.

Experiment with the different materials provided; think about how different shapes and structures will have an impact on the forces applied to the ball and how this will affect your final result.

MAIN CHALLENGE

30-40m

As a group, you're going to design and build your very own ball run.

Firstly, you'll need to discuss and design your ball run before you start your construction. Don't be surprised if you have to redesign sections of your build part way through, this is all part of the engineer's design process, to test prototypes and find the best design.

Using the materials provided, your design must ensure that the ball remains on the run for as long as possible without the ball stopping.

Once completed and tested, there will be a class discussion about your findings.

DID YOU KNOW?

The oldest roller coasters are thought to have originated from Russia in the 17th Century and were built of ice!

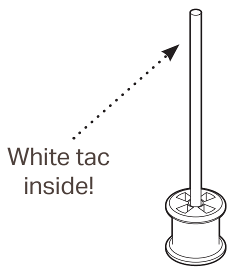
Wood was used up until the 1950's to create these adrenaline rides and it wasn't until 1959 that Disneyland introduced the first steel roller coaster.

BUILDING THE BALL RUN

The ball run itself will be designed by you to meet the criteria of the task. Here are a few tips and tricks that can help get you started with your design!

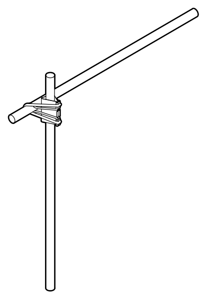
A

Form a stand by sticking a wooden dowel to a cotton real. It may be necessary to pad the cotton reel with a small piece of white tac to gain a good grip. Think carefully about the height that you want the dowel to be!



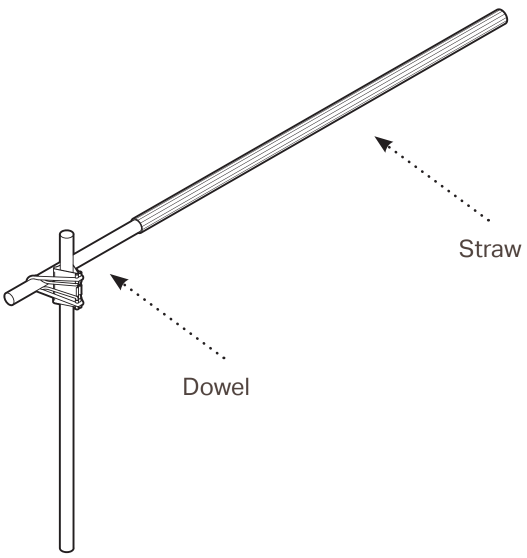
B

Thread a dowel through the openings in the clasps of the bulldog clip and hold in place using an elastic band. Wrap the band around the joint several times to ensure that it is secure.



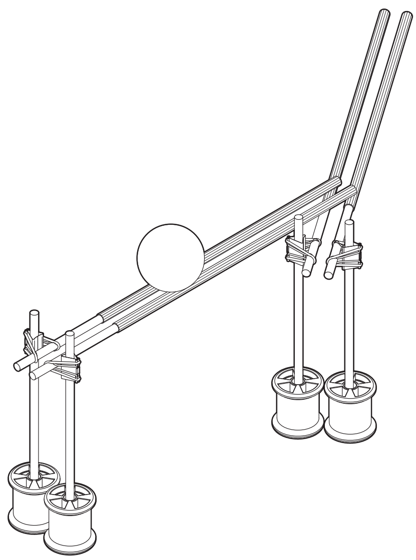
C

Add length to your run by attaching a straw to the end of the dowel.



D

Create several stands with rails and once you have as many as you want, secure the stands vertically to a flat surface using white tac. An example ball run is shown below. Perhaps you could use cotton reels to add stability to the base of your run. Get ready to roll!



BALL RUN

10-15m

GRAVITY

KS1/2 PROOF OF CONCEPT

Think back to when you have ridden a bike. What happens when you ride your bike down a hill compared to when you are riding along flat land? You go faster!

That is because gravity is pulling you down the hill. If you are on a flat surface, there is nowhere for gravity to pull you, so you stay still (unless you are pedalling - but that's a different kind of force!).

Think about your ball run, what changes could you make to make certain parts of your ball run more effective?

KS3/4 DEEPER LEARNING

NEWTON'S FIRST LAW

An object will remain at rest (or in a state of constant motion) unless acted upon by an external force. What would the external force be for a ball on a slope that results in the ball rolling downhill? Gravity! Gravity is pulling the ball downwards.

NEWTON'S SECOND LAW

This describes the relationship between force, mass and acceleration as F = ma. The mass of an object is constant wherever it is in the universe, whereas weight is the force acting on that mass due to gravity.

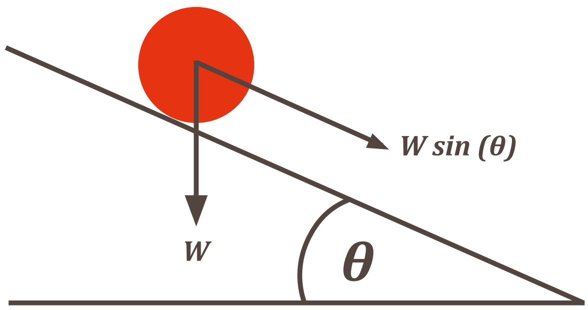
The rate of acceleration due to earth's gravity can be taken as a constant g = 9.8 m/s^2 .
So if we apply the F = ma to look at the force on the ball due to gravity, we have:

$W = mg$ Weight W = mass m x acceleration due to gravity g

NEWTON'S THIRD LAW

Whenever two objects interact, they exert equal and opposite forces on each other.
When a ball is at rest on a table the force of gravity is being cancelled out by an equal and opposite force from the table. However, on a **slope** the force from the surface is acting on the ball at an angle.

We know that the force directly downwards due to gravity is weight, and if we know the angle of the slope we can use trigonometry to calculate what the resultant force in the direction of the slope will be.



Downhill force = sine of 'angle of the slope' (or $W \sin \theta$)

So while the force of gravity on the ball is constant, the maths shows us that the steeper the hill, the greater the force acting in the direction of the slope. This means, as you might expect, the steeper the slope the greater the acceleration.

What does this mean for the design of your marble run?

QUIZ

10-15m

What do you call energy stored in an object called?

....

....

What does every engineer do before starting construction?

....

....

What is friction?

....

....

Why is friction important to consider when designing your ball run?

....

....

Name the force acting on the ball.

....

....

QUIZ

What is an impediment?

....

....

What were the world's oldest roller coasters made out of?

....

....

What happens if you increase the slope angle?

....

....

Where was the first steel roller coaster introduced?

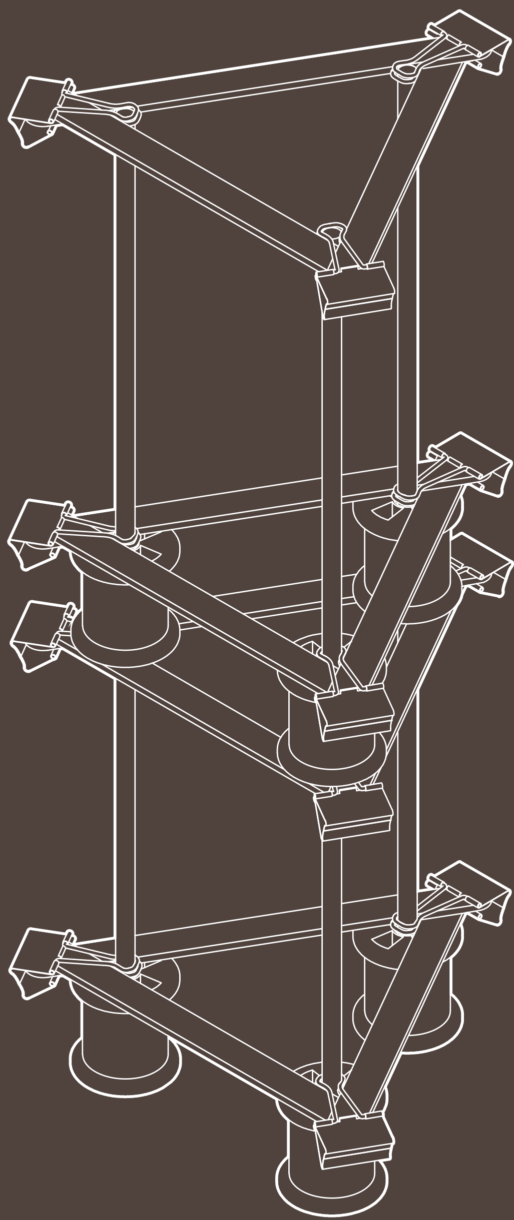
....

....

CHALLENGE 5

TOWER

In this challenge, teams will work together to build the tallest load bearing tower they can using only simple, everyday materials.



TEACHING NOTES

SUMMARY

This hands-on session challenges students to design, build and produce a free-standing tower structure that is stable enough to support a weight for 10 seconds.

Following the engineering design cycle, students will work in teams using limited supplies including lollipop sticks, elastic bands, pegs, bulldog clips and white tac, to create their towers.

They will learn about force, accuracy, precision, angles and most importantly balance. The team with the tallest load bearing tower wins!

LESSON PLAN

ACTIVITY	DESCRIPTION	TIMING
Introduction	Introduce the goal of the session and hand out the student resource sheet. Divide students into teams of 4 students, providing a set of materials to each.	5-10m
Warm-up Activity A	Introduce the tower prototyping exercise and ensure students have the required materials to complete it.	10-15m
Main Challenge	Explain to the students that their tower structures must be as tall as they can manage to build them, whilst also **remaining structurally sound. As a class, agree what you will use as a weight to test the towers with. e.g. a roll of tape.**	30-40m
Measuring Up	When the teams are finished building, they need to record their tower's height and test the structural integrity.	10-15m
Extension Activities	If any of your teams finish their build early, have them try one of the extension activities.	10-15m
Extra Content	Additional educational content for those with enquiring minds.	10-15m
Quiz	Ask your students to complete this quick quiz to test their knowledge.	10-15m
Wrapping Up	Cover the discussion points with the students to close the session.	10-15m

LEARNING OUTCOMES

Students will learn:

- Engineering design and redesign
- Teamwork and problem solving
- The basics of structural engineering
- How geometric shapes, lines, weight and patterns impact their final designs
- How to construct a free-standing tower

CURRICULUM

KS1 Design and Technology

- Design purposeful, functional, appealing products for themselves and other users based on design criteria
- Evaluate their ideas and products against design criteria
- Build structures, exploring how they can be made stronger, stiffer and more stable

KS2 Design and Technology

- Use research and develop design criteria to inform the design of innovative, functional, appealing products that are fit for purpose and aimed at particular individuals or groups
- Apply their understanding of how to strengthen, stiffen and reinforce more complex structures
- Evaluate their ideas and products against their own design criteria and consider the views of others to improve their work

TOP TIP

Ensure each team has enough room to work without the risk of disrupting other teams.

DOWNLOAD

Download and print student worksheets from imeche.org/stemtoolkit

WRAPPING UP

MEASURING UP

10-15m

The ultimate winner of this challenge will be the team whose tower stands the tallest and stays upright when a weight is placed on top of it.

Good weights include: books, stones or marbles in a cup.

EXTENSION ACTIVITY

There are plenty of extra considerations that engineers need to take into account when designing tall structures. If a team finishes early, ask them to try the following task:

A

10-15m

Ask students to alter their design to increase its height further. What considerations must be made if the height is increased?

DISCUSSION POINTS

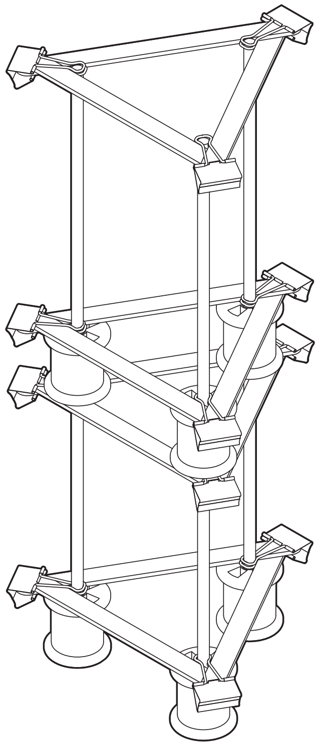
10-15m

To close the session, hold a class discussion and cover the following points:

- How did each team approach the task?
- How much planning did each team do before starting construction?
- Did the teams have to change their original design?
- Which roles did each team member take?
- What worked/didn't work well in each team's design?
- If the teams had to do this again, how would they change their design?

REMEMBER

Provide a recap or short summary to the class highlighting the key engineering skills and what has been learnt during this activity.



TOWER WORKSHEET

GETTING STARTED

5-10m

The tower build is a great way of learning about basic structural techniques in engineering.

You'll have to consider the strengths and weaknesses of the materials you have, before planning, designing and redesigning your structure to ensure your tower is stable.

Be sure to think about the foundations of your tower and how this will impact your final structure.

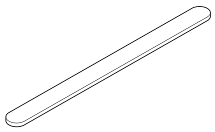
VOCABULARY

Free-standing - A structure that remains upright on its own and is not attached to, or supported by, another structure.

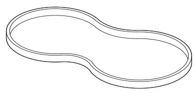
Stability - The ability to remain steady and not move or change under reasonable external force.

Structural - Relating to, or forming part of, the structure of a building or other item.

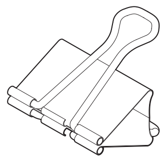
EACH TEAM WILL NEED



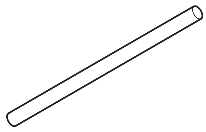
Lollipop Stick
30



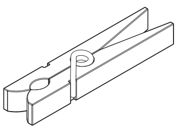
Elastic Band
20



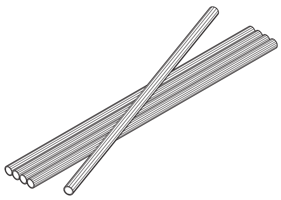
Bulldog Clip
16



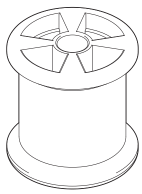
Wooden Dowel
14



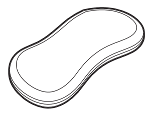
Clothes Peg
10



Paper Straw
10



Cotton Reel
6



White Tac

WARM-UP ACTIVITY

A

10-15m

In teams, experiment with the supplies you have been given to see which combination of shapes and materials provide you with the most stability.

Try to assemble and connect some of these shapes to see which will give your structure the height that you'll need to win the competition. Don't forget to:

- Use your creativity - think of different types of structures that you've seen.
- Be open to suggestions - collaboration is key and can result in different ideas to make the best project.
- Communicate effectively - your ideas might help others think differently.
- Be flexible - remember engineering development is a process. Perseverance, time management, learning from mistakes and previous experiences are all key.

MAIN CHALLENGE

30-40m

As a team, you are going to work together to build a structurally sound tower.

Firstly, you will discuss and design your tower before starting construction, but be open to the idea of redesigning aspects part way through your build. Think about using symmetry in your design as this will reduce weak points.

Using the materials provided, you must build the tallest and most stable structure in the room. The success of this will be judged on the tower's height and ability to hold a fixed weight.

Once completed and tested, there will be a class discussion about your findings.

DID YOU KNOW?

The Burj Khalifa in Dubai currently holds the title of the world's tallest building at over 800 meters tall. By the end of 2021, this is expected to have been overtaken by The Jeddah Tower in Saudi Arabia which, will stand at 1km high!

BUILDING YOUR TOWER

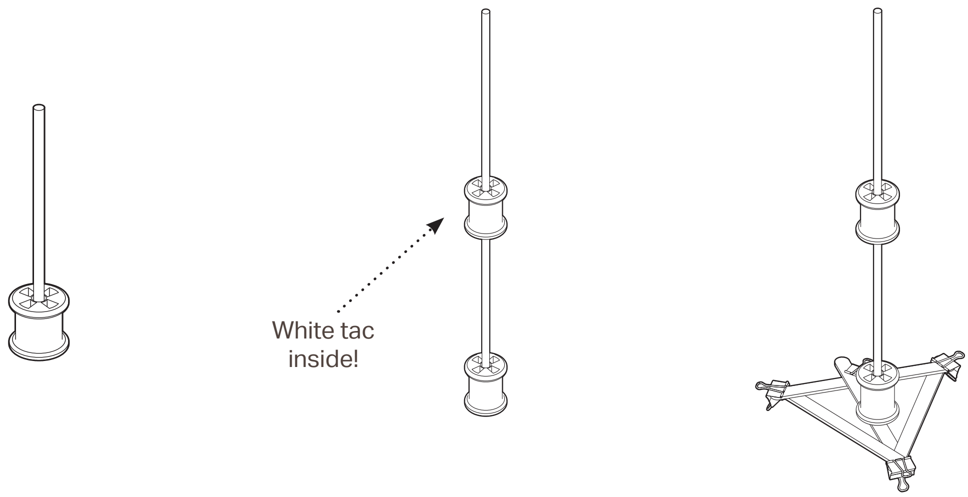
There are many ways to build a tower using the materials provided, but here are a few techniques you could use to get you started. Use your creativity to form innovative, load bearing structures!

TECHNIQUES TO TRY

DOWEL SUPPORT & BASES

Cotton reels act as excellent supports for vertical dowels and straws. These can be stacked several times, with the addition of some white tac, although it's quite likely after reaching a certain height your tower may topple.

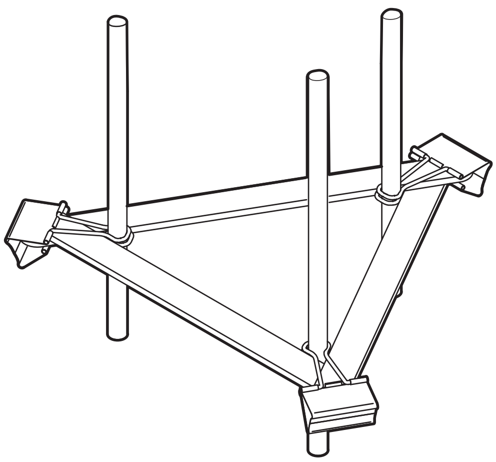
This is due to the centre of gravity acting outside of the footprint of your tower. A simple fix to this is to add a wide base to your tower, which might be attached using white tac, or bulldog clips. When attempting very tall towers, you may need to consider using a wider base as the tower grows!



MULTIPLE STRUTS

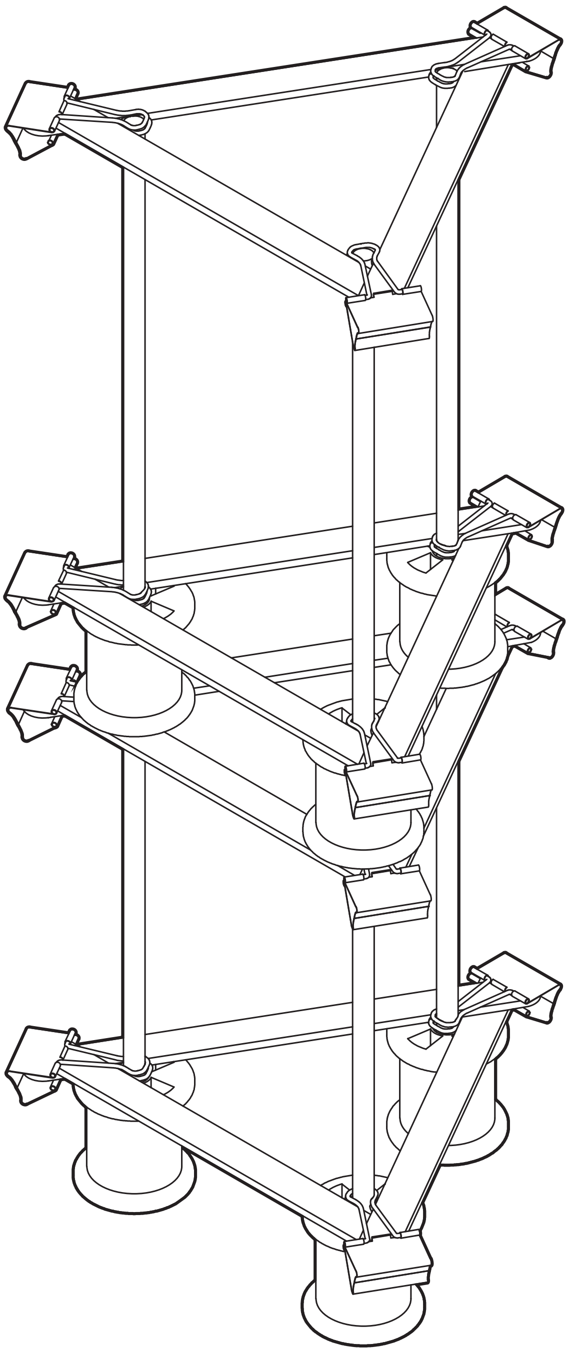
Try using lollipop sticks and bulldog clips as shown to the right to add multiple struts. This technique is great to ensure that your structure keeps its shape. It was used to make the base shown in the right-most image above. You can add white tac or cotton reels at the bottom to add stability.

Remember to make sure that the lollipop sticks overlap each other before you clip them!



EXAMPLE TOWER

We have created a tower using the techniques described. However, there are many approaches you can take, and we encourage you to experiment. It is important to include a platform at the top of the tower to support a load. Now it's your turn!



REMEMBER

Trusses and struts distribute forces throughout a structure. How could they be used to add stability to your load-bearing tower?

TOWER

STABILITY

10-15m

KS1/2 PROOF OF CONCEPT

Try standing up with your legs out wide like a star. Is it easy to balance? Now, compare this to standing on one leg.

Which one did you think was more stable?

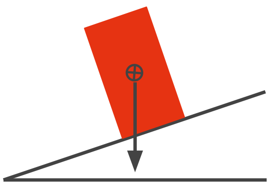
Simply put, when you have a wider base, it is easier to stand because you are more stable.

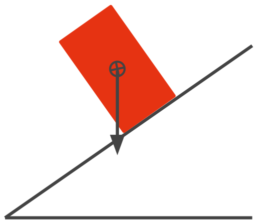
However, when your base is smaller and your top is off-balance, or non-symmetrical, it is harder to balance.

You can apply this knowledge to the towers you built to make your structure more stable.

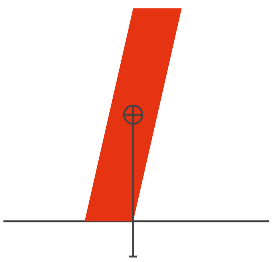
KS3/4 DEEPER LEARNING

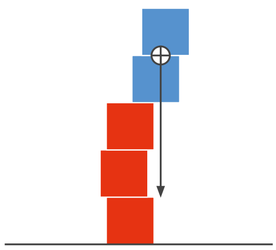
The tipping angle is the point at which a force is sufficient to tip an object over. This is the point at which the force is acting right on the edge - or outside - of the contact area between an object and a plane. This is most clearly understood when looking at objects on inclined planes, but the same principle applies to towers on a flat surface. On the images below, the larger slope on the right would cause the tower to topple over.





The diagram below shows how the weight force could act on the corner or outside of the footprint even if only slightly, ultimately making the tower topple over. This could occur between sections of the tower, causing those blocks to fall off, or for the entire tower to collapse.





QUIZ

10-15m

What does the term "Free-standing" mean in relation to building a tower?

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....

Why are trusses and struts used throughout the design process for a tower?

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What can bracing be used for?

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What does a wider base do for a tower?

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Why is stability important in a tower?

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....

QUIZ

Where does a force have to act to make an object fall over?

....

....

What kind of force is acting on the tower?

....

....

What kind of engineering does tower building come under?

....

....

Which tower is expected to be the tallest in the world by the end of 2021?

....

....

Why is a symmetrical design important when building your tower?

....

....

ABOUT THIS TOOLKIT

BACKGROUND

This toolkit was designed by MakerClub, in collaboration with CREATE Education for the Institution of Mechanical Engineers in order to inspire and educate the next generation of engineers.

Find out more about what each of these organisations is doing to advance the UK education system below:

Institution of MECHANICAL ENGINEERS

With over 120,000 members in 140 countries, the Institution is the largest network of mechanical engineering knowledge, skills and opportunity in the world. We encourage high profile education initiatives which inspire the next generation to consider a career in engineering.

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MAKERCLUB

At MakerClub, we are dedicated to preparing the next generation for the future.

Our class kits and online learning platform teach children programming, computer aided design and invention skills through hands-on project based learning opportunities with real world applications.

Get in touch to see if MakerClub would be a good fit for your school.

makerclub.org

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