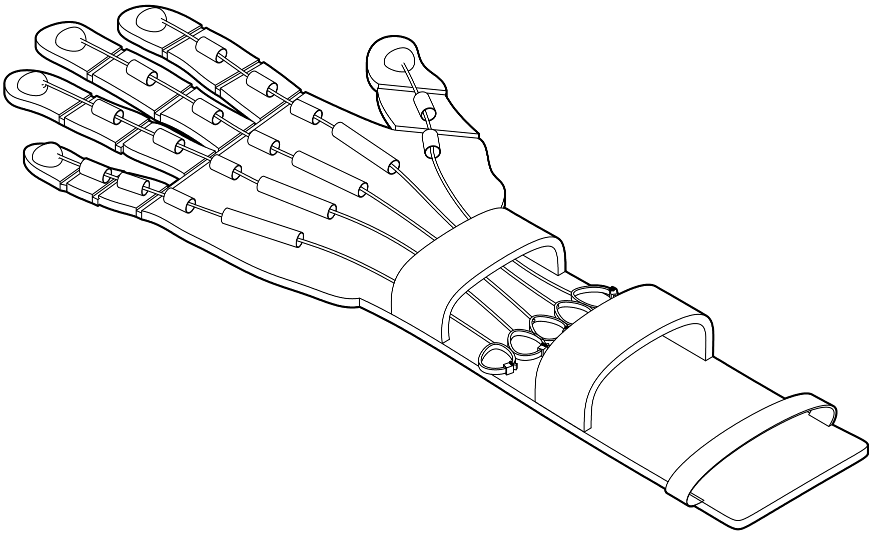


MECHANICAL HAND WORKSHEET

GETTING STARTED

5-10m

The human hand is an amazing, yet complex system of bones, muscles, tendons and joints. Hands allow you to do a wide range of activities from tying your shoelaces to catching a ball without giving it much thought. Designing and building an artificial hand that can do everything a human hand can do, is something engineers have spent years trying to achieve.

The Mechanical Hand build will challenge you to think about some of the factors that these engineers have to consider.

Using everyday materials, such as cardboard, straws and string, you will create a basic working model of a hand that can grip and stack three empty cans.

We encourage you to reuse and recycle materials found around the home to help you complete your build.

VOCABULARY

Biomechanics - the application of mechanical principles to living organisms.

Bioengineering - the use of engineering to tackle challenges in the fields of biology and medicine.

Skeletal Structure - the framework of the body, consisting of bones and other connective tissues.

Tendons - a flexible cord of strong fibrous tissue attaching muscle to a bone.

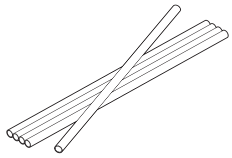
Joint - the area where two bones are attached for the purpose of enabling body parts to move.

Muscles - a band of fibrous tissue that has the ability to contract, producing movement in the body.

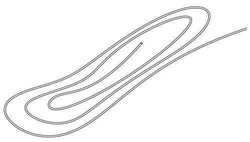
Force - a push or pull that acts on an object.

Tension - a pulling force acting outwards from either end of an object.

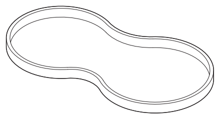
YOU WILL NEED



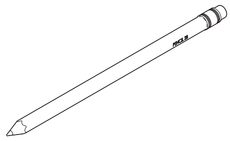
Straws
2



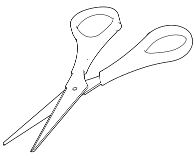
String
150cm



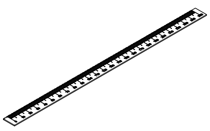
Elastic
25cm



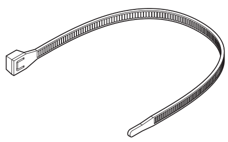
Pencil
1



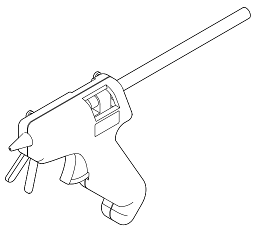
Scissors
1



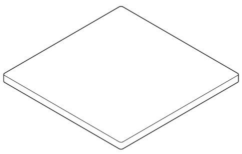
Ruler
1



Zip Tie
5



Glue Gun



Cardboard

WARM-UP ACTIVITIES

A

5-10m

Devices that can reach and grab items have long been used to help people with mobility issues. They have also proven very useful in areas such as hygiene.

Recent global developments have highlighted the importance of hygiene and have led people to consider how best to protect themselves and their loved ones from unnecessary risk.

With this in mind answer the following questions:

1. Which daily tasks could be made safer through the use of a mechanical hand?
2. What would be the best material to use when building the device?
3. Who would benefit from using the device?

B

10-15m

Bones give your body structure and allow you to move, whilst also protecting your internal organs. In this warm-up activity, you are going to focus on the bones in your hand.

Using a pencil and paper, draw an outline of your hand and mark where you think the following parts can be found:

Bones - the skeletal structure.
Muscles - the tissue that has the ability to contract.
Tendons - the tissue attaching muscle to the bone.
Joints - where the skeletal structure fits together.

Think about how many bones might be in each finger, where they connect to each other and how you make them move.

Top Tip - Use the lines on your own fingers to help you with this activity.

MAIN CHALLENGE

30-40m

Working in teams or individually, you are going to build a working mechanical hand.

Before starting construction, make sure you have all the suggested materials needed to complete this activity.

Don't forget that you can substitute any of these materials by repurposing items found at home. For example, we have used an old delivery box for the cardboard.

The mechanical hand needs to be able to grasp and stack three empty cans.

We also recommend that you make the hand slightly larger than your own, so that the structure is easier to work with.

Once you have finished, you can complete a quick quiz to test your knowledge. Good luck!

DID YOU KNOW?

Bioengineers use their knowledge of biology and engineering to design biomedical equipment, including prosthetics, diagnostic machines and even internal organs!
With modern technologies, such as 3D Printing, engineers are able to design and build affordable prosthetics such as hands and legs for people who are missing limbs.
They have even managed to do this for animals as well!

BUILDING THE MECHANICAL HAND

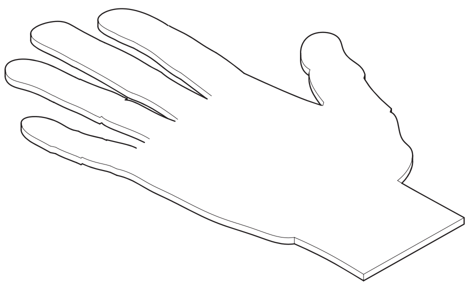
Follow these simple steps to create your mechanical hand:

WARNING - The glue gun is extremley hot, DO NOT touch the nozzle, or leave unattended when in use.

A

Using a pen or pencil, trace the outline of your hand and wrist onto a piece of cardboard. Make sure you slightly exaggerate the size of your hand.

Next, carefully cut out the shape with scissors making sure to cut down each side of the finger. This will enable them to move independently.



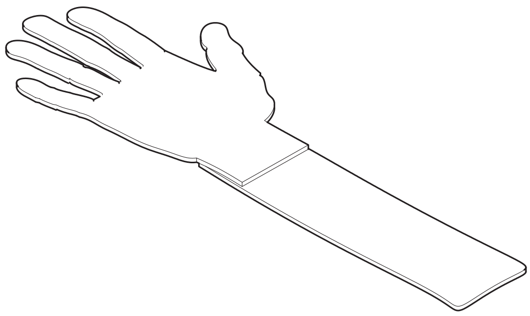
B

Cut another piece of card the length of your wrist to elbow, and glue this to the hand.

WARNING - The glue is extremley hot, be careful not to touch it.

Let the glue dry for 5 minutes.

Top Tip - If you're using thin card, glue two pieces of card together for the arm piece to add stability.

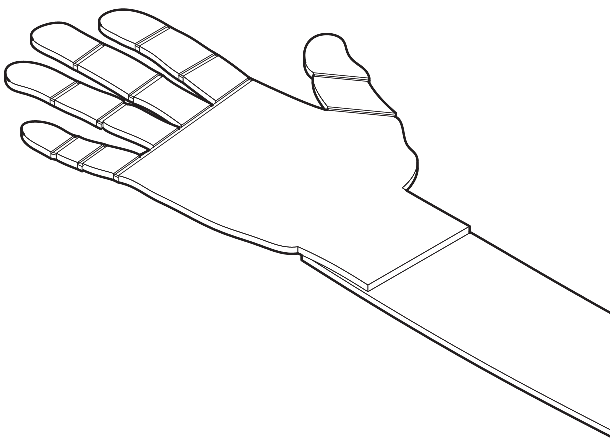


C

Draw lines on the fingers where the joints should be. Use your own hands as a reference.

Using a ruler, push down over the lines and fold the card over the ruler to make harsh straight lines to let the joints flex at the right points.

You should have something that looks like the image below.

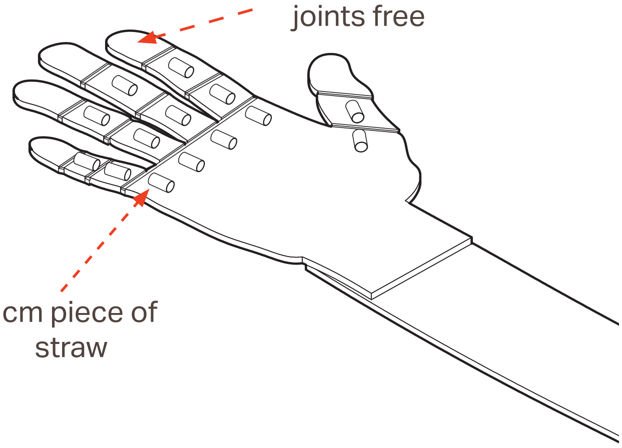


D

Next, cut a 1cm piece of straw and glue this to the lower joint of the small finger. You will need to repeat this another 13 times, to represent where each bone lies. Make sure you leave the top joint of each finger free.

Let the glue dry for 5 minutes.

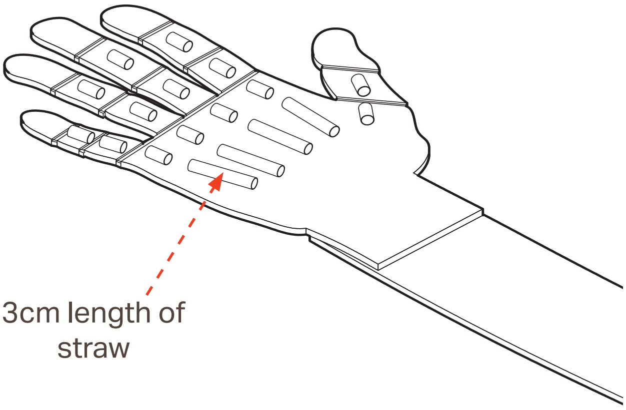
Your build should now look like the image below.



E

Cut another straw into four 3cm lengths and glue them underneath the index, middle, ring and little fingers. Let the glue dry for 5 minutes.

Again, you should now have something that looks like the image below.

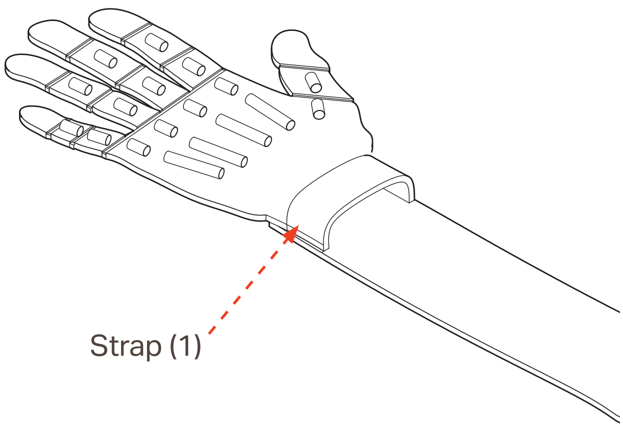


F

In the next two steps, we will cut two strips of 2.5cm wide card, one will act as a guard to help the mechanical hand pick up a can (1) and the other to secure your hand in place (2).

The first one needs to be cut so that it is twice the width of the wrist portion of your model. (Our wrist was 10cm wide, so we have cut a strip that is 2.5cm by 20cm wide).

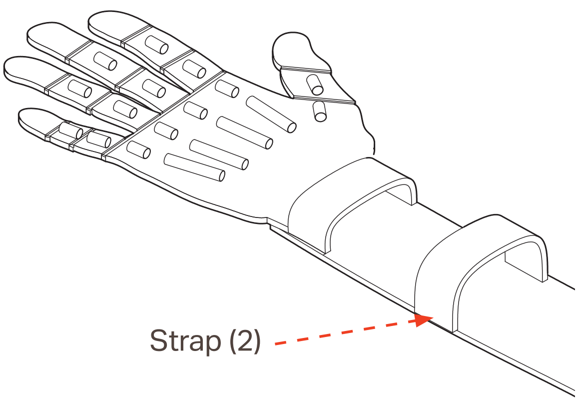
Make a fold 2cm in from each edge and glue these to the underside of the arm in roughly the same position as shown in the diagram below.



G

The second strip (2) will secure the palm of your hand to your model. The length of this strip is approximately the width across your knuckles + 8cm, this should allow for the depth of your hand plus space to attach the card to the underside.

Glue each end to the underside of your model and once the glue has cooled, place your hand through the loop to make sure it fits comfortably.

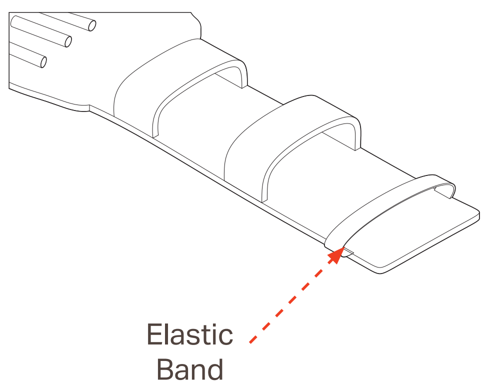


H

Next, using a similar method to the previous step, cut and size your elastic to fit snugly around your forearm and secure it with glue around the bottom of the model.

This will ensure that the mechanical hand is secured onto your arm and won't move around when you're using it.

Take care to let the glue cool before trying it out with your arm!

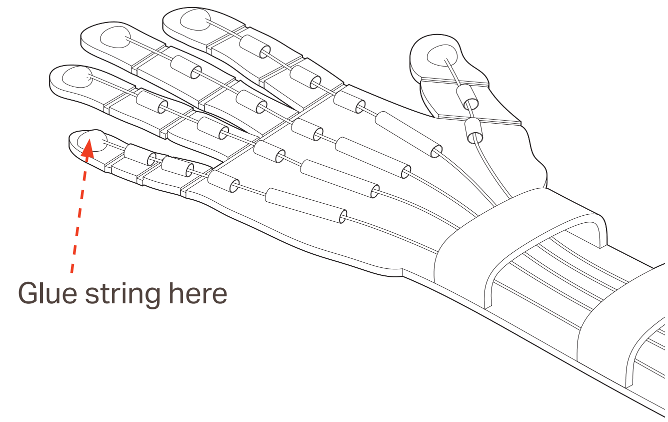


I

Cut five pieces of string, each roughly 30cm in length.

Tie a knot in the top of each piece of string and thread them down through the joints on each finger, leaving the knot at the fingertip.

Secure the knotted end at the top of each finger using a dot of glue.



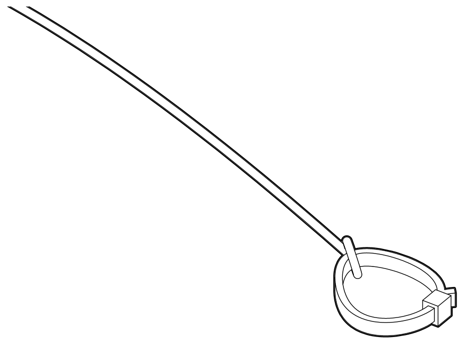
J

Take your zip ties and create 5 loops large enough for your fingers to fit comfortably through. This step can be estimated by eye.

WARNING - DO NOT secure the zip ties around your fingers as they may get stuck.

Tie each zip tie to a piece of string. You will then wear these zip ties like rings around the top joints of your fingers, so make sure that they reach your fingers when they are outstretched.

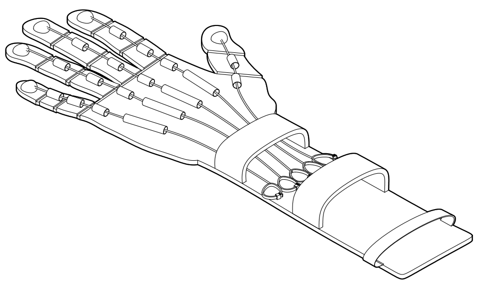
When you are happy with the lengths, cut off any excess string.



K

Finally, place your hand through the elastic band and hold the lower cardboard strap in the palm of your hand, making sure your thumb is on the outside (mimicking your model).

Place the zip ties over each finger and now you're ready to start testing your new hand.

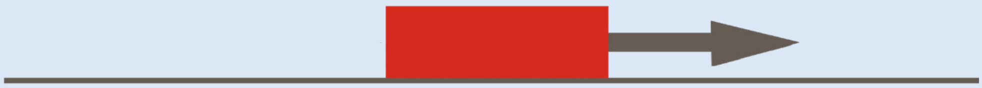


MECHANICAL HAND FORCES

10-15m

KS1/2 PROOF OF CONCEPT

Forces are pushes and pulls in a given direction. We can represent forces with arrows in a force diagram. The direction of the arrow shows the direction of the force and the bigger the arrow, the stronger the force.



If the forces are the same size, but acting in opposite directions, then the forces are balanced. When forces on an object are **balanced**, they will not change its motion. This means, if it is still it will stay still, and if it's already moving it will continue to move unchanged.

When opposing forces acting on an object are not of equal size, they are **unbalanced forces**.

When unbalanced forces act on an object its motion will be changed. It can either start moving or change its speed or direction.

UNBALANCED

BALANCED

When you pull the string on the mechanical hand, you apply a pulling force to the finger. We call this pulling force **tension**. The opposing force that makes the cardboard want to stay straight is much smaller than this tension force, so the forces are unbalanced. This makes the finger move.

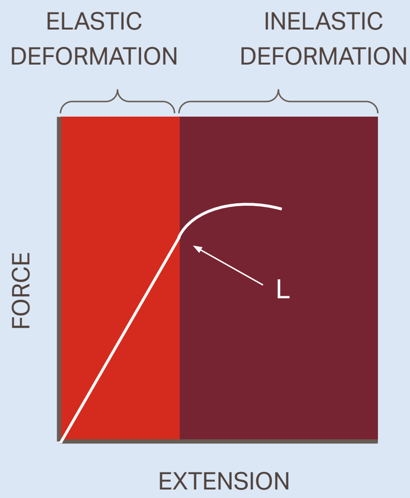
KS3/4 DEEPER LEARNING

When you pull the string on your mechanical hand, this creates tension. Tension is a pulling force acting outwards from either end of an object.

When you increase the tension on the strings in your mechanical hand, the cardboard changes shape. This change is only temporary, as the cardboard roughly returns to its original position once that tension is released. In this case, the cardboard fingers are acting like a spring. Let's have a look at the science behind this and try to figure out if we could make our model more efficient.

Hooke's Law

Using the equation below, Hooke's Law states that as we increase the force on a spring, the extension increases in an equal ratio. We call this relationship directly proportional and is shown by a straight line on a graph.



Take a look at the graph above. As you can see, the larger the force acting on the spring, or elastic object, the larger the extension of that spring or object.

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

The relationship expressed in the equation above, is consistent for the first straight portion of the graph. Here, the material is acting elastically and the object will return to its original point once the force is reduced; we call this region the elastic deformation region. The point at which this changes is defined as point L: this is the Limit of Proportionality.

If we increase the force and extension past this point, however, the material will enter inelastic, or plastic, deformation. This deformation is permanent and no longer follows the equation. In this case, the material will not return to its original shape or length and will eventually break or snap.

Cardboard isn't the most traditional of spring types; what you'll find is that with increased use, the more permanently deformed your mechanical hand will become, which shows that it is regularly operating within the inelastic deformation portion of the Hooke's Law graph.

For our model to be efficient and durable, we want to make sure that we are always operating within the elastic portion of this graph. Otherwise, as the fingers permanently deform, eventually it will be impossible to open up the hand flat again, potentially stopping its ability to pick up or manipulate larger objects.

QUIZ

15-20m

What is force?

....

....

What is the difference between balanced and unbalanced forces?

....

....

What is an application that bioengineers use 3D Printing for?

....

....

How can forces affect motion?

....

....

What is tension?

....

....

QUIZ

What type of deformation occurs when a spring is able to return to its original form once tension is removed?

....

....

What does a straight line on a graph tell us?

....

....

What do we call the point that an object stops behaving elastically and permanent deformation starts to occur?

....

....

What is Hooke's Law?

....

....

What are the four main biological parts that allow you to move your fingers?

....

....