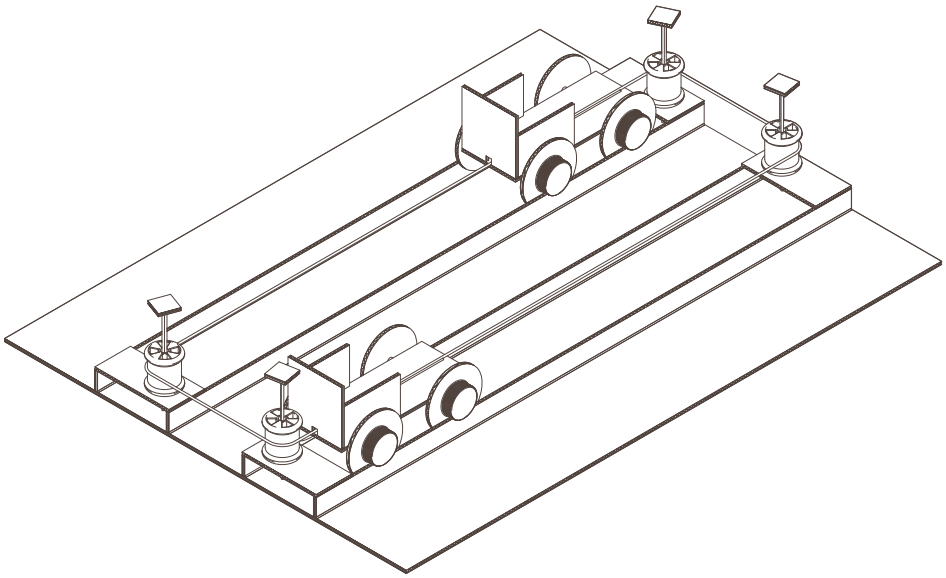


FUNICULAR RAILWAY WORKSHEET

GETTING STARTED

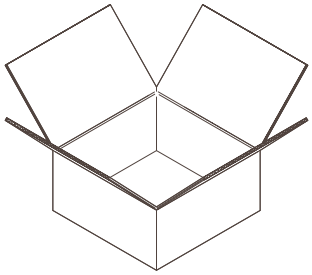
5-10m

Did you know that funicular railways have been used to transport people and cargo up steep slopes for almost 500 years?

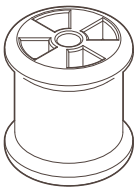
In that time, the engineering system has changed very little because the design still makes the funicular one of the most energy-efficient ways of travelling up steep inclines.

This session will teach you how to build a model funicular railway, incorporating a pulley system and counterbalanced cars.

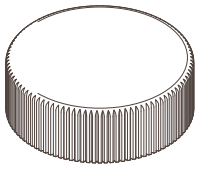
YOU WILL NEED



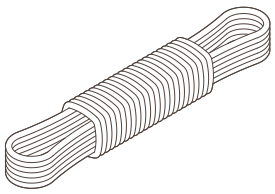
Large cardboard box
1
min. 60x45cm



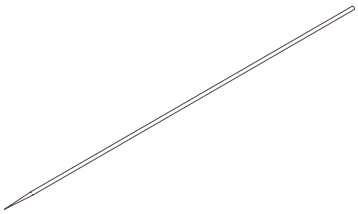
Cotton reels
4



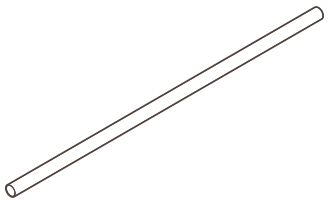
Plastic bottle lids
8



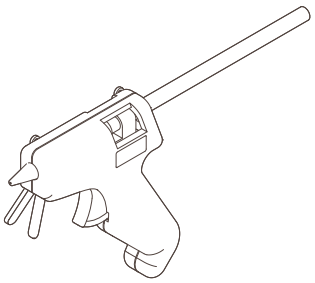
Nylon string
2m



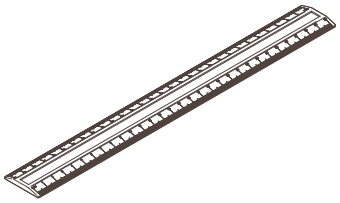
Kebab sticks
6



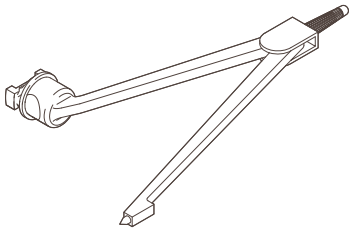
Straws
2



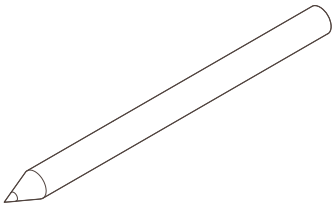
Glue gun
1



Ruler
1



Compass
1



Pencil
1

VOCABULARY

Parallel - Parallel lines are the same distance apart for their entire length.

Pulley - Pulleys are simple machines that comprise of a wheel on a fixed axle, with a groove along the edges to guide a rope or cable.

Gravity - Is a force of attraction that pulls together all matter.

Simple Machine - A mechanical device that changes the direction or magnitude of a force.

Mechanical Advantage - The comparison of the size of the load to the size of the effort force.

Counterbalance - A weight or force that balances or offsets another.

Diameter - A straight line that goes across a circle and through the centre.

Axle - A pin or shaft on which a wheel, or pair of wheels, revolves.

Friction - A force between two surfaces that are sliding, or trying to slide, across each other.

WARM-UP ACTIVITIES

A

5-10m

This project is a great way to get you thinking about how important gravity is to our everyday lives.

Consider and discuss the following:

- When do we feel or see the effect of trying to overcome the force of gravity? For example, always being pulled back down to the ground when we jump in the air.
- What would life be like if there was no force of gravity on Earth?

Thinking about gravity will help you understand how funicular railways can operate so efficiently; often using very little or no power to pull heavy train cars filled with cargo uphill.

B

10-15m

Pulleys are used in almost every industry. They make, move, build, and fix the goods we buy. They also are in the buildings around us, as well as the roads, bridges and tunnels on which we travel.

Using online resources, investigate different types of equipment that use pulley systems for their operation and the benefits of their use. You could begin by looking at:

- Cranes
- Blinds
- Garage Doors

This will help you to understand the variety of uses that pulleys have and also how you can incorporate them into your funicular railway model.

MAIN CHALLENGE

1-2 hrs

Building the funicular railway is a great way to investigate the force of gravity and think about the effect of pulleys.

We have provided you with an example of how to build a funicular railway and suggested some materials to use, but if you are feeling creative we encourage you to design your own.

Once you have put your model together, you can then use your imagination to decide on a cargo for the cars to carry.

Every time an engineer is faced with a problem, they approach it using the Engineering Design Process.

Ask - What's the problem?

Imagine - Choose a solution.

Plan - Design and choose materials.

Create - Make it.

Test - Test your creation.

Improve - Redesign as needed.

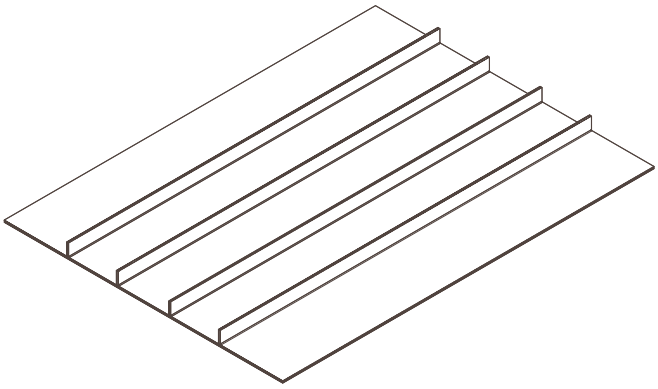
Using this design process, see if you can create a model that runs smoothly using only the power of gravity and pulleys to move the cars. Good luck!

BUILDING THE FUNICULAR RAILWAY

Follow these steps to build your funicular railway!

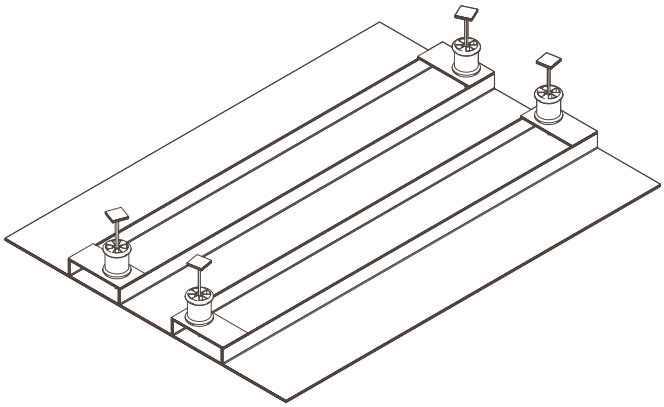
A

To begin, construct the track using a 45cm by 60cm sheet of corrugated cardboard for the base. Draw four parallel lines, 8cm apart, along its length. To make the rails, cut out four 2cm by 60cm strips of cardboard. Carefully, glue the rails along the parallel lines using hot glue.



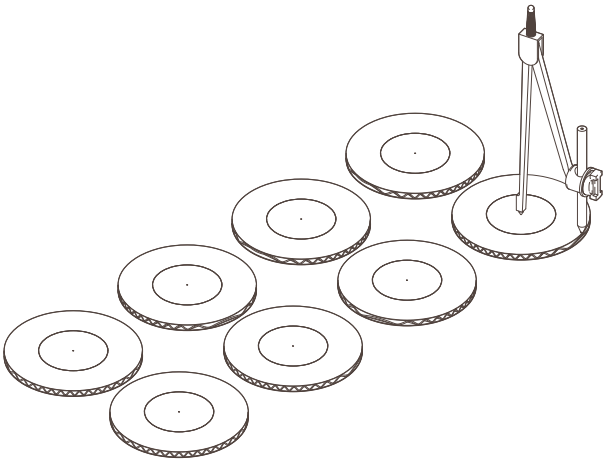
B

Next, begin to build the pulley system by gluing a 4cm by 10cm rectangle of card across the end of one of the tracks. Then, pierce a hole in the rectangle, 3cm from the inside rail. Push two, 10cm long, pieces of kebab stick through the hole to form the shaft for the cotton reel to spin on. Thread the cotton reel onto the sticks and glue a small square of card over the ends so there are no sharp points sticking out. Repeat this step for the other three track ends.



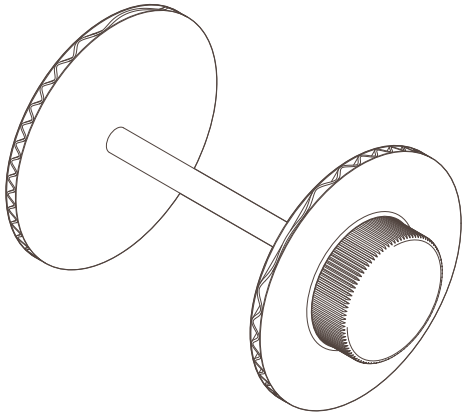
C

To make the wheels for the trains, use a compass to draw eight circles with a 6cm diameter. Then, draw circles with a 3cm diameter inside the larger ones. Cut around the outer circles and pierce a hole in the centre of each disc using the pointed end of a kebab stick (the hole made by the compass point will show where the centre is).



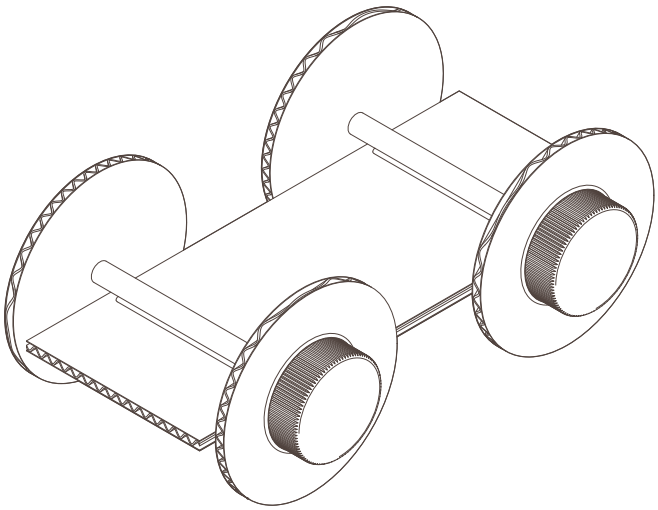
D

Axles will allow the train wheels to rotate freely. To construct an axle, trim a piece of kebab stick to the width of the track (8cm), plus the depth of two plastic bottle tops. Take a 7cm long piece of straw and thread it onto the kebab stick. Then, push a card disc and a plastic bottle top onto either end. Check the length of the axle by positioning the card discs inside the tracks; the wheels should rotate freely all the way along the length. Make any necessary adjustments, then glue the bottle tops onto the card discs, using the smaller circles as a guide to ensure they are attached centrally. Repeat this step 3 more times to create 4 sets of wheels.



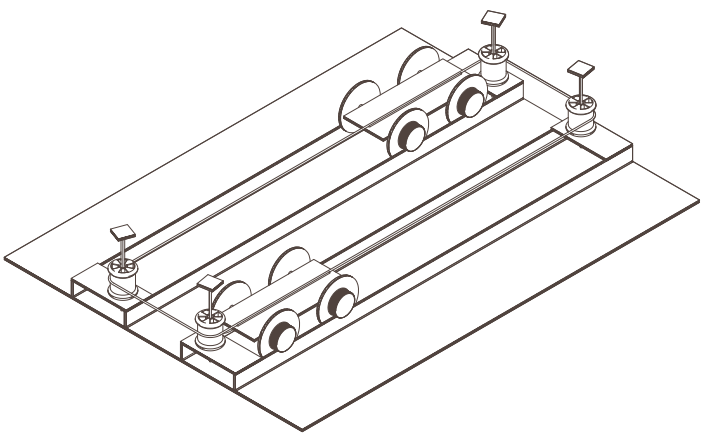
E

Now, begin to put the train cars together. First, cut out two 15cm by 6cm card rectangles to form the bases. Then, glue two axles to each base. Put the trains inside of the tracks and check again that the wheels are running smoothly.



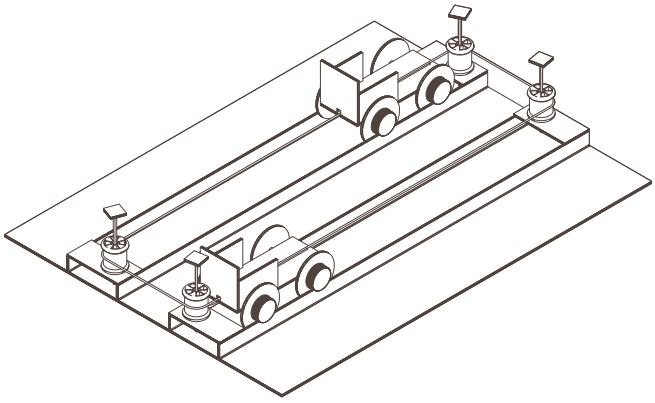
F

Next, connect the pulley system. Begin by glueing one end of the nylon string to a train, then wrap it around the pulleys at each end of the track. Pull the string tightly, so there is no slack, then glue the other end to the same train base to create a continuous loop. So that the trains counterbalance one and another, push them to opposite ends of the track. Then, glue the nylon string onto the base of the other train.



G

Finally, complete the train cars so the funicular railway can carry cargo. Cut out one 6cm by 6cm piece of cardboard with a small hole in one side to allow the nylon string through. Then, cut out two 6cm by 4cm sides. Glue the pieces onto the base centrally so the load is taken evenly over both axles. Repeat this step for the other train. Now the trains can be loaded with cargo, watch how the force of gravity pulling the heavier train to the ground lifts the other train up to the top of the track.



DID YOU KNOW?

The Greek mathematician and engineer, Archimedes, is the first person on record to have used a compound group of pulleys to make lifting easier. He used his block and tackle design to lift a ship out of the water and onto dry land.

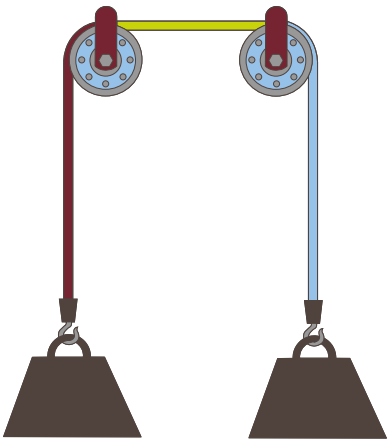
FUNICULAR RAILWAY

10-15m

GRAVITY AND SIMPLE MACHINES

KS 2/3
UNDERSTAND THE SCIENCE

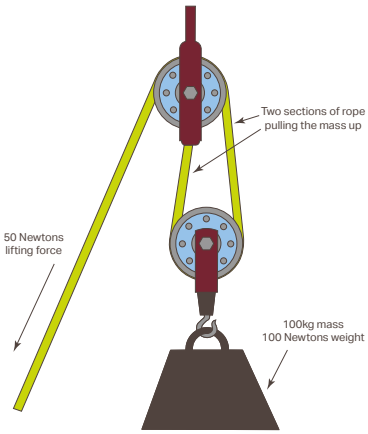
Pulleys



Pulleys are made by looping a rope over one or more wheels.

Pulleys can be used to redirect a force. For example, in the funicular railway model, one of the train cars pulling down on one end of the rope creates an upward pull at the other end. This kind of pulley system is said to have a mechanical advantage of 1 - the same force is required to pull the cars up because the force is all being taken through the same length of rope.

Pulleys can also be combined to create what engineers call 'simple machines,' which can help to multiply forces, making lifting and moving objects easier.



Looping the rope over more wheels, so there are more sections of rope pulling up on the object, increases the upward force. Having two sections of rope pulling up on the object, means you can lift something twice as heavy using the same force. This kind of arrangement, which is sometimes known as a block and tackle, has a mechanical advantage of 2.

In the example opposite, the mass with a weight of 100N is supported by two sections of the same rope. This means it can be lifted by pulling with a force of just 50 Newtons, half of the original weight!

The mechanical advantage generated by a pulley system is equal to the number of sections of rope pulling up on the object. So, by adding more pulleys and creating more sections of rope pulling upwards, greater mechanical advantages can be created.

KS 3/4
DEEPER LEARNING

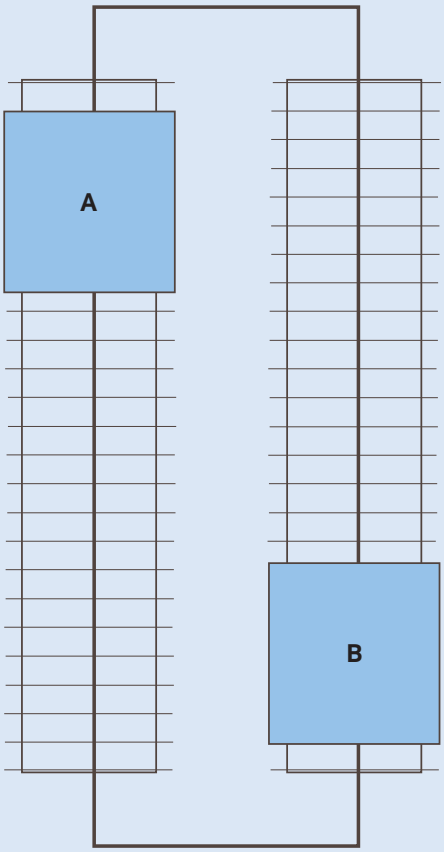
Gravitational Potential Energy

When objects rise above the earth's surface, they gain stored energy called gravitational potential energy.

The amount of gravitational potential energy an object is dependent upon two things:

- Its mass.
- Its height above the ground.

In this diagram, the train car at the top of the track (A), will have more gravitational potential energy than the car at the bottom (B), because it has been raised higher above the earth's surface.



The amount of gravitational potential energy Car A has can been be calculated using the equation:

$$GPE = mgh$$

- **GPE** is the gravitational potential energy in joules, or **J**
- **m** is the mass in kilograms, kg
- **g** is the gravitational field strength in newtons per kilogram, N/kg (on Earth this is 10 N/kg. This means that for each kg of mass, an object will experience 10 N of force)
- **h** is the change in height in metres, or **m**

For example, if the train car weighed 6,000kg and had completed its journey to the top of a 150m high track. Its gravitational potential energy could be calculated as:

$$GPE = 6{,}000kg \times 10N/kg \times 150m$$
$$GPE = 9{,}000{,}000\ J$$

When the car descends back down to the earth's surface, the gravitational energy it stored at the top of the track is transferred to kinetic energy, which works to move the train car. The mechanical work of the car moving down the slope then pulls the cable connecting the two cars, in turn lifting the lower car up to the top.

QUIZ

5-10m

What are parallel lines?

.....

.....

What makes funicular railways an efficient way of travelling up slopes?

.....

.....

What does counterbalance mean?

.....

.....

How can you increase the mechanical advantage of a pulley system?

.....

.....

Who was the first recorded person to use block and tackle pulleys for lifting?

.....

.....

QUIZ

Name some places where pulleys can be found.

.....

.....

What do simple machines do?

.....

.....

What is gravitational potential energy?

.....

.....

What two factors influence the amount of gravitational potential energy an object has?

.....

.....

When is gravitational potential energy transferred to kinetic energy in the funicular railway model?

.....

.....