PRIMARY SCIENCE TEACHING TRUST COLLEGE PROJECT

# Chain Reaction

**Sue Martin, Caroline Galpin, Peter Sainsbury**

## An engaging primary school STEM project for upper KS2 children that is easily adapted to suit any age group.

The notion of 'cause and effect' is one that comes easily to most children; their own life experiences are likely to have provided many examples. Given a collection of simple toys, perhaps cars, ramp/tracks and dominoes, you might expect that even very young children will explore ways to make a car run quickly along the track to knock over dominoes that have been set up on end, so that these then fall over one by one.

Adding further components to the selection, it soon becomes apparent that it is possible to link more of these actions together - and the concept of a 'mechanical chain reaction' develops: the movement of one object leads to that of another and then another, limited by the number of components that are available and the skill of the creator to arrange these in such a way that sufficient energy from one component is passed to the next to enable that object to move.

The 'Chain Reaction' project provides children with the opportunity to: design, test and refine their own chain reaction ideas, utilising both D&T and simple engineering skills; explore the science of forces, simple machines and energy transfers, whilst also working scientifically; and many opportunities for further cross-curricular links (some of which will be explored within this resource).

The project has been trialled successfully in 23 schools in the PSTT Wessex region, with a number of these participating in interschools' events to showcase and extend the ideas. Other schools across the UK have run similar activities. This resource, along with other supporting materials, is intended as a starting point for others to explore the possibilities of using cheap, readily available resources to deliver an age-appropriate STEM activity. It also aims to support teachers with background science information and relevant context.

## Have you ever played Mouse Trap®?

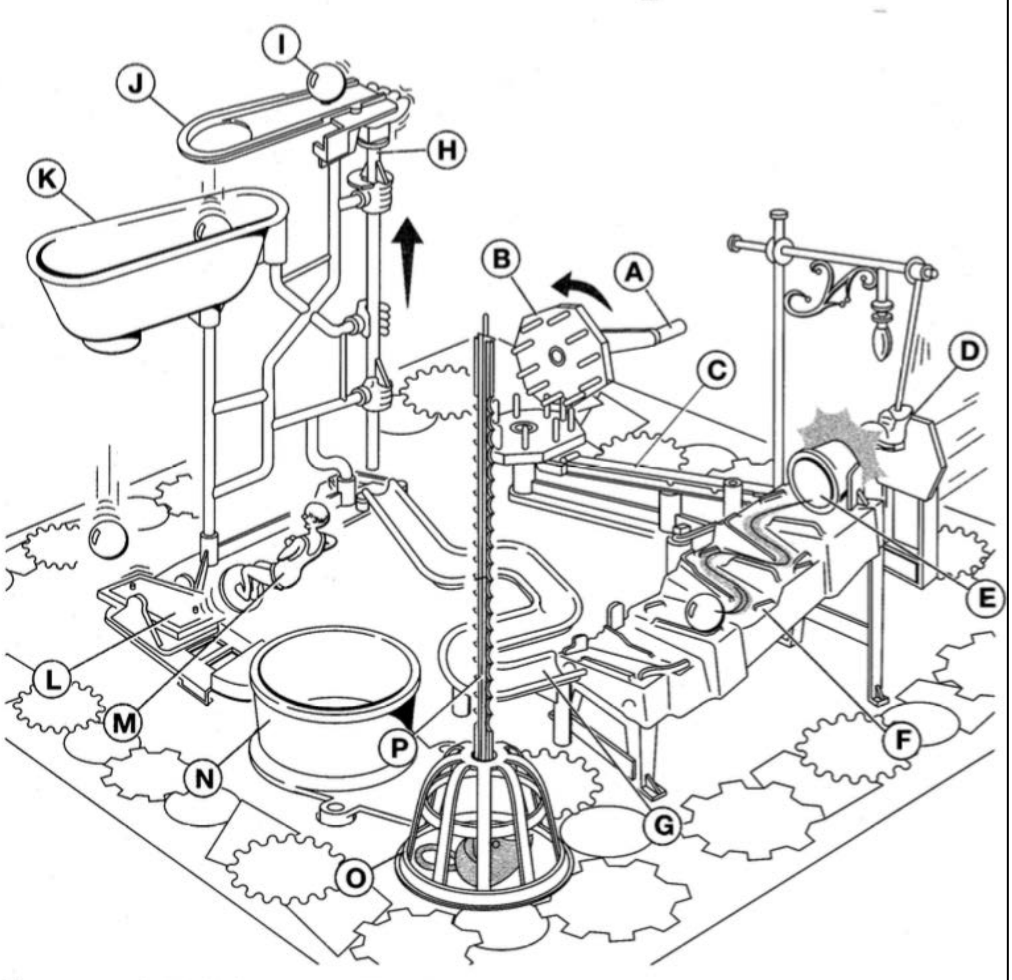
As the game is played, a contraption is built, piece by piece. Eventually, one player will turn a crank handle, which sets the next piece (a gear) into motion, which triggers the next lever, and so on, until finally, the trap itself is triggered and falls on the mouse.

*Follow the diagram, from part A through to O. The only part that the player moves is the first piece – the crank handle (A). After this, the pieces are arranged so they either move the next or they trigger another object such as a ball, a small diver or the trap itself to move.*

*Each of the parts must be carefully positioned to be sure that every movement triggers another.*

Mouse Trap® is, of course, a commercial product, with each piece manufactured so that it should always work. The mouse is trapped at the end of a **mechanical chain reaction**...

### How the Mouse Trap Works

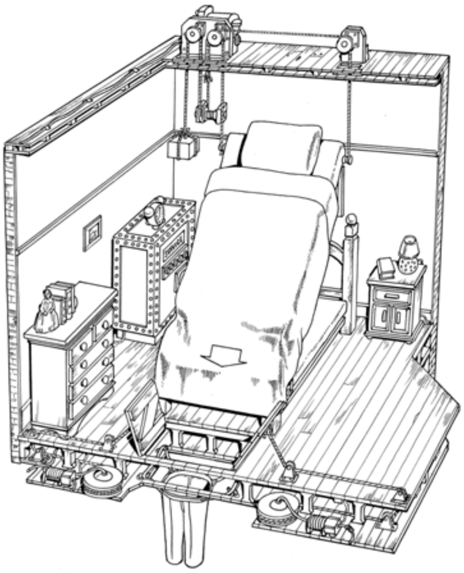



Player turns crank (A) which rotates gears (B) causing lever (C) to move and push stop sign against shoe (D). Shoe tips bucket holding metal marble (E). Marble rolls down rickety stairs (F) and into rain gutter (G), which leads it to the helping hand rod (H). This causes other metal marble (I) to fall from top of helping hand rod through thing-a-ma-jig (J) and bathtub (K), to land on diving board (L). Weight of metal marble catapults diver (M) through the air and into washtub (N), causing cage (O) to fall from top of post (P) and trap unsuspecting mouse.

... by this we simply mean that in setting off the first part of the device, a whole series of movements will occur, each leading to another until the device finally stops with the planned outcome.

Such devices are sometimes known as 'Heath Robinson' or 'Rube Goldberg' devices.

William Heath Robinson and Reuben Garrett 'Rube' Goldberg were both cartoonists/illustrators who drew designs for incredibly complicated machines that performed very simple tasks. You might like to look at some of their ideas online! Children may also be very familiar with the Aardman characters Wallace and Gromit. In the film 'The Wrong Trousers', we see that several machines and mechanical devices are used to tip Wallace out of bed, put on his clothes, deliver him to the breakfast table and spread jam on his toast.





## Introductory Activity

### Watch a video with a Rube Goldberg device, such as the 'page turner'.

https://www.rubegoldberg.com/rube-tube/joseph-herscher-the-page-turner/

Discuss the mechanics of some of the actions seen in the video, including the associated vocabulary, such as rolling, swinging, releasing, pushing, reversing, winding/un-winding, momentum, pull, fall, turn, hit, touch etc. You could relate these to the concept of forces or energy, depending on the age and/or ability of the children.

Allow some time to play with dominoes, marble runs, a Mouse Trap® game, packs of cards, balls, skittles, etc. and explore how each works.

Further excellent examples of Rube Goldberg devices can be found here:

http://coolmaterial.com/roundup/rube-goldberg-machines/

or try searching: 'Rube Goldberg machine ideas for schools'.

Try showing one video to your class – they will want you to show more!

# Main Activity

## Set a homework/holiday activity to create a chain reaction device.

The instructions used by schools involved in our project are given below. The handouts sent home included details of the Mousetrap game and other Rube Goldberg devices as described earlier and we also gave the website links to provide families with the project's context and some inspiration. A timeframe for completion was also set, as the devices created were to be brought into school, set up and run for the whole class to see.

**Why was this task set as a homework/holiday project?**

One of the aims of the project was to engage families in an educational activity that would be fun to complete together.

Evidence from the trials suggested that those children whose families worked with them on the project had an enjoyable and really worthwhile experience; parents valued the opportunity to have something exciting to do as a family. A number of families had clearly spent a significant amount of time together both in the design and implementation of their device.

The machines had to be set up in class by the children, who were required to explain their designs, challenges faced and expected outcomes. More sophisticated devices tended to prove the most interesting to all the children, and they all benefited from both presenting and listening to each other's experiences. The task then generated lots more problem-solving in class and the lessons learned at home proved useful when children had to work together in groups to extend or join their devices together.

**Design and build your own device that creates a mechanical chain reaction**. This does not have to have a specific purpose, although you are more than welcome to set one.

It certainly does not need to be as complicated as the amazing videos or pictures that you might find online, but feel free to develop your ideas in any way you wish!

You can use just about any ordinary, everyday objects that you choose, e.g. cardboard tubes, boxes, ramps, cups, toys such as marbles, balls, cars, dominoes, balloons, etc. You could make parts from Lego® or K'nex® or use parts of larger toy sets such as marble runs or car tracks. Be creative!

There are only a few rules:

- You must be able to set up and run your device a number of times;
- Your device must be portable – in other words, you must be able to carry it into school and set it up again there;
- There must be *at least* 4 different parts to the chain reaction;
- Once you set off your device, it should be able to run through to the end unaided.

You are welcome and encouraged to ask family members for ideas and to work on your device together, but you will need to be able to set it up alone in the classroom and be able to make it work by yourself!

# Follow-up lesson

To ensure the children have an opportunity to explore scientific principles from their contraptions, they should bring them into school to set up, share and discuss.



In this lesson, the children will set up their homemade mechanical devices and then demonstrate them to their classmates, setting them off for everyone else to watch. Taking photos and a short video of each one provides a useful way to look back over ideas together without the time required to set up the devices again. Each pupil could ask their classmates to predict what should happen before the action begins. The teacher's role is primarily to guide in problem-solving situations (it is likely that there will be quite a few issues arising, even though the devices have been tested at home) and assist in the acquisition of additional materials to resolve these issues.

We would encourage teachers to ensure the children discuss:

a. How it works (identifying forces and effects such as movements where possible)
b. The positive elements (what worked well)
c. How it could be modified/improved
d. Whether it would be possible to join it on to another one

If you have time, allow groups to join up and/or reconstruct their devices so they form longer chain reactions.

Whilst setting up their own contraptions, it was evident that the children automatically shared ideas and worked together to solve problems that arose. Children who had spent more time problem solving on their devices at home had a wealth of expertise to bring to the classroom situation. Encourage children to help each other and to suggest and make improvements to their own devices during the construction process.

# Extending the project... interschools' event

A number of our project schools joined together for an inter-schools' event, to share ideas and work together to make one large chain reaction from the individual devices. The schools were given the following information.

(Specific event information - timings, location etc. has been removed).

Set up a *Chain Reaction lunchtime club*. We suggest a half hour + club, for a limited period of time (around 6 weeks), which could involve Y5/6 staff, other staff, TAs and parents. The aim of this club is to make **one larger contraption** that will be brought along to the ***GRAND CHAIN REACTION EVENT***. At this event, we would like to demonstrate the device from each school and then have the children join them together to make a single, very large chain reaction.

Your contraption should:

- contain at least 4 sections with different mechanical movements;
- be as relatively large scale as possible;
- be transportable – you will need to bring it to the event in e.g. a car/minibus;
- be set up in around 1 hour;
- have the possibility to be joined to another device (at either end or both);
- be as varied as your imagination allows.

For creating devices on a larger scale, we envisage utilising materials such as drainpipes, guttering, wooden blocks, etc. This might be a good time to make friends with a local builders' merchant or joinery or to find which of your parents have useful construction skills that they could bring along to your school!

Part of the fun is in not knowing what each child will invent or how each device will turn out at the various schools involved. We are certain, however, that the children will benefit from an exciting event, sharing each other's ideas and looking at different approaches to the same task.

# Extending the project... alternative approaches

For teachers who would like to use the 'chain reaction' idea entirely in school, there are many easy ways to facilitate this.

## Everyday Objects

Provide simple resources for children to explore and build their own devices, such as:

- Cardboard (various sizes and thicknesses, boxes) and paper
- Plastic boxes, yoghurt pots, butter containers etc.*
- Straws
- Marbles, balls or similar
- Balloons
- Elastic bands
- Cotton reels
- Lolly sticks, craft sticks
- Sticky tape, sticky tack, string
- Stationery items such as rulers, erasers, pens (these make great ramps, 'dominoes', and items that roll), drawing pins (good for popping balloons)

*Don't forget, if you use these or similar resources, you must ensure they are cleaned thoroughly

## Playground/PE equipment

Consider utilising playground and PE equipment, such as climbing frames/slides, slopes, building blocks, balls, hoops, ropes, cones, guttering, pipes etc.

Challenge children to use these items in a creative way to create a chain reaction.

## Toys and Games

This project need not be limited to the Year 5 & 6 year groups for which it was originally designed. Start exploring the idea of cause and effect in Early Years classes! The number of events does not need to be specified. Many toys and games are ideal for this:

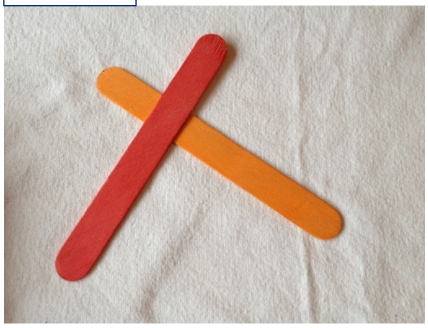
- Garages with ramps and lifts
- Car and train tracks
- Marble runs
- Construction sets, such as Lego and K'Nex
- Gear sets

# A craft stick chain reaction

This is a hugely popular activity with children (and adults) that requires a little patience and practice, but delivers a spectacular chain reaction.

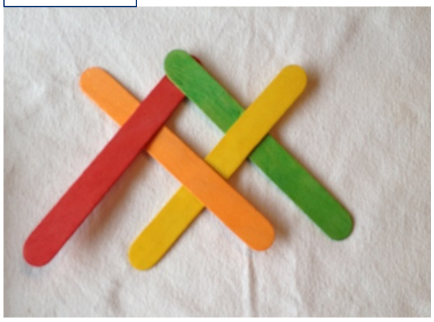
You will need ...

**Step 1**

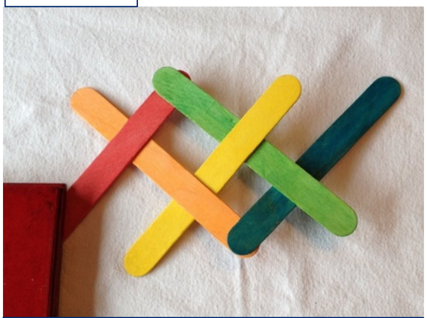


**Step 2**

**Step 3**



**Step 4**



It helps to put a weight on the first stick as the chain length increases.

**Step 5**

**Step 6**

**Step 7** – secure with a 'holder' stick across the other end sticks, ready for release.

**Step 8** – pull the end 'holder' and quickly stand back for their release. The sticks will spring up a long way!

# Extending the project... cross curricular ideas

Activities that reinforce the principle of a chain reaction were explored, with children being part of the chain and unable to move until the prompted by the previous member of the chain. Below are examples that engaged the children, providing a kinaesthetic approach through a large-scale, more physical activity.

Children spread out around the field and 'passed on' a jumping star, comparing speed of transfer (dependent on reaction times and alertness) to the time it took the class TA to cross the field. Similarly, children passed a 'hand touch' around the perimeter of the playground, whilst the TA walked its length.

Group/team challenges based around party games of passing a touch, ball or baton.

Exploring the transfer of movement and energy along a 'rope wave'.

# Extending the project... exploring cause and effect

There are many opportunities within other areas of the primary curriculum to look at the concept of cause and effect or consider 'chain reactions' that are not of the mechanical type explored at the start of this project.

On the next page, consideration has been given to other areas of science that could be explored from this perspective, along with topics in geography, history and to develop personal, social and communication skills.

This is not intended to provide a comprehensive list, nor provide extensive detail of ways to incorporate these ideas into the curriculum, but to prompt ideas for discussion that might help children see possible links between different subject areas.

## Science

**Digestion:** The input of food – breakdown into constituent parts – absorption of digestible chemicals into blood & indigestible/undigested materials leave body.

(Ingest - digest - respire - egest and excrete)

**Food Chains and Species Population Pyramids:** Sun – producer – consumer(s). Exploring the effects of changes to a habitat on dependent species.

**States of Matter:** solid – liquid – gas. Water is an accessible, everyday example of a material children can use to explore cause and effect when changing temperature.

Similarly, children can identify chains involved in **cooking and burning**. Heat source – saucepan – water – vegetables. Conduction and insulation, and fire prevention are useful extensions.

**Electricity:** Although this is at the top end of primary understanding, models and chain reaction examples can help children tackle the theoretical side of electricity. (The Institute of Physics has useful activities that can be applied to chain reactions and the transfer of charge in an electrical circuit.)

**Light:** Light source (e.g. sun or candle) – object – eye. Adding a mirror will lengthen the chain and facilitate further investigation into how chains can be broken.

## Geography

Geography Localised Floods and Effects upon Human Population:

At a famous motor racing venue:

Flash flooding + poor track drainage – severe track flooding – dangerous conditions – event cancellation – 10s of 1000 people leaving or turned away at the same time – too many cars for local roads to cope with – massive traffic grid lock – nobody could travel home + all other road users affected.

Engineering was used to break the chain and find a solution to prevent it happening again.

**Geography and Local Issues: Traffic at Schools**

Your school is popular – lots of parents send their children to the school – travel to school by car increases – too many cars for roads and drop off to cope with – beginning and end of school becomes a nightmare for school and local inhabitants.

Any solutions – please let us all know.

**The Water Cycle**

The water cycle is a commonly used curriculum area that can illustrate the conservation of energy theory and enables children to explore the effects of weather as well as giving a context for understanding changes of state.

## History

The concept of cause and effect is central to the history curriculum. Historical events have consequences, good or bad, for those involved and for future generations. Chain reaction principles can be applied to any historically based topic.

**In particular, longitudinal studies,** which are a key approach in the English 2014 curriculum, are worth exploring. For example:

**Invention of Steam engine** – railways – mass transportation –

a) Increased industrialisation: population move from country to towns/cities
b) Cheaper + easier travel: more people able travel – more holidays – growth of seaside towns
c) Reduction in use of canals

**History and Science Significant Scientists:**

A longitudinal study of microscopes can be found on the Primary Science Teaching Trust and Royal Microscopical Society websites. 'Women in Science', by Rachel Ignotofsky, provides many examples of discovery and innovation (cause) and the beneficial impact (effect) of these.

## Personal, Social and Communication skills

Relationships: Applying 'chain reaction' to children's relationships in school can be a very powerful way to help them understand the complexities of getting on with each other and adults. Unpicking 'playground incidents' with a cause and effect approach helps us to pinpoint what has occurred and begin to understand. Adding in the effect on feeling deepens a child's ongoing understanding of actions and consequences.

**Learning from mistakes and taking responsibility:** Illustrate and provide a model of how and where they might 'break the chain' at a crucial point and highlights opportunities to do so in the future.

Setting up dominoes, blocks with rewritable labels, hoops, chain links or consequent cards personalise this approach, give children ownership and help them visually. Branching models can incorporate good and not so good choices. Some children find drawing their chains and responses instead of verbalising them helpful.

**Reinforcing Positive Behaviour:** Circle time (or similar) can be provide opportunities to explore positive and negative experiences. They can be encouraged to look backwards and forwards, piecing together cause and effect, and event and feeling.

# Background Science

Forces and their effects are part of the English National Curriculum at KS2:

Children should understand that force and motion can be transferred through mechanical devices such as gears, pulleys, levers and springs.

## What is force?

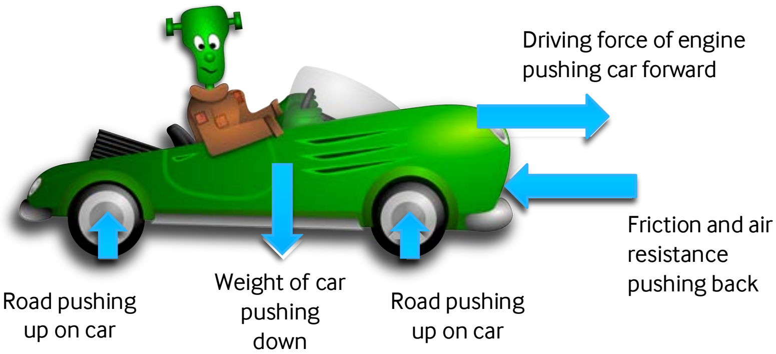
A force is any *push* or a *pull*. Forces are measured in newtons (N). Forces are shown on diagrams using arrows that show the direction of the force; the bigger the arrow, the bigger the force.

## Balanced forces

These are forces of the same size but acting in opposite directions on an object.

When forces on an object are balanced:

- A stationary (still) object will remain stationary
- A moving object will keep moving in the same direction at the same speed




The diagram above shows a car travelling at a steady speed.

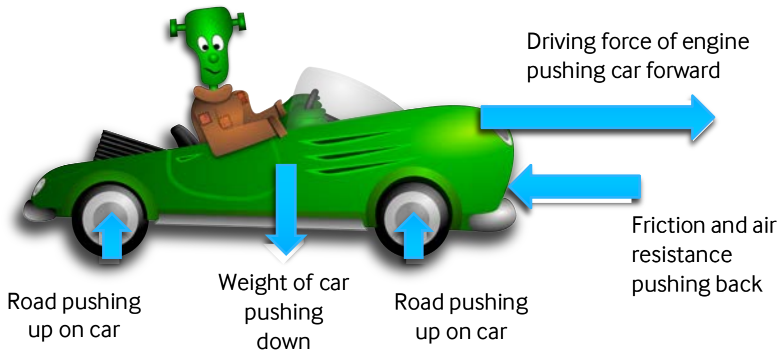
If the car is stationary, there is no driving force The force of air resistance, however, would be balanced in each direction.

## Unbalanced forces

This occurs when a force on an object is greater in one direction than in the opposite direction.

When forces on an object are unbalanced:

- A stationary (still) object may start to move
- A moving object will change its motion: speed up; slow down or change direction
- Objects may change shape




The diagram above shows a car accelerating (speeding up).

The driving force of the engine pushing the car forward is greater than forces pushing back so car speeds up in direction of the greater force.

Forces up and down are still balanced.

Look at the Mouse Trap® game or the children's own contraptions (or a picture of these). Where are forces applied? Are these forces pushes or pulls? How do these forces affect the contraption? (E.g. do they cause a part to change its speed, direction of movement or shape?)

# What is a machine?

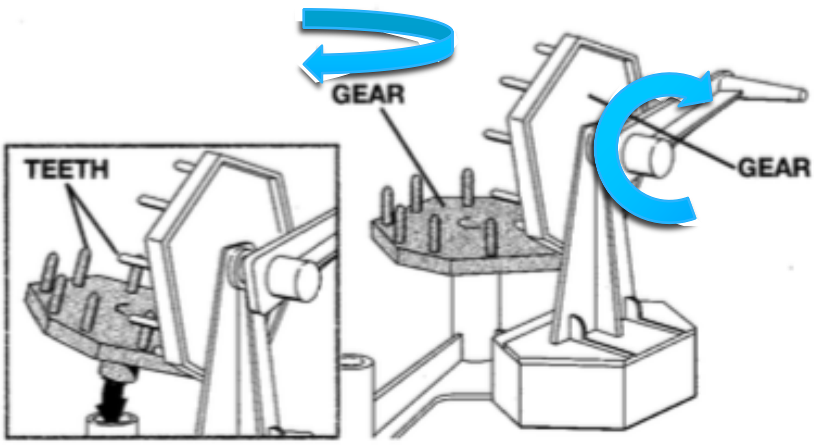
This is any device that is used *to change the size or direction* of a force.

Machines are often used to make a task easier (for example, to lift or move a heavy object using a much smaller force). Common machines include gears, levers and pulleys.

## Gears

Take a look at the start of the Mouse Trap® contraption – you should be able to see 2 gears. The first gear is turned by a crank (handle) and is rotated vertically. The teeth of the first gear interlock with the teeth of the second. This gear turns horizontally.

The gears here act as a machine to *change the direction of the force*.

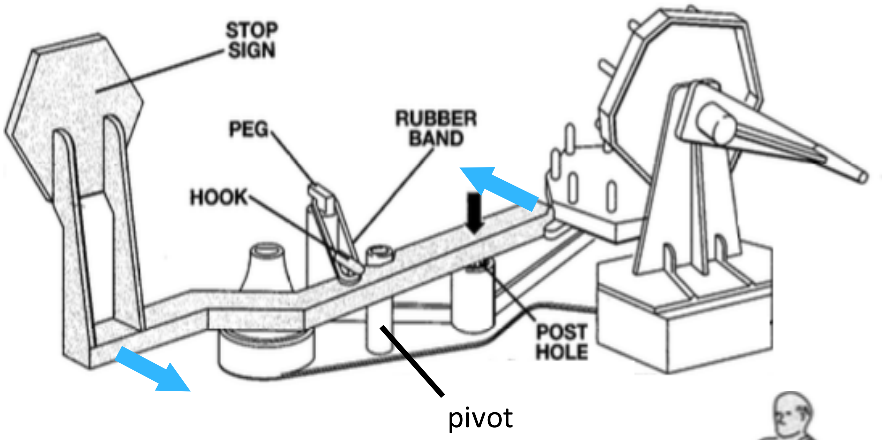


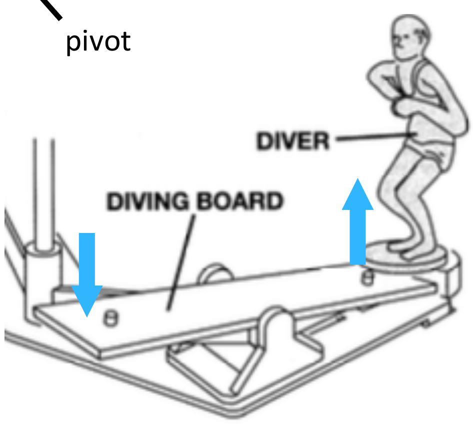

## Levers

These two diagrams have good examples of levers used in the Mouse Trap®.

In the first, the lever is pushed sideways by the horizontal gear – this lever pivots, causing the 'stop sign' to move backwards. A rubber band stretches under this motion and, once the gear has pushed the lever out, this band returns the lever to its original position, *reversing the direction of the force*.

The diving board 'seesaw' should be a very familiar lever for the children. Again, we see that a force in one direction (down) results in an upward force at the other end of the board, due to the pivot point in the middle of the board.



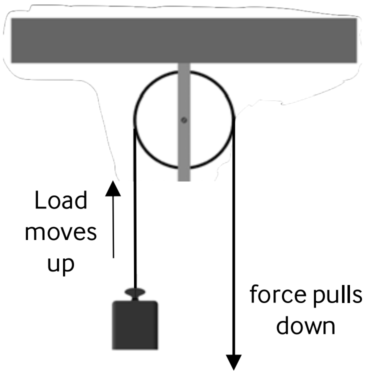



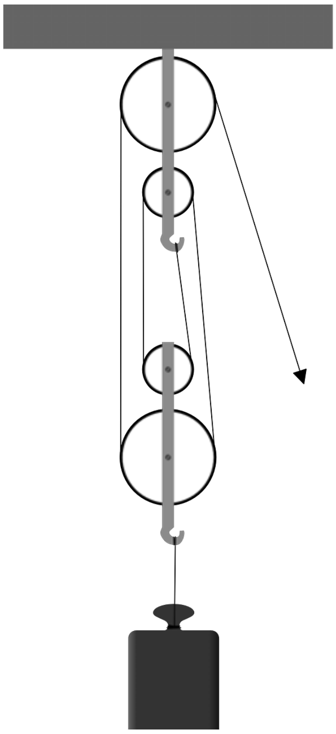

Have the children included any machines in their contraptions?
Can they identify other simple, everyday machines (e.g. scissors, tweezers, kitchen whisk, can opener, garlic press, etc.).
Consider challenging the children to build simple machines from lolly sticks or straws and elastic bands.

## Pulleys

Pulley systems are commonly used to lift heavy objects. The pulley itself is a grooved wheel, around which a rope or cable passes. Children may have seen these used on cranes, over wells, on boats, etc.

The simplest pulley system contains just one pulley. When a force is applied in one direction, the object being pulled moves in the opposite direction. The force used to pull the rope will be the force applied to the object.



More complex pulley systems can easily be created by threading the rope around additional pulleys before attaching a load. As the number of pulleys increases, the force needed to pull a load decreases. The rope will need to be pulled for a longer distance with this smaller force in order to move a heavy load over a short distance.

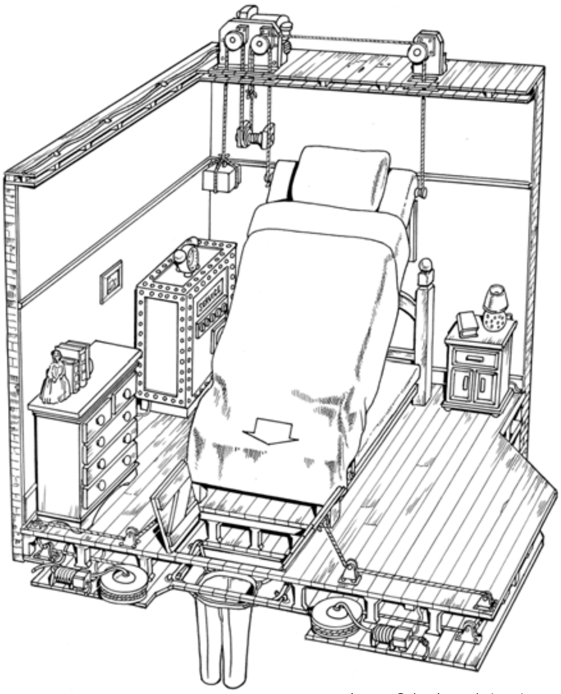


Image © Aardman Animations

Can the children find more examples of pulleys in use?
Can they find pulleys and suggest how these are being used in Wallace's bed contraption or any Rube Goldberg or Heath Robinson devices they find online?

# More Background Science

This is beyond the requirements of the National Curriculum at KS2; however, more able children will readily grasp these concepts and use them correctly when explaining the behaviour of their chain reaction devices.

## What is energy?

A physicist would say that it is the 'ability to do work' – this just means that energy makes things happen!

There are different types of energy. These are discussed below.

### Kinetic energy

- **This is the energy of all moving objects.**

When the moving ball hits the pins, most of its energy is *transferred* to them. The ball slows down and soon stops moving; most of the energy has been given to the pins, so they move instead, falling over.

Whenever anything moves, it possesses kinetic energy. The amount of energy it has depends on the mass of the object (so heavier objects have more energy when they move) and how quickly it moves (the faster an object moves, the more energy it possesses).

You might know this instinctively: if a very heavy object rolls into you, it is more likely to hurt than a very light object; if anything hits you at speed, it generally hurts more than something that strikes you slowly!

The ball was given its energy when it was thrown (let's assume by a person) – the person's energy was transferred to the ball. Where did the person get their energy? ... from food that has been eaten.

### Potential energy

- **This is stored energy.** Different materials store energy in different ways:

 chemical potential energy

 gravitational potential energy

 elastic potential energy

We will explore each of these forms of energy in a little more detail on the next page.

## Chemical potential energy

- **This is the energy stored in materials such as food, fuel and batteries.**

Energy from food is released into our muscles when we move; it is also converted to heat energy to keep us warm.

So, if we throw a ball, we *transfer* our energy to the ball, giving it kinetic energy. We could use muscle energy to do other things too, such as stretch an object or lift it into the air.

From what does a car get its energy? FUEL, such as petrol or diesel; or perhaps it's an electric car and has a battery that stores energy. The petrol or diesel is *burned* in the engine and this energy is then converted into kinetic (moving) energy in the engine.

Energy stored from the chemicals in the battery is converted into electricity (electrical energy) and then into kinetic energy using a motor.

## Elastic potential energy

- **This is the energy stored in objects that are stretched or squashed, such as in an elastic band or a spring.**

This elastic (potential) energy is transferred into kinetic energy when the elastic or spring is released.

In *elastic* materials, the chemical bonds that hold the molecules of the material together are stretchier than in other materials. As the material stretches, energy is stored; when the material is released, so too is the energy.

## Gravitational potential energy

- **This is the energy that an object has whenever it is raised up and so could fall down.**

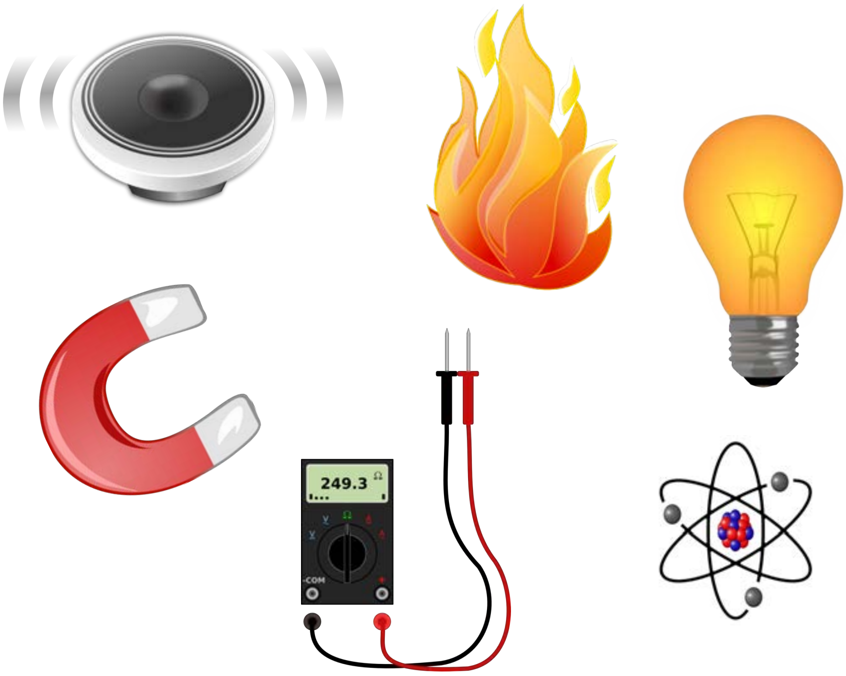
**As the material falls, it loses gravitational potential energy and gains kinetic energy.**

Children should know that gravity pulls objects 'down' (towards the centre of the Earth). In order to move, an object must have energy. Raising an object gives it the energy that is required to fall back down – this is its gravitational potential energy. The higher it is, the more energy it will have.

## Other types of energy...

We have looked at the main energy types that the children may identify in their chain reaction devices. Other types of energy are listed below. Some of these may also be present in their devices...

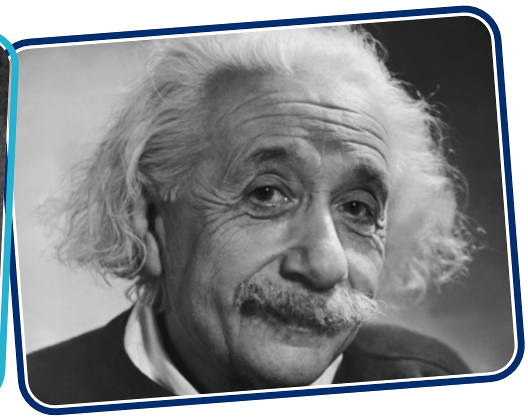
- Sound
- Light
- Heat
- Electrical
- Magnetic
- Nuclear




## Conservation of Energy

Energy cannot be created; it cannot be destroyed.

Energy can be transformed from one type into another



James Joule – British physicist whose practical work established the principle of conservation of energy.

Einstein did not formulate the law of conservation of energy (energy cannot be created or destroyed but is converted from one form to another) – he did, however, relate energy to mass with his famous equation $E=mc^2$ which children might have heard but perhaps not understood.

(Every object has energy 'locked up' in its atoms. In all cases, this energy 'E' can be calculated by multiplying its mass 'm' by a constant value, $c^2$, which is the speed of light squared.)

## Energy Transfers

Which types of energy are present at each stage of this chain reaction?

Which types of energy transfer can you find in your chain reaction?

Turning the crank gives it kinetic energy (which comes from the kinetic energy of the hand turning it, which came from the potential energy stored in the muscle, which came from the energy stored in the food).

This gives the gears kinetic energy, which gives the elastic band potential energy as it stretches.

This elastic potential energy is converted into kinetic energy as the band is released and this is transferred to the kinetic energy of the lever.

The lever gives kinetic energy to the boot, which gives kinetic energy to the bucket. As this moves, it releases the gravitational energy of the ball in the bucket, which is converted into kinetic energy as the ball moves down the zigzag slope and then the curved slope until it hits the frame.

This kinetic energy releases the gravitational energy of the ball on the platform, which moves with kinetic energy down through the bath and drops onto the seesaw.

This gives kinetic energy to the seesaw, which is passed on to the diver. The diver gains gravitational potential energy as it moves up into the air and then this is converted back into kinetic energy as the diver falls down into the yellow bucket.

The movement of the yellow bucket (its kinetic energy) is transferred to the plate under it, which moves the rod that is holding the mousetrap. The trap has gravitational potential energy, which is released by the movement of the rod and this is then converted to kinetic energy as the trap falls.

(Aside – an object can possess more than one type of energy. So, a falling object gains kinetic energy as it loses gravitational potential energy, but the total amount of energy remains the same throughout).

Chain Reaction

## Acknowledgements

We are grateful to the following schools for taking part in the initial project and assisting in its development:

St Martin's School, Bournemouth
St Katharine's CE VA School, Bournemouth
St Mary's Catholic Primary School, Poole
Christchurch Junior School
Winterbourne Earls CE Primary, Wiltshire
Pitton CE Primary School, Wiltshire
Talbot Heath Junior School, Bournemouth
Yarrells School, Poole

... and to all the schools which subsequently took part in the second project.

We really appreciate the support of the following organisations:

EXplora Science, Poole
Carter Community College
TTS Group Ltd
Strouden Joinery, Bournemouth/Poole
ESPC Science Explore and Develop, Wiltshire