Do Try This at Home

From the **Institute of Physics**

Physics for the whole family

Experiments 1-13

As we all adjust to new ways of living, working and teaching at home, we're here to help.

We're the Institute of Physics (IOP), the professional body and learned society for physics in the UK and Ireland. We work with schools to develop the teaching of physics – and now we want to use our expertise to help parents and carers inspire and educate their children at home.

Our expert science communicators, based around the UK and Ireland, have created some great physics experiments in their kitchens and living rooms, specifically to help parents and carers. They use basic household materials to demonstrate physics, with step-by-step instructions and simple explanations of the science behind it all.

We want to make it easy to get your children excited about learning – without having to leave your home.

We hope you and your family have fun trying them out, and we'd love to see how you get on. Why not photograph or film yourselves doing them and share on social media, using #IOPathome?

For videos of the experiments in action, and to see new ones when they come out, visit the IOP website:

iop.org/athome

Please note: These experiments have not been specifically safety tested for home use but we believe them to be safe if the instructions are followed. Adult supervision or direction is recommended as appropriate. All experiments are carried out at your own risk.

IOP Institute of Physics

Experiment 1:
Rubber Band Bass Guitar

Pick up some good vibrations in this activity to try out with your family and discover the physics behind every bass-line.

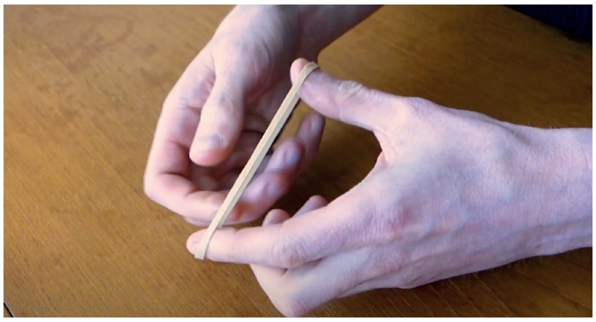
What you'll need:

- A rubber band.
  If you have different shapes and sizes, even better!

What to do:

In this activity you'll be listening to sounds by putting your finger in your ear. Wash your hands before doing this and remember never to force your finger (or any other object) into your ear.

1. Take your rubber band. Stretch it between the index finger and thumb of one hand.



2. Gently put your index finger in your ear. Don't push hard, but make sure there's a seal, as if you were trying to block out a loud noise.

3. Twang the band with the index finger of your other hand. You should hear loud sounds like a bass guitar.

4. Change how much the band is stretched by moving your fingers closer together or farther apart. Stretching the band increases the tension in the band. Can you adjust the band so that you can play two different notes on the two halves of the band?

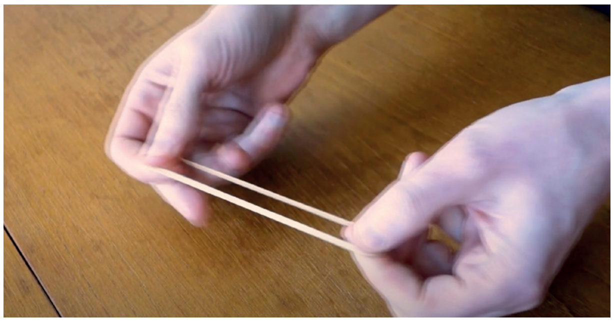
5. Take your finger out of your ear, but keep twanging the band. How does the sound change?

6. Once you've got the hang of it, see if you can play any famous basslines, like Seven Nation Army or Another One Bites the Dust.

What to talk about

- What makes the sound and how does it get into your ear?
- How does the sound change when you stretch the rubber band more or less?

What's going on?



A sound is made when something vibrates. Take your rubber band, stretch it out and give it a twang. You can even see these vibrations! The vibrating band makes the air nearby vibrate, and the vibrations spread out in all directions. If your ear is nearby, you will hear the sound as the vibrations make your eardrum and the bones in your ear vibrate as well.

In our rubber band bass guitar, the vibrations travel through your finger to your ear. Sounds travel better through solids like your finger than through gases like the air. This is because the molecules in a solid are so much closer together than in a gas so it is easier for the vibrations to be passed along. As soon as you take your finger out of your ear, there is a gap of air so the sound gets quieter.

You can change the pitch to create your basslines as you stretch and release the band. The more you stretch the band, the more tension it is under and the faster it vibrates up and down. The number of vibrations every second is called the frequency and this tells you exactly how high or low the note is. A guitarist does the same thing when tuning their guitar by turning the fiddly things on the neck of the guitar to stretch or relax the string.

What next?

Investigate together and discover how the sound changes when you use:

- A thicker or thinner band
- A longer or shorter band (You can shorten a long band by tying a knot in it)
- Knowing what you do about vibrations, can you predict what will happen?

Did you know?

The study of sound itself is called acoustics. This is also the name for non-electronic music – so your rubber band bass experiment is both!

Do Try This at Home

From the Institute of Physics

Experiment 2: Waterproof Hanky

This surprising trick is a great excuse to threaten to pour water over your family. Put their trust to the test as you turn a full glass of water upside down over their head!

What you'll need:

- A drinking glass or transparent cup
- A plate, one with a raised edge works nicely
- Water
- Fabric handkerchief (or any type of cloth really). Don't use a paper hanky, it won't work!

What to do:

In this activity you'll be tipping glasses of water upside down and there will probably be some spillages along the way. We recommend trying the trick outside, in a bathroom or at the very least over a bowl or the sink! You should definitely practise the motion a couple of times before trying it with a person. If you have one, use a plastic cup and plate in case they get dropped when you try the experiment.

1. Push the centre of the hanky into the glass, so that the edges are hanging over the outside of the rim of the glass.

2. Pour water into the glass, through the loose hanky. Make sure that the rest of your family can see the water pouring easily through the hanky into the glass. Keep pouring the water until the glass is roughly half full.

3. Pull the corners of the hanky so that the material is taut over the top of the glass. Hold the glass and hanky so that the material stays tightly stretched over the opening.

4. Place the plate on the top of the glass and tip it all upside down, being careful to keep the hanky pulled tight.

5. Choose the member of your family most likely to forgive you if this goes wrong and you soak them...

6. Hold the upside-down glass and plate combo above their head, making sure that the glass is vertical and the hanky is tight. Remove the plate and... voila! The water stays inside the glass.

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From the Institute of Physics

What to talk about:

- With no hanky, what force makes the water fall out of the glass?
- Have you ever seen a bug walk on water?

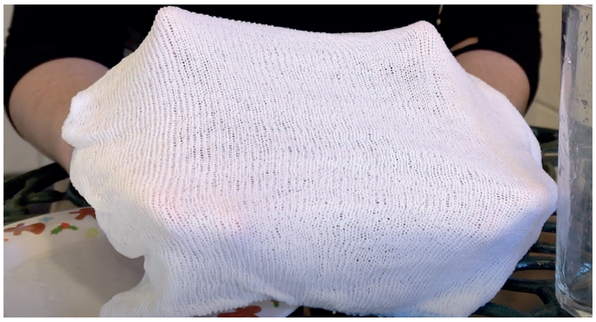
What's going on?

There are three main forces that have an effect when we turn our glass of water upside down. Gravity pulls down on the water, and is the force that makes the water pour out of a glass.

There are also upward forces on the water due to both air pressure, which pushes on everything around us all the time (in this case the air will be pushing up through the mouth of the glass) and surface tension, which tries to hold the water together across the mouth of the glass. Surface tension is what gives water an elastic-like skin at the surface. This elastic skin has real effects – it's what pulls water into droplets like you might see on a spider's web early in the morning, it's what holds up water strider bugs walking across ponds and it's what lets you overfill a glass before it spills.

This trick makes use of the fact that the strength of surface tension depends on the size of the hole; the smaller the hole, the stronger the surface tension. Without a hanky, the hole is large and the surface tension is nowhere near strong enough keep the water together. The upward forces aren't big enough to balance the downward force of gravity and so the water pours out (and as the water moves out of the way, air pressure makes the air rush into the glass to replace the water).

A hanky is made of a material that's woven together and has tiny holes.



Putting one across the mouth of the glass makes the hole through which water is trying to get through much smaller and so the surface tension much stronger. There is a strong stretchy skin across each hole. The surface tension, combined with the push due to air pressure is large enough to balance the force of gravity so that the water stays inside the glass – and you stay friends with your family.

What next?

If you want to investigate further with your family, you can put the strength of surface tension to the test (do this bit over a sink, not over somebody's head!)

- Almost fill a glass with water and put Clingfilm over the rim of the glass. Turn it upside down like you did with the hanky. Of course nothing happens... Clingfilm is waterproof!
- Can your family predict what will happen if you keep it upside down and prick small holes in the Clingfilm with a pin?
- How many small holes can they make without the water escaping?
- How big can you make the hole before water starts to drip through?
- Now that you've found out about surface tension, gravity and air pressure, can you work out what's going on?

Did you know?

The surface tension of water is pretty strong, but it's the element mercury (a metal that is liquid at room temperature) that has the highest surface tension.

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Experiment 3: Shrinking Coin

2D or not 2D, that is the question. To find the answer you'll need to get your family thinking outside the box!

What you'll need:

- 1x small coin like a 1p or €0.10c coin
- 1x large coin like a 2p or €2 coin
- piece of paper (approx 10cm x 10cm)
- pencil
- scissors

What to do:

1. Lay your small coin in the centre of the piece of paper. Trace around it using the pencil.

2. Cut out the centre of the circle so that you're left with a piece of paper with a hole in the centre.

3. Demonstrate that the small coin slips easily through the hole.

4. Challenge your family to get the larger coin through the hole – WITHOUT ripping the paper or altering it in any way. Give them some time to try (it might be a nice idea for each person joining in to have their own coin and piece of holey paper).

5. Show them how it can "really" be done:

6. Take the piece of paper and bend it in half. Hold the paper so that the bend is at the bottom. Drop the big coin between the sides of the paper into the centre of the hole.

7. Grasp the paper between finger and thumb near the bend, on either side of the coin. Slide your fingers upwards around the coin. Allow the paper to buckle around the coin – you don't want to keep it tight all the way around.

8. The coin should now slip through the hole! A top tip for you here though – try to use fresh sheets of paper with each experiment, as the folds you make might give them a clue...

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What to talk about:

This is definitely a challenge and to solve it your family will have to put their problem solving skills to the test. The answer isn't obvious, so how can you help them along the way?

Firstly, work out exactly what the problem is.
So set up the trick – first with the 1p and then 2p piece (or equivalent). See if they can pinpoint exactly why it won't work.

- For our coins it is pretty simple, the 2p coin is too big for the hole!

Now that you know exactly what is stopping the coin, ask your family if there is anything that they can change?

- We can't change the coin, but we can change the paper – ripping it is against the rules but is there anything else they can try?
- Folding it in half turns the round hole on our flat (2D) piece of paper into a slit across the bottom of our folded (3D) one. Of course our problem is still there: the points on either side of our coin are still too close together for it to fit through the slit.

Finally, don't be afraid to be creative! Because we have folded the paper we can now pull these two points apart very gently and the paper will bend to allow the slit to get wider and not tear. The coin slips through, almost like it has shrunk.

Physics is all about understanding our world, and as we solve problems like our shrinking coin we find out a little something more about how our Universe works – and it can be fun too! Who doesn't like to find out how a trick works?

What next?

This is a really nice experiment to try out first with the youngest member of your family. Once they have worked it out, you can put them in charge of the puzzle and they can challenge everyone else with the mystery of the amazing shrinking coin!

Did you know?

There are more dimensions than just the three you are familiar with. Time is sometimes thought of as the 4th dimension.

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Experiment 4: Reversing Arrow

After seeing arrows seemingly change directions in front of their eyes, your family won't know if they're coming or going...

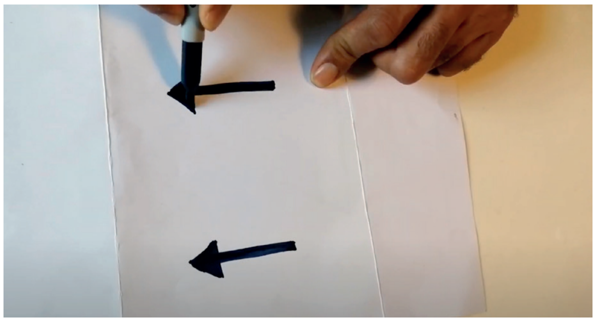
What you'll need:

- A glass or jar with straight sides
- A piece of paper
- A marker pen
- Water in a jug or bottle for pouring

What to do:

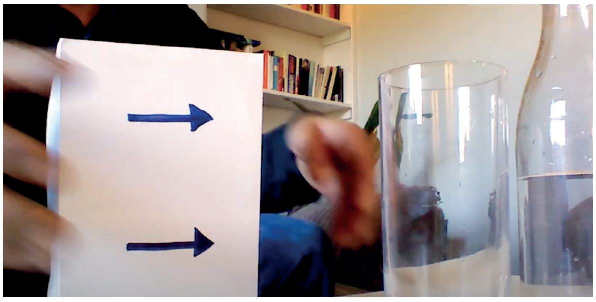
Before setting up this demonstration it's important to know that it only works if you're looking at it from the right place. Set up a chair for your family member so you know where the demo will be viewed from. Now you're ready to get started.

1. Draw two short horizontal arrows, both pointing the same way, on your piece of paper, they should be about as long as your glass is wide



2. Find a way to stand up your paper – fold the sides, lean it against a wall, box or book (etc.)

3. Put the glass in front of your arrows, and pour water into your glass until the level of the water is above one arrow but below the other.



4. Move the glass towards and away from where your audience will be sitting in the chair until you find the spot where the bottom arrow is reversed and the same size as the top one.

5. Once you've worked out where that is, pour the water back into the jug and put the empty glass back into position. You're now set up.

6. Get your audience in position.

7. To perform the trick, all you need to do is pour water into the glass and watch their amazed faces as the arrow reverses before their eyes.

What to talk about

- When you're drinking through a straw, has it ever looked like the top and bottom half don't meet up?
- Have you used a magnifying glass to change the way things look?

Do Try This at Home

From the Institute of Physics

What's going on?

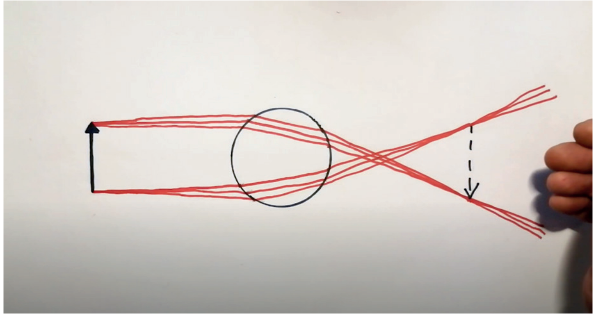
Optical illusions are images or pictures where we "see" something that is confusing to our brains or different to the way it really is, just like our reversing arrow.

Without the glass of water, we see both arrows as they are, pointing left to right. You can imagine light spreading out from the tip of the arrow, travelling in straight lines called rays. Some of the rays reach your eyes, that's how your brain sees where the tip of the arrow is.

However, when we add our glass of water it gets a bit more complicated. Instead of spreading out in straight lines, the light changes direction both when it enters and leaves the glass of water. This change of direction is called refraction and it happens because the light slows down as it enters the glass and speeds up again as it leaves.

To work out the way every light ray turns when it hits the round glass, you can imagine each ray as a car driving from the road onto something more difficult like sand. As the car moves from the road to the sand it will slow down. As one of the front wheels hits the sand before the other, that wheel will slow down first and the whole car will turn towards that wheel. The opposite thing happens as the car leaves the sand and speeds up, the car will turn away from the wheel that hits the road first. The path the light takes changes in a similar way.

Our optical illusion is that our round glass of water ends up changing the path of the rays of light enough for them to cross over and spread back out. Now, for anyone looking at it, it looks like the rays of light are spreading out from an arrow pointing right to left instead. So we are tricked into seeing the tip of the arrow in a different place.



What next?

Investigate together with your family. Discover how what you see changes if:

- You use a bigger glass or one with different shaped sides.
- You move the glass towards and away from the arrows.
- To make yourself part of the experiment, sit somewhere different to look at the illusion from a different place.

Once you've worked out what happens with something simple like an arrow, you can try out different shapes, letters and pictures to see what happens! Can you predict how they will change when you look at them though your water?

Did you know?

Lots of different optical illusions are caused by refraction, from mirages in the desert to swimming pools looking shallower then they really are.

Experiment 5: Wobbly Stick

Explore inertia as you have a friendly competition with your family – who is best at balancing sticks and how can you use physics to win?

What you'll need:

- A stick/ broom/ something long-ish (over 50cm) and straight
- A lump of modelling clay/ plasticine/ blu-tack etc

What to do:

In this activity you'll be trying to balance long sticks on your fingertips. To minimise any breakages in your home we recommend trying the trick outside if possible, or clear yourself as large a floorspace as you can away from valuables!

- To set up the demo, place a lump of modelling clay about the size of your fist around the stick, close to one end. Now you're ready to challenge your family to a balance-off.

- First, hand them the stick with the modelling clay end at the bottom and ask them to try balancing the stick on the tips of their fingers. Maybe time yourselves, to see who can balance the stick the longest.

- Now turn the stick over so the modelling clay is on the top and try balancing again. Does it make a difference to how long you can balance it for?

It should be much easier the further the modelling clay is from your hand.

What to talk about

- Which way up was your stick when you balanced it for the longest?
- Try holding the rod at one end and waving it from side to side. Is it easier to move with the clay end next to your hand or far away?

What's going on?

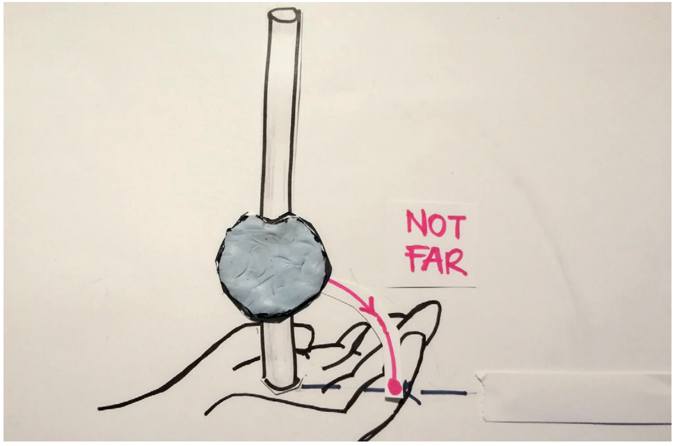
For the stick to stay balanced you need to be able to keep your hand directly underneath the heavy blob of clay. When things are perfectly balanced, gravity is pulling the heavy blob (or mass) straight downwards while your hand is pushing straight upwards to counteract it.

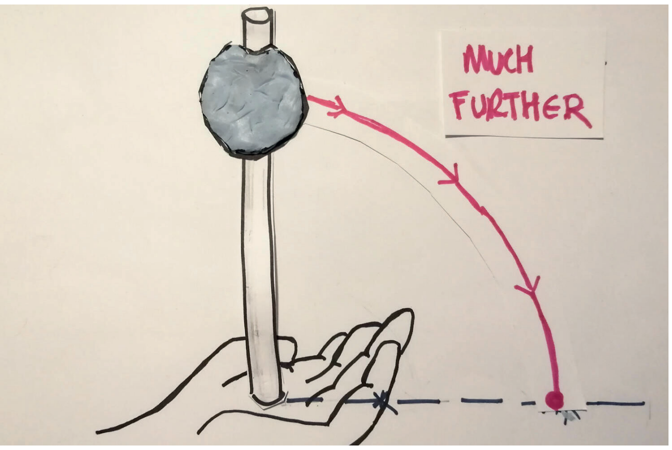
But this can't last. As soon as the rod tips over slightly, these two forces are no longer lined up. Gravity is still pulling straight down on our mass, which makes the stick tip over more and more, faster and faster. To rebalance the stick you have to move your hand directly underneath the mass so the forces line up once more.

With the mass at the top, the stick tips over more slowly. It has to move further and that takes longer than with the mass at the bottom, giving you more time to move your hand. But why?

Do Try This at Home

From the Institute of Physics





The word for how difficult it is to start (or stop) something is called inertia. The harder it is to start something moving the more inertia it has. You will probably have come across this when playing in the park, which until recently was full of moving objects called children. Think of pushing someone on a swing – the heavier they are the harder it is to get them started. Still in the playground but on to the roundabout: if someone wants you to push them it's much harder if they stand near the edge. The inertia of an object moving in a circle depends both on its mass and how far it is from the centre

For our stick and blob of modelling clay, the further the lump of modelling clay is from your hand, the more inertia it has. The stick with most of the mass at the top tips more slowly, is easier to keep balanced and means that you know how to win a balance-off every time.

What next?

With the same materials you can investigate how the balance-ability of the stick changes if you:

- Try using larger or smaller lumps of modelling clay.
- Try moving the mass to different places along the stick, not just the ends.
- If you want to go further, you can do some more experiments together testing out the inertia of different things. Maybe try using your wobbly stick to help you balance on one leg!

Did you know?

Tightrope walkers use the physics in this experiment when balancing. By holding a long pole as they walk along the rope they have more time to rebalance if they wobble.

Do Try This at Home

From the Institute of Physics

Experiment 6:
Milk Carton Sprinkler

An amazing invention that will make watering your plants a breeze and leave you dizzy with excitement! You'll never look at a milk carton the same way again...

Warning: This experiment uses scissors to poke holes in cardboard – please be careful and closely supervise any young people doing this experiment.

What you'll need:

- A piece of string (how long is up to you!)
- An empty juice carton / plastic milk bottle
- A pair of scissors
- Water
- A washing up bowl / or just a regular bowl

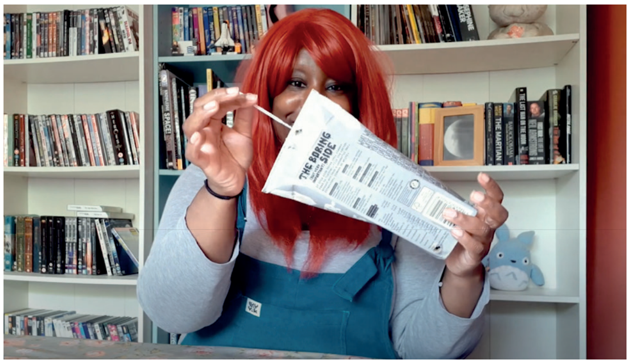
What to do:

Make sure you supervise this experiment very carefully. Not only will you be using sharp scissors as a stabbing tool, but there's also the risk of getting water absolutely everywhere. You might need to do some of these steps either with (or for) your family, depending on their ages and how sensible they are.

1. Take your scissors and carefully poke a hole in the bottom left corner of each side of your juice carton – or you could do bottom right if you feel strongly about it, as long as you're consistent.

2. Poke another hole in middle of the top flap. If you have a hole punch, it might work a bit better than scissors for this one.

3. Thread your string through the hole at the top of your carton and tie a knot so you can hang it up later.



4. Now head to your designated sprinkle zone (somewhere outside or the bathroom – water will go everywhere!).

5. Put some water in your bowl, stand the carton in it and then fill the carton up with water.

6. Lift the carton up, watch (and maybe get out of the way) as it starts to spin.

7. Wonder why you ever spent money on a watering can.

Do Try This at Home

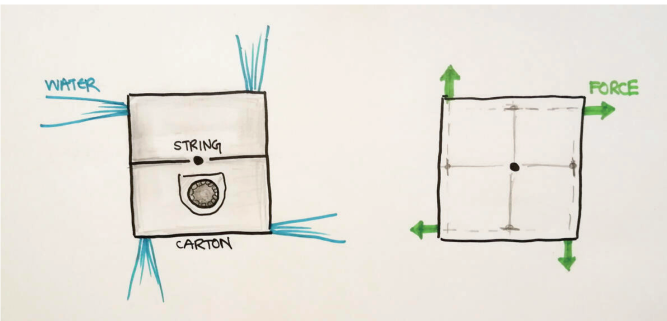
From the Institute of Physics

What to talk about:

- Why do you think the water squirts out more slowly as the carton empties?
- Have you seen anything else that spins around like this? What was pushing it around?

What's going on?

The water at the bottom of the carton is under pressure because the water above it is pressing down on it due to gravity. Without any holes, the water at the bottom of the carton pushes outwards equally on all sides. When you make a hole, the water squirts out, so it isn't pushing on that part of the carton anymore – but on the opposite side of the carton there's still a pushing force.



It's important that the holes are in the corner, not the middle of each side. Making the holes off-centre makes the pushing forces off-centre as well. The turning effect of a force is called a moment and the bigger the distance of the force from the turning point (string), the larger the moment. You'll have seen moments in action before – they're what make windmills turn and Catherine wheels spin.

The experiment also illustrates an important difference between solids and liquids. If we filled the carton with water and froze it, no water would come out of the holes and the carton wouldn't spin at all. That's because ice is a solid and that means all of the very tiny particles that make it up (water molecules) are stuck together tightly. When water is a liquid, the molecules can slide over each other and so rush out of the holes.

What next?

If you have enough cartons you can have a go at modifying and perfecting the design of your sprinkler. Think together about what would happen if:

- You added more holes
- You changed the pattern of holes on each side
- You use a different shaped carton
- You made your holes bigger or smaller

Did you know?

There was a physicist called Richard Feynman who built a sprinkler that sucked in water instead of pushing it out, because he wanted to find out what would happen. The sprinkler exploded because the pressure inside became too high.

Experiment 7: Rocket Balloon

If you've ever wanted to boldly go to infinity and beyond, or to a galaxy far, far away, you can start by sending balloons across your living room to find out how a rocket works!

What you'll need:

- A balloon (any shape or size)
- String (a few metres)
- A straw (we've used a paper one)
- Tape and scissors
- Clothes peg (optional)

What to do:

Before you start, decide how far you'd like your string to span, whether it's all the way across the room or less. Choose a location so that everyone in your family will be able to see your rocket balloon fly!

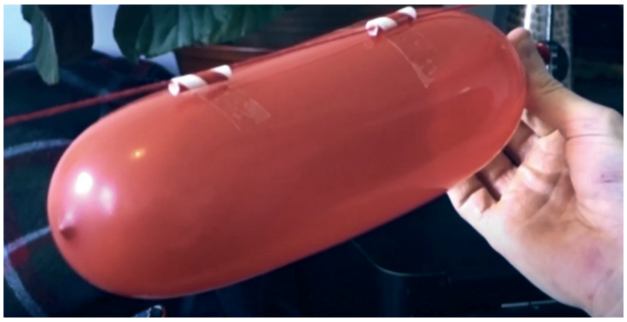
1. Cut the string to the right length that you decided above (but don't tie it yet!)

2. Cut your straw in half so you have two short lengths of straw.

3. Thread the two bits of straw onto the string and then tie the string to two secure points somewhere in the room. When you tie it make sure the there's a little bit of tension in the string so it's nice and taut.

4. Cut two short lengths of tape and place the middle of them on each bit of straw. These will hold the balloon in place.

5. Blow up the balloon, but don't tie it off. Hold the end closed with one hand, or use a clothes peg, and stick it to your two bits of straw (get a helper for this bit if required).



6. Start your countdown and let go when you reach zero. We have liftoff!

What to talk about:

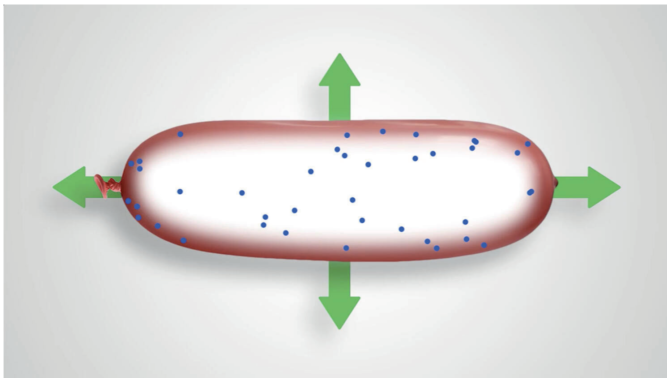
- Which way will the balloon go when I let go?
- In which direction does a real rocket start moving when it launches? What about the fuel?

What's going on?

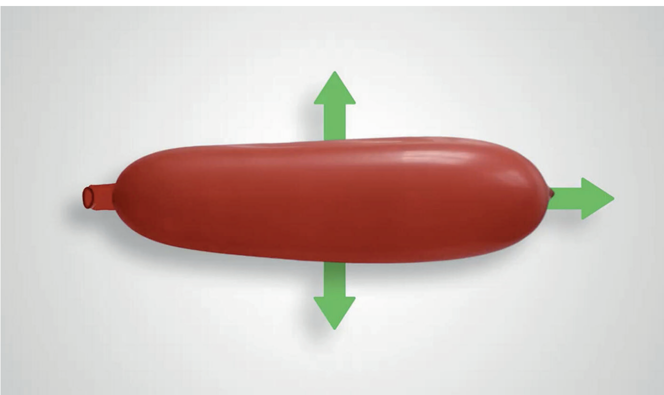
A rocket is a vehicle that carries everything it needs with it. Our rocket balloon carries air inside it and that's what makes it go.

To inflate the balloon you have to blow pretty hard. This is because once you put some air inside, it starts pushing back against you.

Air is made up of particles called molecules, moving around in all directions and at very high speeds. They push against anything they bounce off. When the balloon is inflated and closed off, there are loads and loads of air particles trapped inside. They're whizzing about, crashing into each other and the insides of the balloon. All these tiny pushes add up to a force that is large enough to hold the balloon in its round shape. The air particles push equally to the left, right, up and down. Overall the forces cancel each other out, they are balanced forces and that's why the balloon stays where it is.



When you let go, the air can't push on the part of the balloon where the opening is. There's nothing to push on. But on the opposite side, inside the balloon, the air is still pushing. The left and right forces aren't balanced anymore, and it's this unbalanced force – due to the air particles bouncing off the front the balloon – that sends it forwards.



Real rockets use fuel, but they work on the same principle called Newton's third law of motion. You may have heard "for every action there must be a reaction", which means that it's impossible to move in any direction without pushing something else in the opposite direction. Our balloon rocket moves air backwards for it to move forwards. In a real rocket, the rocket must push fuel downwards (very quickly) to start moving upwards.

What next?

You could challenge your family to design the perfect rocket balloon. Here are a few top tips to get you started:

- Try changing the shape of the balloon
- Try using larger and smaller balloons
- Can you change the way the air comes out? Maybe try taping an extra piece of straw into the opening
- Can you change the direction the air comes out? Try taping the balloon so that the neck of the balloon isn't totally lined up with your string.
- Once you've perfected your living room design, can you find a way to launch your balloon straight up like a real rocket?

Did you know?

The Russian Soyuz programme is the longest running and most successful way of getting rockets into space. The programme has been going since 1967 with over 1680 successful launches!

Do Try This at Home

From the Institute of Physics

Experiment 8: Hot Water Rising

We're sure that this experiment will float your boat! Discover why a difference in temperature makes hot water rise in this colourful balancing act.

What you'll need:

- Four identical see through bottles. If you can only find two, just do it twice! These can be made from glass or plastic but be very careful if using glass as there is a risk of dropping or breakage
- Jug of cold water from your cold tap
- Jug of hot water from your hot tap (run until it is hot, not just warm)
- Food colouring. Two colours would be great, one is fine
- Teaspoon
- Funnel/large straw or just steady hands
- Scraps of thin card. If you don't have thin card, paper works better than thick card
- Sink or waterproof tray in case it all goes wrong (or do it outside)

What to do:

In this activity you'll be tipping bottles of water upside down and then trying to balance them. There will be some spillages along the way but we don't want any breakages so we recommend doing this in a bowl, sink or using plastic instead of glass. Finally, the demo needs hot water, but this should never be boiling or hot enough to burn, out of the tap works just fine!

1. Choose different food colouring for your hot and cold water.

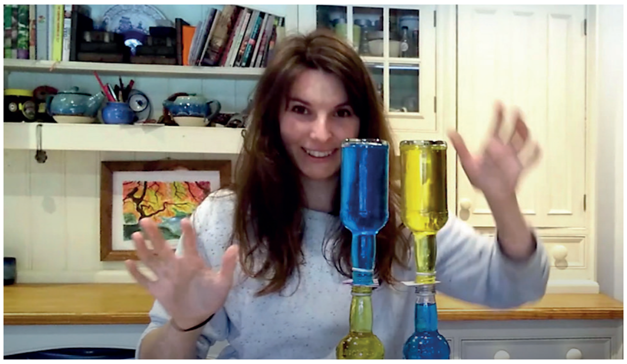
2. Add a small amount of food colouring to your water jugs. Give each jug a good stir with a spoon. We used blue for our cold water and yellow for the hot water – if you only have one food colouring, leave one pair of water bottles uncoloured.

3. Fill two bottles all the way to the top with cold water and two to the top with hot water. Use the funnel if you need to. (You might want to do this in the sink or the drip tray in case there are drips from your jug).

4. Put one hot water bottle and one cold into your drip tray/sink.

5. Put the card over the top of your hot water bottle. Holding the card in place, flip the bottle over and then balance it on top of your cold water bottle.

6. Do the same with your cold bottle, balancing it on top of the hot water bottle.



7. Carefully remove the cards separating the bottles, making sure that the bottles stay balanced. Get some help for this bit if you can!

8. You now have two experiments going at the same time:

9. Be amazed as the water mixes extremely quickly in one set of bottles.

10. Be surprised as the water forms perfect layers that don't mix at all in the other.

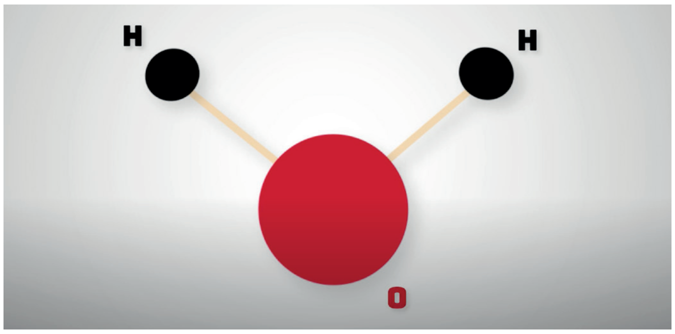
What to talk about

- Why do you think some things float and others sink?
- Why does rice rise and fall when you cook it?

What's going on?

If you've been swimming, you may have noticed that the water near the surface is warmer than the water deeper down. This is because the warm water is less dense and it floats on the cold water – in the same way that a cork floats because it is less dense than water.

So, why is the warm water less dense? Water is made of molecules (H20).



The temperature of the water is a measure of how fast they move and its density tells you about how tightly the molecules are squished together. If we could zoom in far enough we would see the water molecules wobbling and moving. The higher the temperature, the more they move and the greater the average distance between them. The molecules in water at 60°C (which feels hot) are more spread out than the molecules in water at 10°C (which feels cold) making the warm water less dense.

What about our experiment? In the pair of bottles with hot water at the bottom, the cold water sinks and the hot water rises so that it floats on top. In the process the two mix. In the pair of bottles with the cold water on the bottom there is no movement because the cold water has nowhere to sink to, so everything stays in perfect layers.

The movement in any liquid or gas due to a temperature difference is called convection. It is the same process that makes the grains of rice rise and fall when you cook them; rice is carried upwards by hot water rising and downwards as the water at the surface cools and sinks. Convection is also the process that makes smoke rise out of chimneys and how your central heating warms up a whole room, not just the air next to the radiator!

What next?

Once you've perfected balancing bottles, you could raid your kitchen cupboards for some more convection experiments.

- Try adding coloured hot water to an empty spice jar (the ones with the sprinkle top) and drop it to the bottom of a bowl of cold water. You can watch the hot water rise out of the spice jar in front of your eyes.

- Have a couple of different temperatures of water, from ice cold through warm to hot and mix a different colour into each. Try the bottle experiment again, with the different temperatures of water. How big does the difference in temperature need to be before convection starts to occur and the colours mix?

Did you know?

Even though it has a pretty dramatic effect, the difference in density between cold water at 10°C and warm water at 60°C is less than 2%.

Experiment 9: Electric Balloons

We're sure this electrifying demo will be a positive experience for you and your family. Find out about electric charges and how they can be used to attract and repel. We hope it doesn't rub anyone up the wrong way…

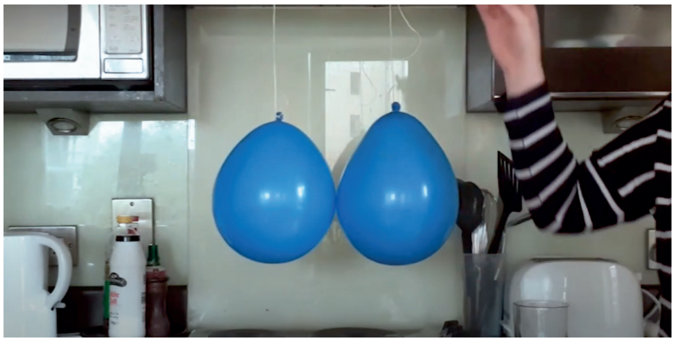
What you'll need:

- Two balloons
- Sticky tape
- A woolly jumper or glass
- Ball of string/ wool/ thread
- Someone with a full head of hair (optional)

What to do:

This experiment works best on a dry day. Water vapour in the air makes the balloons discharge as you're trying to charge them, so for this experiment humidity is definitely the enemy!

1. Inflate the balloons and tie them off.
2. Tie string around the knot of each balloon.
3. Find somewhere in your house to tape the balloons up so that they have space to move and so that your family can reach them. You might need to adjust this bit based on the heights of your family, so make sure you have enough string.
4. Tape the balloons so that they just touch when you let them hang straight down.



5. On the spot where the balloons have just been touching, rub each balloon on your jumper or a glass or even your hair. In fact, it's a good idea to rub them all over just in case the balloons twist or turn in mid-air.
6. Notice that where the balloons were touching, they aren't any more. You can even push one balloon towards the other and the other one will move away.

What to talk about

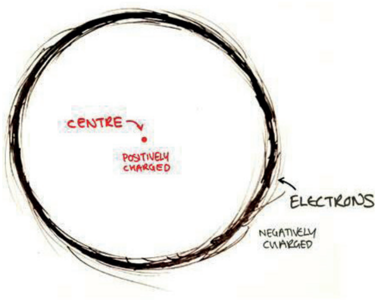
- Have you ever seen someone make their hair stand up by rubbing it with a balloon before?
- If you listen closely to the balloons can you hear them crackle? What do you think could be making the noise?

What's going on?

Everything is made up of atoms that have a positively charged centre and negatively charged outside made of particles called electrons. Each atom has the same amount of positive and negative, so usually the charges cancel out and we don't notice them.

Do Try This at Home

From the Institute of Physics



When you rub two things together you can move the negatively charged electrons from one material to another. Some materials are more likely to lose their electrons than others, in our experiment the rubber balloon is much better at holding onto its electrons than the other materials, so as the balloon is rubbed it gains electrons and the thing doing the rubbing loses them.

As the balloon gains more and more electrons it ends up with a negative electric charge. The glass/jumper/hair in our experiment has lost its electrons so now has the opposite charge – a positive electric charge.

Opposite charges attract and so there's a small force that pulls the balloon towards the jumper or glass. If you rub a balloon against your hair and then lift it up, the attractive electrical force is large enough that it can overcome the force of gravity pulling down and it becomes a hair-raising experience!

When you rub both balloons, both end up with negative charge. Similar charges repel so the balloons push away from each other. You can even use one balloon to push the other around!

Finally, there needs to be a way for all those extra electrons to discharge somehow. In physics this is called earthing or grounding, and works by providing a path that the extra electrons can travel along to the ground. This can either be by touching the balloon to the ground directly or touching it to something that electrons can travel through, like your body or the water in the air.

What next?

If this experiment has sparked your curiosity here are a few more things to try:

- Now that you know that opposites attract, try charging up a balloon using different materials and see how long and how well it sticks.
- Experiment with grounding the balloons. How long does it take for the balloons to discharge and come back together if you:

- Don't touch them at all
- Flick or spray water into the space between the balloons
- Touch each balloon with your finger once?

Did you know?

The ancient Greeks rubbed amber with fur to investigate what happened. That's where the negatively charged particles gets their name. In ancient Greek, the word for amber was "elektron".

Do Try This at Home

From the Institute of Physics

Experiment 10: Vanishing Coin

We can all make money disappear, but your family won't believe their eyes as a coin vanishes right in front of them in this experiment. You'll leave them wondering whether it was all just smoke and mirrors...

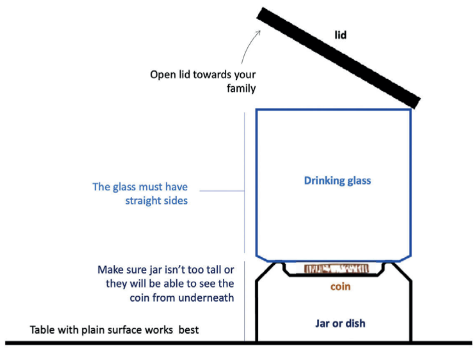
What you'll need:

- A glass with straight sides
- Small jar or dish with a dip in the bottom (a concave part) – a ramekin is ideal
- A coin
- Water
- Jug for pouring
- Lid for your glass (can be anything to cover the top)
- Tea towel/ drying cloth

What to do:

Before setting up the trick, it's important to know that it only works if you're looking at it from the side (not the top) so set up a chair for the members of your family you want to amaze and astound. Now you're ready to get started.

1. To measure how much water you need, fill your glass all the way up with water then pour carefully into your jug.
2. Dry off your glass inside and out. Now you're set up.
3. Get your family into position and introduce your trick.
4. Place the small jar upside down and the coin on top.
5. Place the glass on top of that. There should be a gap of air between your coin and your glass but your family should be able to see the coin. Make a big deal about how you can make it disappear.
6. Hold the lid open - but make sure your family can't see through the top of the glass. Here's how it should look:



7. Carefully pour the water into your glass all in one go and drop the lid. Your coin should have vanished from view!
8. Once your family have recovered from the shock, lift the lid.

What to talk about:

- Have you ever noticed seeing reflections in a glass or a window?
- What do you notice about the coin you can see in the side of the glass from the top?

What's going on?

Making the coin disappear might seem like magic, but like many optical illusions it only works if you're looking at it from a specific angle.

When you look at a coin normally, you can see it because light bounces off it in all directions and some of that light travels in a straight line to your eye.

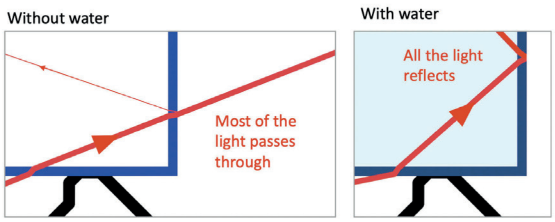
In the first part of the trick, with the coin underneath the empty glass, things are a little bit more complicated. Light bouncing from the coin now has to travel through the air, the bottom of the glass, the air again, the side of the glass and – finally – though the air to your eyes. Each time the light goes from one material to another it changes direction but most of it still gets through and so your family can still see the coin.

But only most of the light reaches your family, a small amount will be reflected off the side of the glass instead, bouncing back inside the glass and not reaching your eyes.

Whether the light travels through a material or gets reflected depends on the angle the light is travelling at and the materials it is travelling between. That is why adding water to the glass is the final stage to our trick. The light from the coin at the bottom now has to travel through:

1. The air
2. The bottom of the glass
3. The water
4. The side of the glass
5. The air again to your family

But the water changes the angle enough that instead of leaving the glass all of the light is reflected. When 100% of the light reflects in this way it's called total internal reflection.



With the glass filled all the way to the top, none of the light from the coin at the bottom can escape through the sides. It's trapped. It can never reach your eyes and so the coin seems to vanish.

Of course, this only works if you're looking through the side of the glass. We need a lid for the top so no one can see in. This is also why you need a straight edged container; the size doesn't matter, but it can't have any curvy bits or the light can "leak" out.

Knowing the physics behind what's going on will help you set everything up, and soon you'll have all your family wanting to know the secret of the vanishing coin. Lifting the lid gives a clue – there's a very clear reflection of the coin and if they look closely the writing is back to front. Our five layers combine to make the perfect mirror.

What next?

Once you've perfected the vanishing coin, there are a few extra things you can try out:

- Find the tallest straight-edged glass in the house. How many reflections of the coin can you see?
- Remove one of the air layers by filling the dip in the jar with water (the coin reappears) or run a wet finger behind the reflection of the coin (the reflection disappears).
- Replace the coin with a torch. Switch it on and off. Where does the light come out?

Did you know?

The cables used for high-speed broadband work in the same way, but without the water! Optical fibres are made of two different types of glass so that a light switched on and off at one end can be used to send a message over long distances to the other (a bit like Morse code).

Do Try This at Home

From the **Institute of Physics**

Experiment 11: Toilet Roll Solar System

This is the perfect activity for anyone that loves space – prepare to have your mind blown by the incredible distances between the planets!

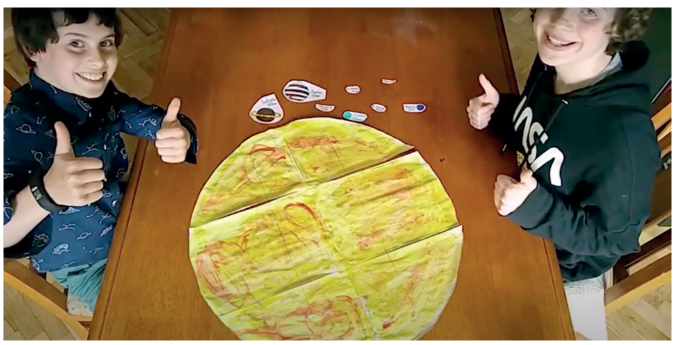
What you'll need:

- A fresh roll of toilet paper with at least 150 sheets
- Felt tip pens or colouring pencils
- Ruler
- 6 sheets of A4 Paper
- List of planet sizes and distances (below)

What to do:

1. Build your worlds

a. This activity takes the 4.5 billion kilometres from the Sun to Neptune and squishes them onto a single loo roll. On this scale most of the planets are too small to see (and draw) – so we've cheated and made them 100 times larger than they should be.



b. Make your planets using the cut-offs using the guide below. Colour in and label each planet.

Planet	Diameter	Colour	Number of toilet roll sheets from the Sun
Mercury	2mm	Brown	2
Venus	5mm	White	$3^{1/2}$
Earth	5mm	White	5
Mars	3mm	Red	$7^{1/2}$
Jupiter	62mm	Brown stripes with a red spot	26
Saturn	50mm	Brown with rings	$47^{1/2}$
Uranus	20mm	Light blue	95
Neptune	20mm	Dark blue	149

2. Build your Solar System

a. Start with the Sun, and place the loo roll at the edge. The start of the toilet paper is the start of space.

b. Unroll the loo roll and stick down Mercury at the right distance from the Sun (2 sheets).

c. Then do the same for all the other planets. Remember to keep track of how far you've gone!

d. Roll up your Solar System and treasure it forever.

What to talk about:

- We've gone as far as Neptune. Have you heard of anything further away?
- Do you have a favourite planet? Why is that?

What's out there?

At the middle of the Solar System is our Sun, a very ordinary star about halfway through its lifetime. The Sun accounts for 99.8% of all of the mass in the Solar

System. But the Solar System is so much more than the central star. It has planets, dwarf planets (such as Pluto), loads of moons and millions of asteroids, comets and more. So let's head out:

Mercury is the first and smallest of the planets. It's just bigger than our Moon and covered in craters.

Venus is next. It's another rocky planet with a thick poisonous atmosphere – temperatures here can reach over 470 0 C, which is about the temperature of a pizza oven.

Third rock from the Sun, our home. **The Earth** is a little bit bigger than Venus and we're just far enough away from the Sun for water to be a liquid.

Moving on to **Mars** – the final rocky planet. It's about half as wide as the Earth and it's the next place that we humans would like to visit. On average it's a chilly -63 0C with ice caps made of solid carbon dioxide.

Leaving these small inner planets behind, we travel though the **asteroid belt**. This is a lot of space rubble – we know of nearly one million asteroids and they range in size from tiny to hundreds of miles across!

The next planet is **Jupiter**. The first of the gas giants, and it really is giant – over 11 times as wide as the Earth and has a mass that's 2.5 times that of all of the other planets put together!

Moving on again we have another gas giant, **Saturn**, the second largest planet in the Solar System – the lord of the rings. It isn't the only planet to have rings, but it definitely has the most beautiful ones, made from chunks of ice and rock.

Six planets down and two to go. These final outer planets are called that for a reason. It took the Voyager spacecraft five years to travel this distance.

Uranus is a type of planet called an ice giant and it was the first planet to be discovered using a telescope. It's sometimes called the sideways planet, because instead of its North and South poles pointing "up" and "down", one points towards the Sun and one points away.

And finally **Neptune**, the last planet in the Solar System, is about the same size as Uranus. It's another ice giant surrounded by supersonic winds, Neptune has only travelled around the Sun once since it was discovered back in 1846!

But the Solar System doesn't stop there. Up next is the **Kuiper belt,** an outer asteroid belt, filled with icy space debris. Even if you haven't heard of it, you will have heard of the most famous denizen of the Kuiper belt, the dwarf planet **Pluto**.

Finally we have the **Oort cloud**, which astronomers have predicted, but nobody has actually seen. We think these far away reaches of the Solar System are home to icy lumps of rock that stretch out a quarter of the way to the next closest star, over 3,000 times further from the Sun than Neptune.

What next?

Remember that the Sun and planets are all 100 times too big for the toilet paper. Why not make everything to the right scale by going for a 2km walk or bike ride?

- Make an extra set of planets exactly the same size as above
- Start at your house or a local landmark
- Plan your route using the Solar System Scale Model Calculator : **https://thinkzone.wlonk.com/SS/SolarSystemModel.php**

Did you know?

More than 300 spacecraft have travelled beyond the orbit of the Earth, but only two have left the Solar System. These spacecraft, called Voyagers 1 and 2, have been travelling constantly since they were launched over 40 years ago.

Do Try This at Home

From the **Institute of Physics**

Experiment 12: Ping Pong Pick-Up

Try this game whenever you need a "pick-me-up"! Lift your spirits at the same time as your ping pong balls as you challenge your family to... Ping Pong Pick Up!

What you'll need:

- A large, empty plastic bottle – we've used a two litre fizzy drink one
- Scissors
- Sticky tape
- A marker pen
- A bowl
- A few ping pong balls / anything small and round
- A mug (or anything circular to draw around that's wider than a ping pong ball but not as wide as the bottle)

What to do:

Make sure you supervise this experiment very carefully. We're using sharp scissors as a piercing tool – combined with the risk of ping pong balls flying everywhere. You might need to do some steps either with (or for) your family depending on their ages and how sensible they are.

Before you can start to play, you need to make your "picker-upper":

1. Turn your bottle upside down and put it in the mug. Using the mug as a template, draw a circle on your bottle in marker pen and take the bottle out again.

2. Cut along the line you've drawn. To get started you have to stab a hole in the bottle first using the pointy end of your scissors. An adult should definitely do this part.

3. We're only using the bottom of the bottle – it should look like a tall container with a small curved lip. If you've made any sharp or jagged edges with your scissors, cover them up with sticky tape so that your "picker-upper" is safe to hold and use. Now you're ready to play Ping Pong Pick Up.

Playing the game:

4. Challenge your family to pick up the ball without touching it or turning the bottle, and then drop it into the bowl. Once they've tried – show them how it's done.

5. With the ball on your table, grip the picker-upper firmly. Put it over the ball and start moving the bottle in small, fast circles.

6. Once you've got the ball spinning, lift it up (anyone else in the room should watch out for flying ping pong balls in case it goes wrong!) and drop it into the bowl.

7. And then it's a case of practice makes perfect! The challenge is to get the ball as quickly as possible from table to bowl.

What to talk about

- Does the picker-upper have to be a special shape for it to work?
- What happens if your hand gets tired and you slow down?

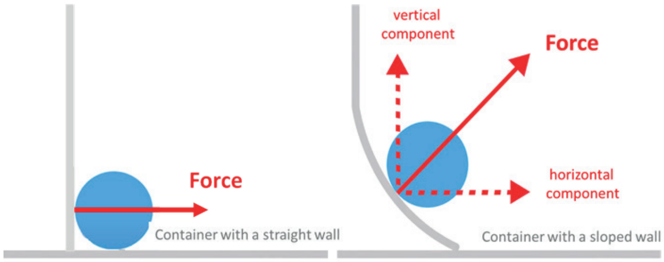
What's going on?

It's the shape of the ping-pong-picker-upper that's at the heart of this challenge. You can't just use anything!

Think about a ball moving around inside a straight-sided container like a plastic glass. As it spins, the ball wants to fly out but the glass won't let it. As it presses on the inside wall of the container, the wall pushes back and it is this force that makes the ball goes around in a circle. But a straight-sided container can't pick up the ball, it only pushes inwards. To lift the ball, we need an upward push to overcome gravity.

Our picker-upper has sloped walls and that's why it works. The push of the wall on the ball is diagonally upwards and we can think of this force as having two parts: an inwards part that makes the ball go around in a circle, and an upwards part that balances the downward pull of gravity.

The upwards and inward parts are called the vertical and horizontal **components**. If you keep the ball spinning quickly you can balance gravity using the vertical force component.



What next?

The game should work with any round object inside a container with a mouth narrower than its body. You could:

- experiment to see how high you can lift the ping pong ball
- challenge yourself by moving your bowl further away or using a smaller container for drop off
- challenge the adults in the house to a game with wine glasses and Maltesers

Did you know?

As part of their training, astronauts are spun just like a ping pong ball in a picker-upper. The sideways push of the wall recreates the large forces they experience when launching into space.

Do Try This at Home

From the Institute of Physics

Experiment 13: Bouncing High

In the last experiment in this collection, we hope it will put a spring in your step... but hopefully not a hole in your window!

What you'll need:

- Some eye protection (swimming goggles, sunglasses, anything will do!)
- A basketball or football, make sure it is fully inflated
- A tennis ball
- A hard surface, preferably outdoors, without anything breakable around you

What to do:

In this activity you'll be using your basketball to launch the tennis ball high into the air. To minimise any breakages in your home we recommend trying the trick outside (or try our suggestions for a more indoor friendly version further down).

1. To start, drop the tennis ball from shoulder height – make a note of how high it bounces back up.
2. Then do exactly the same with the basketball.
3. For this next bit, you'll need to put on eye protection and ask everyone to step back. Make sure you line up the centre of the balls so that the tennis ball is exactly on top of the basketball.
4. Give a dramatic countdown and let them go at the same time so that they drop straight downwards.

5. Be astounded by how high the tennis ball flies!

What to talk about:

- Which bounced higher when dropped by itself, the tennis ball or the basketball?
- When you dropped the balls together, which bounces first: the basketball or the tennis ball?

What's going on?

To start off with the balls are dropped separately, so let's think about what happens to them during their journey down to the Earth (another massive round ball) and back up.

If they were dropped from shoulder height at the same time, gravity pulls down on both and so makes them get faster and faster so that they reach the Earth at the same time, with the same speed. They bounce because the collision with the Earth squashes them and as they spring back into shape they launch themselves upwards.

Each ball then travels upwards, slowing down as gravity pulls on them, until they momentarily come to a stop at the top of the bounce. For the tennis ball this is about half the height it was dropped from, and for the basketball it's a bit higher.

Do Try This at Home

From the Institute of Physics

So what's different when you drop the tennis ball on top of the basketball?

On the way down there is no difference. The balls fall together and both reach the same speed as before. However, the basketball bounces first. It bounces off the ground and so is moving upwards when the tennis ball bounces off it.

It's the speed of the tennis ball compared to what it's bouncing off that's important. This is called the **relative speed**. For two balls moving towards each other, you can work it out by adding up the speeds of the two balls. The tennis ball bounces higher because the relative speed when it bounces off the basketball is almost double that for when it hit the ground.

What next?

There are lots of different ways to mix this experiment up.

- Try the experiment again, but this time watch what happens to the basketball (you can't get something for nothing!)
- Try three balls stacked on top of each other: ping pong ball on tennis ball on basketball (definitely do this one outside).

If you don't have the space outside, try our indoor version using:

- A ping pong ball for the top ball
- A golf ball or tennis ball for the bottom ball

Did you know?

Dropping balls stacked up like this (from heaviest to lightest) is called a Galilean cannon. The world record for the highest bounce from a Galilean Canon currently stands at 13.08m!

We hope you have enjoyed this series of Do Try This At Home!
Visit the IOP website for more fun things to do with your family:

https://iop.org/explore-physics

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