PHYSICS TO GO

The following short experiments are written for students to follow. The explanation of the science behind the experiment follows each set of instructions, However, you may want to cover this section up when you are photocopying the pages for your class.

Videos showcasing most experiments can be viewed at physics.org by following the link at the top of each page.

Experiments

education@iop.org

www.physics.org/interact/physics-to-go/alka-seltzer-rocket

ALKA-SELTZER ROCKET

01

Turn simple, familiar household ingredients into an awesome rocket.

What to do:

1. Break the Alka-Seltzer in half and place half in the film canister.
2. Add about 1 cm of water.
3. Fit the lid onto the canister, making sure that the seal is tight.
4. Turn the canister upside-down and place it on a flat surface.
5. Stand back.

You will need:

- an empty film canister
- an Alka-Seltzer tablet
- some water

Tips for success

Make sure that the film canister lid is tightly fitting or you will only get a disappointing “fizz”. You should also clean the canister lip and lid between launches so that no pieces of Alka-Seltzer get stuck between them, ruining the seal. You will need to stand well back when your rocket launches.

What’s going on?

When water is added to the Alka-Seltzer tablet, bubbles of carbon dioxide gas are given off. When the lid is fitted tightly to the canister, this gas is contained in an enclosed space. As more gas is given off, the pressure inside the canister rises until there is enough force to overcome the seal of the lid. The built-up pressure exerts enough force to shoot the canister into the air, creating a rocket.

Did you know?

The Chinese began building chemical-powered rockets as long ago as the 1150s. One of the great pioneers of modern rocketry, N I Kibaltchich, was executed in 1881 after manufacturing the bomb that was used to assassinate Tsar Alexander II.

www.physics.org/interact/physics-to-go/waterproof-hanky

WATERPROOF HANKY

02

This is a great excuse to threaten to pour water over your friends, but with a surprise twist, thanks to physics.

What to do:

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

2. Pour water into it, through the loose hanky. Make sure that everyone can see the water easily passing 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. Secure it with an elastic band.

4. Place the plate on top of the glass and tip it all upside-down, making sure that the hanky is pulled tight.

5 Choose a likely suspect from your audience to threaten with a drenching. Hold the upside-down glass and plate above their head, making sure that the glass is vertical and the hanky is tight. Remove the plate and... nothing happens – the water stays inside the glass.

You will need:

- a large, sturdy plastic glass
- a small plastic plate
- some water
- a hanky or dish cloth

Tips for success

Don't try to substitute a paper tissue for the handkerchief because it won't work. If the glass isn't held vertically, some water may dribble out at the edges.

What's going on?

This experiment is based on surface tension. When the hanky is loose, the water can pour through the gaps in the fabric. However, when the hanky is pulled tight, the water molecules can form a single surface or membrane across the material. At the same time there is a pressure difference between the inside and the outside of the glass. The pressure of the atmosphere surrounding the glass is greater than the pressure inside, and this helps to hold the water inside the glass.

Did you know?

Galileo was among the earliest to demonstrate the existence of surface tension in water by showing that an iron needle will float lengthways on water, but not on its point.

www.physics.org/interact/physics-to-go/straw-oboes

STRAW OBOES

03

A noisy, amusing demonstration of the physics of music.

What to do:

1. Flatten one end of a straw about 2 cm from the end to the tip.
2. Make two cuts in the now flattened end of the straw to form a triangular tip.
3. Insert the triangular tip of the straw into your mouth and blow hard. You should hear a loud "buzzing" sound.
4. While blowing on the straw "oboe", get a volunteer to cut the straw shorter – about 1 cm at a time. With each cut you will hear the pitch of the sound go up.

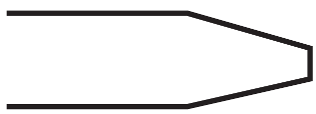
You will need:

- some new plastic straws (which need to be straight - cut off the bendy bits, if there are any)
- a pair of clean scissors

Tips for success

It can take some practice to get the right sound. If it doesn't work straightaway then slowly move the straw in and out of your mouth while still blowing, until you hear the sound. It may help to press down on the straw with your lips or teeth.

Remember to tidy up afterwards and put all used straws and bits you've cut off in the bin.



The tip of the straw oboe

What's going on?

The flattened triangular tip acts like the reed found in most wind instruments. Blowing on the reed causes the straw to vibrate. A standing wave pattern is created along the length of the straw, which we hear as sound. As you shorten the straw you shorten the wavelength of the standing wave pattern and increase the pitch of the note.

Did you know?

As long ago as the 5th century BC, Pythagoras and his followers were experimenting with standing waves and calculating the values of their harmonics. Another way to set up a standing wave is to blow across the top of a bottle filled with water. The note gets deeper as you empty the water out.

www.physics.org/interact/physics-to-go/cloud-in-a-bottle

CLOUD IN A BOTTLE

04

Now you see it, now you don't.

What to do:

1. Place a splash (~1 teaspoon) of water into the plastic bottle.
2. Light the match and make sure that it is burning well, then drop it into the bottle.
3. Quickly screw the cap on, and squeeze the bottle with your hand five or six times (for larger bottles you may have to do this more). You should see a cloud form in the bottle, then magically disappear when you squeeze it.
4. Pass the bottle round to give everyone a chance to experience it for themselves.

You will need:

- a 2 litre flexible plastic bottle with a cap (e.g. from most fizzy drinks)
- some water
- a safety match

Tips for success

Try adding a small amount of food colouring to the water. This can help to increase the visibility of the effect.

What's going on?

Clouds are formed when water droplets in the air cool and then collect on dust particles.

In this demonstration the dust particles are provided by the smoke from the match. The amount of air is constant, but squeezing the bottle raises the temperature and changes the volume of the gas, while letting the bottle expand causes the air temperature to drop.

In this case the drop in temperature is enough to cause the water gas to form a liquid – the cloud.

Did you know?

This demonstration involves building a small cloud chamber exactly like those used to record the tracks of subatomic particles (alpha and beta radiation) by Charles Wilson in 1911. He was awarded the Nobel Prize in 1927 for this discovery.

www.physics.org/interact/physics-to-go/lifting-lemon

LIFTING LEMON

05

Levitate a slice of lemon using a few simple ingredients.

What to do:

1. Pour water into the bowl until it is about 1 cm deep.
2. Push three matchsticks into the slice of lemon in the shape of a triangle, with the match heads together at the top to form a pyramid.
3. Place the lemon and matchsticks in the centre of the bowl, floating on the water.
4. Light the fourth match and use it to light the other three together.
5. Invert the glass over the lemon and matches, letting it sit inside the bowl with its rim under the water.
6. Watch as the lemon slice rises up inside the glass.

You will need:

- a slice of lemon
- four safety matches
- a large glass
- a glass bowl - one with a flat base is best
- some water

Tips for success

The lemon slice needs to be thick enough to support the matches but light enough to float on the water.

What's going on?

The simplicity of this trick belies the complexity of the physical processes that contribute to the effect.

First, there is a simple air pressure effect caused by the expansion and contraction of the gas in the glass as it heats up and cools down. The heat from the three matches causes the air inside the pint glass to get hot. When all of the oxygen is exhausted, the matches go out and the air cools down. The cooler air takes up less space, so water gets pushed up into the glass to take up the extra volume.

Second, the combustion reaction changes the types of gas present, which changes the volume of gas in the glass. When the matches burn they use up oxygen. The products from the burning matches are carbon dioxide and water. The water is a liquid, so there will be less gas in the glass, causing the water to be pushed up into the glass to fill the volume.

Did you know?

This demonstration is based on the methodology used by Joseph Priestley to demonstrate that oxygen is a component of air, and to estimate the proportion of oxygen in the air.

www.physics.org/interact/physics-to-go/power-of-words

THE POWER OF WORDS

06

All you need is a ruler and a sheet of newspaper for this physics trick.

What to do:

1. Lay the ruler over the edge of the table so that about one-third of its length is over the edge.
2. Hit the ruler so that it flips off the table.
3. Replace the ruler. Fold up a sheet of newspaper as small as possible and place it at the back end of the ruler so that it acts as a counterweight. Hit the ruler again and it still flips off the table, this time along with the newspaper.
4. Replace the ruler. Lay a single sheet of newspaper flat on the table and on top of the ruler with the ruler roughly in the centre. When you hit the ruler it will stay on the table.

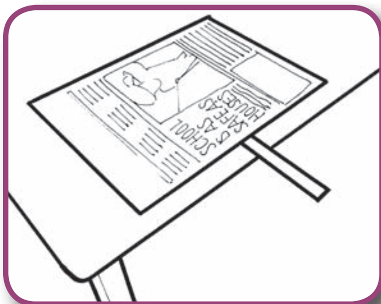
You will need:

- a table with a flat edge
- a ruler
- a newspaper

Tips for success

For optimal effect, make sure that as little air as possible is under the newspaper by smoothing it out flat prior to hitting the ruler.

Use eye protection if you are concerned about the ruler flying across the room.



What's going on?

It all comes down to air pressure. Atmospheric pressure exerts a downward force on the sheet of newspaper. The area of the sheet is large, so the downward force of the atmospheric pressure exerted on the newspaper is strong enough to counter the upward force from the ruler when you hit it. The folded-up newspaper has a smaller surface area over which the atmospheric pressure can act, so it doesn't prevent the ruler from flipping off the table.

Did you know?

During the scientific revolution it was common to think of air pressure in terms of the total weight of a column of air pressing down on a unit area. In 1643 Evangelista Torricelli, a pupil of Galileo, inverted a mercury-filled glass tube, sealed at one end, into a basin also containing mercury. He found that the weight of air over the basin was sufficient to support a column of mercury to a height of 76 cm. This invention is the basis of using "millimetres of mercury" as a unit of air pressure.

www.physics.org/interact/physics-to-go/potato-straw

POTATO STRAW

07

Probably one of the quickest ways to make holes in a potato.

What to do:

1. Challenge your volunteers to see who can insert a straw the farthest into a potato. To increase the excitement you may want to line up a row of them, each with a straw and a potato, and run the demonstration as a race.
2. Give them a while to try the challenge – they will almost certainly twist the straws slowly into the flesh of the potato. When their straws are bent and won't go any further, show them how to do it:
   a. Hold the potato between thumb and fingers (don't have your hand behind the potato).
   b. Grasp the straw firmly about two-thirds of the way up so that you have plenty of straw to go into the potato.
   c. Use a sharp, thrusting movement to force the straw through. Be confident – it really will go.

You will need:

- some plastic straws (which need to be straight - cut off the bendy bits, if there are any)
- some large baking potatoes (not for eating)
- some volunteers

Tips for success

The straws need to be straight, with no defects. Don't reuse straws. Have confidence that the straw will go through – you don't have to be particularly strong to make this trick work but you do need to be aggressive.

If you still have difficulty getting the straw very far into the potato, try changing your grip – some people find that holding the straw with their thumb over the other end works best, while others like to pinch the straw part-way down.

Remember to dispose of your potato and any little bits that have wedged in your straw properly afterwards.

What's going on?

There are two principles contributing to this trick:

1. The sharp, thrusting movement delivers a much larger instantaneous force than the slow, gradual, twisting motion, thereby making the straw go farther.
2. The end of the straw has a very small surface area, so the force that you apply is concentrated strongly. If you try the trick with a pencil roughly the same size as the straw, you will find it more difficult – you will need to displace a much greater area of potato, which will require a much greater force.

Did you know?

This effect (the concentration of force into a small area) can be seen quite frequently in everyday life (e.g. a stiletto heel sticking in a vinyl floor). The inverse effect is illustrated by extra wide tyres on tractors and wheelbarrows, which spread the force across a wider area to prevent damage to the ground.

www.physics.org/interact/physics-to-go/erupting-fizz

ERUPTING FIZZ

08

An impressive demonstration using things you can find in the kitchen.

You will need:

- a large glass
- a fizzy drink – preferably a clear one
- some vegetable oil
- some food colouring
- an Alka-Seltzer tablet
- some salt
- a stirrer

What to do:

1. Half-fill the glass with fizzy drink
2. Pour vegetable oil into the glass so that it is roughly two-thirds full.
3. Add a few drops of food colouring and stir the mixture. Wait until the two layers have clearly separated.
4. Add approximately two tablespoons of salt to the liquid in one go. A great foam eruption occurs. Observe the liquids after the eruption has settled down. You should be able to see a lava-lamp-style bubble effect.
5. Add an Alka-Seltzer tablet to the liquid. You should see some interesting bubbling effects from the gas given off by the Alka-Seltzer, and the change in the speed of those bubbles as they travel through water versus oil. You can prolong the effect by breaking the Alka-Seltzer tablet into smaller pieces.

Tips for success

This trick can keep working for quite a while – just add more Alka-Seltzer. You won't see the big fizzy eruption once the drink loses its fizz, but the bubble effect is still very clear. The salt will tend to supersaturate the drink solution after a while, making it go cloudy and reducing the effect of the trick. Make sure that your fizzy drink isn't too dark to allow you to see the bubbles passing through the liquid.

What's going on?

Water and oil do not mix – they are called immiscible liquids. Water is more dense than oil, so it sinks to the bottom of the glass, leaving a layer of oil on top. Food colouring is water-based, so it will only mix with the water, leaving the oil layer its original colour.

Adding salt to a fizzy drink causes a release of large quantities of the trapped carbon dioxide, creating the highly visible eruption. Pouring the salt into the liquid in one go also causes some oil to be dragged down into the water layer. As the salt dissolves in the water, the oil is released and rises back through the water layer, creating the lava-lamp effect.

When Alka-Seltzer is placed into water it starts fizzing, giving off bubbles of carbon dioxide. The bubbles are much less dense than either the water or the oil, so they travel upwards through the liquid layers. Oil is more viscous than water, so the bubbles travel through the layers at different rates. You may also be able to see small coloured bubbles passing through the oil layer. When the coloured bubbles get to the top and are released, the coloured water sinks back down through the oil layer.

www.physics.org/interact/physics-to-go/magical-match

MAGICAL MATCH

09

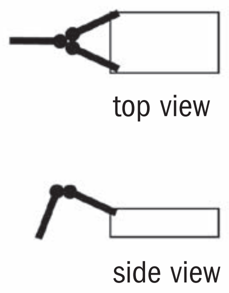
A neat physics-related magic trick to wow your friends.

What to do:

1. Lie the empty matchbox flat on a heat-proof surface, slightly open, with the empty section facing upwards.
2. Insert two matches so that the heads point out. Close the matchbox as much as possible so that the two matches are held securely.
3. Angle the two matches so that the heads touch.
4. Rest a third match so that the head meets the other two with the tail resting on the table, pointing away from the matchbox. The three should now form a pyramid with the three heads at the top.
5. Use a fourth match to light the others from underneath.
6. Watch as the third match rises off the table.

You will need:

- *an empty matchbox*
- *some safety matches*
- *a heat-proof surface*



Tips for success

For the greatest amount of lift, make sure that the matches are placed as symmetrically and as securely as possible.

What's going on?

When the three match heads ignite, they fuse together. In the case of the third match, the top and bottom surfaces burn at different rates, causing a gradient in the surface temperature and tension across the match. The different tensions across the third match cause an upward force to be exerted on it. The two original matches are fixed in place, so the three heads form a pivot point, from which the third match rises.

Did you know?

The same effect can be seen in many domestic thermostats. This can be demonstrated by joining together two strips of material with different rates of expansion (e.g. a bimetallic strip). As the temperature rises, the greater expansion of one metal causes the combined strip to curve further and further. This can be incorporated into a switch that will connect and cut off a heating apparatus when a particular temperature has been reached.

www.physics.org/interact/physics-to-go/amazing-marshmallows

AMAZING MARSHMALLOWS

10

Find out what happens to marshmallows in a vacuum with this physics demonstration.

What to do:

1. Roll the marshmallows gently between your hands until they are small enough to pass through the opening of the wine bottle. If they become sticky, roll them in cornflour so that they don't stick to the sides of the bottle.
2. Insert the vacuum stopper.
3. Pump the vacuum pump a few times. The marshmallows will begin to expand. Shake the bottle gently up and down to distribute the marshmallows throughout the bottle, then pump again. Watch as the marshmallows start to take over the bottle.
4. Let the air back into the bottle by releasing the valve on the vacuum stopper. The marshmallows will rapidly shrink back to their normal size.

You will need:

- some marshmallows (and maybe some cornflour, depending on the type of marshmallows)
- an empty glass bottle (which must be clean and dry with the label removed, and preferably made from sturdy, clear glass)
- a vacuum wine saver pump and stopper (following its instructions for use)

Tips for success

Don't try to reuse the same marshmallows too much or they'll stretch and stop working properly. Long, thin marshmallows work best because they are less sticky than the traditional sort. If you have access to a vacuum pump and a bell jar, this trick works beautifully.

You shouldn't use unusual-shaped wine bottles or those with decorative mouldings because these may implode when being evacuated. If you don't want to use a wine bottle then you can buy plastic jars that also use a hand pump to evacuate the air.

What's going on?

Marshmallows have small bubbles of air trapped inside them. These are at atmospheric pressure. When the air inside the glass container is sucked out, the volume of the container remains the same although there is much less air inside, so the pressure decreases. The air bubbles inside the marshmallows are therefore at a much higher pressure than the air surrounding the marshmallows, so the bubbles push outwards, causing the marshmallows to expand. When air is let back into the glass container, the surrounding pressure increases again and the marshmallows deflate back to their normal size.

Did you know?

Although aircraft cabins are pressurised, they are not kept at sea-level pressure. A similar effect to the marshmallow experiment can be observed by drinking half a bottle of water during a flight. When the aircraft lands you will see that the sealed plastic bottle becomes slightly crushed by the higher atmospheric pressure at about the same time as your ears pop on the approach to landing.

www.physics.org/interact/physics-to-go/cartesian-diver

CARTESIAN DIVER

11

Make a diver out of a straw, pipette or ketchup sachet – anything that contains a bubble of air.

What to do:

1. Cut the straw to about 4 cm in length.
2. Use small blobs of Blu-Tack to seal each end of the straw.
3. Check that the sealed straw just floats in the glass of water. It should slowly rise to the top of the water after you drop it in. If it sinks, remove some of the Blu-Tack. If it floats too easily, add more Blu-Tack.
4. Drop the straw diver into the bottle.
5. Fill the bottle with water from the glass, if necessary, and screw the cap on the bottle.
6. Squeeze the sides of the bottle (fairly firmly). The diver will sink. Let go of the bottle and the diver will return to the top.

You will need:

- a 2 litre plastic bottle with a lid, filled with water
- a glass filled with water (for testing the "diver")
- a straw
- some Blu-Tack
- a pair of scissors

Tips for success

Don't be scared about pushing hard on the sides of the bottle – they can take a lot of force. It may be easier to rest the bottle on a flat surface and then use both hands to push the sides. If the diver keeps floating then take it out and add more Blu-Tack, making sure to test it in the glass of water to be sure that it doesn't sink immediately – you'll find it easier to get it out of the glass than out of the bottle if it does sink.

What's going on?

The diver contains an air bubble. The combined density of the straw, air and Blu-Tack is slightly lower than that of the water, so it floats. When you squeeze the sides of the bottle you increase the pressure pushing on the air bubble, making it compress into a smaller space. This decrease in volume causes the air bubble to increase in density, so that the overall density of the diver is greater than that of the surrounding water, making it sink. Releasing the pressure (by letting go of the bottle) allows the air bubble to expand back to its normal size, allowing the straw diver to float again.

Did you know?

Sperm whales regularly dive to depths of at least 1000 m, where the water pressure is in the order of 100 atmospheres. In the process the whale's ribcage folds and collapses, and the lungs compress down to 1% of their size at the surface. The associated change in buoyancy is essential to keep the animal at such a great depth.

www.physics.org/interact/physics-to-go/balloon-kebabs

BALLOON KEBABS

12

A great physics trick to challenge your friends with. All it needs is a bit of nerve.

What to do:

1. Blow up the balloons (not fully) and tie them off.
2. Challenge your audience to make a "balloon kebab" – to pierce a wooden skewer all the way through the balloon without popping it. Let a few people have a try – they will invariably try to insert the skewer fairly slowly through the side and the balloon will pop.
3. Show them how physics can make the trick work:
   a. Start by lining up the skewer point with the darker patch on the balloon, opposite the tie end. Gently push the skewer through. You may find that a twisting motion works best.
   b. Once the skewer is through one side, push it gently through the balloon until the point of the skewer is at the opposite end – the darker area around the tie.
   c. Insert the skewer tip gently through the soft part of the balloon where the tie is. Again, use the twisting motion if it helps.

You will need:

- some balloons
- some wooden kebab skewers
- some volunteers

Tips for success

This trick works best with round balloons (rather than long skinny ones), mainly because the skewers reach from one end to the other. Don't blow up the balloon too much or it will pop, even if you do it correctly. Make sure the skewer ends are fairly sharp – blunt skewers are more likely to pop the balloon. You may find that your balloons sometimes burst even when you follow the instructions.

What's going on?

This trick works because of surface properties. A balloon is formed by inserting air into a flexible, thin rubber sheet. Most of the balloon is stretched evenly, but there are two points where it is least stretched, and here is where the surface tension is at its lowest. These correspond to the tied section and the darker patch at the opposite end of the balloon – the darker colour indicates that the balloon is less stretched over that region. Most of the balloon is under high tension, so attempting to push the skewer through just makes the balloon pop. At the low tension sections, however, it is possible to make a small hole without breaking the overall surface of the balloon.

LAVA LAMP

13

Traditional retro lava lamps are familiar to most, but try this home made version.

What to do:

1. **Three-quarters fill the glass with fizzy drink.**
2. **Stir it to release some of the bubbles.**
3. **While it is traditional to use nuts for this, you may want to use raisins or sultanas instead in case of nut allergies. Tip a few in.**
4. **Watch as they gradually float up to the surface of the liquid, then fall back down again, just like a lava lamp.**

You will need:

- a fizzy drink - preferably a clear one
- a large glass
- a handful of nuts or raisins
- a spoon

Tips for success

This trick works best if the fizzy drink doesn't have too much gas in it. If the nuts or raisins all float on the top then there is too much gas. Conversely, if the drink is too flat then they will mostly stay on the bottom.

What's going on?

This effect relies on the gas in the fizzy drink. The nuts at the bottom of the drink have imperfect surfaces, where small pockets of air will form. The longer they stay still, the larger the bubbles of air become. Eventually they become large enough to provide enough buoyancy to counter the weight of the nuts, thereby lifting them off the bottom of the glass. When they get to the top, the bubbles burst, removing the buoyancy from the nuts and causing them to fall back down.

Did you know?

This demonstration has been in use for several centuries and was very popular at Versailles, where a single raisin would be dropped into a flute of champagne and would bob up and down all afternoon.

www.physics.org/interact/physics-to-go/shrinking-coin

SHRINKING COIN

14

Most people won't believe this trick can be done – but with some 3D thinking it's easy.

What to do:

1. Lay the 1p coin in the centre of the piece of paper. Trace round it using the pencil.
2. Cut out the circle so that you are left with a piece of paper with a hole in the centre.
3. Demonstrate that the 1p coin slips easily through the hole.
4. Challenge your volunteers to get the 2p coin through the 1p-sized hole – without ripping the paper or altering it in any way.
5. Show them how it can be done:
   a. Take the piece of paper and bend it in half. Hold the paper so that the bend is at the bottom. Drop the 2p coin between the sides of the paper into the centre of the hole.
   b. 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 outwards in the direction perpendicular to the coin. The coin should slip through the hole.

You will need:

- a 1p coin
- a 2p coin
- a piece of paper (approximately 10 cm x 10 cm)
- a pencil
- some scissors
- some volunteers

Tips for success

Don't use the same piece of paper too often or it will develop permanent folds in it, which can cause the coin to get stuck and help your audience to guess how the trick is done.

What's going on?

This is all to do with non-Euclidean geometry. The small 2D hole may be stretched in the third dimension to produce a slit that is large enough to allow the larger coin through.

www.physics.org/interact/physics-to-go/extra-bounce

EXTRA BOUNCE

15

Add a ball to give it extra bounce.

What to do:

1. Pick up the large ball and hold it out at shoulder height.
2. Drop the ball and see how high it bounces.
3. Pick up the small ball and repeat this, again noting how high it bounces.
4. Hold the small ball on top of the large ball at shoulder height and then drop them. The small one will shoot off much higher than the sum of the original bounces put together. Repeat and watch the larger ball. You will see that it hardly bounces at all.

You will need:

- one large ball that bounces (e.g. a football)
- one small ball that bounces (~10 cm in diameter)

Tips for success

For indoor spaces use a small ball that isn't too bouncy or it may cause some damage.

What's going on?

This experiment is all about conservation of energy and momentum. When the balls are dropped together, most of the momentum from both is transferred to the small one. Both the kinetic energy and the momentum of any moving object depend on its mass. If the smaller ball receives all of the kinetic energy and momentum from the larger one, it will bounce much higher than the original larger ball because it is so much lighter. Add to that the original energy and momentum in the smaller ball and you get a bounce that is much greater than the sum of the two original bounces. There are also complications due to the materials used to make the balls (bouncy balls go wild). This experiment can also be used as a good demonstration of chaos effects – small changes in the initial conditions (e.g. exactly how the two balls are held above each other) can cause large differences in the end result.

THE SWING THING

16

A great demonstration to investigate our perception of 3D.

What to do:

1. Use the Blu-Tack to stick together the 2p coins to make a weight. Tie the string to the weight. You now have a pendulum.
2. Ask your volunteer to watch the pendulum. Get them to stand about 2 m away from you and swing the pendulum so that it is perpendicular to the line between them and you. Ask them what direction the pendulum is swinging in.
3. Break the sunglasses in half at the nose so that the two lenses are separate. Get your volunteer to hold one lens in front of one eye, keeping both eyes open. Swing the pendulum again, exactly as before. Ask them what direction the pendulum is swinging in. They will see it going in a circle.
4. Get the volunteer to hold the lens in front of the other eye. They will see the pendulum going in a circle in the opposite direction.

You will need:

- a piece of string (~1 m long)
- two 2p coins
- some Blu-Tack
- an old pair of sunglasses
- a volunteer

Tips for success

Some people don't see the effect so quickly – they may need to move the lens back and forth in front of one eye to see the difference.

Neutral-density filters will work just as well as sunglasses.

What's going on?

Sunglasses block some of the light travelling towards them so that less light reaches your eyes when you wear them. This makes your eyes more sensitive to light. If you think about how a camera works, in darker conditions it is necessary to increase the size of the aperture and the exposure time to get a decent photo. In the same way, your eye's aperture (the pupil) automatically increases in size, and the timing of the signals being sent from the eye to the brain is delayed when you wear sunglasses.

You don't normally notice this effect because both eyes are covered up and so both signals are delayed by the sunglasses. However, in this experiment only one eye is covered, so you can distinguish the difference between the two. The eye with the lens in front of it sees the pendulum delayed with respect to the normal eye – and therefore in a different position. This has the effect of tricking your brain into thinking that the pendulum is moving in three dimensions instead of two (i.e. in a circle instead of a straight line). When you swap the lens to hold it in front of the other eye, you swap which signal is being delayed, thereby changing the apparent direction of swing.

www.physics.org/interact/physics-to-go/egg-citing-physics

EGG-CITING PHYSICS

17

Ever mixed up your eggs? Some simple physics will enable you to avoid that problem in future

What to do:

1. **Place the eggs on a flat surface and set them both spinning.**
2. **Gently and briefly place your finger on the top of each egg.**
3. **Notice that the hard-boiled egg is much easier to spin, but it stays still when you take your finger off. In contrast, the raw egg is difficult to start spinning but will keep spinning when you take your finger off.**

You will need:

- *a raw egg*
- *a hard-boiled egg*

Tips for success

Don't set your eggs spinning too fast or they may roll off the table.

What's going on?

Momentum is the key to this demonstration. A raw egg is filled with a liquid, whereas a hard-boiled egg is solid. First consider what happens when you stop the eggs. When you gently place your finger on the top, you stop the shell of both eggs from moving. The hard-boiled egg is solid, so all of it stops moving and it remains stationary when you remove your finger. However, the liquid inside the raw egg keeps spinning even when you have stopped the movement of the shell. The drag of the liquid on the shell starts the raw egg spinning again when you let go. A hard-boiled egg is easier to spin because the solid egg spins as a single entity, whereas the raw egg and its shell spin at different rates – the shell starts first and then gradually the liquid inside begins to spin as it is dragged round by the shell.

www.physics.org/interact/physics-to-go/one-in-the-hand

ONE IN THE HAND

18

Eggs are traditionally thought of as being very fragile, but in fact the physics behind their shape is astounding.

What to do:

Challenge your volunteers to break the egg just by squeezing it. Let them wrap the egg in a plastic bag or wear a glove, if they're worried. Believe it or not, it can't be done.

You will need:

- *a raw egg*
- *a plastic bag or glove*
- *some volunteers who are scared of getting messy*

Tips for success

Ask your volunteers to remove any rings, etc before trying this trick – the sharp uneven force from such metal objects can cause the egg to break. Check your eggs for hairline fractures before attempting this trick. If there is any existing damage to the egg, it won't work.

What's going on?

The shape of an egg is one of the strongest designs possible. The curved structure means that applying pressure to any particular area actually spreads the force out over the entire surface, so just squeezing it won't cause it to break. Of course, applying a very sharp force to one point will break it, which is why we usually tap an egg on the side of a bowl to break it.

Did you know?

The ornate and intricate arched doorways and ceilings in many old buildings aren't just there for their aesthetic qualities – arches are in fact one of the strongest structures. In effect, every brick or piece of masonry in the arch is falling on all of the others, distributing the weight evenly over the structure.

www.physics.org/interact/physics-to-go/bernoulli-balls

BERNOULLI BALLS

19

A simple hairdryer becomes a levitation device through an understanding of the principles of fluid flow.

What to do:

1. Point the hairdryer nozzle upwards and turn it on.
2. Place a ball carefully in the airstream. It will balance in the air, appearing to levitate.
3. Gently move the hairdryer from side to side. The ball will stay in the airstream (i.e. will also move back and forth). Repeat this process, moving the hairdryer up and down.
4. Carefully tilt the hairdryer. The ball will still stay in the airstream, hanging in mid-air with nothing directly underneath it.
5. See how many balls you can "hold" in one airstream.

You will need:

- a hairdryer (PAT tested if used in the classroom)
- some small light balls (e.g. polystyrene or ping-pong balls)

Tips for success

Use a hairdryer with a "cool" setting so that it doesn't overheat. Make sure that the balls aren't larger than the airstream or it won't work. Tilting the hairdryer to too great an angle will cause the ball to fall out of the airstream, but you can always see how far you can move it.

Some hairdryer designs, such as those with uneven airflow, may be unsuitable.

What's going on?

The upward pressure from the hairdryer balances the downward force of gravity, keeping the ball "levitating". The more impressive part of this trick – being able to move the ball with the hairdryer and hold it at an angle – is based on the Bernoulli principle. This states that fast-moving fluids (including gases, such as air) are at a lower pressure than slow-moving fluids. The airstream from the hairdryer is therefore at a much lower pressure than the air outside. A ball that is smaller than the diameter of the airstream can therefore be held within it. If the ball starts "falling" out of the airstream to one side, the higher pressure of the air outside the airstream will push the ball back into the centre. This is the process that enables the ball to balance inside the airstream and move around as the hairdryer is moved around.

Did you know?

The Bernoulli effect can also be demonstrated by holding up two sheets of paper and blowing between them. Instead of moving apart, they are drawn together. If you thought anyone could have worked this out, remember that Daniel Bernoulli was awarded his master's degree at the ripe old age of 16.

www.physics.org/interact/physics-to-go/tame-tornado

TAME TORNADO

20

This is a great demonstration of forces, and in particular vortices.

What to do:

1. Fill one of the bottles with water until it is almost full.
2. Screw the tornado adapter into the empty bottle.
3. Turn the empty bottle upside-down and screw the other side of the tornado adapter into the water-filled bottle.
4. Turn the whole thing upside-down.
5. Grasp the top and middle of the set-up and spin it in a circular motion – clockwise or anticlockwise.
6. Once a vortex forms in the upper bottle, stop spinning – you should see the vortex form throughout the liquid and continue as long as there is liquid in the upper bottle.

You will need:

- two large (~2 litre) empty fizzy drink bottles
- a tornado adapter (available online or from most science centres and museums)
- some water

Tips for success

Try adding food colouring to the water for a more colourful visual effect. Practice making the vortex until you're sure how to do it. If it doesn't work straightaway, try reducing the size and increasing the speed of the circles that you make. Make sure that the bottles are held vertically and your circles are centred. Replace the plastic bottles if they get too bent out of shape – they need to be round to make a proper vortex.

What's going on?

This demonstration produces a vortex such as those observed in cyclones, tornadoes and whirlpools. As the water spins round the bottle there is a downward pull due to the water passing through the opening into the empty bottle below. The initial small rotation caused by spinning the bottles gains speed as the water is sucked through the opening. As the rotation speeds up, the vortex forms.

Did you know?

It's commonly believed that, because of the Earth's rotation, water always goes down the plughole in a clockwise direction in the northern hemisphere and anticlockwise in the southern hemisphere. Unfortunately, this so called Coriolis force is too small to have an effect in your home, so it is the shape of the basin and the movement that you make in the water as you take the plug out that cause water to drain down the plughole in one direction or the other. However, large bodies of liquid, such as the oceans and the atmosphere, are affected by the spinning of the Earth. The whirlpool was first mechanically induced in a bathtub in 1968 by Roy Jacuzzi.