SCIENCE ON STAGE EUROPE

THE EUROPEAN NETWORK FOR SCIENCE TEACHERS

THE SCIENCE BEHIND MAGIC

ADRIAN ALLAN & RUTE OLIVEIRA

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How did it all start and who we are

It all started when at the 2022 Science on Stage fesEval in Prague, when we met in person.

Adrian Allan "I am a chemistry teacher at Dornoch Academy in Scotland, UK. I am interested in the use of magic illusions to teach science concepts to students."

Rute Oliveira "Because I love learning and I love science I'm a Chemistry and Physics Teacher in Nobel Algarve BriEsh InternaEonal School, in Portugal."

The Project

Aims

To use magical science demonstrations to make science exciting for everyone, particularly students, parents and teachers. To enhance students confidence, communication and presentation skills, allow them to creative and see the links of science with a performing arts such as magic.

Magical science demonstrations are a visually exciting way of presenting and teaching science. They require many useful skills such as practice, showmanship, audience interaction and generating suspense. This project will involve developing and sharing resources for teachers that will help them present science in a magical and entertaining way. We also intend to teach students how to perform magic demonstrations to either teachers, parents, or other students. This can be done in class, at science fairs or presented online. This will help enable students to learn science concepts, develop confidence, communication skills and experience the great feeling of being able to astonish others.

21 Magic Tricks

1. The Vanishing Liquid

Tutorial - How to perform

Effect

Water is poured into an opaque plastic cup. When the cup is turned upside down no water comes out. The water has mysteriously vanished.

Tutorial - Click

The Science behind

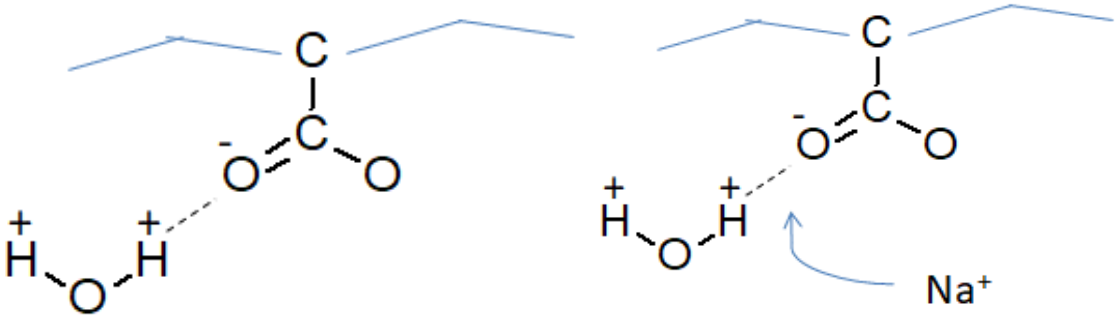
The plastic cup secretly has some hydrogel powder in from the start. This can be done using hydrogel powder extracted from nappies or you can buy a product called slush powder for about £5 from internet suppliers such as Amazon. When water is added to the hydrogel it forms a solid gel that stays in the cup when inverted.

The Science - Click

There are granules of sodium polyacrylate (with a molecular weight of over 1 million) in the hydrogel. There are sodium carboxylate groups along the carbon chain. When water is added to the polymer, the sodium ions migrate leaving negatively charged carboxylate groups on the chain. The negative charges repel each other so the chains unwind, and the polymer increases in volume. At the same time, there is an electrostatic attraction between the ions and the water molecules. Many water molecules are attracted to the carboxylate groups and are electrostatically held to them. The polymer absorbs water.

The water can be recovered from the hydrogel using salt. The sodium ions take the place of the bound water molecules and release them from the polymer.

The addition of salt can be used as a magic powder to recover the vanished water if time allows.



What you will need:

- 3 polystyrene drinking cups

- The lining from a disposable nappy. (Cheap ones will do – remove plastic backing but the inner layer nearest the baby can be left).

- A measuring cylinder.

- A beaker of water.

Before the demonstration

Cut circles, the diameter of the bottom of a cup (about 4.5 cm), out of the lining.

Place one in the bottom of one of the cups. It should be a snug fit.

The demonstration

Measure out 10-15 cm^3 of water (no more or the nappy will not absorb all of it) and place it in one of the cups. Colour if desired with a few drops of food colouring.

Make a great play of switching round the cups (but making it obvious which one has the water) and asking the audience to say which one has the water in it.

Each time they get it right, pour the water from the cup into the second empty cup.

On one occasion, pour the water into the 'empty' cup that contains the nappy liner.

Then when they predict the cup with the water, take the others in turn and show they do not contain water by attempting to pour from one empty cup to the other. (It also gives time for the nappy to absorb the water). This should convince the audience they are correct in their prediction. Now attempt to pour from this cup into one of the empty ones. Heh presto! The water has 'disappeared'.

It is the responsibility of teachers doing this demonstration to carry out an appropriate risk assessment.

Sustainable Development Goals (SDG)

By using water as a medium for the magic trick, it provides an opportunity to discuss the importance of clean water and access to safe drinking water, which is a critical aspect of SDG 6. This trick can serve as a conversation starter to raise awareness about water-related challenges and the need for sustainable water management.

Access to clean water and sanitation is critical for poverty eradication (SDG 1), clean water and sanitation are essential for achieving food security (SDG 2), providing clean water and sanitation increased school attendance because fewer illnesses children get (SDG 4), because women and girls are disproportionately affected by the lack of access to clean water and sanitation. In many communities, women and girls are responsible for fetching water (SDG 5).

2. Coin through rubber

Tutorial - How to perform

Effect

A coin is seen on top of a rubber sheet which is stretched over a clear glass beaker. A volunteer places their finger on the coin and proceeds to push the coin through the rubber into the beaker. No hole is left in the rubber sheet, solid has passed through solid!

Tutorial - Click

Method

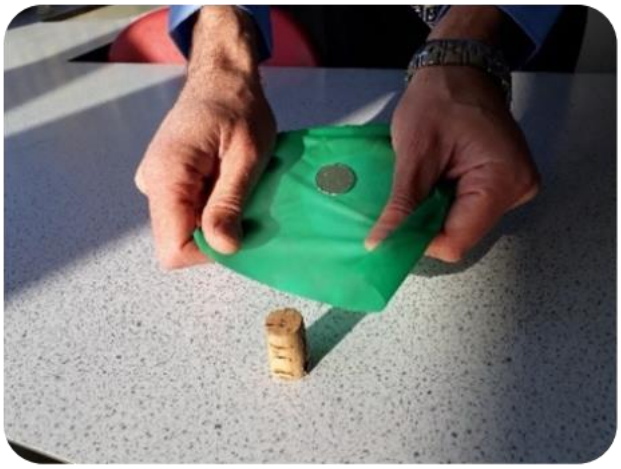
The coin through latex trick is marketed under various names, usually Pena Coin, which can be bought for about £5 from Amazon for 3 sheets. Your local dentist or an internet dental supplier may sell small rubber sheets called dental dams which may be cheaper. I got mine from Amazon.

Put 10p piece and rest it on a cork or bung. When the rubber is stretched over the coin is becomes transparent and clings to the coin, creating the illusion the coin is on top of the latex when it is gripped underneath. Adding a coin tucked beneath this slightly enhances the illusion. Get a pupil to push to the coin through and they will get a pleasant shock. Check for latex allergies beforehand.

The Science behind

This article shows a real time application of polymers for potentially making smart windows, using a polymer like latex that becomes transparent when stretched. The premise is that the intensity of light passing through the polymer can be controlled by stretching.

The Science - Click



This article shows a real time application of polymers for potentially making smart windows, using a polymer like latex that becomes transparent when stretched. The premise is that the intensity of light passing through the polymer can be controlled by stretching.

http://news.mit.edu/2016/tune-polymer-material-transparency-smart-windows-0122

Sustainable Development Goals (SDG)

The magic trick involves the use of scientific principles, demonstrating how innovation and scientific knowledge can create awe-inspiring experiences. It emphasizes the importance of investing in research, technology, and infrastructure to foster creativity and discovery.

This magic trick can be linked with the study of smart windows made with polymers like latex. These windows can automatically adjust their transparency in response to external conditions, such as sunlight and temperature which can enhance energy efficiency in buildings.

Smart windows, on the other hand can reduce the need for excessive heating and cooling, leading to lower energy consumption and reduced greenhouse gas emissions.

3. Arc illusion

Tutorial - How to perform

Start the trick by presenting the two arches to the audience, one above the other vertically. Ask a spectator to point out which arch is smaller. After the spectator chooses, ask him to help you stretch the smaller arch until it is the size of the other one. Show the arcs vertically again, one on top of the other, but now switch the order (the one that was stretched and was initially on top is now on the bottom). Play with the audience and say, now I think we have stretched it too far. Tutorial - Click

This magic trick demonstrates the crucial importance of measuring and comparing accurately. In science, relying solely on our eyes can be misleading. To obtain reliable results, it is essential to use rigorous measurements and appropriate tools.

The Science Behind

Explanation

This illusion is commonly known as the Jastrow illusion. It is an optical illusion where two identical figures are placed next to each other. Although they are both the same size, one appears to be larger. When the positions of the two shapes are reversed, the impression of which is the larger is also reversed.

Scientists are not yet certain what causes one figure in the Jastrow illusion to appear larger than the other. The fact that the shorter side of one figure is next to the longer side of the other somehow tricks the brain into perceiving one shape as longer and the other as shorter, although it is unclear exactly why this is so.

The Science - Click

4. Metal bending

Tutorial - How to perform

Effect

Tutorial - Click

A card is selected by a volunteer and committed to memory. The volunteer is a given a short piece of wire and is asked to think of their card and place it into a beaker of hot water. The wire starts to bend and form a shape that matches the card selected by the volunteer.

The Science behind

Method

The Science - Click

Various people, most notably Uri Geller, have claimed to have psychokinetic powers, claiming to bend metal with their minds. To create this illusion, wiregrams can be used which can change into the shape of a card when immersed in hot water (care with scalding). These are available from internet magic shops and eBay. You need to be able to force a specific card on a pupil which can be achieved in various ways, the easiest being having a pack with all cards the same. The wiregrams are made of nitinol, a memory metal which can 'remember' its shape heated or when an electrical current is passed through it. This makes it useful for stents in clogged arteries and robotic hands. Good memory metal resources are available from Mindsets, such as springs that uncoil in hot water.

Sustainable Development Goals (SDG)

The magic trick involves the use of scienEfic principles, demonstraEng how innovaEon and scienEfic knowledge can create awe-inspiring experiences. It emphasizes the importance of invesEng in research, technology, and infrastructure to foster creaEvity and discovery.

5. Anti-gravity water

Tutorial - How to perform

Effect

A jar is filled three quarters full of water. A piece of laminated card is placed over the top of the jar and is turned upside down. The card stays on under the jar. When the card is removed the water stays in the jar, defying gravity! Tutorial - Click

Method

Preparation

1. Place a glass jar upside down on a piece of fiberglass insect screen.

2. Trace the mouth of the jar onto the screen.

3. Carefully cut out the circle of screen. Note: The circle of screen should be slightly smaller than the outside of the jar's rim.

4. Hot glue or superglue the screen to the top of the jar so that students cannot easily see the screen.

Procedure

1. Pour tap water through the screen until the jar is about three-quarters full.

2. Place a laminated card over the top of the jar and hold the card down tightly with one hand. The water will form an adhesive seal with the laminated paper.

3. Quickly invert the jar 180° over a sink or other container, such as a plastic tub or bucket.

4. While holding the jar steady, remove your hand from the laminated card. The card will remain in place over the mouth of the jar! The water forms a tight adhesive seal and external air pressure holds the card in place.

5. Carefully slide the card out from under the jar with one hand while holding the jar steady with the other hand. A little water may spill out, but most of the water will stay in the jar! The mesh screen provides a surface for the formation of hundreds of tiny surface-tension "membranes" that, in addition to air pressure, will support the weight of the water.

6. Tilt the jar a few degrees to allow air to enter the jar. The water will immediately spill out of the jar—gravity still works!

Note: To ensure the success of the trick, the glass is typically pressed against the surface quickly to create the low-pressure zone before any significant amount of water can start to fall out.

Tips and notes

There are variations that can be done on this demonstration. Rute has made jars with a metal lid that have a circle cut through it, with the insect mesh inserted in the top as shown in the video Anti-Gravity Water I. If the mesh holes are large enough, wooden toothpicks can be pushed through the mesh and floated to the top of the bottle when turned upside down.

Magic shop shops will sell glasses called hydrostatic glasses which have a plastic insert which can placed over the mouth of the glass and have a hole drilled in the side of the glass. The glass is filled with water, the plastic insert is secretly placed over the mouth of the glass covered with a card and the glass is inverted (the hole should be covered with the thumb). When the card is removed, the

water stays in the glass and can be released when the thumb is removed from the hole. A performance of this can be seen in the video Anti-Gravity water II.

The Science Behind

The Science - Click

This trick relies on scientific principles and clever manipulation of air pressure and water tension.

When the glass is turned upside down and pressed against a flat surface (e.g., a plastic sheet or piece of cardboard), the surrounding air tends to stick to the curved surface of the glass due to the Coanda effect.

When the glass is pressed against the flat surface the air pressure inside the glass becomes lower than the atmospheric pressure outside.

The water molecules create a surface tension that helps keep the water inside the glass. This surface tension, along with the low-pressure zone created by the Coanda effect, prevents the water from falling out of the glass, despite it being upside down.

The forces acting on the water in the glass are balanced due to the combination of surface tension and low air pressure inside the glass.

Sustainable Development Goals (SDG)

By using water as a medium for the magic trick, it provides an opportunity to discuss the importance of clean water and access to safe drinking water. This trick can serve as a conversation starter to raise awareness about water-related challenges and the need for sustainable water management.

Because women and girls are disproportionately affected by the lack of access to clean water and sanitation, we can use this trick to promote the discussion around gender equality since in many communities, women and girls are responsible for fetching water.

Access to clean water and sanitation is critical for poverty eradication. Inadequate access to clean water and sanitation facilities can exacerbate poverty by affecting health, hygiene, and overall well-being. So, we can also talk about the Sustainable Development Goal - No poverty, using this trick with water and its unique chemical and physical properties.

6. Cut and restored newspaper

Tutorial - How to perform

Effect

A strip of newspaper is folded in half and cut with a scissors and seen to be restored when opened out again. Tutorial - Click

Method

There is a good torn and restored newspaper demonstration from Flinn Scientific. This relies on rubber cement to keep the paper together and provides a context for intermolecular forces between molecules.

https://www.flinnsci.com/api/library/Download/5537422a07664d95a1213f2504eb536d

Prepara5on

1. Cut a 2-inch strip of newspaper from the length of a sheet of newsprint.

2. Coat one side of the strip of newspaper with rubber cement and allow it to dry.

3. Lightly coat the dry rubber cement with baby powder.

Procedure

1. Show the uncoated side of the strip of prepared newspaper to the students.

2. Bring the bottom edge of the newspaper up so that the two coated sides face each other. Note: Keep the uncoated side toward the students.

3. Keep a finger between the top edges of the newspaper but lightly press the bottom folded area together.

4. Cut above the fold with sharp scissors.

5. Let the back edge of the newspaper fall; this will keep the uncoated side toward the students. The strip of newspaper will stay connected giving the illusion of an uncut strip of paper.

6. Repeat as desired.

Note

A suitable alternative to rubber cement is spraying the newspaper with two coats of repositionable glue spray, this was used in the video shown. Always check the risks and safety of the glue you use!

The Science behind

Timstar and Mindsets online sell auto heal or self-healing tape. This silicon polymer sheet embodies the remarkable property of almost instant self-healing. If two freshly cut edges are pushed back together, new bonds form and in seconds it becomes virtually impossible to pull the cut open. Similarly, if two clean surfaces are brought together, new bonds immediately form – making this one of the few known materials that can be welded to itself using pressure alone. It bonds to itself and only itself. The Science - Click

7. Magic is ...

Tutorial - How to perform

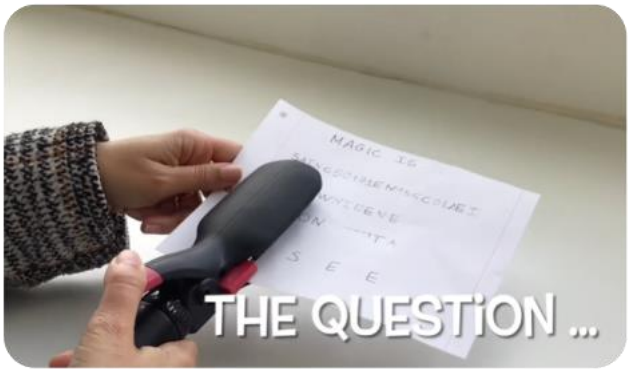
Effect: This trick creates the illusion of ink magically disappearing from a surface when subjected to heat, using a friction pen. Tutorial - Click

Materials:

- A friction pen, available at most stationery or magic supply stores.
- A regular pen with the same colour of the friction pen.
- A piece of paper or any surface where you want to perform the trick.
- A heat source, such as a hairdryer.

Procedure:

To prepare the trick write a message with a normal pen. Hide this message using a friction pen. For example write random letters between the letters of the message. This way what is written is imperceptible to the public.



Ask someone in the audience to say the magic words: **"For the words to show, heat must bestow."**

As the heat is applied to the ink marks, they will "magically" disappear right before the audience's eyes!

The Science Behind

Frixion pens contain thermochromic ink which vanishes when the heat from the friction of erasing is used to make the ink disappear. This can be used to reveal secret messages as shown in the video, by using heat to make the thermochromic ink disappear and leave visible writing done in ink from a normal pen. The Science - Click

8. Water on fire

Tutorial - How to perform

Tutorial - Click

Safety First

This activity should only be carried out by a teacher.

Before performing the experiment, please check the risks and safety of Lighter Fluid at the following link: Zippo Lighter Fluid - Safety Data Sheet

There is a lot of interesting chemistry in this demonstration. You can discuss density, combustion, miscible and immiscible liquids, polar and nonpolar liquids as well as observation skills.
It is recommended that safety goggles are worn for this demonstration. Before the demonstration, a little lighter fluid is added to the bottom of the flask (less than a ml). The students should be unaware of this.
Drink from a bottle of water. Fill the flask to just below the lip with tap water, don't let the flask overfill and lose the lighter fluid. Light the liquid on top of the flask. Put the flask on the table. Let the students make observations and figure out what is happening as the lighter fluid is completely burned away. The Science - Click

The Science Behind

Water, of course, does not burn. The students should deduce that there is something other than water burning. The immiscible flammable liquid added before the demonstration is less dense than water, floats to the top and is flammable when lit.

Sustainable Development Goals (SDG)

The trick symbolizes the transformation of water into fuel, illustrating the importance of clean and sustainable energy sources. Sustainable energy is essential for achieving SDG 7, which aims to ensure access to affordable, reliable, and sustainable energy for all.

In this trick the audience is made to think that the water is on fire. We can use this trick as an introduction to the discussion about fossil fuels, renewable and non-renewable energies, and their impact. With this trick we can ask the question: Can we use only water as fuel? Then we can make a connection with these two SDGs.

Emphasise that the transition to cleaner energy not only benefits the environment but also leads to more resilient and inclusive urban communities, aligning with the principles of SDG 7 and SDG 11.

9. The bottomless glass

How to perform – Tutorial

Tutorial - Click

Safety First

This activity should only be carried out by a teacher.

Before performing the experiment, please check the risks and safety of acetone at the following link:

Safety Data Sheet: Acetone

Tips for a Safe Performance:

- Perform the trick in a well-ventilated area to avoid inhaling acetone fumes.
- Use acetone sparingly to avoid excessive reactions.
- Dispose of any used acetone and Styrofoam responsibly and safely.

You'll need an opaque container that viewers can't see is acetone inside. This acetone cannot be the solvent acetone that we oven find in supermarkets and that is used to remove nail polish, as it is not pure and does not achieve the same results in this trick.

The lower the container and the higher the piece of Styrofoam, the greater the impact.

Start by showing that under the container there is nothing but the table where it is and that it has no hole through which it can get out. If the table doesn't have a tablecloth so that viewers can see freely under the table, the greater the impact.

The Science behind

Expanded polystyrene articles are manufactured from polystyrene granules that incorporate a blowing agent – a substance which, when heated, gives off a gas. This may be a volatile liquid (such as pentane) or a carbonate. These granules are then steam-heated and the gas from the blowing agent expands to produce a foam plastic. This gas is eventually exchanged with air. Thus, the gas in the solid foam is largely air.

The expanded polystyrene does not actually dissolve in the propanone; it merely softens as it absorbs the propanone and allows the air to escape, thereby collapsing the foam. An interesting example of a gas formed not by a chemical process, but by a physical process. The resulting colloidal gel consists of propanone molecules dispersed in a network formed by a tangle of large polystyrene molecules – a similar structure to ordinary jelly in which water molecules are dispersed in a network of protein molecules.

The Science - Click

Sustainable Development Goals (SDG)

Sustainable Cities and Communities: SDG 11 advocates for sustainable urban development, which includes creating resilient and resource-efficient cities. Styrofoam insulation in house walls can help reduce energy consumption and greenhouse gas emissions, promoting sustainability in the construction sector. In the magic trick using styrofoam we can explore its use in construction, and we can also take the opportunity to discuss whether this is a sustainable material and possibly think about alternatives.

10. Magic strip

Tutorial - How to perform

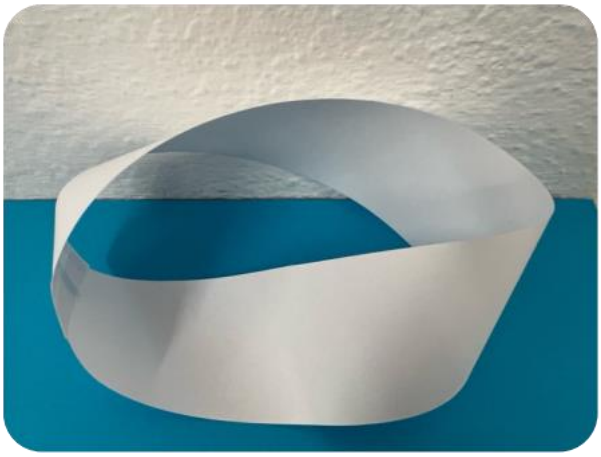
Trace the Surface: Indicate that you are going to launch a challenge: Ask to trace on one side with one colour and on the other side with another colour. Emphasise that no matter where they start, they will end up back at the starting point without lifting the pen or crossing an edge. The audience will be amazed that they can't do it and end up where they started having used just one colour and not two as stated in the challenge. Tutorial - Click

Cutting the Möbius Strip: Ask the audience what will happen if you cut the Möbius strip down the middle. Wait for the answers.

Now, explain the surprising property of the Möbius strip when you cut it down the middle. Unlike an ordinary loop, which would yield two separate loops when cut, the Möbius strip produces a single, larger loop. This time, have a physical Möbius strip ready to demonstrate this by making a single cut along the strip.

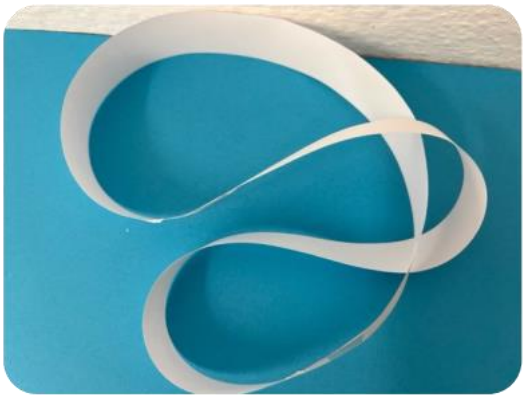
How to prepare the **Möbius strip**:

If you have strips of paper available, you can invite the audience to create their own Möbius strip. Instruct them to take a long, thin strip of paper, give it a half-twist, and then glue or tape the ends together.



Tutorial - Click

The Science behind



A Möbius strip is a one-sided surface that can be constructed by affixing the ends of a rectangular strip after first having given one of the ends a one-half twist. This space exhibits interesting properties, such as having only one side and remaining in one piece when split down the middle. The properties of the strip were discovered independently and almost simultaneously by two German mathematicians, August Ferdinand Möbius and Johann Benedict Listing, in 1858.

If you cut it straight in half, (that would mean two cuts) you just get two strips half the original size. However, try to cut it lengthwise and you fail to separate the strip. You still get a ring with a couple twists that's not a mobius strip. Cut that lengthwise again and you get that same shape with a mobius strip half the length interlocked.

An animation of how this works can be found here:

Animation - How this works - Click

A nice explanation of how to do the effect can be found here:

Animation - Click

Applications: Möbius strips are found, such as in conveyor belts or certain types of industrial machines. This shows that even though the Möbius strip may seem like a curious mathematical concept, it has practical uses.

11. Teflon – Secret message

Tutorial - How to perform

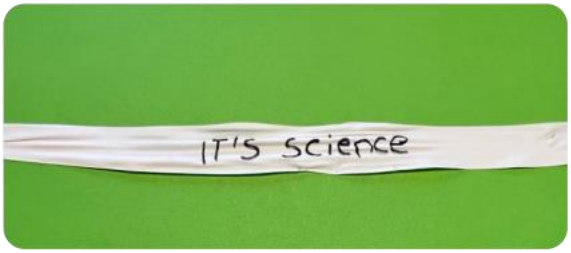
Instructions

1. Cut a piece of Teflon Tape.
2. Place your strip of Teflon Tape on a flat surface.
3. Write your secret message on the Teflon Tape.
4. Stretch the tape from top to bottom, making your message taller until you cannot read your message anymore.
5. To reveal the message Pull firmly on the tape from end to end stretching your message longer.

Tutorial - Click

The Science behind

Teflon Tape is a type of polymer called polytetrafluoroethylene (PTFE). If you try to stretch the tape end to end before stretching it from top to bottom, you won't be able to stretch it much at all. That is because the polymers are bonded to each other very tightly. But there are lots of chains stacked on top of each other. These stacks make it possible to pull the tape from top to bottom and stretch your secret message. When the polymer chains are pulled from top to bottom, they slide over one another and reduce the number of chains in a section without breaking the chains themselves. When the tape is pulled back end to end, the chains are realigned, and your message is legible again.



12. Euro millions Number

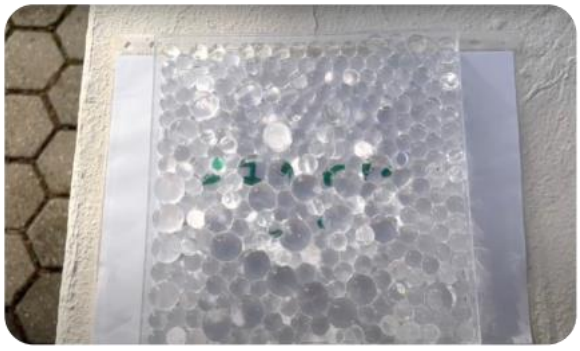
Tutorial - How to perform

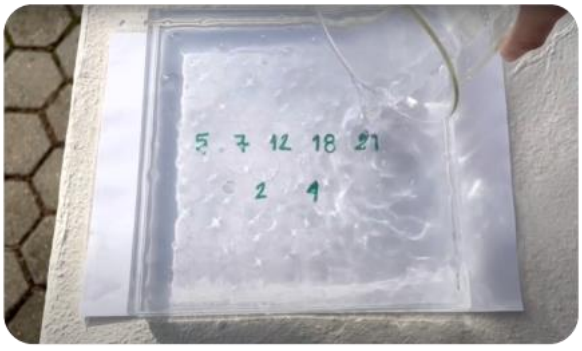
Effect

A message is placed behind or underneath a transparent glass filled with hydrogel spheres.

After this set up ask the audience to read the message we have for them.

Tutorial - Click





The Science behind

Aqua water beads when hydrated overnight, they have the same refractive index as water so are virtually invisible when covered with water. I like to put a beaker of beads on each bench and ask them to test the temperature, so they get a surprise when the feel the gel beads.

Hydrogels are virtually invisible in water.

A similar effect can be obtained with Pyrex and vegetable oil or glycerol as they have the same refractive index. We only see things when a refraction is when the light changes direction.

The message looks scrambled under the hydrated spheres because the light reflected off of the message is scattered in every direction by the water-filled hydrogels. It's like trying to read through broken glass, in other words, impossible! When water is added to the dish, the light rays pass straight through the water and the spheres into your eyes without being scattered. This is due to the hydrogels identical index of refraction with the water. So, it seems like you're looking through a cup of plain water and can easily read the message. These demonstrations can be used to link this with invisibility cloak technology developments.

13. Linking Paperclips catalyst demo

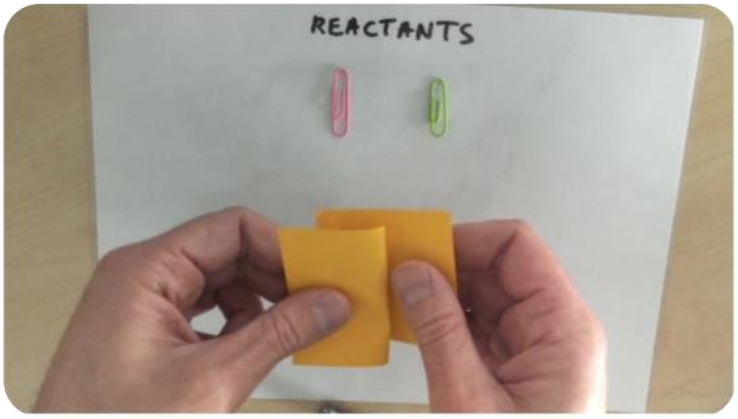
Tutorial - How to perform

With this trick we can demonstrate how a catalyst acts as a surface for reactants to come together and form a product. Based on an old magic trick, this idea came from Paul Nugent from Science on Stage Ireland. The ending is a nice surprise for students! Tutorial - Click

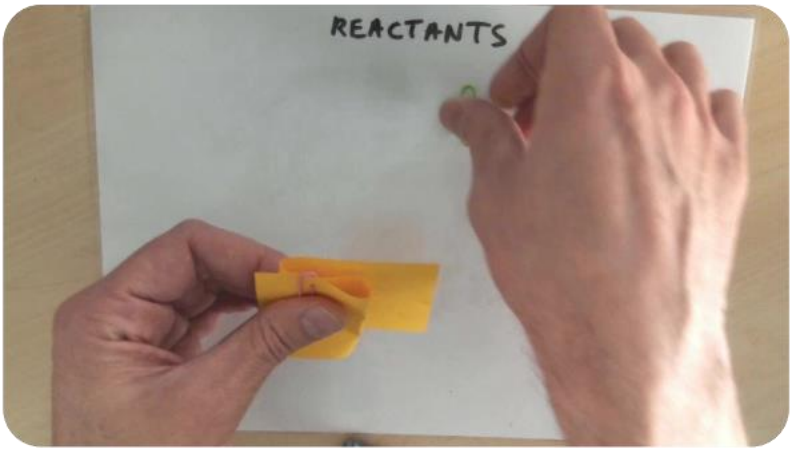
Effect

Two paper clips are shown. They represent two different reactant molecules. If molecules (paperclips) have the correct orientation and energy (energy greater than activation energy) to collide, they will link with other and from a chemical bond. This is shown the performer links the paperclips.

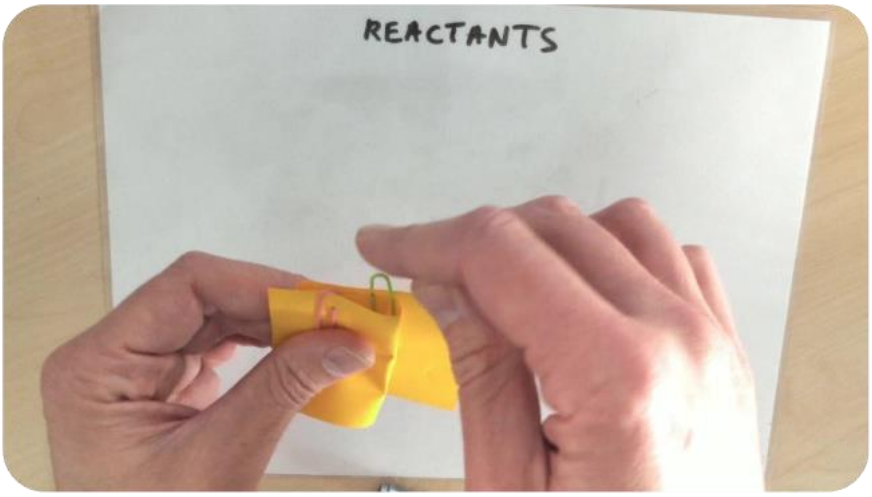
The paperclips are unlinked and put on a folded piece of paper which represents a catalyst. A catalyst speeds up a reaction, provides a surface for the reactants and lowers the energy required to perform the reaction. The paper is pulled, the paperclips (which were unlinked) jump off of the paper and are now linked showing the catalyst has worked!



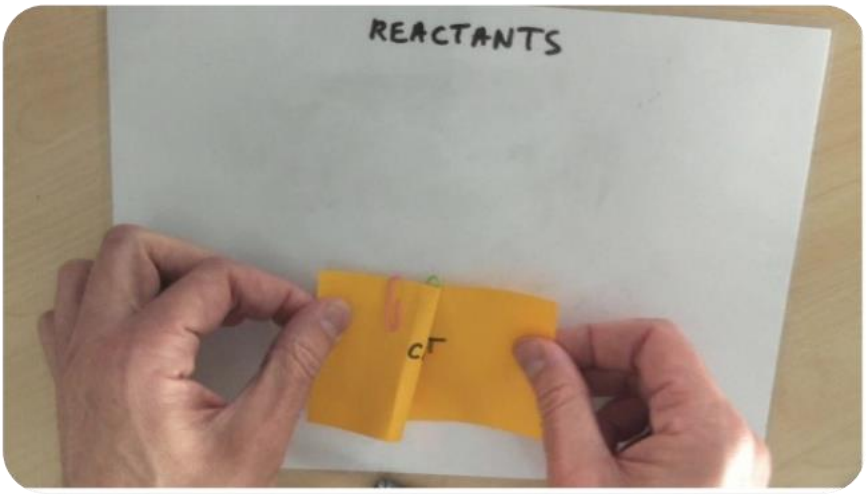
Take a piece of paper or money note (which is often smooth and easier to use) and fold into an S shape.



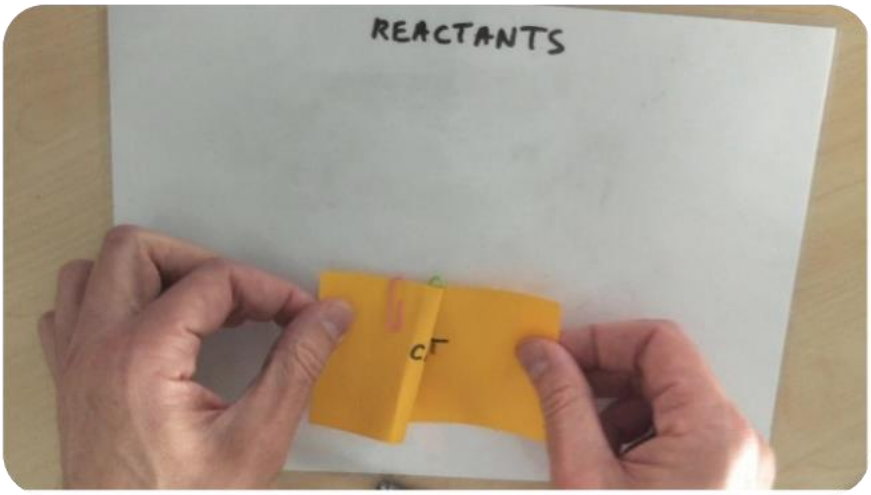
Place the first paperclip onto the note like shown in the picture below You want to join the front of the paper with the first ‘fold’ of the ’s’-shape.



Place the second paperclip on the note like shown in the picture below, joining the second fold of the ’s’-shape with the back of the paper.



Time for the **magic moment**. Holding the ends of the note or piece of paper between your forefingers and thumbs (see the picture below, pull the ends in opposite directions as to ‘unfold’ the note.



Time for the **magic moment**. Holding the ends of the note or piece of paper between your forefingers and thumbs (see the picture below, pull the ends in opposite direcEons as to ‘unfold’ the note.

Credit should go to Ireland’s Paul Nugent who performed this at a Science on Stage webinar in 2021.

Sustainable Development Goals (SDG)

The paperclips catalyst trick can show how less energy is needed when using catalysts and they can be reused.

Energy efficiency measures help reduce energy consumption and contribute to SDG 7's goal of ensuring sustainable energy use.

14. Invisibility

Tutorial - How to perform

Preparation of the trick (must be done before the audience is present): Prepare a container with vegetable oil. Inside this container should be a Pyrex glass test tube.

Show small pieces of Pyrex glass and point out that they are from a test tube that has broken, something that often happens in a school laboratory. Point out that we can, with a magic liquid, get our test tube back in one piece. Insert the small pieces of Pyrex glass into the container with vegetable oil. The audience will see the pieces 'disappear'. You can then ask the audience to help you with a magic word to get the tube back intact. Then remove the test tube that was inside the vegetable oil.

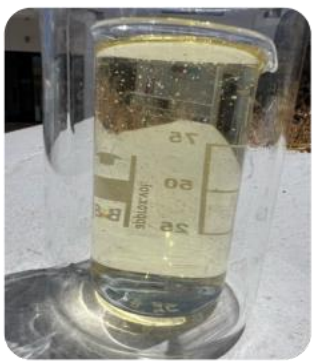
Tutorial - Click

The Science behind

By adding vegetable oil to these Pyrex glasses, we will witness the light changing direction, also known as refraction.

When light travels from one medium (like air) to another medium with a different refractive index (like Pyrex glass or vegetable oil), its speed changes, causing the light rays to bend, change direction. This bending of light is what we refer to as refraction. Refractive index is a measure of how much light slows down when passing through a particular material. The higher the refractive index of a material, the slower light travels through it, and the more it bends.

The index of Pyrex glass is similar to the refractive index of vegetable oil, so the light will have the same speed in both media, it will not bend when passing from the Pyrex glass to the vegetable oil and vice versa, which gives us the feeling that there is no other Pyrex glass inside of vegetable oil.



15. The ketchup trick

Tutorial - How to perform

To prepare the trick, simply place a ketchup packet inside a plastic bottle of water. Check that the ketchup packet floats in the water. Close the bottle tightly with the cap.

Tell the audience that you will get the ketchup packet down with your mind power. However, as you can see in the video below, the ketchup packet doesn't move (because you're not doing anything).

Next, involve the audience, ask them to help you. Ask them with the power of their mind to make the ketchup packet go down. Now squeeze the base of the bottle, without the audience realising, everyone will see the ketchup packet go down. Thank the audience for their support.

Note: Asking the audience for support is always a good idea, make them feel involved in the magic trick.

Tutorial - Click

The Science behind

The ketchup packet has some air inside. Squeezing the bottle with water increases the pressure and the air in the ketchup packet is compressed. This compression leads to a decrease in the volume of the packet, thus an increase in its density, because the mass remains the same. The density of the ketchup packet becomes greater than the density of the water and it sinks. When you let go of the bottle, the pressure decreases, returns to its initial value and the packet becomes less dense than the water in the bottle, causing it to float again.

Note: Sometimes the ketchup packet doesn't float, it sinks when placed in water. This is related to the density of the water used (which is not the same everywhere) and the density of the ketchup. Sometimes adjustments have to be made to the density of the water. If the ketchup sinks, we have to increase the density of the water, for example by adding salt.

16. The head that lost its body

Tutorial - How to perform

How the Illusion Works:

Visitors place their heads inside the opening of the table, and from the outside, all other museum visitors see is the top of their heads, seemingly floating without a body.

Prepare the Table: Ensure that the table has a sturdy base and is at a comfortable height for visitors to place their heads inside. Sand any rough edges and paint the table in a color that matches the illusion's theme.

Create the Opening: On one side of the table, measure and mark the area where visitors will put their heads. The opening should be large enough for people to comfortably place their heads through but not too large to spoil the illusion. Cut out the opening using a saw or other suitable tools and smooth the edges.

Lay the clear acrylic sheet over the table opening. Make sure it fits perfectly and covers the entire opening.

The Science behind

This is just a simple reflection of light creating this illusion.

17. The wildest race

Tutorial - How to perform

Show two tubes of the same size, one made of copper or aluminium and one made of plastic (not telling the public what material they are made of).

Drop a magnet through the aluminium or copper tube. The magnet falls much more slowly than if it were in free fall.

Drop the magnet again but now bring a ferromagnetic ring on your finger close to the tube. The magnet stops falling. Repeat but now with a plastic tube, the magnet will fall in free fall.

To perform this trick, we can ask for a volunteer to run a race, whoever takes the longest to get through the tube wins. We give the metal tube to the volunteer and keep the plastic one, count to 3 and drop the magnet at the same time. We congratulate the winner for managing to slow down the fall.

Tutorial 1 – Click Tutorial 2 - Click

The Science behind

This magic trick is related to the Lenz's Law, a fundamental law of electromagnetism that explains the direction of an induced current in a conductor in response to a changing magnetic field, with the induced current creating its own magnetic field to oppose the change. This law is named after the Russian physicist Heinrich Lenz, who formulated it in the mid-19th century.

Lenz's Law tells us that the direction of the induced current is such that it opposes the change in the magnetic field that caused it. In other words, the induced current creates a magnetic field that counteracts the change in the original magnetic field.

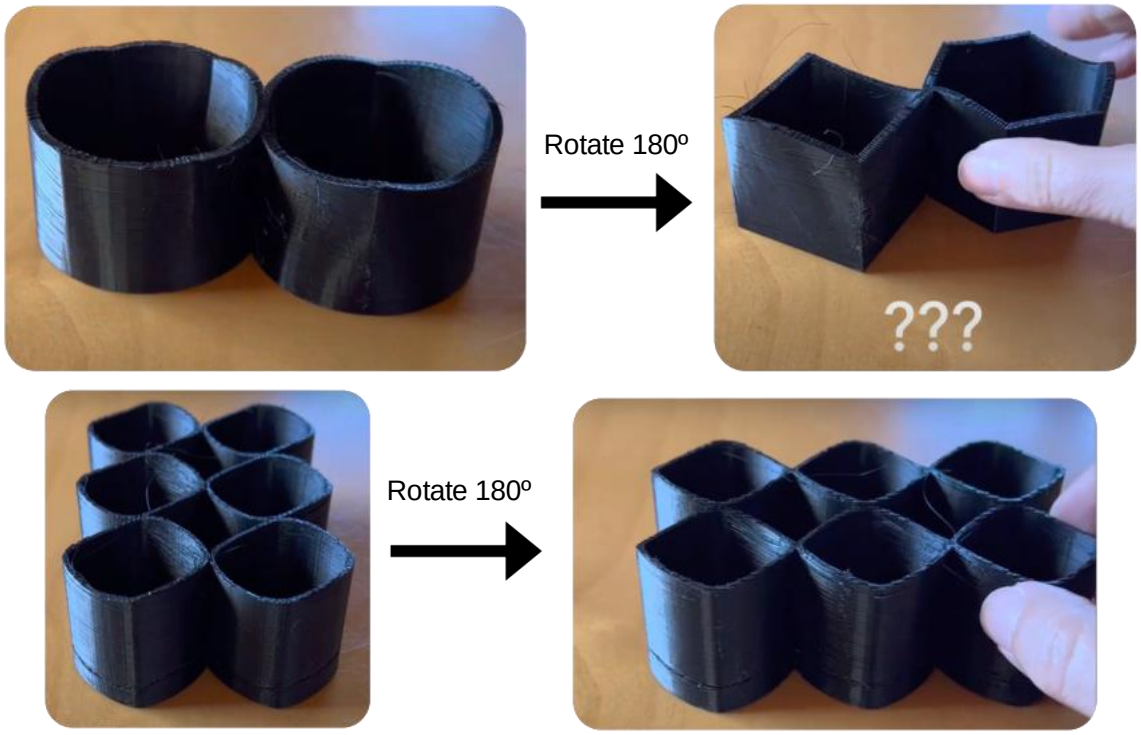
A common example used to illustrate Lenz's Law is the experiment with a magnet and a conducting tube (e.g., a copper or aluminium tube). When you move the magnet towards the tube, the changing magnetic field induces an electric current in the tube. According to Lenz's Law, the induced current creates a magnetic field that opposes the motion of the magnet.

This opposition between the induced current's magnetic field and the original magnetic field is the reason why objects, like the magnet, experience resistance or "drag" when moving through conductive materials.

18. Ambiguous cylinder illusion

Tutorial - How to perform

Place the cylinder it on a flat surface, such as a table. Stand directly above the cylinder and tilt your viewpoint at approximately a 45-degree angle. Now, begin slowly rotating the cylinder. As you do so, observe the shape closely, and you'll notice that it alternates between appearing as a circle and a square. Finally, complete the experiment by rotating the cylinder 180 degrees to observe the captivating transformation. Tutorial - Click



The Science behind

This enigmatic cylinder defies logic! From one angle, it presents itself as a square, but shift your perspective, and it magically transforms into a circular shape. Astonishingly, when you place it before a mirror, you witness both sides simultaneously—the circle before you, and its reflection in the mirror as a square, or vice versa. However, this bewitching illusion only unfolds when viewed from a specific angle. The cylinder is carefully made to create an amazing trick. It looks like a square from one side and a circle from the other, but only when you look at it from a special angle - albeit exclusively when viewed from an elevated 45-degree angle. Nevertheless, a true revelation awaits those who choose

to look directly down upon it, exposing its actual form. The top and bottom of the cylinder are not flat; they are curved. When you look at it from a certain angle, your mind gets confused and thinks the curves are flat. This makes your brain tricked into seeing either a square or a circle, depending on which side you look at the cylinder from. It's like a cool magic trick!

See the explanation in the next video and take the opportunity to make the connection with the constellations.

https://youtu.be/GfOcBwOwssw

19. The Liquid of Invisibility

Tutorial - How to perform

Begin by creating a drawing or using a small picture (depending on the context of the trick, in the following video are several examples). Tutorial - Click

Insert the drawing into the plastic bag, ensuring that it is fully sealed inside. Draw or write with an acetate pen what you want to see when you submerge the plastic bag in water.

Fill a container with Water.

Submerge the Bag in Water.

Observe the Illusion: As you lower the bag into the water, you will notice that the drawing seems to disappear, and we can only see what has been drawn or written in acetate pen.

The Science behind

The trick involves a simple optical illusion that demonstrates the concept of total internal reflection.

The illusion occurs due to a phenomenon called total internal reflection. When light travels from a denser medium (in this case water) to a less dense medium (in this case the air inside the plastic bag), the light can undergo reflection at the boundary between the two mediums. However, if the angle at which the light strikes the boundary is too shallow, the light does not escape but reflects entirely back into the denser medium.

In this trick, the plastic bag acts as a boundary between the water and the air inside the plastic bag. When you submerge the bag in water, light from the drawing inside the bag encounters the bag's surface at a shallow angle. Due to total internal reflection, most of the light reflects back into the water, making it difficult to see the drawing clearly.

It gives the impression that the drawing on the inside of the bag has disappeared.

Idea: This illusion can be performed with children to demonstrate the importance of hand washing.

Sustainable Development Goals (SDG)

This illusion can be used to demonstrate the importance of hand washing.

Washing our hands is not just a simple task – it's a powerful way to keep ourselves healthy and well.

This connects to "SDG 3: Good Health and Well-Being."

20. The magic number

Tutorial - How to perform

Give a volunteer from the audience an envelope with a prediction.

Show 9 cards numbered from 1 to 9. Ask a member of the public to choose 3 cards.

Write the chosen numbers on a board or sheet of paper. For example, if the numbers 2, 5 and 8 have been chosen, the rule is to put the largest number on the left (but this instruction should not be communicated).

Write down the number 852.

Now ask them to subtract the inverse, i.e. 852 - 258. Write the result 594 and add the symmetric.

Write down the result 1089.

Now ask the person you gave the envelope to open it and ask them to read the number written on it: it's 1089.

Tutorial - Click

The Science Behind

Let us assume that the iniEal number is the larger and has digits a, b and c. So, when we reverse and subtract we will have (100a + 10b + c) – (100c + 10b + a)

This is the same as 100a + 10b + c – 100c – 10b – a = 99a – 99c = **99**(a – c)

Because a and c are integer numbers, at the end of the first part of the process we will always end up with a mulEple of 99.

The three digit mulEples of 99 are: 198, 297, 396, 495, 594, 693, 792 and 891.

Now, note that the first and last digits of each number add up to 9.

So, when we reverse any of these numbers and add them together we get 9 hundreds from the first digit, 18 dozens from the second digits and 9 units from the third digit.

So we get **900 + 180 + 9** = 1089.

21.Phoenix from the ashes

Tutorial - How to perform

Safety First

This activity should only be carried out by a teacher.

Before performing the experiment, please check the risks and safety of experimental activities with fire. This torn and restored demonstration involves setting fire to some craft tissue paper rolled into a tube. Tutorial - Click

The Science Behind

This causes the air inside the tube to become less dense and rise, carrying the ashes with as they float. The ashes can be caught and restored using a duplicate piece of paper hidden in the catching hand.

This can be done with certain types of teabags, or a special type of craft paper found in packets of flying wish paper. Ordinary tissue paper is too heavy, craft paper from florists is the paper that was used in the video. The Science - Click

Magic for the youngest

When children see a magic trick, they are enchanted and motivated to understand how it works. This natural curiosity is a great starting point for introducing scientific concepts.

The power of the mind

Concept: Density

Tutorial - Click

This magic trick is great for children to choose or create their own role-play.

The bottle of water may represent the seabed and the ketchup packet may represent a submarine or a fish. The water bottle could be down the rabbit hole and the ketchup packet could be Alice. These are just two examples of stories that can be used as context for the trick.

The bottle itself can be animated with children's drawings.

This is the same trick on page 30 that can also be used by primary school teachers to explain the concept of density and how submarines work.

The liquid of invisibility

Concept: Straight-line light propagation and refraction.

This illusion can be performed with children to demonstrate the importance of hand washing.

Instructions:

1. Start by asking children to draw what they think are germs on our hands.
2. Insert the drawing into the plastic bag, ensuring that it is fully sealed inside.
3. Children should now draw their hand on the bag with a permanent pen.
4. Fill a container with Water.
5. Submerge the Bag in Water.

Observe the Illusion: As you lower the bag into the water, you will notice that the drawing germs to disappear and we can only see what has been drawn in acetate pen, a clean hand.

The trick involves a simple optical illusion that demonstrates the concept of total internal reflection. Although this is a complicated concept for young children, it can be explained in a very simple way: - Imagine you are playing with a flashlight. When you shine the flashlight on a mirror, the light bounces back, right? That's called reflection. What happens in this experiment is that the light is reflected without letting you see the drawing that is inside, we call this total reflection.
Tutorial - Click

Sustainable Development Goals (SDG)

This illusion can be used to demonstrate the importance of hand washing. Washing our hands is not just a simple task – it's a powerful way to keep ourselves healthy and well. This connects to "SDG 3: Good Health and Well-Being."

Secret messages

Concept: Light and its characteristics.

This very simple activity can be performed by children in Pre-School and Primary as a simple magic trick, the magic paper that reveals secret messages and much more! An opportunity to talk about light and colour.

Tutorial - Click

INSTRUCTIONS

1. The child should draw his/her message or drawing on the paper using only a blue pencil.

2. Then, they should hide the message/drawing with a red, orange and yellow pencil, using circular movements (do not paint evenly, as the result will not be the same).

3. Use red cellophane paper (which can easily be replaced by some candy wrapping paper) to reveal the hidden message/drawing.

This activity can also be carried out using red gelatine. Just make sure that the container containing the gelatine is transparent so that you can see the message behind it.

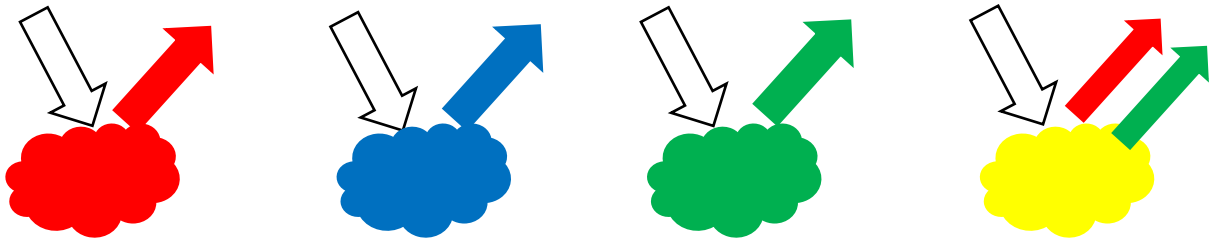
Gelatine and secret message - Click

SUGGESTIONS

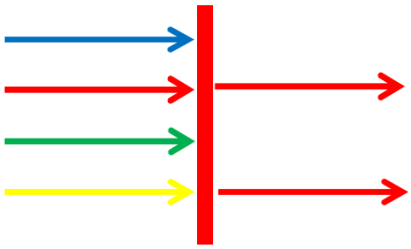
This activity can be done at festive times, such as a card with a Christmas message, it could be an activity carried out on St Valentine's Day or to hold an exhibition where children draw what they think, inspired by Laurent Moreau's book "What do you think about?". They can draw what they think in blue and hide it with red, orange and yellow, and only with very special glasses (with red filters) will we be able to see what they've drawn.

The science behind

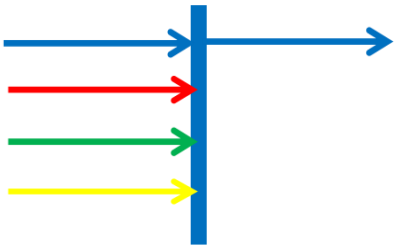
Our eyes see objects through the light they reflect.



Filters absorb some light and transmit other light. So using filters to observe objects causes them to be observed in different colours.

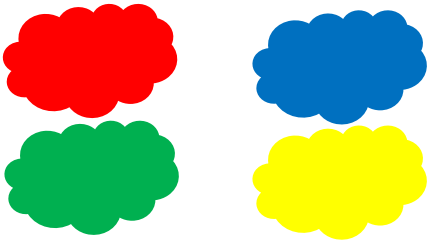


Red filter



Blue filter

Using the red filter



No filter

With red filter

A red filter absorbs all lights but the red light it transmits.

So, as the colour white reflects all lights, when we use a red filter we will only observe the colour red.

A white cloud will look red.

The colour **red** reflects red light, so using a red filter a red cloud will look red.

The colour **blue** reflects blue light, so using a red filter a blue cloud will look "black" (although scienEfically speaking black is the absence of colour) as the filter does not let blue light through and no light reaches our eyes.

The colour **yellow** reflects red and green light, using a red filter a yellow cloud will appear red because the filter lets through only red light.

The colour **green** reflects green light, by using a red filter a green cloud will look black (no colour) as the filter does not let green light through and no light reaches our eyes.

So, as the colour white reflects all lights, when we use a red filter we will only observe the colour red.

A white paper will look red.

The colour red reflects red light, so using a red filter a red drawing will look red.

The colour blue reflects blue light, so using a red filter a blue message/drawing will look "black" (although scientifically speaking black is the absence of colour) as the filter does not let blue light through and no light reaches our eyes.

The Science - Click

Curve or square?

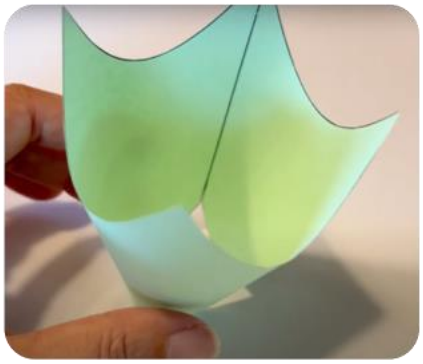
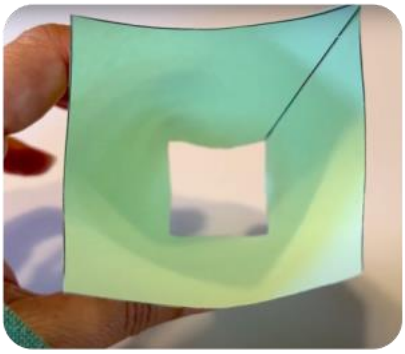
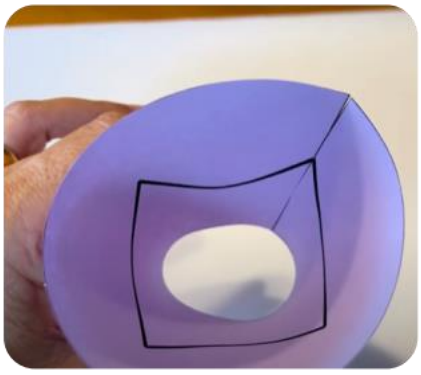
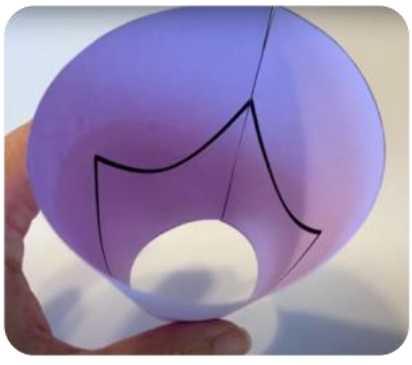
This trick can be used in Pre-School and Primary to talk about shapes using a story.

For older students we can use this trick/illusion to talk about perspective.

How about using this story for the little ones and adding this illusion?

Tutorial - Click

"Once upon a time there was a square named Claire. Claire liked to play and explore. One day, something magical happened. Claire started to change. She became a curve, Claire giggled with joy, rolling like never before. She discovered a new way to play. Bute as the sun began to set, Claire wanted to be a square again. With a wish and a twist, she turned back."

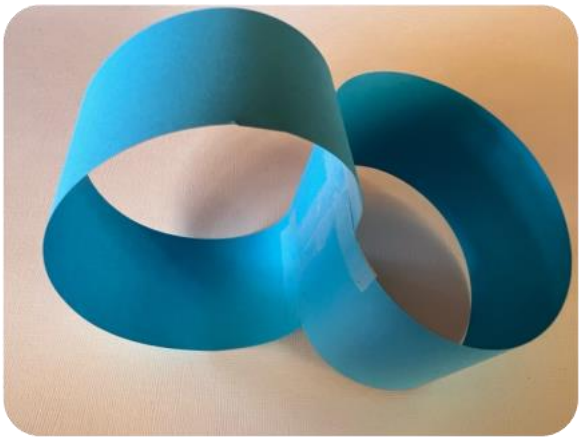
How to transform 2 circles into a square?

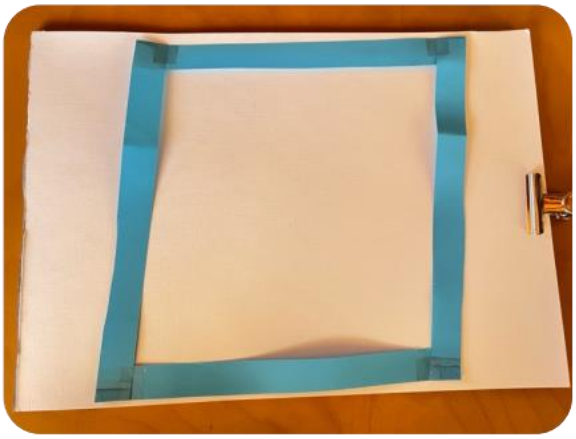
Concept: Geometric shapes

Tutorial - Click

This trick can be used in Pre-School and Primary to talk about shapes using a story.

For older students we can use this trick/illusion to talk about perspective, point of view and to talk about our differences and how we can try to eliminate what divides us.





How about using this story for the little ones and adding this illusion?

"Once upon a time, there were two intertwined circles called Twirly and Whirly. They always saw things differently, and neither could understand the other's point of view.

One day, they realized that these differences were tearing them apart. They decided to take some time to understand each other and work together.

With patience and some tweaking, counting their differences, they found a way to align their views. In doing so, they magically transformed themselves into a frame and both of them, at the same time, could understand each other because they were looking to the same thing at the same time.

We learn from Twirly and Whirly, we can overcome differences and that we can find a way to see the world in the same way and understand each other's point of view."

Math Tricks

The magic number

Tutorial - How to perform

Give a volunteer from the audience an envelope with a prediction.

Show 9 cards numbered from 1 to 9. Ask a member of the public to choose 3 cards.

Write the chosen numbers on a board or sheet of paper. For example, if the numbers 2, 5 and 8 have been chosen, the rule is to put the largest number on the left (but this instruction should not be communicated).

Write down the number 852.

Now ask them to subtract the inverse, i.e. 852 - 258. Write the result 594 and add the symmetric.

Write down the result 1089.

Now ask the person you gave the envelope to open it and ask them to read the number written on it: it's 1089.

The Science Behind

Let us assume that the initial number is the larger and has digits a, b and c. So, when we reverse and subtract, we will have (100a + 10b + c) – (100c + 10b + a)

This is the same as 100a + 10b + c – 100c – 10b – a = 99a – 99c = **99**(a – c)

Because a and c are integer numbers, at the end of the first part of the process we will always end up with a multiple of 99.

The three-digit multiples of 99 are: 198, 297, 396, 495, 594, 693, 792 and 891.

Now, note that the first and last digits of each number add up to 9.

So, when we reverse any of these numbers and add them together, we get 9 hundreds from the first digit, 18 dozens from the second digits and 9 units from the third digit.

So, we get **900 + 180 + 9** = 1089.

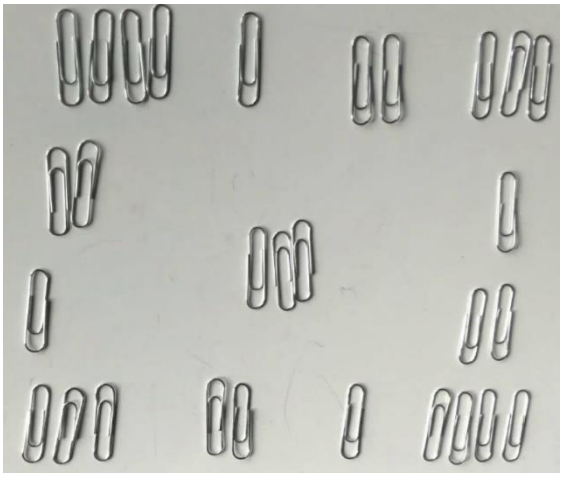
Perfect Ten Paperclip Paradox

Tutorial - How to perform

Tutorial - Click

The Perfect Ten Paperclip Paradox is a mathematical puzzle that was published in the book, The Art of Astonishment- Volume 3 by Paul Harris. A new paperclip is added to the outside of a square composed of paperclips three Emes, but the mysteriously, the number of paperclips on each side remains the same.

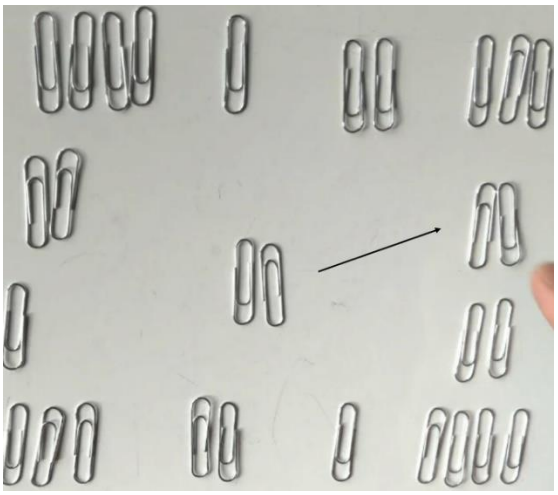
Get 29 paper clips and arrange them on a table as shown below as shown in figure 1.



1

The square is a perfect ten on all sides. Count the top rows, lev side, right side and bottom row to check.

Pick up a single clip from the pile in the middle and move it to the right row as shown in figure 2.
Move one clip from the lower right corner to a middle spot on the bottom row as shown in figure 3.



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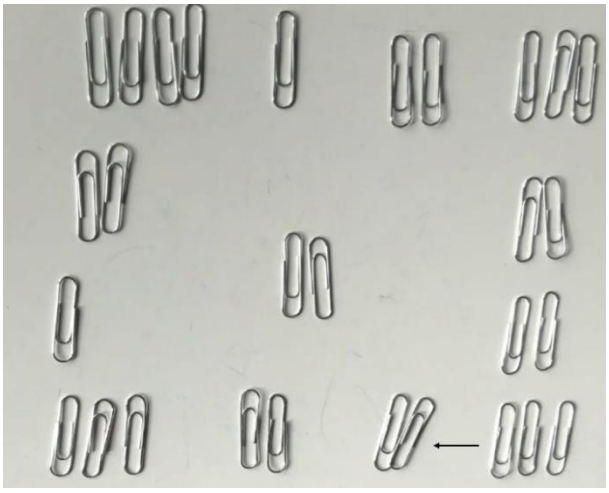
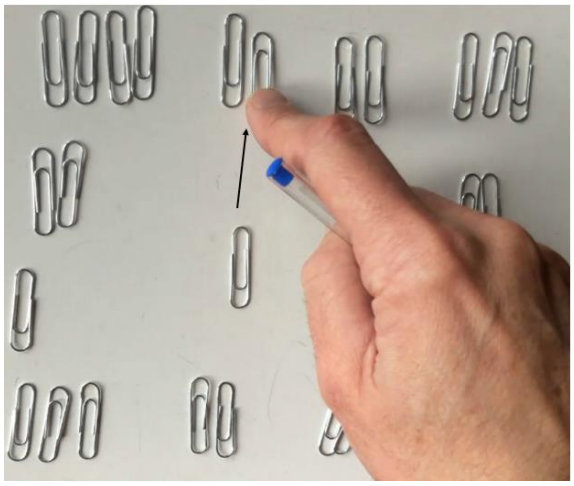


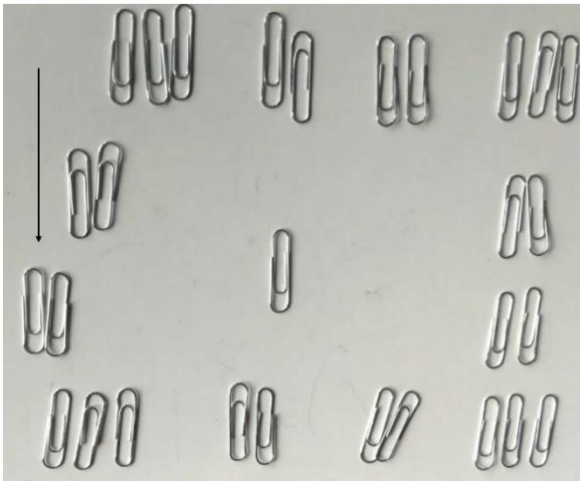
3

Count the rows. Each row has ten clips even though have just added one. It appears that a paper clip has vanished!

Take another clip from the pile in the middle and put in the top (Figure 4). Now move one clip from the upper lev corner to the lev side (Figure 5).



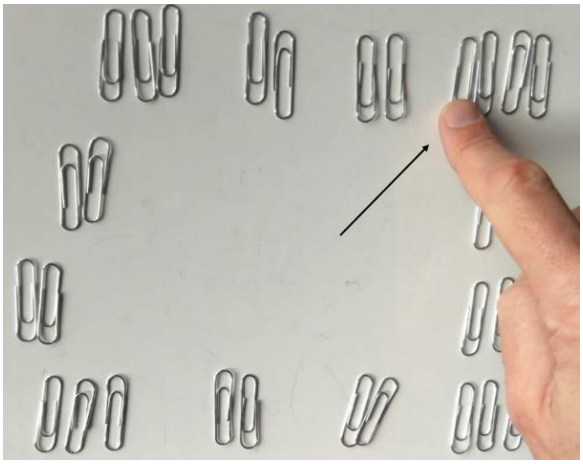
4



5

Count the rows again, there should ten clips in each row. Another paper clip has mysteriously vanished.

Pick up the final clip in the middle. Put it in the top right corner as shown in figure 6. Move two clips from the same corner - one goes in the top row, and the other in the right-side row as shown on figure 7. Count the four rows again. Where did the clip go?



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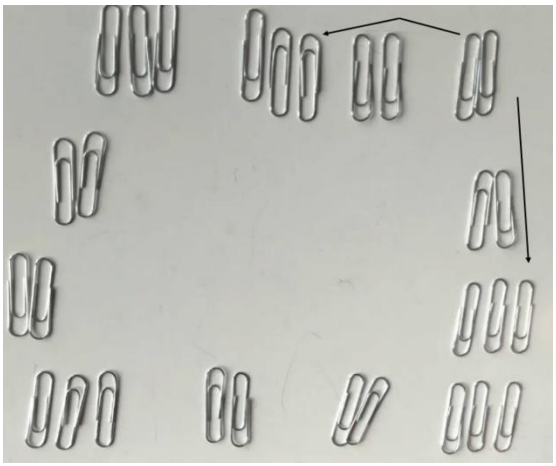


7

The Science Behind

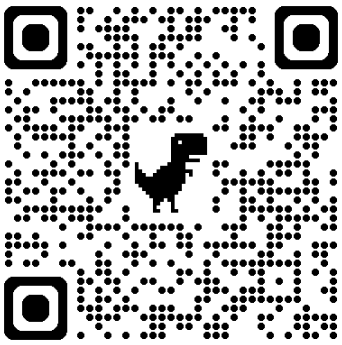
[The Science - Click]

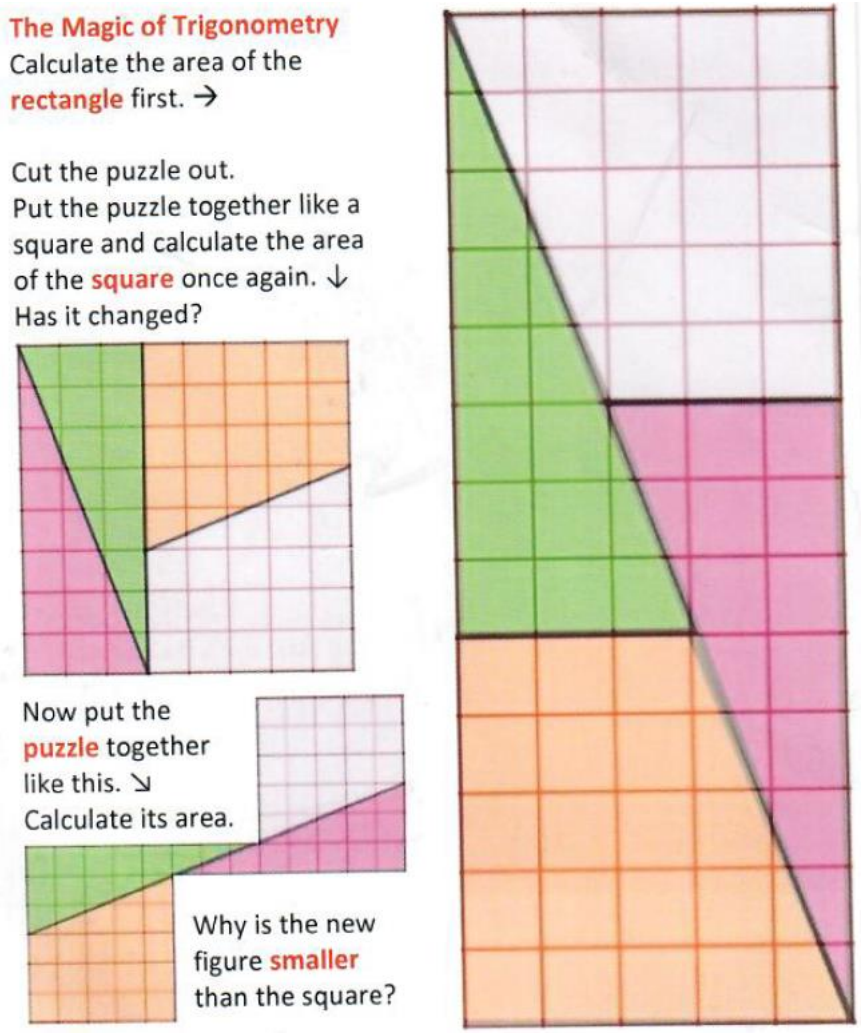
The explanation for this puzzle is due to the arrangement of the clips. When counting the clips, the ones in the corner are counted twice, as they are part of a horizontal row and a vertical side. The clips between the corners are counted only once during the counting process. When a clip is added to a row or side, there are initially eleven clips in the row or side. However, when a clip is then moved from a corner to a place between the corners, it is only counted once, which keep the numbers of clips at 10 when counted for each row or side. A video explanation is also available for this puzzle by using the link.

Vanishing square puzzle

Tutorial - How to perform

This magic puzzle was presented by Dieter Kadan from Austria, at the 2019 Science on Stage festival. It is based on a magic puzzle invented by a New York Magician named Paul Curry, although the principle of this paradox has been known since the 16th century (https://en.wikipedia.org/wiki/Missing_square_puzzle).





When the shapes are assembled, the number of squares in the rectangle is 65, the square has 64 squares, and the final shape has sixty-three squares. It appears the squares are vanishing each time the pieces are reassembled!

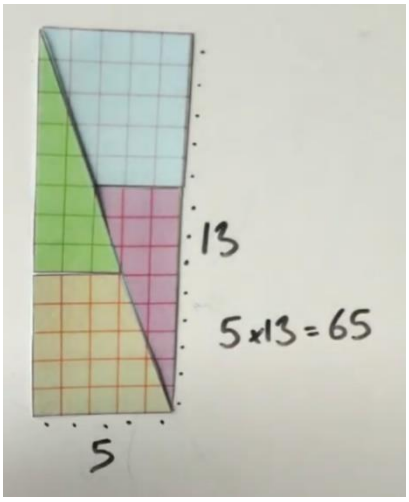
Tutorial - Click

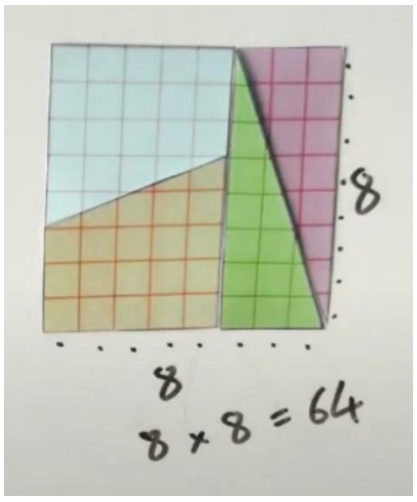
The Science Behind

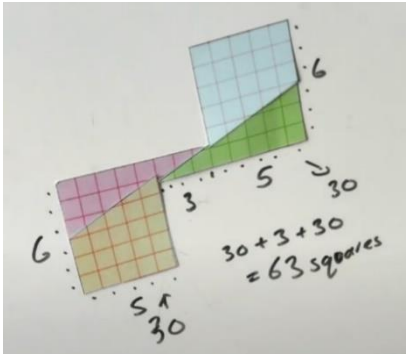
Explanation

The true number of squares is 64 as seen in the square shape. When the shape is assembled into a rectangle, the pieces don't align completely. There is a small amount of space from the top lev to bottom right diagonal. This space is equivalent to the area of one extra square, giving the illusion of 65 squares in this shape. When the other shape is reassembled, there appears to be 63 squares, as the pieces have to overlap each other slightly to form the shape. The area of overlap is the same as one whole square, so it appears there is one square less.

This is a nice way to show how care and precision are required in science to generate accurate data. If care isn't taken when gathering data, then the results can be variable as shown when trying to count squares in shapes if the pieces aren't aligned properly. [The Science - Click]







Mathematical Mind Reading

Tutorial - How to perform

Tutorial - Click
Try this!
1: Think of a number from 2 to 10
2: Multiply your number by 9
3: Add the two numbers of your total together
4: Take 5 away from your answer
5: If your answer is 1, it equals A; if it's 2, it equals B; if it's 3, it equals C; if it's 4, it equals D (no need to go any higher, as the answer will of course always be D)
6: Think of a country in Europe beginning with your letter
7: Think of an animal, not a bird or a fish, beginning with the second letter of your country
8: Think of the colour of your animal
Most of you will be thinking of a grey elephant in Denmark!

The Science Behind

This is a self-working math's trick. Any single digit number multiplied by 9 will give two-digit number. If you add the digits of the two-digit number, it will always add up to 9.
So, if you choose 7, 7 x 9 = 63, 6+3 = 9. If you subtract 5 from 9 you will get 4.
D is the fourth letter of the alphabet. The country most people will think of is Denmark. Don't give people too much time to think or they may come with Djibouti or Dominican Republic. The second letter of Denmark is E so most will think of elephant when asked for an animal beginning with E. The colour of an elephant is grey which you announce to the class as evidence of your mindreading abilities.
The Science - Click

Water Math Answer

Concept: Refraction of light

Tutorial - How to perform

1. Draw the following numbers, on your piece of paper:

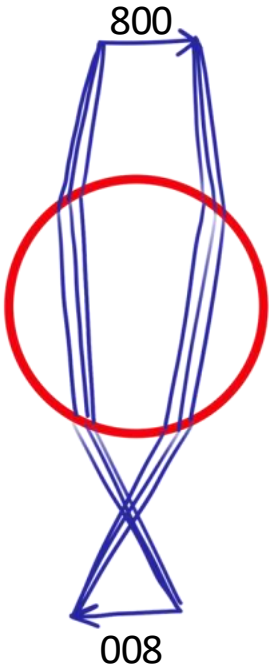
2. Find a way to keep your paper standing;
3. Put the glass in front of your numbers;
4. Pour water into your glass until the level of the water is above the numbers;
5. Move the glass towards and away from you until you find the spot where the numbers are reversed;
6. Once you've worked out where that is you are ready to perform the trick.
7. To perform the trick, cover the glass with a small card or handkerchief before adding water to create a greater effect.

[Tutorial - Click]

The Science Behind

When we add water to the glass 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.

Without water in the way we see the numbers as they are. This is because light spreads out in all directions and some of it will travel in a straight line to our eyes. When there's water in the way the light bends.



Reversed numbers

[The Science - Click]

Final Thoughts

This project has brought us immense joy and satisfaction. Working together from different countries, we shared ideas, knowledge, and a part of ourselves in this collaborative effort. We created this resource to share with teachers, including videos that explain both the magic trick and the science behind it. These videos are available through easily accessible QR codes and links.

Additionally, we organized a science fair where our students presented the magic tricks to the school community. You can see a glimpse of this science fair dedicated to magic in the following link.

The Science Fair Video - Click to watch

We hope you enjoy this material as much as we enjoyed creating it!

Adrian and Rute