The Scottish Science and Technology Roadshow

SCI-FUN

Exhibit Booklet

V4 – October 2017

Helpful Hints

Thank you for volunteering to be a guide for the visit of the SCI-FUN Roadshow. You will be required mostly for the hands-on exhibit part of the Roadshow session. During this time you will either be guiding a group of S1 or S2 pupils around the activities, or you will be stationed at a particular group of exhibits.

Guiding a group

- You will be allocated one group (usually of 4 or 5 pupils) and you can then begin guiding this group around the exhibits. You can start at any activity.
- It's important to get as many pupils in the group as possible to actually do the activities; it's easy to fall into the trap of just demonstrating the exhibits. Try to highlight the principal scientific ideas behind each item.
- If you need to check anything, you (or the pupils) can read the card beside most of the exhibits; alternatively, you can refer to this booklet.
- You should have about forty minutes in this session, so don't linger on any one activity for too long!

Stationed at exhibits

- If you don't have a group, then you will be assigned one or more exhibits, for which you will be the demonstrator.
- Groups of pupils will go around the activities and try them out. Your task is to ensure that the pupils have a reasonable understanding of the scientific idea behind each exhibit(s) to which you are assigned.
- Referring them to the accompanying card or poster for most of the exhibits could be the easiest way to do this, once you have explained the underlying ideas.

Make sure you refer to the Health and Safety section at the end of this booklet.

Contents

Animal Tracks

What to do

- **Smooth out the sand.**
- **Take one animal foot cast and print it hard on the surface.**
- **Try to work out what animal could have made the print, before lifting the flaps to find the answer.**

What does it tell us?

- Studying the tracks allows you to identify the animals that made them.

- Animals leave different impressions in the ground depending on how they walk:

    a) A <u>Plantigrade</u> animal walks with the entire sole of its foot on the ground. (Examples are Humans, bears and squirrels.)

    b) A <u>Digitigrade</u> animal walks with the whole length of its foot on the ground but not the sole, so the impression in the ground will show only the toes. (Examples are dogs, cats and foxes.)

    c) <u>Ungiligrades</u> animals are hoofed mammals that walk on their tip toes (horses, cows, deer).

A full cycle of motion of a mammal walking or running is called a *stride*. By studying animal tracks we can work out the speed at which the animal was moving, because the faster the animal moves, the further apart are its tracks.

BMI (Body Mass Index)

A person's BMI is calculated by measuring their height and weight and performing the following calculation:

$$\textbf{BMI} = \textbf{Weight (Kg)} / \textbf{Height}^2 \textbf{ (m}^2\textbf{)}$$

To measure the person's height

- Hold the device horizontally, with the white panel on top of the person's head. Use the spirit level to ensure it is level.
- Press the red button until a beep is heard.
- Continue to hold the device steady until a double beep is heard (about 5 seconds).
- The height (in metres) can then be read from the display.

Note: make sure the device is facing the right direction; the red button should be on the underside when you press it, otherwise you will be measuring the distance between the person's head and the ceiling!

To measure the person's weight

- Tap the scales to ensure they are switched on and display reads "0".
- Get the person to stand still on the scales until the display stops flashing: the weight will be displayed in kilograms on the screen.
- Use the table provided to match up the person's weight and height to determine their BMI.
- Healthy values of BMI vary with age and also depending on whether someone is male or female; healthy ranges are shown underneath the table.
- BMI does not take into account muscle mass, so people who have a large amount of muscle may have a BMI above the healthy range while still being healthy.

Body Clocks

What to do

- **Are you a morning person (a LARK) or an evening person (an OWL)?**
- **After reading the information on the board, work out when you (think you) are at your best: early on, or later in the day.**
- **Spin the centre dial of the disk and read the information in the windows: find out what the best time of day is for eating, exercising and lots more (including dropping dead...)**

Turn the exhibit around to find out more about body clocks and their role in your everyday life.

How does it work?

- Every cell in your body contains a rhythmic timekeeper: a *clock*. Our brain contains a "master clock" – the *Suprachiasmatic Nucleus* – that makes sure cells throughout the body are kept in synchronisation with each other.
- Body clocks help control nearly every process in our bodies, from sleeping patterns to our digestion.
- For example, body clocks help warm our muscles up and raise our blood pressure just before we wake up so that our bodies are ready to use straight away.

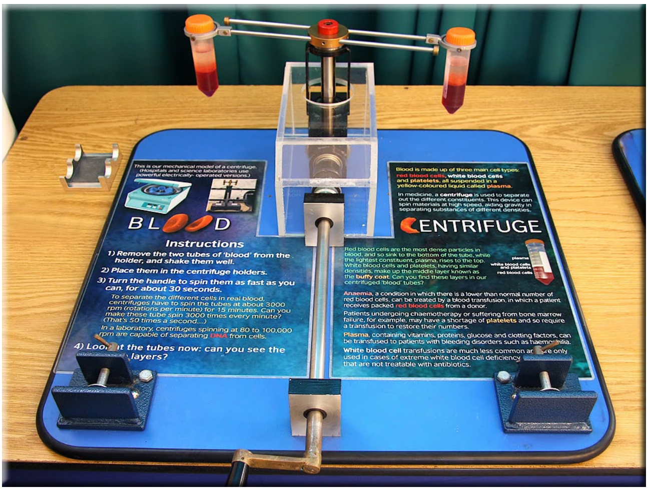
Centrifuge

How to use the centrifuge

- **Shake up the tubes to ensure that all the layers are well mixed.**
- **Place one tube in either arm of the centrifuge, behind the plastic screen.**
- **Get a member of your group to turn the handle as fast as they can for about 20 seconds.**
- **Once the centrifuge has stopped remove the tubes: three distinct layers should now be visible.**

Can you name the three layers, based on the board notes?

Safety note: Ensure all members of your group are in front of the plastic safety screen before spinning the tubes.



How does it work?

- The three main components of blood have different densities.
- The centrifuge apparatus spins them at high speed, which causes heavier cells to be forced to the bottom of the tube while lighter cells remain on the top of the sample, allowing the three different layers to form from each different type of cell found in blood.

The Coandă Effect

What to do

- **To start place the ball over the jet of air. (The base unit has a red switch on top if the exhibit is not on.) The ball is able to hover on the jet.**
- **Gently hold the end of the nozzle (not over the top!) and slowly tilt it sideways. If you are careful enough, the ball will remain levitating for longer than you might think...**

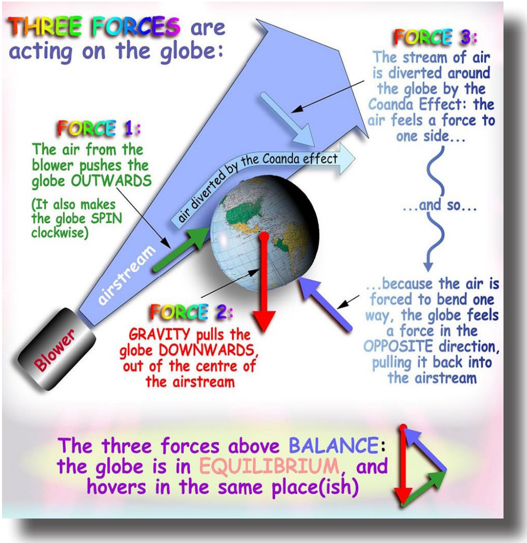
How does it work?

- In the starting position (pointing straight up), there are two main forces at work. Gravity tries to pull the ball down, but the jet of air balances this and levitates the ball. (The ball may "bounce" up and down to start with – this is the gravitational and jet forces finding a balance.)
- When you move the end of the nozzle, the ball will remain levitating since there is a third force acting upon it. If there were only the forces of gravity (pulling the ball down) and the jet of air (pushing the ball away), the ball would quickly fall.
- The extra force is caused by the *Coandă Effect*, which is the tendency of a stream of liquid or gas to stay attached to a convex (curved) surface, rather than following in its original direction of travel. (Note that there is a misunderstanding of the Coandă effect, which we discuss on the next page.)

Continued on the next page.

Safety Note: *The jet of air for this exhibit travels at approximately sixty miles per hour, so it important that the pupils do not aim it at their own or anyone else's face. Although very unlikely, if a piece of grit gets caught in the jet of air it could potentially cause some significant eye damage.*

The Coanda Effect (cont.)



- When the jet of air reaches the ball, part of the jet stays attached to the ball, following it around part of its upper curved surface (as you can see opposite): this is known as *skin adhesion.* As the jet moves along this surface, friction acts just as it would between any two surfaces, and so the jet of air slows down here. The key point to understand is that the *direction* of the jet is changed.
- Newton's third law tells us what happens to the ball: the jet feels a force, caused by the ball (the skin adhesion effect) which bends the jet downwards. The ball therefore feels an *opposite* force from the jet, pulling it upwards.
- The Coandă effect is named after Henri Coandă (1886 – 1972), a Romanian inventor whose work in aerodynamics led to the development of the modern jet aircraft.

1) The Coandă effect *only* applies when one fluid or gas moves through the *same* fluid (such as in our exhibit). It does *not* apply when, say, liquid flows through air. When a teaspoon is held vertically in a stream of water and is diverted to one side, for example, this is caused by *surface tension*, and *not* by the Coandă effect (as you may read online).

2) You will often read that this exhibit works because of the Bernoulli effect, which relates pressure of a gas to its velocity. The Bernoulli equations apply *only* to a *single* "flow field", in which all of the air passing the object is initially at the same speed/direction. With this exhibit there are *two* flow fields: the upper one from the blower, and the lower one (no flow at all). Bernoulli's equations do *not* apply!

Colour Box

What to do

- **Look through the hole into the box with the lid closed – what colour do you see?**
- **Keep looking through the hole as you lift the lid. What colour do see now?**

How does it work?

- When light hits an object, some is absorbed and some scattered. The scattered light from the object then enters our eyes, making it visible to us: we see the colours that are not absorbed.
- When looking into the colour box with the lid down it looks black, but when the lid is lifted it allows white light to shine in. White light is made up of lots of colours, which we are able to see in a rainbow: red, orange, yellow, green, blue and violet.
- Most of these colours in the white light are absorbed by the paint inside the box, but yellow light is reflected to our eyes.
- Another good example is the leaves of green plants which contain a pigment called chlorophyll. This pigment absorbs blue and red light but reflects green light.
- It's actually a bit more complicated than this: an object which reflects both red and green light will also look yellow to our eyes, because of the way the receptors in our eyes have evolved. We can detect red, green and blue light: yellow light activates both the red and the green receptors.
- By putting together various combinations of the primary colours red, green and blue we can fool our visual system into seeing most of the colours in the visible spectrum. We can even see colours such as magenta (red and blue), which don't actually exist in the spectrum as a pure colour!

Components of Blood

The plastic tubes contain representations of the three main components found in blood:

- Red blood cells
- White blood cells
- Platelets

Each of these is responsible for a different function; these are explained in depth on the board. The speed at which the different components fall through the tubes depends on their size and shape.

Can your group correctly predict which cells will reach the bottom of the tubes first?

Conflicting Signals

What to do

- **Your task is to read the *colour* of the word, and not the word itself. For example, you should read "BLUE" as "RED", because the *colour* is red.**
- **Now turn the board around, and try the words on that side. Again, you must read the *colour* of the word rather than the word itself. Is it easier or harder to do the exercise now that each word has been mirror-reversed?**
- **Try reading the paragraph on the A4 card; how easy do you find this task?**

How does it work?

- Your brain is receiving conflicting signals regarding the colour you are seeing. Through life we have been taught that is RED, and the word "BLUE" relates to this colour:
- Therefore, when we are presented with the word "BLUE" written in red, our brain receives two signals: the word (blue) and the colour (red). Our brains are well trained to say the word, and this signal gets in the way: it makes us hesitate when we try to quickly say what colour the word is.
- Mirror-reversing the words should in theory make it easier, because this lessens the effects of the word signal to the brain, and the word makes less sense. Some people, however, find this task more difficult. One theory suggests that in seeing a reversed word we automatically try to put it back round the correct way to make sense of it. This adds an additional mental step which confuses us further.
- The paragraph on the card is quite readable despite the random alterations. Spoken and written language has lots of redundancy: you can still work out what is being said even when there are errors or whole pieces missing. Some sentences can prove more difficult if we don't randomise the letter order: ***A dootcr has aimttded the magltheuansr of a tageene ceacnr pintaet who deid aetfr a hatospil durg blendur***. In this case we see what might look like real words, which is confusing.

Crystallography

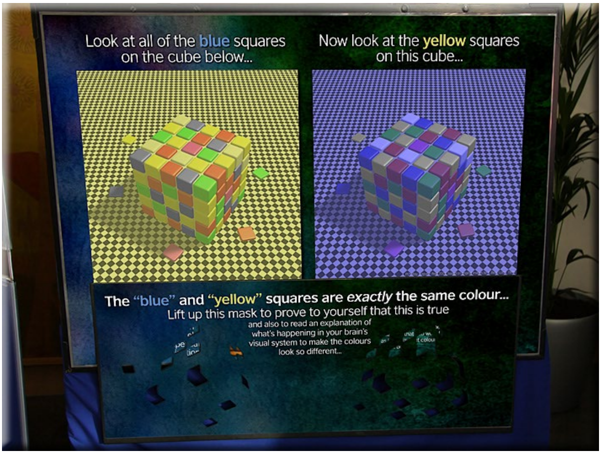
What to do

- **Using the scoop, collect and gently pour marbles into the upside-down pyramid.**
- **When you've filled the shape, keep carefully pouring marbles: try to build a full pyramid to complete the shape. Resist the temptation to use your fingers!**

How does it work?

- Perfect crystals contain a large number of identical molecules or atoms arranged in a *lattice*: a regular, highly-ordered structure repeated in all three dimensions.
- Here, the marbles represent the molecules or atoms. When you pour the marbles into the container, they start to form a lattice. As you continue to pour, the next layer of marbles fits into the most stable position, set by the two-dimensional lattice of the layer below, and fixed in position. As each layer forms, the crystal continues to grow.
- You should be able to complete the entire shape, called an *octahedron* (it has eight sides), by gently pouring the marbles: they will tend to find the correct position. In our model it is the frosted coating for the marbles that gives them just the friction needed to stay in position. In a real crystal it is the atomic attraction between molecules or atoms that helps them to fit into the pattern.
- Many other crystalline shapes occur in nature, depending upon the atoms or molecules involved. They are of great use in helping to understand the structure of compounds.

Cube Illusion



What to do

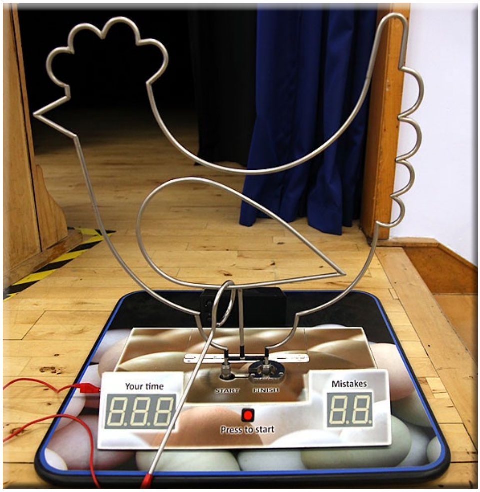
- **In the cube on the left (the one in yellow light), look at the blue squares.**
- **In the cube on the right (the one in blue light), look at the yellow squares.**
- **It seems as if these two sets of squares are totally different colours.**
- **Now lift up the flap, and look at the squares again through the holes. You should notice something unusual...**

How does it work?

- This illusion works because our brain compensates for the fact that the two cubes appear to be lit by entirely different coloured lights.
- The retinas of our eyes see exactly the same colour of squares in both cases (grey), but our brain changes what we see to account for the surroundings. The visual centres of the brain have evolved in a world where – in yellow light – this shade of grey *should* represent something that is blue. In blue light, however, the exact same shade of grey actually represents something that is yellow.
- When the flap is then lifted, the surroundings are covered and there is no context; we now see both squares as the colour they have been printed: grey.
- This colour processing is done entirely unconsciously. (In fact, these capabilities of our ancestors' visual systems were present long before conscious humans had evolved: they are simply a way to let an animal make sense of its changing surroundings.)

Dexterity Chicken

What to do



- **Make sure the wand is at the bottom-right of the chicken, before pressing START.**
- **Guide the wand around the chicken, making sure not to touch the wire. Each touch causes the error score to go up.**
- **Touch the right-hand ring at the end, to stop the clock.**

How does it work?

- This exhibit measures your dexerity – in this case how steady your hands are – as you guide the wand around the wire frame.
- Hand-eye coordination varies from person to person, and can be improved by training, but there is a limit to just how steady your hand and arm can be, and in the use of your vision to direct the movement.
- The way in which you guide the wand depends upon a sense that is not often considered: *proprioception*, which is your knowledge of parts of your body, such as the position of your limbs, hands and feet. This sensory "knowledge" is combined with the information from your eyes – distance to the object, and depth perception from your stereoscopic vision – to help you guide the wand.
- We are not born with this ability. Babies "discover" their hands as part of their bodies at about six to eight weeks, although they have an early "gripping" reflex. At about five to six months, they can direct their arms and hands towards objects, and begin to learn how to move more precisely. Eventually the "circuits" in the brain adapt to allow the hand to move to the correct position every time.

Forensics

Forensic scientists use clues found at crime scenes to figure out who was responsible for the crime.

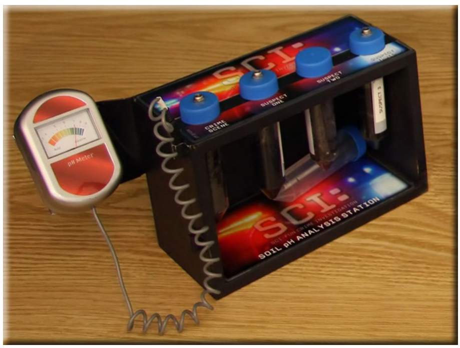
What to do

Get your group to work through each clue to determine who was responsible for the crime in this case. Each clue can help you eliminate one suspect: lift the flap at the end to see if you were correct.

• *Clue 1: Soil Samples*

Soil from different areas will have a different pH value depending on how acidic or alkaline it is.

Check the pH of soil collected from the crime scene and from the shoes of the suspects. See if each suspect can be ruled out or linked to the crime scene.



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Forensics (cont.)

• *Clue 2: Fingerprints*

Each person has a unique set of fingerprints that identify them as different from everybody else.

Match the fingerprints of each suspect with those found at the scene of the crime.

• *Clue 3: DNA Fingerprinting*

Our DNA is what makes us truly unique. DNA found at a crime scene can be matched up to samples taken from victims and suspects to determine who was at the scene of the crime. DNA samples from the crime scene will be likely to contain both that of the suspect and the victim, putting the card under the UV lamp shows the DNA present in the sample.

Compare the DNA found at the crime scene with that of the victim and each of the suspects to work out who could have committed the crime.

Gyrowheel

What to do

- **Stand on the turntable, holding the black handles of the wheel with both hands.**
- **Spin the wheel then try to tilt it up and down.**
- **What happens?**

How does it work?

- A gyroscope hates changing position, so it will always try and stay at the same angle when it is spinning.
- When the wheel is tilted, it applies a force to the person holding it which in turn moves the turntable the pupil is standing on.
- When you tip a spinning gyroscope, it feels a force in one direction at the top and a force in the opposite direction at the bottom and both parts will rotate in that direction instead of tipping downwards.

Gyroscopes move in strange ways that seem to defy gravity. The properties of gyroscopes make them important in many things from your bicycle to the navigational systems of aircraft and spacecraft.

Safety note: when a pupil steps on or off the base plate, put your foot on the plate to stop any unwanted rotation.

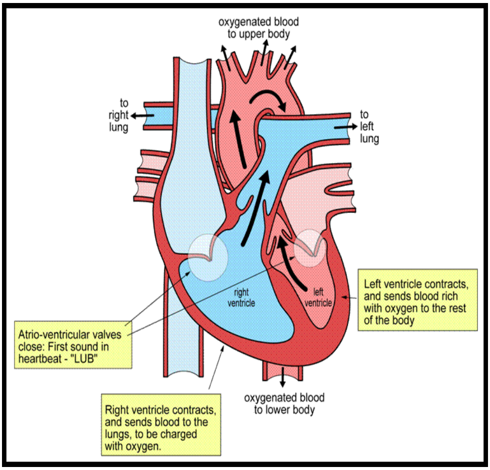
Heartbeat Monitor

What to do

- **Hold onto the copper handles and keep as still as possible. The display will update and you should be able to compare the shape of your pulse on the computer with the image on the poster.**

The Heart

- Consists of four chambers: left and right *atria* and left and right *ventricles*.
- The heart pumps blood to and from the lungs – where it is loaded with oxygen – and then around the body to deliver the oxygen needed for the many processes that keep us alive.
- The heart chambers are made of cardiac muscles which contract under the control of electrical signals.
- Unlike the skeletal muscle, this cardiac muscle can charge and discharge independently of the central nervous system.
- Hormones such as adrenaline (epinephrine) are also used to regulate heartbeat, for example to increase heart rate as part of the "fight or flight" response to danger.



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Heartbeat Monitor (cont.)

What do the peaks show?

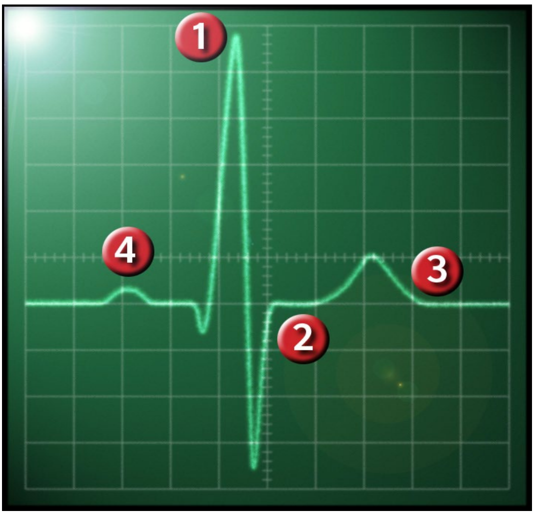
- Electrical signals from your cardiac muscles are detected by measuring the voltage differences between your hands whilst holding onto the handles, giving rise to these peaks on the computer screen.

1) Both ventricles contract.
   Right ventricle sends deoxygenated blood to the lungs.
   Left ventricle sends oxygenated blood around the body.

2) Atrioventricular valves close.

3) Aortic and pulmonary semilunar valves close.

4) The atria both contract, refilling ventricles with blood from the lungs and body respectively.



Hole in the Hand

What to do

- **Hold the plastic tube up to one eye and then hold your other hand next to the tube with your palm facing you. Keep BOTH eyes open.**
- **One eye will see the distant image at the end of the tube and the other eye will see the palm of your hand. What is happening?**
- **Look at the chessboard: which square is darker, A or B?**
- **Square A should look darker than square B. Now pick up the additional card with the two holes cut in it, and place it over the poster. Is A still darker than B?**

How does it work?

- Hole in the hand: your brain quickly tries to combine these images in a “sensible” way producing an optical illusion of a hole in your hand.
- Our eye is a complex structure that works by capturing light and transforming it into impulses that the brain can interpret as images.
- Our eyes see roughly the same image, but there is a small difference between each eye. Our primate brains have evolved to quickly combine the left and right images to construct a 3D model of the world around us.

Human Battery

What to do

- **Place your right hand on the copper plate.**
- **Place one finger from your left hand on any one of the metals (aluminium, copper, brass and steel).**
- **You are now part of the circuit allowing electrons – and therefore electricity – to flow.**
- **The meter measures the current and voltage: these will vary depending on the metals in the circuit.**

How does it work?

- Inside a battery an electrochemical reaction produces electrons and positively charged ions. The negatively charged electrons collect on the negative terminal and the positively charged ions collect on the positive terminal. If you connect a wire between the negative and positive terminals, electrons will flow from the negative to the positive terminals.
- Your skin and two different metals can create a battery, with a thin layer of sweat on your hands acting like a weak acid.
- In an electrical circuit, the number if electrons that are moving per second is called the current (measured in amps). The "pressure" pushing the electrons along is called the voltage (measured in volts).
- The sweatier your hands are the faster the electrons will flow, causing a higher current to be shown on the meter. This is how lie detectors work: if asked a question that we lie about, we are more likely to sweat so the current will quickly increase. (This is not very accurate, however.)

Human Circuit

What to do

- **Hold onto both of the metal handles: you will act as a conductor allowing the lamp to light.**
- **Try it with more than one person. Can your whole group form a human circuit with the people on the ends holding the handles – does the light still go on?**

How does it work?

- Circuits are closed paths for electricity. For the circuit to work, electrons (or other charged particles) must flow from the negative to the positive end to create a flow of electricity (electric current).
- Electricity needs a conductor in order for electrons (or negative charges) to flow. Conductors are materials in which it is easy to get electrons to move (mostly metals, such as gold, silver, copper, iron and lead, although humans can also act as conductors).
- By holding onto the handles you are acting as a conductor, completing the electric circuit and allowing the lamp to light.
- Currents are measured in milliAmps (mA), and a current as small as 50 mA could be fatal. The headlamp on the exhibit needs about 700 mA to light up; if this were to pass through your body you would be killed. (A current of about 10 mA can be painful but not harmful, and at around 20 mA your muscles will contract sharply.)
- This circuit uses transistors as a current amplifier. A transistor uses a small electrical current in one part of the circuit to control a large change in current in a separate circuit. (This makes the circuit safe to use: you only touch the first part.) The three transistors in our exhibit boost the tiny current by 70,000 times to light the lamp.

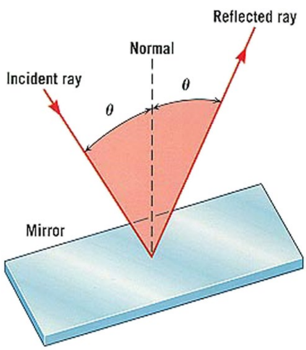
Infinity Box

What to do

- **Get the pupils to look down into the infinity box.**
- **They should observe a tunnel or shaft effect outlined and highlighted by the lights.**
- **The effect should continue down some distance, apparently through the table.**

How does it work?

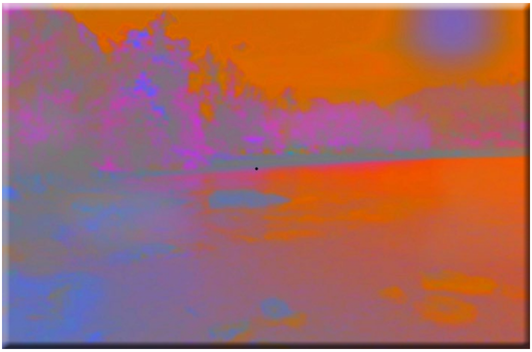
- The infinity box works by using two mirrors: a normal mirror and a two-way mirror. A two-way mirror reflects some percentage of the light and lets most of the rest pass through.
- The two mirrors reflect the light between them. This continued reflection back and forth between the mirrors creates the tunnelling effect you can see.
- A two-way mirror can be used between a dark room and a room that is brightly lit. The difference in light level allows one side to be reflective while allowing the other side to be viewed through. People in the darkened room can easily see into the light room, but people in the light room would simply see an ordinary mirror. A two-way mirror does not work between equally lit rooms.



- Law of reflection: The beam of light before striking the mirror is called the incidence ray and the reflected beam is the reflected ray. The law of reflection states that the angle of incidence always equals the angle of reflection.

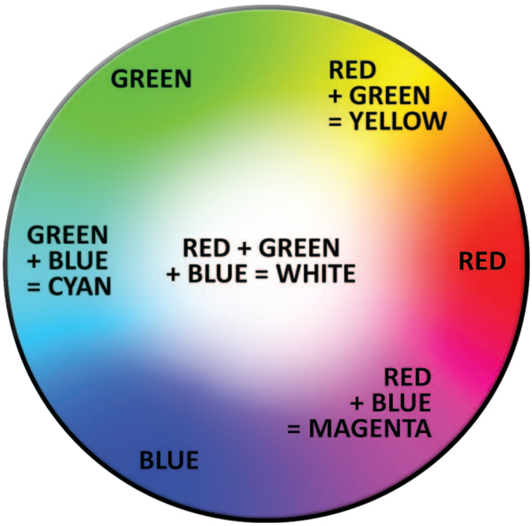
Inverse Colour Illusion

What to do



- **Press one of the four buttons, and a reversed-colour image appears.**
- **Stare at the black dot in the centre without blinking, until the count goes to zero. The picture will change to a BLACK and WHITE image.**

How does it work?



- The monitor combines the primary colours RED, GREEN and BLUE to make a range of colours, including all shades, up to white light.
- As you can see opposite, the three primary colours are mixed by your eyes and brain to make others: RED and GREEN make YELLOW, for example, and RED and BLUE make MAGENTA (purple).
- When you stare at a colour for a long time, the cells in your eye that see that colour become tired, and don't send as many signals to your brain...

Continued on the next page.

Inverse Colour Illusion (cont.)

How does it work? (continued)

- For example, if you stare at a RED object for a while, the cells that respond to RED become tired, and send fewer signals to the brain.
- Then, when you look at a WHITE (RED+GREEN+BLUE) surface, the RED signals are temporarily decreased, and you see only the GREEN and BLUE, which mix to give CYAN: you see the opposite colour on the wheel on the previous page...

- Each button below causes a REVERSED colour image to appear for a while. If you stare at the dot, your eyes will respond less to those particular colours. Then a black-and-white photo will appear, and you should for a moment see a full-colour image: all of the white areas will appear in the opposite (correct) colours...

Inverse Handwriting

What to do

- **Holding the pen, put your hand through the hole below the panel.**
- **Look over this panel and into the mirror, and try to write your name. Don't cheat!**

How does it work?

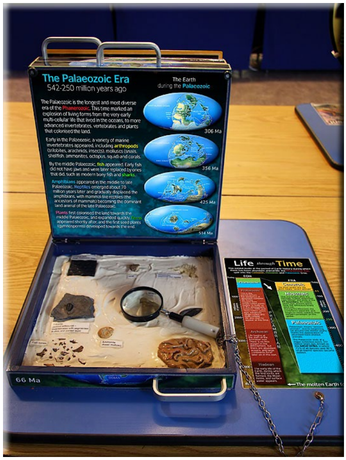
- As mentioned on the *"Dexterity Chicken"* page, the way in which you guide the pen normally depends upon a sense that is not often considered: *proprioception*, which is your knowledge of parts of your body, such as the position of your limbs, hands and feet. This sensory "knowledge" is combined with the information from your eyes to help you guide the pen.
- This exhibit destroys that link between vision and proprioception: your eyes tell you that you should move the pen one way, but when you move your hand, the pen goes in the opposite direction. You have to overcome that learned link between the two senses. Interestingly, you don't have to spend too long before you *unlearn* the normal connection, and the task becomes easier.

There is a related task you can try: fold a piece of paper and hold it to your forehead with your left hand (if you're right-handed). Then take a pen in the other hand, turn it to the paper, and write your name on the paper. When you look at it, you may be surprised to see that you have written the name backwards!

This happens because you visualise the name as being the correct way round, and then you guide the pen to form that shape: but your hand is turned to face the other way...

Life Through Time

What to do



- **Let the pupils lift up the various sections of the history box and read the appropriate text for the different eras.**
- **The main thing they should take away from this exhibit is the way in which scientists can work out what life was like in each era, and how it adapted to the different conditions.**

How does it work?

- This exhibit involves examining the various eras which are collected together under the Phanerozoic aeon. (Phanerozoic means “visible animals.”)
- This exhibit is based largely on information taken from fossils and from different types of drilling cores taken from the earth, such as ice cores.
- Using this information, scientists can work out what previous environmental conditions were like (including the temperature, rainfall and sea-level, as well as what life was present).
- Another idea which could be drawn into this discussion is evolution: how animal species have adapted or failed to adapt to changing environments and why certain characteristics are found in various species.

Lifting is Believing

What to do

- **Grip the bottom tube, and lift both tubes upwards. How heavy do the two tubes together feel?**
- **Now lift only the small top tube: how heavy is it? Is it heavier than the combined tubes?**

How does it work?

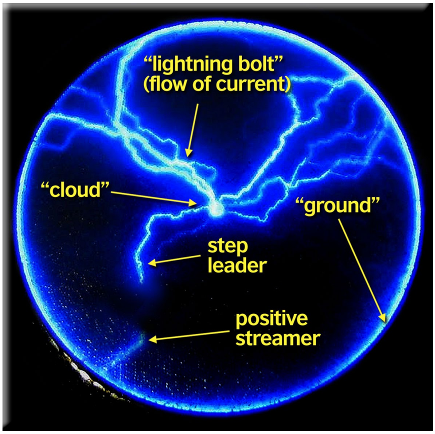
– The large tube is very light, and the combined weight of the two is almost identical to the small one on its own.

– The illusion depends on the fact that a large object (the combined tubes) and a small object (the small tube) are the same weight: the brain interprets the discrepancy as indicating that the smaller one is actually heavier than it is.

- Our senses tell us what is happening around us, and our brain needs to make decisions based on that information. Both the brain and the senses have evolved to survive in a complicated world. But sometimes they can become confused, and we reach the wrong conclusions.
- There are basic rules that are wired into our brains and senses, which don't involve any thinking, and improved the chances of survival for our ancestors. For example:
  - *if it's smaller, it's further away;*
  - *if it's getting louder, it's getting closer;*
  - *if it's smaller, it should be lighter (this exhibit).*
- This simple exhibit shows us that our brains can make the wrong decision, even when we know all of the facts.
- The top tube on its own can't be heavier than both tubes together! But it's hard to feel that, when you lift it. (Try closing your eyes when you lift one and then both tubes...)

Lightning on a Desk

What to do



- **Move your hand to the centre of the circular plate (to touch the "cloud").**
- **Using your fingers, control the lightning strikes, and where they contact the "ground" round the edge of the plate.**
- **There should be enough energy in the cloud to create two or three strikes: not enough for four, and too much for just one. Can you prove this statement wrong?**

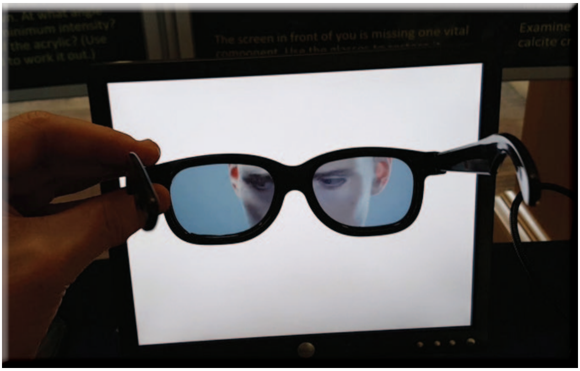
How does it work?

- Real lightning is the transfer of electrical energy through the air, from a highly charged cloud, often to the earth. A *step leader* feels its way down from the cloud, zig-zagging through the ionised air (the charge is so great that electrons are stripped from the atoms), looking for a path to the ground.
- From the ground, *positive streamers* are conducting paths that try to join up with the descending step leader. When one does join, the circuit is made, and the flash of lightning occurs.
- The *crackle tube* is a safe way to simulate some of these properties. The tube is filled with small beads, coated with a substance that ionises under charge (and glows).
- The central electrode is at several thousand volts (but with only a tiny current), and represents the cloud.
- Your fingers can draw off tiny amounts of current, changing the properties of the "air", and altering the path of the step leader, as it tries to make contact with the "ground".

The Magic Screen

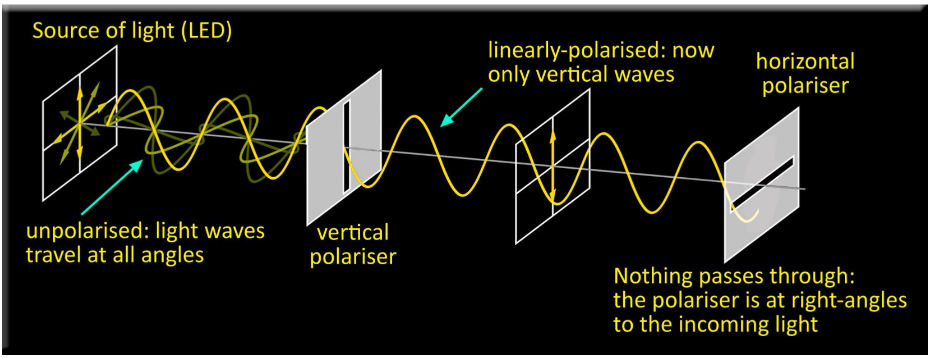
What to do

- **Using the glasses, look at the blank screen; what do you see?**
- **What happens when you rotate or reverse the glasses?**



How does it work?

- Ordinary light is *unpolarised*: its waves travel at all possible angles. Materials such as liquid crystals will restrict light to only one angle: it is *polarised*. The diagram below shows light being polarised by passing through a sheet that restricts it to vertical movement only.



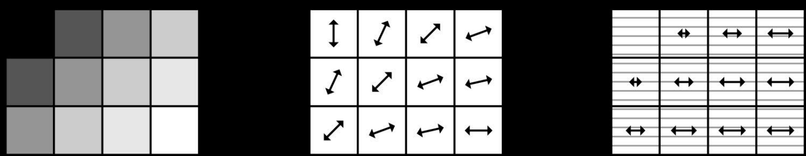
- When light that is polarised passes through another polarising sheet that is at right angles (see above), *nothing* gets through. If the second polariser is at an angle to the light, a reduced amount does get through, which is the key to how modern LCD (sometimes called LED/LCD) screens work, as described next.

Continued on the next page.

The Magic Screen (cont.)

How does it work? (continued)

- An LCD (liquid crystal display) screen works by polarising light, and then twisting the light in each pixel, according to how bright we want it to be.
- Each pixel has the light twisted to be vertical, horizontal, or any angle in-between (diagram below).



An LED screen, with pixels that show intensity. Our eyes can detect differences in brightness, but not polarisation.

An LCD screen, with pixels that show polarisation: this is what you see without the glasses, just a bright, white screen. (We've removed the front polarising sheet.)

Place a polarising sheet in front, to select only one direction. (Compare with the first diagram.) This is what happens when you use the glasses.

- All polarised light looks identical to the human eye: without the glasses you can see only a bright, white screen.
- Usually, there is a final polarising sheet (third diagram) to select only the horizontally-polarised light: we then see different brightnesses.
- We removed the final polarising sheet, so you only see polarised light. The glasses have pieces of that sheet, and they will convert the polarisation into different brightnesses: the image appears!

Note that although you will sometimes read about “LED screens”, the vast majority are LCD screens such as described here, which use white LEDs simply to generate the background light: they are properly called LED/LCD displays. More recent developments in organic LEDs (or OLEDs), however, is leading to their increased use in devices such as smartphones.

Magnet and Coil

What to do

- **Move the magnet in and out of the coil at the front-left of the board; when does the LED display move?**
- **Now turn the handle on the generator: what happened in both cases? What's different?**

How does it work?

- When a wire and a magnet move past each other, an electric current is created. (When they are stationary, nothing happens.) The LED display shows you the direction of the current that flows in the wire: it reverses when the magnet changes direction.
- The coil on the board, and the rotating part of the generator, are both made up of hundreds or thousands of turns of wire, which magnifies the production of current.
- Almost *all* of our electric power (apart from solar panels) involves wires moving past magnets: nuclear, coal, oil and gas power stations; wind turbines; wave and tidal generators… all of them make electricity by moving wires past magnets! **This exhibit is at the heart of our modern world!**

Note that one reason why *alternating current (AC)* is common today is that a spinning generator like our exhibit will naturally make current that continually reverses direction.

Microscope

What to do

- **Place one of the slides from the collection onto the microscope stand.**
- **Select a magnification level. It's best to start at low power (×20), and then the higher powers in turn, up to ×200.**
- **Turn the focusing knob on the microscope very gently, to bring the image on the slide into sharp focus.**

How does it work?

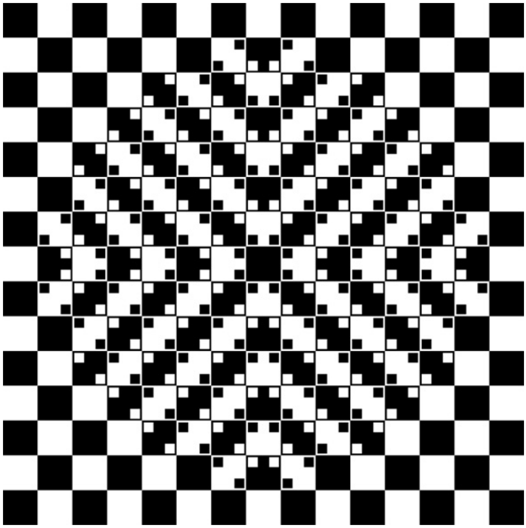
- This is a modern version of the first type of microscope, which uses visible light to magnify small objects. A small camera has been placed at the eyepiece, and the image is viewed on the laptop screen.
- Our microscope can magnify up to around 200 times, although the subject under view must be very securely held: even the slightest shake will make the image hard to see.
- Light microscopes can magnify up to about 1500 times. A general principle of magnification is that the size of the light waves used to view the object must be smaller than the object size itself.

  The following analogy may help to explain this. If you were to use your hands to try to feel the shape of an object, and you had to wear boxing gloves, you would only be able to make out very general shapes. Wearing just a normal pair of gloves (equivalent to using much shorter wavelengths of light), you could detect much smaller variations in an object's shape.
- To see smaller objects, we use shorter light waves (such as UV), or even *electrons*: quantum physics tells us that particles such as electrons can be thought of as having very short wavelengths.

Giant Optical Illusions

What to do

- **There are several large optical illusions mounted around the exhibition.**
- **Each of them has a small instruction panel, to describe what to do, and what you should (or shouldn't!) see.**



How do they work?

- Optical illusions are fun to look at, but many of them have been designed (or discovered) to highlight the way in which the visual system works.
- We tend to think of seeing as "just looking at something": it all seems to happen with no effort at all. In fact, many dozens of incredibly complex things are happening to make our experience of the world seem so easy!
- Our visual system has evolved over tens of millions of years to help us survive by *quickly* understanding the world, in *real time*. It's such a complex task that our brain and eyes carry out many short-cuts, some of which can be exploited by the illusions.
- We need to be able to pick objects out from the background, or to understand the depth and shape of things, or how they are moving, or their colour. The illusions in our exhibition can let us understand how some of these tasks are carried out in the brain, and how they can be fooled, so that we see "impossible" things, like movement where there isn't any, or lines that should be straight, but aren't…

Pangaea: Solving the Mystery

What to do

- **First, arrange the continents to look like today's world map.**
- **You may notice several strange things. (These are described on the poster.)**
- **Now rearrange the continents to take the shape of Pangaea. (The red outline on the board should help you.)**

How can it be explained?

- These unusual findings can only make sense if we shift the continents across the globe from their current positions, going backwards in time, and using the lava compass directions, about 200 million years ago an amazing thing occurs: all of the continents come together in one supercontinent: Pangaea.
- This exhibit illustrates the process of *plate tectonics*.
- The surface of the earth is made of a thin layer of rock called the crust (or lithosphere) and a lower part called the mantle (or aethenosphere) which demonstrates a flowing motion over long periods of time: it is still a solid, but it can very slowly “creep”, under the right conditions. The lithosphere is made up of different tectonic plates which can be carried by the slow-moving lower mantle.
- This movement is extremely slow (it flows about the same rate as our fingernails grow), but over time has led to continents moving to the positions they occupy today.

Periodic Table

What to do

Test your group's knowledge on the elements present in:

- **water**
- **sugar**
- **table salt**
- **elements in the human body**
- **petroleum**
- **main greenhouse gases**
- **radioactive elements**
- **most abundant element in atmosphere/earth/the universe**

Press the buttons to find out if you're right and lift the flaps to find out more information.

What is the periodic table?

- The periodic table arranges all the known elements in order of increasing atomic number from left to right and from top to bottom.
- The atomic number of an element tells us the number of protons (positively charged particles) present in each element, helps us to identify what the element is and what chemical properties it has.
- The periodic table groups similar elements together from metals (alkali metals, transitions metals) on the left-hand side to non-metals (halogens and noble gases) on the right-hand side.
- Elements are named after many different things including people, planets, minerals and sometimes their chemical properties. Some more recently discovered elements are given systematic names (e.g. elements 112-118) until such time as an official name is decided upon.
- (Recently (May 2010), element 112 has been named *Copernicium.*)

Note*: element 117 is listed as "undiscovered": no form of it has been found that is stable enough for it to be regarded as a new element.*

Power Bike

What to do

- **How much power can each member of your group generate?**
- **Pedal as fast as you can and see how much power is generated.**
- **The amount of power in Watts required to power various electrical appliances is shown on the side of the scale; see which member of your group can produce the most power.**

How does this work?

- The bike is attached to a device which measures the power produced while pedalling.
- The display will light up and show you how much power is being generated.
- Power is measured in Watts and tells you how much energy you are producing every second (1W = 1 Joule of energy per second).

Safety note: Keep one foot on the back of the bike to ensure it does not slide too far forward. If the bike moves too far forward take care when returning it to its initial position that the display and power wiring does not get trapped under the wheels.

Puzzles

These are mechanical puzzles – sets of mechanically interlinked pieces. Puzzles of this type came from Greece in about the third century B.C.

Warning: the following text will give you subtle hints on to how to complete the puzzles!!

Packing Squares

- **What to do: Try to fit all 11 blocks into the base.**
- **Tips**: Do not put all the blocks in so they look like squares from above. Instead, put the blocks in so they like squares and diamonds. You should be able to fit the blocks in now!

The Three Rings

- **What to do: Arrange the pieces so they look like 3 of the 5 interlocking Olympic rings by the end.**
- **Tips**: Start with the small central pieces. Arrange these so that they look like the picture to the right and the rest should fall into place.

Chinese puzzle

- **What to do: Use the pieces to make the star shape outlined on the board itself.**
- **Tips**: Start with the two larger pieces in opposite corners and keep them there. You should now find it easier to put the smaller pieces in around these to complete the task.

Rattleback

What to do

- **First spin the rattleback anticlockwise, and watch what happens to its motion.**
- **Then try to turn it clockwise: what happens now?**
- **Try simply rocking the rattleback, back and forwards: what happens?**

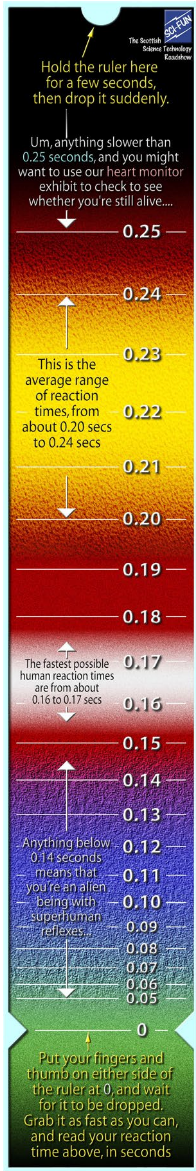
How does it work?

- The rattleback seems to spin normally in the anticlockwise direction. However, when spun in the other direction it begins to rock back and forth (or ‘rattle’) and eventually reverse its spin direction.
- The rattleback changes its spin direction because of its shape. Rattlebacks are not symmetrical (even though it looks as though they are) in their distribution of mass.
- Because of this off-centre shape, if you rock a rattleback, it will tend to start spinning anticlockwise: this is the direction in which it tends to move.
- When you spin it clockwise, the asymmetric shape means that instabilities in movement grow and it begins to rock back and forth.
- As we’ve seen, the off-centre curved shape transfers the energy from rocking to rotation in the anticlockwise direction. So the rattleback soon stops moving clockwise, rocks up and down for a short time, then ends up moving anticlockwise.

Reaction Timer

What to do

- **In this exhibit we use specially-marked rulers to measure human reaction times: the markings are not in centimetres, but in seconds.**
- **One person must hold the ruler by its top, ready to drop it at some random time.**
- **Another person must be ready to catch it, holding their fingers on either side of the "0" mark on the ruler (but not quite touching it).**
- **They must catch the ruler when it is dropped, by closing their fingers. The person dropping the ruler should give no advance warning.**
- **When the ruler is caught, read the number nearest to the point where the fingers have gripped it: this is a direct measure of their reaction time in seconds.**



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Reaction Timer (cont.)

How does it work?

- The average human reaction time is between 0.2 and 0.25 seconds, with the shortest times being around 0.13 seconds. Reaction time can be affected by factors such as age, gender, tiredness and external stimuli (including distractions).
- The reaction time is the period from the moment of a change in the environment (stimulus) to the beginning of your response.
- The response is coordinated by the *nervous system* which regulates the activity of the muscles and initiates actions.
- There are two different parts of our nervous system:
  a) *Central Nervous System* (CNS): brain and spinal cord
  b) *Peripheral Nervous System* (PNS): nerves and neurons outside the CNS

The nervous system recognises a stimulus, and neurons within the CNS transfer this information to the brain and other nerves. The PNS send a message from the brain to spinal cord; this message is then delivered to your muscles telling them whether to contract or expand.

Reuleaux Curves

What to do

- **Roll the giant coin through the upper slot of the backboard: do you notice anything unusual?**
- **Place two of the axles under the plastic sheet (at the front of the base-board), press your hand on the sheet and move back and forward.**
- **Look at the top of the sheet: does it move as you would expect? Are the wheels and axles moving smoothly?**
- **Can you answer the question: why are loose man-hole covers circular, and not square, triangular or elliptical? What *other* shape could they be?**

How does it work?

- We know that circles have a constant diameter: this is why they roll easily. Circles are not, however, the only shapes that can behave in this way. The giant 20 pence coin and the axles in the exhibit are also examples of shapes with a constant width, known as *Reuleaux curves*.
- The simplest version is an equilateral triangle with circular arcs along each side.
- The 50 pence coin was the first to be made as a Reuleaux curve; this means that it rolls in the same way as other circular coins (in coin slot machines, for example), while being easier to identify for people with visual impairment.The construction techniques for the 50 and 20 pence coins are shown on the poster beside the exhibit.

The Reverse 3D Dragon

What to do

- **Stand at least a couple of metres from the dragon, and close one eye.**
- **Move your head from side to side, and up and down, as you look into the dragon's eyes.**
- **You should notice the very unusual way it turns its head to follow you…**
- **If you are far enough away, and once the effect begins, you may find that the illusion continues when you open both eyes.**
- **If you are too close, (especially if you have both eyes open to begin with), you may find that the illusion won't work.**

How does it work?

- Our visual senses evolved to allow our ancestors to survive by quickly working out the distance, shape and depth of objects. Our two eyes give us *stereoscopic* vision: the images are slightly different to each eye (*parallax)*, and we can estimate the object's properties Closing one eye reduces the information on depth.
- The front of the dragon's body (with the '3') and the right-hand part of the face are actually sticking out backwards, and all the parts of the head on the left – the ears, top of head, eyes, snout, teeth – are actually *reversed*, but the shapes (and the light shining through them to make them brighter) make it *look* as if they are on the top of the head, as we would expect.
- Then, when we move our eye, the shapes turn in the opposite direction to the way we would expect, and the dragon appears to be turning its head and gaze to follow us round the room!

Spinning Chair

What to do

- **While the pupil holds the two weights, press the button of the seatbelt before you buckle the pupil in, otherwise the buckle won't engage.**
- **Place your foot on one corner of the base (this helps to keep the chair stable) and make sure the pupil's arms and legs are stretched out.**
- **Spin the chair only once for each pupil, clockwise (see below).**
- **After one complete rotation ask them to tuck their legs and arms in.**
- **Get the pupil to change the position of their limbs a couple of times, before asking the pupil to keep their arms and legs stretched so that you can stop the chair.**

They will rotate noticeably faster when their arms and legs are tucked in and will slow down when they stretch their legs.

Safety Note: Make sure you secure the seat belt before starting.

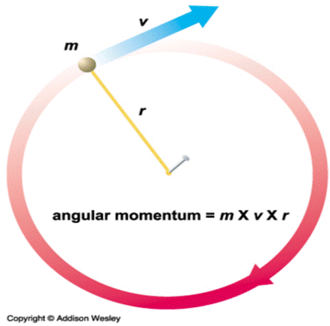
Rotate the chair clockwise; rotating the chair anti-clockwise may loosen the bolts at the bottom of the chair, making it unsafe.

Keep one foot on a corner of the board to stop it moving. Keep an eye on the audience: make sure they are not too close, or they could be hit.

Continued on the next page.

Spinning Chair (cont.)

How does it work?



- It is all to do with *angular momentum*.

- Basically, angular momentum is related to the mass of the object, the velocity of the object, and its distance from the rotation axis (or radius), as shown by the equation below:

Angular momentum = mass × velocity × radius

- Angular momentum is a *conserved quantity* and therefore remains constant (unless acted on by an external *torque*, or twisting force). When you ask the students to bring their arms and legs in, the radius of the student's body overall is reduced but the mass remains the same. Therefore, in order to conserve angular momentum the speed has to increase.

- The basic rule is: *if one of the quantities above increases, one or both of the others must decrease.*

- The conservation of angular momentum explains many phenomena in sports:

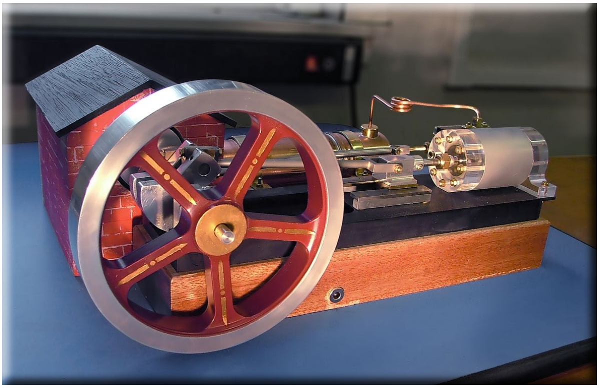
  - Figure skaters tuck their arms and legs in order to rotate faster. Later, they extend their limbs so they slow down and can skate away from the spin more easily.

  - On the uneven parallel bars, gymnasts will carry out a spin with the body at full length on the top bar, and will then tuck themselves in to reduce the radius of rotation, and thus greatly increase their angular velocity (spin).

Steam Engine

What to do

- **Press the button and watch the engine move.**



How does it work?

- Water is heated until it boils into steam. (This is only simulated in our little model, of course.)
- Steam accumulates in a chamber where it expands.
- The steam is then passed into a cylinder at high pressure, pushing a piston outwards.
- The steam is then passed to a cool secondary cylinder, where it rapidly cools down and contracts, creating a vacuum, pulling the piston back.
- This repeated expansion and contraction of the steam in the cylinder causes the piston to move rapidly back and forth.
- The piston drives the sliding rod, making the flywheel move.

This exhibit shows you how force is transferred from expanding gas in the cylinder into the connected rod, eventually moving the flywheel.

This principle is still used today: over 90% of our electricity is generated using steam turbines.

Stem Cells

What to do

- **Do you think stem cells could be useful in treating some human conditions?**
- **Choose your answer for each human condition by pressing the *yes/no* buttons, and find out if you are right or wrong…**
- **Lift each of the flaps for a detailed explanation on each of the human conditions shown on the exhibit.**

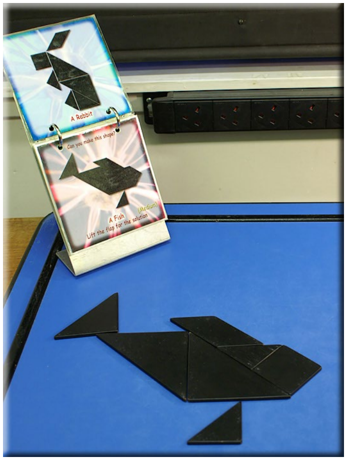
How does it work?

- Stem cells have the ability to develop into more specialised cell types such as brain cells (neurons), liver cells, heart cells etc…
- Scientists are now able to transform stem cells into more specialised cells in the laboratory.
- Stem-cell based therapies have the potential to change the treatment of some serious human diseases.

An example: Parkinson's disease results from reduced activity in some neurons. By using stem cell therapy, new fully-functional neurons could be developed to replace those that have been damaged, reducing (and perhaps in future even reversing) the symptoms of the disease.

Tangrams: The seven boards of cunning

What to do



- **Try to make each of the patterns on the board and some of the examples on the flip card.**
- **You must use all seven pieces, and none of them can overlap.**

History:

The tangram puzzle was invented in China, but nobody knows exactly when. The earliest known reference was in 1780 when an American ship owner brought a set back for his son. The Chinese word for "tangram" literally means "seven boards of cunning". Napoleon reputedly had a set during his imprisonment on St Helena.

You need logic and problem-solving abilities to complete these geometrical puzzles, both skills that are essential in science!

Tippy Tops

What to do

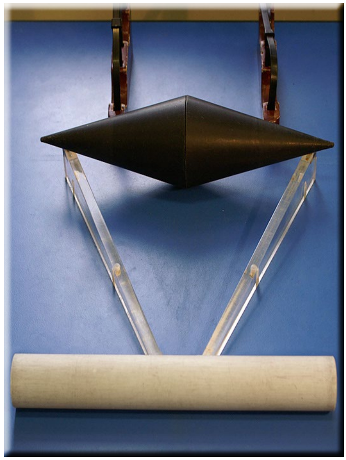
- **Place the tippy top in the tray, and spin it using the stem.**
- **Why does the tippy top suddenly flip over and start spinning on the other end?**

How does it work?

- The important thing about a tippy top is its “mushroom” shape: it must have a smooth, spherical surface with no sharp points.
- After it starts spinning the top will wander about on the table, and will also begin to tilt, or wobble, an effect known as *precession*.
- As it does this it moves, so that the point of contact with the table is not in line with the axis of rotation, and this makes it unstable.
- Friction with the table causes this point of contact to move further and further away from the vertical. The top wants to be in a more stable position and the only way for it to do this is to flip over.
- The centre of gravity of the top rises when it flips, which would *appear* to violate the conservation of energy: energy is needed to raise the top. Having flipped, however the top is then spinning much more slowly, so energy has been lost overall.
- Another interesting property of the tippy top is that it completely reverses it spin while it flips over. If you look at it from above, you see that, before and after it flips, the top spins in the same direction, relative to the table. But, since it is upside down after it flips, the top itself is actually spinning backwards!
- At some point during the flip over, the top stops spinning and reverses, which can be seen in slow motion films of a top spinning.

Uphill Gravity

What to do



- **Place the silver tube at the top of the slope and let it go… it will roll down, as you would expect.**
- **Place the black object at the top and it should stay there. Place it at the bottom and it will roll… up?!**

How does it work?

- This apparently odd behaviour can be explained using the idea of the *Centre of Mass* (or Centre of Gravity).
- Gravity acts on an object as if the entire object's mass was located at one point (the centre of mass). Gravity is the force by which all objects attract each other – in this example the Earth and the tubes are being attracted to each other. This means that the silver tube is pulled down and the Earth pulled up (although the Earth is so big you don't really notice the planet moving upwards…)
- The movement of the black object seems to go against common sense initially, but it doesn't… To see why, crouch down and look closely at the distance between the middle of the double coned black object and the board. You'll see that the bottom edge of the black object actually gets closer to the board as it travels "up" the slope, confirming it is indeed attracted by earth.

The Tippy Top exhibit seems to defy this rule: its centre of gravity moves upwards when it turns over… Check out its exhibit page to find out why.

Upside-down Faces

What to do

- **Do the faces on the board look odd? Slowly turn them so they're the right way round: how do they look?**
- **Slowly turn them back: when do the eyes and mouth start to look normal again?**

How does it work?

- Parts of the human brain – in particular a region known as the *fusiform gyrus* – have evolved to respond only to faces, and in particular to the eyes and mouth.
- We respond to the eyes and mouth when they are the right way up – i.e. when we would normally see a face: the brain strongly reacts to these shapes.
- The faces in the exhibit have been altered, turning the eyes and mouth upside-down (and then smoothing the edges), so that when the faces are themselves turned upside-down, the eyes and mouth are now the right way round, and your brain thinks that they look "normal". This visual signal is so strong that it overrides the fact that the whole face is the wrong way round: it just seems to look *right*.
- But when you turn the faces round, suddenly the eyes and mouth look very wrong, even though the rest (head, nose, ears) are correct.
- Very slowly, turn the faces back round: at some point, about half-way, each face should suddenly 'click' into looking normal again… The effect is quite sudden, for many people.
- Note that this effect doesn't happen when, for example, we turn the nose upside down: the face looks strange either way.

The Virtual Pig

What to do

- **Stand back from the box, and look through the slot on the front panel: your eyes will be at exactly the right height.**
- **Can you see the pig rotating on the top of the box?**
- **Try to pick it up...**

How does it work?

- When we see something we are detecting the light that has reflected or scattered from the surface of that object, and entered the pupils of our eyes, landing on our retina.
- When we look in a mirror, the light we detect doesn't travel straight to our eyes; it has reflected from the mirror, then into our eyes. The light comes from the direction of the mirror, so we see the image in front of us, seeming to be behind (or inside) the mirror.
- Since we are used to looking in mirrors, we know from experience that what we see is not really in front of us. However babies, cats and dogs tend to believe that the image is another animal.
- The mirage unit uses two curved mirrors to change the direction of the incoming light (there's an old unit that we've sliced in half, to show you the curved shape inside the box):

    a) Light reflects from the pig onto the upper mirror.
    b) The light reflects from the upper mirror onto the lower mirror.
    c) Finally, light reflects from the lower mirror back into our eyes.

- The result of this is that we can see an image of the pig, the right way up, floating just above the top mirror. The exhibit board has a cut-away diagram showing the light ray paths.

Viscosity Tubes

What to do

- **Turn the rack over so all the balls start to fall through the liquids.**
- **Which ball gets to the bottom first?**
- **Why?**

How does it work?

- We can explain this effect using the principle of viscosity**.**
- The viscosity of a liquid is a measure of how quickly it flows. For example, shower gel is more viscous than water: it flows more slowly. The more viscous a liquid, the more difficult it is for objects to move through it.
- The tubes contain: water, orange squash, cooking oil, shower gel and washing-up liquid.
- When you turn the tubes over, gravity causes the balls to begin falling. The more viscous the liquids are, the more they will resist the downward movement of the balls, thus increasing the time taken for the ball to reach the bottom.

Tip: Make sure the pupils realise that viscosity doesn't go hand in hand with transparency. Some S2s may expect that the orange juice will be the most viscous as they cannot see through it.

Health & Safety

Spinning Chair: Make sure you secure the seat belt before starting. Rotate the chair clockwise: rotating the chair anticlockwise may loosen the bolts at the bottom of the chair, making it unsafe. Make sure you keep a foot on a corner of the board to stop it moving. Also, keep an eye on the audience: make sure they are not too close or they could be hit.

Coanda Effect: The jet of air for this exhibit travels at approximately sixty miles per hour, so it's extremely important that the pupils do not aim it at their own or anyone else's face. If a piece of grit gets caught in the jet of air it could cause some significant eye damage (although this is very unlikely).

Gyrowheel: When a pupil steps on or off the base plate, put your foot on the plate to stop any unwanted rotation.

Centrifuge: Ensure all members of your group are in front of the plastic safety screen before spinning the tubes.

Power Bike: Keep one foot on the back of the bike to ensure it does not slide too far forward. If the bike moves too far forward take care when returning it to the initial position that the display and power wiring does not get trapped under the wheels.

That's about all. If having read this book you have any other questions, find someone in a SCI-FUN (or University of Edinburgh) T-shirt and just ask: we'll be happy to help.

Thank you