SCIENCE

on Stage 2017

Demonstrations and teaching ideas

selected by the Irish team

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Science on Stage 2017

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on Stage 2017

10th Jubilee

Debrecen, Hungary

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Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less.

Marie Curie

The science of today is the technology of tomorrow.

Edward Teller

Education is what remains after one has forgotten what one has learned in school.

Albert Einstein

Science makes people reach selflessly for truth and objectivity; it teaches people to accept reality, with wonder and admiration, not to mention the deep awe and joy that the natural order of things brings to the true scientist.

Lise Meitner

Disclaimer

The National Steering Committee for Science on Stage has made every effort to ensure the high quality of the information presented in this publication. Teachers should ensure the safety of the demonstrations in their own laboratories. This document has been produced by volunteers and, thanks to our sponsors, is distributed free of charge. It is intended as a resource for science teachers and is not published for profit. SOS (Science on Stage) permits educational organisations to reproduce material from this book without prior notification, provided that it is for educational use and is not for profit and that suitable acknowledgement is given to SOS. We would be grateful to receive a copy of any other publication using material reproduced from this booklet.

Any comments or suggestions would be welcomed by the committee and can be sent to the Chairperson: Dr. Eilish McLoughlin, Science on Stage, CASTeL, School of Physical Sciences, Dublin City University, Dublin 9.

www.scienceonstage.ie/

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Foreword

It is a pleasure to introduce this science teaching resource which presents demonstrations and teaching ideas prepared and selected by the Irish Science on Stage team that attended the European Science on Stage festival held in Kölcsey Convention Centre in Debrecen, Hungary on the 29 June - 2 July 2017. Under the motto "Inventing the Future of Science Education" 450 primary and secondary school teachers from 30 countries shared experiments and teaching ideas for science, technology and mathematics education at stands, in workshop and on stage over four days in Debrechen.

The Science on Stage programme (www.science-on-stage.eu/) is an innovative, pan-European science education activity, designed to foster a renewal of science teaching in Europe by encouraging the exchange of new concepts and best practice among teachers from all over the continent. It follows from the success of the three editions of the Physics on Stage programme from 2000 to 2003. Innovative and inspirational science teaching is seen as a key factor in encouraging young people to engage with scientific issues, whether or not they finally choose a career in science. Hence, Science on Stage is a network of and for STEM teachers of all school levels, it provides a European platform for the exchange of teaching ideas and serves to highlight the importance of science and technology in schools and among the public. Each programme culminates in a four-day long festival, combining a science teaching fair with on-stage activities, parallel sessions and workshops. The teaching fair provides an array of vibrant and stimulating displays from thirty countries across Europe with a multitude of languages and enthusiastic participants who take every opportunity to exchange teaching materials and ideas.

This project was made possible by the coordination and support of CASTeL at Dublin City University and Institute of Physics in Ireland. Science on Stage Ireland gratefully acknowledges funding support received from the Science Foundation Ireland 2017 Discover Programme.

The gratitude of the thousands of teachers and educators who receive this free booklet of demonstrations and teaching ideas must principally go to the very hard-working team of 2017 contributors: Enda Carr, Declan Cathcart, Robert Clarke, Maire Duffy, Sean Fogarty, David Keenehan, Eilish McLoughlin, Paul Nugent, David O'Connell, Nicola Sheehan. In particular, sincere thanks to Rory Geoghegan for his tremendous work in the arduous task of proofing and editing this booklet and working on it right through to the final stages of production. All of these teachers work full time, yet, despite this, they tested and produced this excellent collection of demonstrations selected from the Science on Stage conferences and this publication would not have happened without their very professional commitment.

It has been our pleasure to work with these inspiring science teachers and educators in co-ordinating the SOS2017 programme and producing this booklet, which we hope you will find an invaluable classroom resource. For further information on Science on Stage in Ireland and for electronic copies of all the POS/SOS booklets, please visit: www.scienceonstage.ie/

Dr. Eilish McLoughlin
Chair Science on Stage Ireland
CASTeL, Dublin City University

Mr Paul Nugent
co-Chair Science on Stage Ireland
IOP Physics Teacher Coordinator

The Irish Team at Science on Stage 2017

A team of nine delegates represented Ireland at the European Science Teaching Festival "Inventing the Future of Science Education", held in Kölcsey Convention Centre in Debrecen, Hungary on the 29 June - 2 July 2017. The team consisted of: Paul Nugent, Santa Sabina and IOPI teacher network coordinator; Declan Cathcart, Temple Carrig School; Máire Duffy, Clonkeen College Dublin; Robert Clarke, Confey College Leixlip; Ncola Sheehan, Donabate Community College Dublin; Enda Carr, St. Marys Secondary School Glasnevin; Sean Fogarty, St. Mary's Seconday School Wexford; David Keenehan, IOPI Teacher Network Coordinator; David O'Connell, Christian Brothers' Cork.

At the festival Robert Clarke and Declan Cathcart received highly commended awards for their projects. Paul Nugent, co-Chair of Science on Stage in Ireland was elected to the executive board of Science on Stage Europe.

The Irish Science on Stage 2017 team in Debrechen July 2017

Left to right: Paul Nugent, Robert Clarke, Sean Fogarty, Maire Duffy, Nicola Sheehan, David O'Connell, David Keenehan, Enda Carr, Declan Cathcart.

The Wonderful World of Woodlice

Background

Woodlice offer an excellent model organism for student investigations. Students learn how to work carefully and ethically with animals in the laboratory. They also gain experience with the investigative skills such as forming hypotheses, designing experiments, presenting data, and communicating their findings using a variety of media. Formative assessment is carried out using rubrics. A digital portfolio can be created by each student using the SeeSaw app or similar.

You will need...

- ✓ Pooters,
- ✓ woodlice,
- ✓ large plastic box containing leaves,
- ✓ soil,
- ✓ twigs etc,
- ✓ cardboard boxes,
- ✓ trays,
- ✓ sticky tape,
- ✓ scissors,
- ✓ desk lamps,
- ✓ small fans.

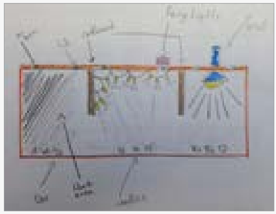
Follow these steps

1. Students find and collect woodlice, which are kept in a "woodlice hotel" (plastic box with decaying leaves, soil, twigs etc.

2. Students choose one environmental factor to investigate, form a hypothesis and plan their investigation
3. Provide students with materials to construct "choice chambers" from cheap and readily available materials (cardboard, shoe boxes, paper, tape etc.).
4. By giving woodlice choices, students collect data on what conditions the woodlice prefer (e.g. light or dark, humid or dry, warm or cold, windy or sheltered etc.)

So what happened?

Students built choice chambers and observed the preferences of woodlice given choices. Woodlice are observed to move to dark/humid/sheltered areas when given a choice.



Students can present their data in charts, draw conclusions, and relate their findings to their hypotheses.

What next?

- ✓ This investigation also lends itself to using video, photography, screen casts and other media to compile a laboratory investigation digital portfolio by way of a lab report.
- ✓ Students can investigate further by looking at the effect of temperature on metabolic rate by measuring respirations rates (using a traditional respirometer or a digital carbon dioxide gas sensor.
- ✓ Run a debate on the ethics of experimenting on animals in the laboratory.

Biology

The effect of salinity on crop plant (grass) germination and on seedling

Background

Salination of soil can have an impact on crop production in many parts of the world. Salination may be due to natural causes or human activities such as irrigation, land-clearing, or substituting perennial crops with annual ones.

Some crops are more salt-sensitive than others. Students can investigate the salt-sensitivity of different crops (rice, wheat, barley), or they can investigate the salt-sensitivity of different strains of the same crop species (e.g. different strains of wheat). Germination rates and seedling growth can be used as an indicator of salt sensitivity.

You will need...

- ✓ Petri dishes (or other suitable containers)
- ✓ Cotton wool or filter paper
- ✓ NaCl solutions (0.2%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, 3.0%)
- ✓ Crop plant seeds (rice, wheat, barley, canola etc.)

Follow these steps

1. 10 to 20 seeds are placed in each Petri dish on cotton wool or filter papers are placed in Petri dishes with 7 to10 ml of different concentrations of salt.
2. Petri dishes are allowed to germinate over a period of days.
3. Seeds are observed daily to check for germination.
4. Time to germination is recorded as well as numbers of seeds germinating, at each concentration.
5. Growth rates of seedlings can then be monitored over time by measuring seedling length and calculating averages per plate.

So what happened?

Rice is generally more sensitive to salt than other crops.

What next?

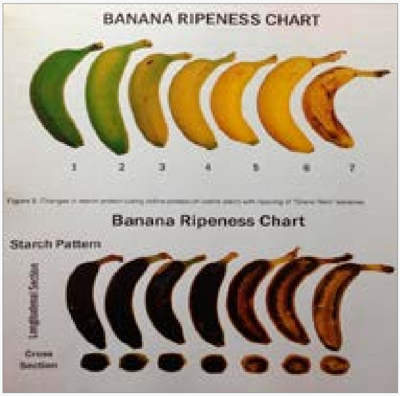
Salt-tolerance of different barrier grasses planted in sand dunes to prevent coastal erosion can be investigated.

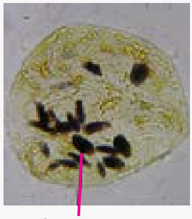
Going bananas!

Background

Bananas offer students a lot of opportunities to learn about the chemistry of ripening and the role of different enzymes in this and other biochemical processes. Students are asked to investigate: Why is a ripe banana sweet, soft and tasty, whereas an unripe fruit is hard, sour and starchy. Why does the colour change from green to yellow to brown as it ripens?

Starch	amylase	Maltose
Chlorophyll	hydrolase	Anthocyanin
Pectin	pectinase	'Softer' substances
Acids	kinases	Neutral substances
Large molecules	hydrolases	Flavour substances





Starch grain

You will need...

- ✓ Bananas of different ripeness
- ✓ Light microscope and microscope slides
- ✓ Refractometer
- ✓ Lugol's iodine
- ✓ Boiling water

Follow these steps

1. Use a refractometer to measure the sugar content and a graph is drawn showing sugar content versus ripeness
2. Stain, with Lugol's iodine, longitudinal and transverse sections of bananas at different stages of ripeness. Compare the results with the sugar content measurements.
3. Examine thin sections of stained banana and examine under the light microscope. Take photos of the images using the camera on a tablet or smart phone.
4. Dip one half of a banana into boiling water. Note the colour change

So what happened?

The sugar and starch content of bananas changes with ripeness.

Chlorophyll and other compounds are broken down by hydrolases changing colour and flavour.

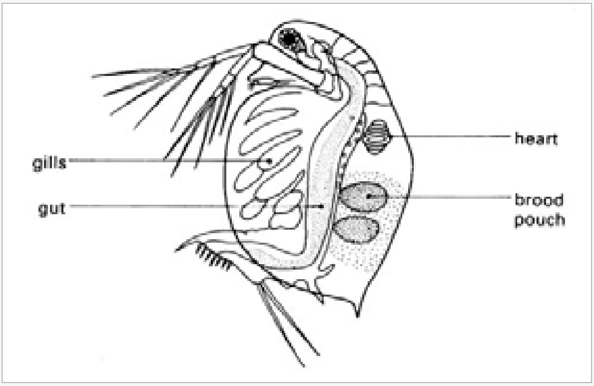
Heat from boiling water destroys the cells on the edge of the banana peel. The enzyme tyrosinase is released which starts the production of melanin. The peel isolates the inner tissue cells and prevents the heat denaturation of the enzyme

What next?

- ✓ Investigate catalase activity.
- ✓ Isolation of DNA.
- ✓ Chromatography and/or extraction of colour compounds.
- ✓ Links to biogeography, business, fair trade, colonialism.

Biology

The effect of alcohol and caffeine on the heart rate of the water flea, *Daphnia pulex*



Background

The small heart of the water flea, *Daphnia*, is easily visible under low magnification using a standard light microscope. The heart rate (which can be up to 300 beats per minute) can be monitored and counted in different conditions – for example changing water temperature, or changing the type and concentration of chemicals added to the water. The procedure provides an interesting technique for investigating the effects of different chemicals on a metabolic process in animals.

Live cultures of *Daphnia* can be purchased from various suppliers, including pet shops and local aquarists. Some scientific suppliers sell viable dried Daphnia eggs and culture kits

You will need...

- ✓ 3 Daphnia
- ✓ 3 microscope slides (concavity slides are ideal)
- ✓ 3 plastic pipettes
- ✓ 1% caffeine solution
- ✓ 1% alcohol

Follow these steps

1. Add one *Daphnia* to each of the solutions (water, ethanol, caffeine) using a plastic pipette and set a timer for 5 minutes
2. Transfer each of the *Daphnia* onto a glass slide using a plastic pipette. Narrow tips can be cut off at a 45° angle to avoid damaging the insects
3. Remove most of the liquid from the slide using a pipette but leave the *Daphnia* in a small drop.
4. Using a stopwatch, count the number of heart beats in 20 seconds. The heartbeat of *Daphnia* is very rapid, so count the beats by making dots on a piece of paper in the shape of a letter S. Count the dots and convert the heart rate to number of beats per minute. Record the results in a table.
5. Repeat for each of the 3 individual *Daphnia*.

So what happened?

Alcohol causes a decrease in heart rate whereas caffeine causes an increase in the heart rate of Daphnia.

What next?

The effect of different concentrations of alcohol or caffeine can be investigated (e.g. 1% to 10% alcohol), so that graphs of increase in heart rate against concentration of substance may be plotted. The effect of different temperatures on heart rate may also be investigated. A useful video guide to experimenting with *Daphnia* in the school laboratory can be found at https://youtu.be/HhOUw-lOdxkA.

Nature’s impact on your well-being

A simple way to show how much air we can hold

Background

This activity looks at the effect of environment on pulse, blood pressure and sense of well-being

You will need...

✓ a sphigmomanometer

Follow these steps

1. Students measure their pulse, blood pressure and self evaluate their sense of well-being on a ten-point scale, first in the classroom and then after a 1 km maximum walk in the countryside with a good view.

So what happened?

Blood-pressure and pulse rate were lowered and sense of well-being increased in 96% of students involved.

What next?

Extend activity to other locations and activities

Image from Wikipedia

6

Biology

Which fertiliser would you use to grow onions

Background

This activity looks at socio-scientific issues and active citizenship through a series of inquiry-based activities

You will need...

- ✓ Onion sets.
- ✓ Vermiculite
- ✓ A variety of fertilisers

Follow these steps

Students grow onion sets in vermiculite which acts as a nutrient-devoid medium and add different fertilisers while recording the changes in onion growth.

So what happened?

Comparisons between different fertiliser Nitrogen, Potassium and Phosphate content are charted against onion growth.

What next?

Extend activity by considering eutrophication and hydro-ponics

Make your own 3D cell

(The Netherlands)

Background

This project will help the students to understand the form and structure of organelles and cells. Physically making the cells and organelles will aid the students to retain the information.

You will need...

- ✓ Styrofoam balls (10”, 3” and 1.5”) (≈ 25 cm, 7.5 cm, 4 cm)
- ✓ acrylic paint in a variety of colours
- ✓ craft foam sheets/felt sheets in a variety of colours
- ✓ thick craft glue
- ✓ glue gun
- ✓ toothpicks
- ✓ white paper labels
- ✓ scissors
- ✓ measuring tape
- ✓ marker
- ✓ knife
- ✓ paint brush
- ✓ rubber bands
- ✓ teaspoon
- ✓ hole punch

Follow these steps

1. Cut a slice from the bottom of the largest ball so that it won’t roll.
2. Stretch the rubber bands around the ball to section it into quarters.
3. Cut one quarter away.
4. Cut a quarter from the 3” ball and the 1.5” ball in the same way. Keep all the pieces.
5. In the centre of the opening cut into the 10” ball, use the knife and a teaspoon to carve out a hole large enough to hold the 3” ball.
6. Paint the parts of the cell:
7. Cell membrane (outside of 10” ball and a ¼” ring around the inside edge)
8. Cytoplasm (inside of 10” ball) – leave white and do not paint
9. Nucleus (outside of the 3” ball)
10. Chromatic (inside of the 3” ball)
11. Nucleolus (quarter wedge of 1.5” ball)
12. Let the paint dry.

13. Glue the 3” nucleus into the opening carved into the 10” ball.
14. Glue the nucleolus into the centre of the nucleus.
15. Cut out the remaining cell parts from different colours of craft ‘foamies’ or felt referring to diagrams in books or on the internet for shapes.

So what happened?

Students took ownership of their learning as they had to construct each part. The time input meant that students were engaged in the material for a considerable amount of time, which allowed them to become more familiar with the organelle.

What next?

1. Label the parts of the cell. Print names of cell parts, cut out, and attach to toothpicks. Peer assessment, as students test each other on their knowledge.
2. Making structures for the digestive system, respiratory system, the eye etc.
3. See: https://www.youtube.com/watch?v=p5_Cf-gX-so0

Chemistry

Zippie Chemistry 1: Acid-Base Reactions

Experiments carried out in Ziploc bags (1L or 3L)

Background

This experiment allows the implementation of IBSE while involving hands-on, minds-on activities for students using acid-base reactions. These acid-base reactions produce CO_2 gas.

Ziploc® bags (1L or 3L) have a plastic zip closure mechanism which ensures that the bag is watertight and airtight

Safety

✓ Goggles

✓ Disposable gloves

For Zippy Chemistry 1–4 you will need...

✓ Ziploc bags (1L or 3L)

✓ Condiment cups (marked at 5 cm^3 using a permanent marker if using a 1 L bag or at 15 cm^3 if using a 3 L bag)

✓ red cabbage indicator made by boiling it for approximately 10 minutes.

Use the red cabbage indicator to make the following solutions in 500 mL bottles:

✓ vinegar (approximately 2/3 of the volume in the bottle)

✓ water

✓ dilute lemon juice

✓ sodium hydrogen carbonate (1 teaspoon ≈ 5 mL)

✓ sodium carbonate (1 teaspoon)

✓ Epsom salts

✓ anhydrous calcium chloride

✓ dilute iodine (a few drops)

Follow these steps

1. Create a mixture in the Ziploc bag involving an acid and a base e.g. 1 tsp (5 mL) of washing soda crystals with 1 tsp of any other solid (Place them in opposite corners of Ziploc bag using spoon).
2. Add 5 cm^3 vinegar or lemon juice by placing the liquid in a condiment cup.
3. Expel air from the bag when sealing it and leave reactants undisturbed.
4. Mix reactants by shaking and observe.

So what happened?

The red cabbage indicator may change colour and the reaction will be slightly exothermic. As the bases in this experiment are carbonates, carbon dioxide will be produced.

What next?

1. Try the experiment with other materials and liquids
2. Use a pH meter to check the pH of the solution against the colour

Zippie Chemistry 2: Precipitation Reactions

Experiments carried out in Ziploc bags (1L or 3L)

Background

In a precipitation reaction crystals of an insoluble salt are produced in solution. This is also referred to as settling out of solution and the product symbol attains a $\downarrow$.

Safety

✓ Goggles

✓ Disposable gloves

You will need...

✓ Ziploc bags (1L or 3L)

✓ Sodium carbonate

✓ Epsom Salts or calcium chloride

Follow these steps

1. Create a mixture in the Ziploc bag involving solutions of sodium carbonate and either magnesium sulfate or calcium chloride
2. Add 5 cm^3 of the chosen solutions.
3. Expel excess air from the bag when sealing it and leave the reactants undisturbed.
4. Mix reactants by shaking and observe

So what happened?

The formation of a precipitate may occur which will break into smaller pieces.

Na_2CO_3 (aq) + $MgSO_4$(aq) $\rightarrow$ Na_2SO_4(aq) + $MgCO_3 \downarrow$

What next?

1. Try the experiment with other materials and liquids and compare crystal colours and sizes
2. Filter the crystals and dry
3. Research how centrifuges are used in relation to precipitates

Zippie Chemistry 3: Endothermic / Exothermic

Background

When atoms / ions rearrange, energy is transferred. When energy is transferred to the surroundings by a reaction, it is exothermic. Self-heating cans of food or drink often use the exothermic reaction of calcium oxide and water to heat their contents.

Safety

- ✓ Goggles
- ✓ Disposable gloves

You will need...

- ✓ Ziploc bags (1L or 3L)
- ✓ water
- ✓ magnesium sulfate or calcium chloride
- ✓ condiment cup
- ✓ (thermometer)

Follow these steps

1. Put 5 g of magnesium sulfate (or calcium chloride) in the bag
2. Put 5 cm^3 of water in the plastic cup.
3. Place the cup in the bag, expel excess air and seal the bag without spilling the water.
4. Mix reactants by shaking and observe.
5. Is there a noticeable change in temperature?

So what happened?

The solvation of magnesium sulfate is endothermic while that of calcium chloride is exothermic.

What next?

1. Research the meaning of solvation energy.
2. Describe how you would use a temperature sensor to measure the change in temperature.

Zippie Chemistry 4: Gel Formation

Background

Gels are solid jelly-like materials that have a cross-linked structure that prevent them from flowing. They may exhibit adhesive characteristics (tackiness).

Safety

- ✓ Goggles
- ✓ Disposable gloves

You will need...

- ✓ Ziploc bags (1L or 3L)
- ✓ cornflour (corn starch)
- ✓ calcium chloride

Follow these steps

1. Create a mixture in the Ziploc bag involving both cornstarch and calcium chloride
2. Add 5 cm^3 of water or of one of the solutions listed in Experiment 1.
3. Expel air from the bag when sealing it and leave reactants undisturbed.
4. Mix reactants by shaking and observe.

So what happened?

The solvation of calcium chloride is exothermic so it cooks the cornstarch and a gel forms.

What next?

1. Try the experiment using the liquid where iodine is present and note the colour change from orange to black.

Hydrophilic or Hydrophobic Compound

using PolyPocket sleeves (Belgium)

Background

Hydrophilic molecules or molecular components have interactions with water and that are more favourable (thermodynamically) than their interactions with oil or other hydrophobic solvents. They are typically polar and readily dissolve in water.

Photocopy this page and place it in a polypocket for use during the experiment.

You will need...

- ✓ polypocket + a photocopy of this page
- ✓ ethanol,
- ✓ octane,
- ✓ water
- ✓ a magnifying glass (optional)
- ✓ eye droppers

Follow these steps

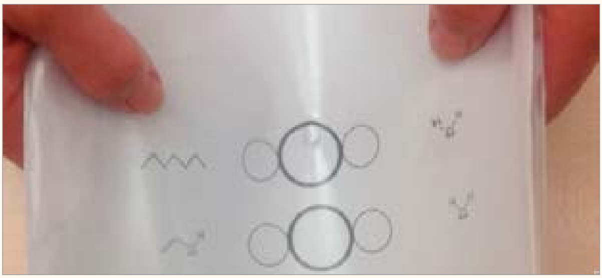
1. Put one drop of water on the left circle and one drop of ethanol or octane on the right circle.
2. Then fold paper to slide the two drops towards the large circle in the centre.
3. Observe

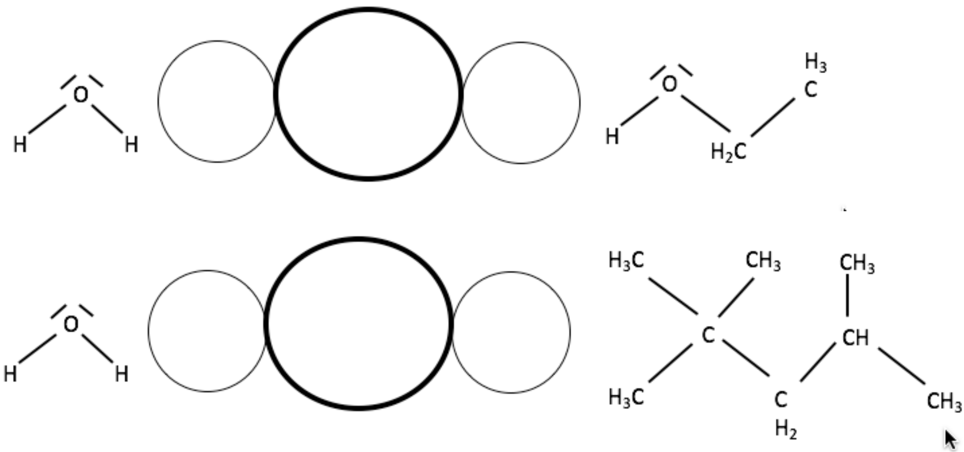
So what happened?

Heptane will not mix with water whereas ethanol will.

What next?

1. Make models of these compounds using moly-mods
2. Blu tack, markers and post-its can be used to discuss electronegativity, intermolecular bonding.





Precipitation using PolyPocket sleeves

(Belgium)

Background

In a precipitation reaction crystals of an insoluble salt are produced in solution. This is also referred to as settling out of solution. The precipitate is indicated by the symbol ↓ or (s).

Safety

Photocopy this page (or similar) and place it in a polypocket for use during the experiment.

You will need...

- ✓ 1.2 M Na_2SO_4 solution
- ✓ 2 M $CaCl_2$ solution, a magnifying glass (optional)

Follow these steps

1. On the left circle, place one drop of 1.2 M Na_2SO_4 solution.
2. On the right circle, place a drop of 2 M $CaCl_2$ solution

3. Then fold paper to slide the two drops towards the large circle in the centre.
4. Observe

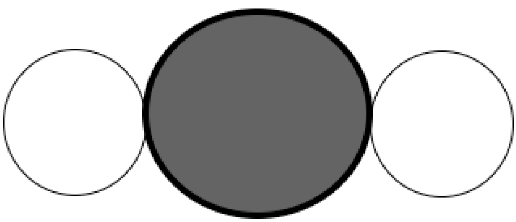
So what happened?

When ionic compounds are dissolved in water, they break apart into their constituent ions. In this case the ions re-arrange to form calcium sulfate (insoluble in water) and sodium chloride (soluble in water.

✓ $Na_2SO_4(aq) + CaCl_2\ (aq) \text{-->} CaSO_4(s) + 2NaCl\ (aq)$

What next?

Explore the nature of covalent or ionic compounds, relative molecular mass and stoichiometry



Electrolysis using PolyPocket sleeves:

(Belgium)

Background

Background: It is not possible to obtain reactive metals from their solutions by electrolysis.

When you electrolyse a solution of a highly reactive metal, hydrogen – not the metal is given off at the cathode.

Safety

- ✓ Goggles
- ✓ Disposable gloves

You will need...

- ✓ 0.1 M $CuCl_2$ solution
- ✓ 0.2 M KI
- ✓ vegetable oil,
- ✓ a magnifying glass (optional)

Follow these steps

1. Put two pencil leads on the horizontal lines and fix them with sticky paper. Connect these electrodes to a 4.5 V to 9 V battery with crocodile clips.
2. Place a 0.1 M $CuCl_2$ solution in the circle and observe what happens beside the pencil leads.
3. Add a drop of 0.2 M KI solution to the circle and continue the electrolysis.

4. Then add a drop of oil which must touch the drop which has been electrolysed and observe.

So what happened?

Electrolysis of copper (II) chloride solution:

Cathode (negative): $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Anode (positive): $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

Redox

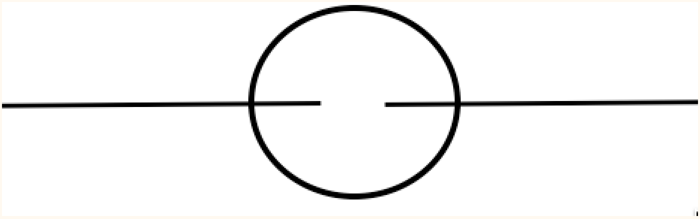
Iodide is a good reducing agent. It reduces copper from a +2 oxidation state to a +1 oxidation state.

$2CuCl_2 + 2KI \rightarrow 2CuCl + I_2 + 2KCl$

The presence of C=C double bonds in the oil can be detected by iodine; the more double bonds there are, the more iodine is used up.

What next?

Nature of covalent or ionic compounds, relative molecular mass and stoichiometry



Electrochemistry in hydrogel balls

(Hungary)

Background

Hydrogels are examples of new polymers that are regarded as ‘smart’ materials due to their possible applications. They are polymer chains with a few cross-linking units which creates a matrix that can trap water. Smart gels can shrink or swell up to 1000 times their volume due to changes in pH or temperature.

Follow these steps

1. Prepare the hydrogel balls (this needs to be done in advance). First, wash the hydrogel balls several times in distilled water, then leave them to swell in more distilled water for at least 2 hours. Approximately 500 mL of distilled water is needed to soak 30 hydrogel balls.
2. Place a piece of filter paper onto the tile or Petri dish. Drip some sodium chloride solution onto the filter paper, as an electrolyte.
3. Place two hydrogel balls on the filter paper and insert an electrode into each hydrogel ball.
4. Using a Pasteur pipette, insert some silver nitrate solution into the hole in each hydrogel ball where the electrodes enter it.
5. Clip the cables to the electrodes and the battery. Close the electrical circuit.
6. Observe the changes and record them.
7. Repeat for the other electrolytes.

So what happened?

The equations of the electrolysis reactions are:

Electrolysis of silver nitrate solution:

Cathode (negative electrode): $2Ag^{+}(aq) + 2e^{-} \rightarrow 2Ag(s)$

Anode (positive electrode): $H_2O(l) \rightarrow ½\ O2(g) + 2H^{+}(aq) + 2e^{-}$

Electrolysis of zinc iodide solution:

Cathode (negative): $Zn^{2+}(aq) + 2e^{-} \rightarrow Zn(s)$

Anode (positive): $2I^{-}(aq) \rightarrow I_2(s) + 2e^{-}$

Electrolysis of water:

Cathode (negative): $4H_2O(l) + 4e^{-} \rightarrow 2H_2(g) + 4OH^{-}(aq)$

Anode (positive): $2H_2O(l) \rightarrow O_2(g) + 4\ H^{+}(aq) + 4e^{-}$

What next?

Anti-microbrial uses of hydrogels and metals in medicine to combat MRSA in post-operative care. Nature and uses of aerogels. An interesting video to show the simulation of a miniature steam engine using hydrogel balls is available at: https://youtu.be/9oQc-gAvUS4

Precipitation reactions in hydrogel balls

(Hungary)

You will need...

for each student or group:

- ✓ one hydrogel ball for each experiment
- ✓ a white glazed ceramic tile, glass plate or Petri dish
- ✓ two syringes fitted with hypodermic needles (assembled in advance by a teacher / technician)
- ✓ distilled water
- ✓ a pair of disposable gloves
- ✓ a pair of safety glasses.

Reagents:

- ✓ Sodium hydroxide (NaOH) solution (1.0 M)
- ✓ Iron(III) chloride ($FeCl_3$) solution (1.0 M)
- ✓ Nickel(II) chloride ($NiCl_2$) solution (1.0 M), or nickel(II) sulfate ($NiSO_4$) solution (1.0 M)
- ✓ Sodium sulfide (Na_2S) solution (1.0 M)
- ✓ Potassium hexacyanoferrate(II) ($K_4[Fe(CN)_6]$) solution (1.0 M)

Follow these steps

1. Prepare the hydrogel balls (this needs to be done in advance). Prepare the hydrogel balls (this needs to be done in advance). First, wash the hydrogel balls several times in distilled water, then leave them to swell in more distilled water for at least 2 hours. Approximately 500 ml of distilled water is needed to soak 30 hydrogel balls.
2. Place a swelled-up hydrogel ball on one white tile.
3. Fill a syringe with one of the solutions containing a heavy-metal compound (e.g. iron(III) chloride solution) and inject a small amount of reactant into the centre of the ball.
4. Fill the next syringe with sodium hydroxide solution and inject a similar amount into the hydrogel ball through the same hole.
5. As the reaction proceeds, observe the colour change and record what you see. You should observe a coloured, solid precipitate form inside the ball.
6. Using another hydrogel ball, repeat the experiment with the next heavy-metal compound (e.g. nickel(II) chloride solution), again reacting this with the sodium hydroxide solution.
7. Continue repeating the experiment with the other reagents:
   - nickel(II) chloride with sodium sulfide
   - iron(III) chloride with potassium hexacyanoferrate
8. Finally, compare the results of the different precipitation reactions.

So what happened?

The equations and colour changes for these reactions are:

$Fe^{3+}(aq) + 3\,OH^-(aq) \rightarrow Fe(OH)_3(s)$ (red−brown precipitate)

$Ni_2^+(aq) + 2\,OH^-(aq) \rightarrow Ni(OH)_2(s)$ (green precipitate)

$N^{i2+}(aq) + S^{2-}(aq) \rightarrow NiS(s)$ (black precipitate)

$4\,Fe^{3+}(aq) + 3\,Fe(CN)_6^{-4}(aq) \rightarrow Fe_4[Fe(CN)_6]_3(s)$
(Prussian blue precipitate)

See: https://www.youtube.com/watch?v=fJ3sk8BIrfY

Dry water

Background

Hydrophobic silica is a form of silicon dioxide (silica) that has hydrophobic groups chemically bonded to the surface. The hydrophobic groups are normally alkyl or polydimethylsiloxane chains.

(Wikipedia)

You will need...

- ✓ Hydrophobic silica powder
- ✓ Water
- ✓ Kitchen blender

Follow these steps

1. Mix 3 grams of hydrophobic silica powder with 100 grams of water in a kitchen blender for between 30 and 60 seconds.

So what happened?

The hydrophobic silica does not mix with the water.

This activity demonstrates the concept of chemical affinity between water and surfaces such as umbrellas and waterproof clothes.

What next?

Applications:

- ✓ Cosmetics.. delivery of active compounds for skin hydration, make-up.
- ✓ Fire fighting.. painting with water rich compounds.
- ✓ Agricultural spraying… precise and controlled delivery of water.

Chemistry

Investigating the effects of acid rain

Background

This activity looks at the effect of acid rain on the environment by examining the behaviour of *Daphnia* in differing solutions of different pH.

You will need...

- ✓ *Daphnia*
- ✓ pH probe
- ✓ dilute hydrochloric acid
- ✓ lime water
- ✓ pipettes
- ✓ spotting tile
- ✓ binocular microscope

Follow these steps

1. Students place *Daphnia* in the well of a spotting tile and measure the heart rate.
2. Either acid or base is added dropwise and the pH determined and the heart rate of the *Daphnia* is again recorded

So what happened?

Heart rate is affected by the pH of the solution.

What next?

Extend activity by measuring the pH of local waterways.

Technology of metal manufacturing

(Czech Republic)

Background

The aim of the project is to get pupils familiar with the characteristics of metal and the technology of metal manufacturing.

Safety note

Hot metal can cause severe burns.

Minimal safety equipment:

- ✓ heavy duty heat proof gloves
- ✓ heat proof apron
- ✓ goggles or welding mask.

Metal casting requires a lot of practice and should not be undertaken without the appropriate guidance.

You will need...

- ✓ tufa limestone
- ✓ tool for carving the stone
- ✓ flame
- ✓ pliers
- ✓ screwdriver
- ✓ hammer
- ✓ tin, copper and alloys of these
- ✓ sandpaper

Follow these steps

1. Carve desired shapes into the stone, ensuring that you have a cone and drainage channel carved also.
2. Smelt the desired metal/alloy and allow it to fall onto the stone.
3. Allow the metal to cool and solidify.
4. Remove the piece from your mould.
5. Sand the rough edges.
6. Complete jewellery design using wires, pliers etc.

So what happened?

The melted metal formed shapes that corresponded to the shapes carved by the students. These shapes could then be used to make personal items, jewellery, decorations etc.

What next?

1. Soldering in electronics
2. Mixing pure metals to create alloys

Violent vinegar volcano

Background

Students explore the concepts of chemical reactions, acids and bases and states of matter.

You will need...

- ✓ 1 × Alka Seltzer© tablet
- ✓ 1 × vinegar
- ✓ 1 × washing up liquid
- ✓ 1 × red food dye
- ✓ 1 × volcano toy
- ✓ 1 × dish

Follow these steps

1. Add some vinegar, red food dye and washing up liquid to the volcano toy.
2. Explain that matter exists in three states – solids, liquids and gases and show examples of each.
3. Place the volcano on a dish and then quickly add in the alka seltzer tablet.

So what happened?

The Aka Seltzer tablets release carbon dioxide gas when added to the vinegar. A chemical reaction takes place between the two substances. The vinegar is an acid and is neutralised by the basic alka seltzer, to produce a neutral salt and water solution. Because alka seltzers contain sodium hydrogen carbonate, carbon dioxide gas is also released. The gas gets trapped in the washing up liquid and it starts to foam up and out of the volcano.

What next?

Repeat using other liquids in place of the vinegar, such as hot water, cold water, fizzy water, fizzy drinks and investigate if they lead to more or less vigorous reactions than the vinegar.

Simple Harmonic Motion

A smartphone application

Background

All smart phones have an accelerometer in their internal hard drive. If you allow students to bring their own device to class there are numerous free apps that you can use for physics.

You will need...

- ✓ Smart phone,
- ✓ Sensor Kinetics app (or Sensor Kinetics Pro, Physics Toolbox Sensor Suite etc.),
- ✓ a retort stand
- ✓ a helical spring,
- ✓ bubble wrap bag.

Follow these steps

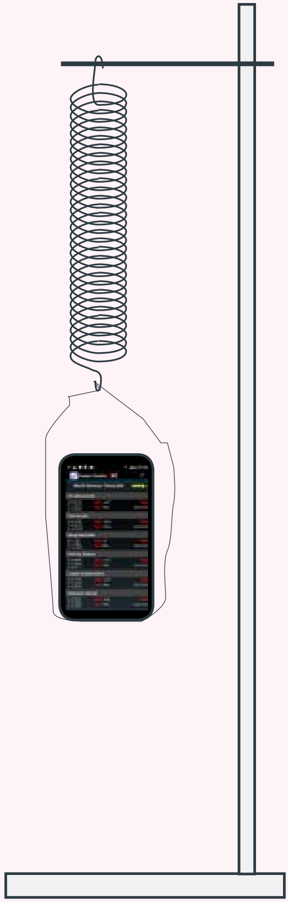
1. Download *Sensor Kinetics* app (free).
2. Open the accelerometer.
3. Place the phone in the bubble wrap bag (bubble wrap protects phone if it falls!).
4. Attach a spring to the top of the bag.
5. Press start on accelerom-eter.
6. Stretch the spring and release.
7. Observe graph on phone.

So what happened?

The phone moves with simple harmonic motion. The motion automatically graphed on the phone producing a sinusoidal graph.

What next?

1. Change the distance in which the spring is stretched and see how the frequency and amplitude changes.
2. Add more mass to the bag and note the effect on the period of the oscillation.
3. If the total mass is doubled what is the effect on the period?



Falling meter sticks bearing equal loads

Background

The UK Physics teacher, David Featonby, once asked the question; "if two identical meter sticks have two identical Aluminium blocks taped to them as shown, which reaches the floor first when they are released simultaneously?" In one case the block is positioned at the midpoint and in the other case the block is positioned at one end of the meter stick.

You will need...

- ✓ Two identical meter sticks
- ✓ two identical metal blocks
- ✓ Sellotape and
- ✓ a ruler

Follow these steps

1. Tape the blocks securely to the meter sticks as shown.
2. Support them at the high end by a ruler and position the low end of the meter sticks against the skirting board between a wall and the floor. An angle of about 70 degrees to the horizontal works well.
3. Remove the ruler by a sharp upward movement allowing the sticks to fall.

So what happened?

The stick with the mass taped to the mid-point struck the floor first.
This often causes some surprise. Instinct suggests to many that the stick with the weight further from the fulcrum would have the "greater turning effect" and so should strike the floor first. Moments of inertia and angular momentum account for the outcome that is observed. Angular momentum   is the same for both but I is less for the stick loaded at its mid-point so its angular velocity   is greater.

What next?

Hold a dumbbell in each hand and sit in a swivel chair (and wear a seat-belt). Then go for a spin with arms outstretched horizontally, and while still spinning bring your arms to the vertical with the dumb-bells over your head. What do you notice? How does this relate to the falling meter sticks?

:

Friction and normal reaction

Background

Friction is a force which acts between two rough surfaces in contact when one tries to move relative to the other. The force of friction increases so as just to prevent sliding up to a maximum value called limiting friction. The value of limiting friction F is given by

$$F = \mu R$$

The coefficient of friction μ is the ratio of the frictional force F between two surfaces and the normal reaction R between those surfaces. It has no units.

You will need...

✓ A uniform rod ideally timber and about 1.5 meters long.

Follow these steps

1. Identify the centre of mass of the rod and place a light visible marker there (e.g. a yellow elastic band).
2. Use the index fingers of both hands to provide horizontal supports that the rod can rest horizontally.
3. Position your index fingers at the locations shown in the picture by blue arrows.
4. Try to move both fingers simultaneously towards the visible marker.

So what happened?

Initially, only the finger further from the mark moved, no matter how hard you try to get both moving.

The reaction force R, is greater at the left arrow (in the case shown below). The frictional force is greater there and so sliding occurs first at the right side until they are both equidistant from the centre, at which time, both fingers move equally.

What next?

Use other kinds of support in place of your fingers.

Try supports that are different left and right.

:

Dynamics and Statics

Gravity and Friction

Background

This demonstration looks at both the force of gravity and the force of friction. Gravity acts all the time, friction only acts briefly. The consequence is that the seemingly improbable, actually happens

You will need...

- ✓ Two identical glass jars,
- ✓ two identical plastic containers,
- ✓ a place mat (for a dinner plate),
- ✓ two balloons filled with sand.

Follow these steps

1. Position the “place mat” with its smooth face in contact with the rims of the glass jars.
2. Place the plastic containers on the rough upper surface of the mat, directly above the jars.
3. Place the balloons containing sand on top of the plastic containers. While holding the glass jars securely with one hand, slap the edge of the place mat horizontally with your other hand.

So what happened?

As the mat moved quickly in a horizontal direction, the plastic containers scattered out of the way and the balloons dropped into the jars. Friction only acted very briefly but for long enough to take the plastic containers out of the way. The force of Gravity acted continually on the balloons (containing sand) causing them to fall down into the jars.

What next?

Try the magician’s trick of pulling the table cloth from under the best china tea set you can find (with care!) or alternatively pull a sheet of paper from under a book or a cup.

Hanging hammer

Background

When a uniform beam overhangs a cliff edge by more than 50% we would expect it to fall. When additional weight is hung from the over hanging beam then it seems more certain that it should fall. Yet the photo shows it balancing.

You will need...

- ✓ A table,
- ✓ a uniform beam (e.g. a meter stick)
- ✓ a hammer and
- ✓ some string.

Follow these steps

1. Choose strong string and tie a loop of string in such a way that it supports the hammer and holds it with the head hanging freely and the tip of the handle in contact with the beam.
2. Carefully position the beam above the edge of the table in such a way that the head of the hammer is under the table sufficiently far that the centre of mass of the system is on the "correct side" of the fulcrum for stability.

So what happened?

The beam and hammer hung in equilibrium.

What next?

Scale up the project to a heavier hammer with a longer handle as shown below.

Let’s twist again

Euler’s disc from computer hard drives (UK)

Background

Magnets attract certain metals including key rings.

Thread is spun from multiple fibres.

You will need...

- ✓ A transparent plastic tube (e.g. tube used for holding tennis balls
- ✓ a strong neodymium magnet,
- ✓ a steel washer,
- ✓ a pencil,
- ✓ a key-ring,
- ✓ strong thread.

Follow these steps

1. Drill a whole at opposite sides of the open end of the tube so as to allow a pencil to act like a crane which can lower the key-ring at the end of a length of thread, towards the magnet which sits at the closed end of the tube.
2. Position the washer outside the bottom of the tube in such a way as to anchor the magnet.
3. Lower the key-ring towards the magnet and observe the behaviour when it gets close.

So what happened?

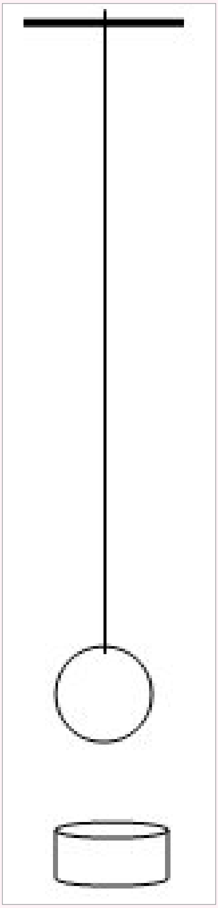
The ring started to spin rapidly and after a while stopped and spun in the reverse direction….this happened a number of times.

The explanation is that the thread is made by twisting several strands together. Under tension it tends to untwist.

If this happens quickly enough it may temporarily wind a bit in the opposite direction, ultimately causing the key-ring to pause and then spin in the other direction.

What next?

When spinning of the key-ring is in progress, try turning the tube on its side or even upside down.

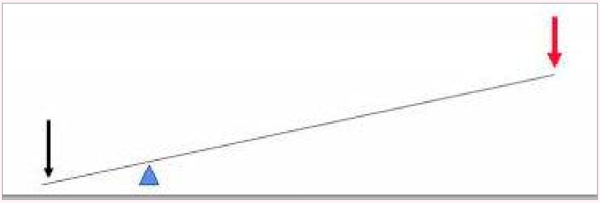


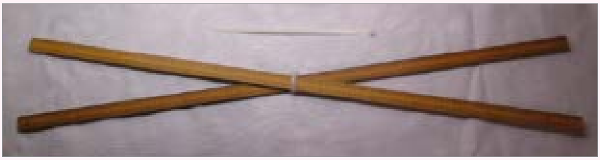
Levers and fulcrums

(Ireland)

Background

A lever is mankind's oldest machine and in many ways still the most often used. A lever is essentially any rigid object that is free to rotate about a fixed point called a fulcrum (or pivot or hinge). Levers are at work in scissors and tweezers for example.





You will need...

- ✓ Two meter sticks,
- ✓ a cable-tie and
- ✓ the cap of a white-board marker.

Follow these steps

1. Place one meter-stick on top of the other and fix the cable-tie around the midpoint of both.

So what happened?

The meter sticks were moved relative to each other to show the action of a scissors.

Then the cable tie was moved towards one end and the cap of a white-board marker (or a wine cork) was positioned near the cable-tie. When the meter sticks were clasped near the middle, the action of a "tweezers" was apparent.

What next?

Build a simple wheel-barrow to show the lever handles lifting a load by rotating about the fulcrum (i.e.the axle of the wheel).

The Magnus effect with plastic cups

Background

The lift generated by a spinning ball or cylinder is called the Magnus effect.

You will need...

- ✓ Two plastic cups
- ✓ a wooden kebab skewer (or stick)
- ✓ duct tape and
- ✓ a strong elastic band.

Follow these steps

1. Cut the wooden skewer to a suitable length as shown.
2. Glue it to the base of one of the cups.
3. Tape the cups together as shown (with the stick along the diameter.
4. Loop the elastic band around one end of the stick.
5. Clasp the stick between your thumb and index finger. With the stick vertical, use your other hand to stretch the elastic band horizontally. A very slight forward tilt of the stick can work well. Release the stick.

So what happened?

The cups travelled more or less horizontally and due to the "backspin" imparted when launched, they seemed to float as they travelled. The Magnus effect is at work, whereby the upper-side of the cup is rotating in harmony with the air through which it passes whereas the underside of the cup is clashing with the air through which it passes. This gives rise to a certain amount of uplift which accounts for the perception that they are floating through the air.

What next?

Try it with different types of cup and different shaped objects

Pulleys in equilibrium

Background

A sash window offers a practical use of pulleys. The window to be raised is attached to a pair of counter-weights, whose sum equals the weight of the window. The ropes connecting the window to the two counter-weights, pass over smooth pulleys. Because the system is in equilibrium, very little effort is needed to open the window. Also, the window will stay at rest at any position that is required.

You will need...

✓ Two identical picture frames (remove the backing to expose the glass) two pulleys and two suitable weights and some string. A timber frame needs to be constructed to mount the pulleys and support the windows in a manner that they can move.

Follow these steps

1. Obtain two identical picture frames of a suitable size.
2. Cut suitable lengths of timber to make the window frame and glue together using wood adhesive.
3. Fix the pulleys to the top of the frame.
4. Attach the two weights to the top of the lower picture frame using string (that passes over the pulleys)
5. Adjust the amount of weight so that the system can move freely and so that it rests in equilibrium when no force is applied.

So what happened?

The window was raised and lowered with minimal effort due to the state of balance between the forces. It also stayed ar rest at any desired height.

What next?

Put your head out the open window and see that it doesn't fall on your head.

Slinky Seismometer

Background

Robert Mallet, (1810 – 1881), Irish geophysicist, civil engineer, and inventor is sometimes called the father of seismology. A seismometer is an instrument that measures motion of the ground, caused by, for example, an earthquake.

In this demonstration the physical shaking of a building is detected by a small induced electrical current in a coil which then deflects the needle of a galvanometer.

You will need...

- ✓ A slinky,
- ✓ strong neodymium magnet,
- ✓ a coil of wire (400 turns),
- ✓ a galvanometer,
- ✓ 2 wires and
- ✓ a tall plastic cylinder (or similar support structure).

Follow these steps

1. Attach the galvanometer to the coil.
2. Place a sponge under the galvanometer to absorb any unwanted vibration.
3. Place the coil in “the basement” of a tall building.
4. Suspend the slinky from the top of the building so that it hovers just above the coil.
5. Test that the galvanometer deflects if there is relative motion between the magnet and coil.

So what happened?

The table was shaken slightly to simulate an earthquake. The “building” shook and a weak “shock wave” travelled through the slinky. The resulting slight motion of the magnet induced an electric current in the coil which deflected the galvanometer (and so the earthquake was detected)

What next?

Explore if the scale of the galvanometer could be calibrated to indicate the severity of the earthquake.

Rolling spools with wide and narrow hubs

Background

Two spools made of identical materials but constructed differently as shown are rolled down an incline. Which gets to the bottom first?

You will need...

- ✓ Four identical discs,
- ✓ six identical bolts,
- ✓ 18 nuts,
- ✓ a power drill and
- ✓ a spanner.

Follow these steps

1. Measure and mark, where the holes are needed in the discs. Drill the holes. Position the bolts. Tighten the nuts with the spanner.
2. Place the two spools at the top of an inclined ramp.
3. Release them simultaneously so that they roll down the ramp.

So what happened?

The spool with the bolts close to the centre reached the bottom of the ramp first.

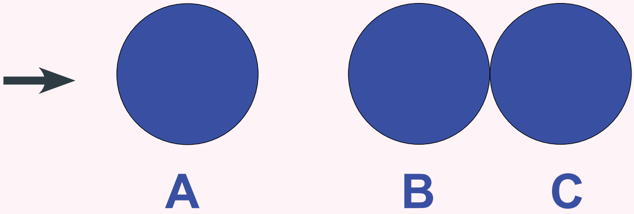
What next?

Review the demonstration about falling meter sticks or hold a dumbbell in each hand and sit in a swivel chair (and wear a seat-belt). Then go for a spin with arms outstretched horizontally, and while still spinning bring your arms to the vertical with the dumbbells over your head. What do you notice? How does this relate to the rolling spools?

Three discs

Background

The principle of conservation of momentum may be demonstrated with three discs.



You will need...

- ✓ Three identical smooth discs and
- ✓ a smooth horizontal table.

Follow these steps

1. Three smooth flat discs are place on a smooth table.
2. Hold disc B firmly against the table by pressing downwards with your hand.
3. Disc C, initially in contact with B seems to be protected by B as A moves to collide with B.
4. It might be expected that A will rebound if B is firmly held and that C stays at rest.

So what happened?

After A collided with B it stopped and C moved off to the right with a velocity similar to what A had originally.

What next?

Try it with three equal coins.

Compare the behaviour to Newton’s cradle

The vector nature of momentum

Background

The principle of conservation of momentum is important throughout Physics. Most calculations focus on the magnitude of the velocity or mass after a collision. However, since momentum is a vector quantity the direction of motion is also important.

You will need...

- ✓ A basketball and
- ✓ a tennis ball

Follow these steps

1. Hold the basketball directly above the tennis ball and in contact.
2. Let them fall to the floor at the same time.

So what happened?

When they landed they travel in exactly opposite directions. The tennis ball with less mass travelled further than the more massive basketball.

The event was repeated several times and it was observed that the directions were always opposite and quite random. Quite often the balls bounced a bit, but sometimes they rolled along the floor without any bounce. It depended on how they landed.

What next?

Try it with different types of ball.

What does the scales say?

Background

Archimedes noted that when objects are immersed in water they experience an upthrust or buoyancy force. Will the kitchen scales in the picture detect this upthrust?

You will need...

- ✓ kitchen scales,
- ✓ a large jug half filled with water and
- ✓ a litre bottle of water.

Follow these steps

1. Place the jug which is half full of water on the scales. Note the reading on the scales.
2. Hold the bottle of water inside the jug in such a way as not to touch any part of the jug.
3. Lower the sealed bottle into the water until about half of bottle is under water.
4. Observe the reading on the scales

So what happened?

The water level in the jug rose, and the reading on the scales increased.

What next?

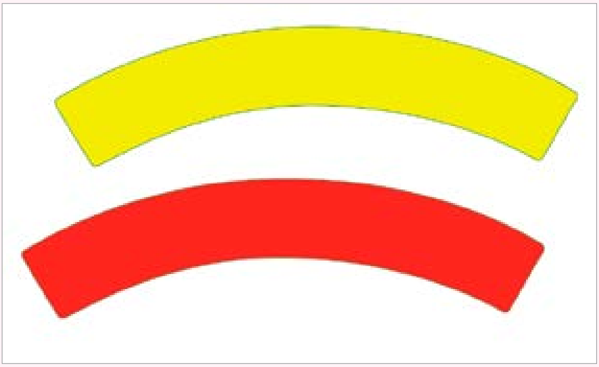
Draw a diagram of the forces acting on the bottle and a separate diagram of the forces acting on the scales.

Optical illusion cards

Can you believe your eyes?

Background

Two arc-shaped cards are used to show students that their eyes cannot always be trusted to give accurate measurements. Turning the cards around (they are both the same colour on both sides) also encourages the students to think about the problem and challenges their misconceptions about measurement.



You will need...

- ✓ 2 cards – cut into a curved arc shape ideally made of plastic or stiff cardboard. The cards should also be two different colours (red and yellow work well)
- ✓ Sellotape
- ✓ Scissors
- ✓ A ruler and string or an opisometer

Follow these steps

1. Cut out the shapes of the two cards.
2. Place one card on above the other and show them to the students. Ask them which card is bigger?
3. Then, hold the cards the other way around.
4. Now ask them 'Which is the bigger card now? Why? How?'

So what happened?

Because the cards are curved, the upper one always appears shorter. This can be used to show students the importance of measurement in science, not believing everything we see with our eyes!

What next?

Superimposing the two cards shows that they are in fact the same size.

Dancing raisins

The behaviour of raisins in sparkling water

Background

Students explore the concepts of density, flotation and gases.

Fizzy water contains carbon dioxide gas which is released gas when the bottle is depressurised. Raisins are added to the water in the bottle and their behaviour is examined.

You will need...

- ✓ a 2 L bottle of sparkling water in a clear, plastic bottle with the label removed
- ✓ a small packet of raisins
- ✓ a large plastic basin

Follow these steps

1. Open the bottle of fizzy water and explain to the students that the sound they hear when the cap is released is due to the carbon dioxide gas escaping due to the pressure difference.
2. While standing the bottle in a basin, students add a small handful of raisins into the bottle of fizzy water and observe what happens.

So what happened?

When the raisins are added, they initially begin to sink down through the fizzy water (because they are denser than the water). As the bubbles of carbon dioxide rise up to the surface, they become 'trapped' in the wrinkles and crevasses on the surface of the raisins. This causes them to float.

Once the raisin reaches the surface, the bubbles burst and the gas escapes. The raisins then begin to sink back down through the liquid again, but pick up more bubbles once more, thus beginning the cycle again. This behaviour of 'dancing raisins' repeats until the raisins either absorb too much water and become too heavy to float upwards or until all of the gas escapes from the water.

What next?

'Density Towers' can be created by layering different types of liquids on top of one another in a tall glass. Try oil, golden syrup, water, food dye, salt water, alcohol etc.

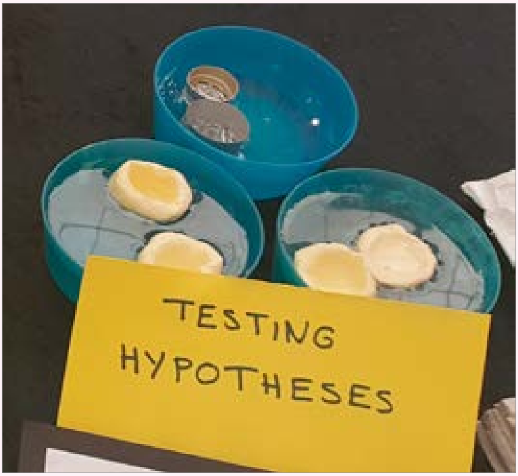
See also: https://www.youtube.com/watch?v=Qm3oOE-bwgyQ

The boat full of holes

Background

Students are presented with a boat made of margarine with holes in the hull. They are convinced that it will take in water and sink.

Challenging this conviction, using simple materials, encourages students through a series of hypotheses and experiments. The boat full of holes conflicts with students' expectations and provokes a wonder followed by and immediate urge to seek a logical explanation. Students develop their understanding and construct their own knowledge.



You will need...

✓ a bowl of water
✓ a pack of margarine
✓ a knife
✓ a pin
✓ "Night light" candles

Follow these steps

1. Present the margarine boat full of holes to students. The reaction is often sceptical – students assume they are being tricked or cheated.
2. Encourage students to develop one or more hypotheses and carry out experiments. For example:
   - the holes don't go all the way through – shine a torch through the hull of the boat
   - there is something transparent in or on the holes allowing light through, but not water – blowing through the holes and feeling the air coming through the other side of the holes.
3. Challenge the class to a competition: construct a boat of a given amount of margarine with the largest possible number of holes in the bottom. Students document their project with photos and video. The winning boat design is voted by the class.
4. Ask students to investigate which factors determine whether the boat takes in water or not – size of holes; distribution of the holes; the construction material (margarine or night-light casing); the weight of the boat (or its cargo), etc.
5. Students present their findings to the rest of the class.

So what happened?

Students learn to observe, make predictions, formulate and revise hypotheses, design and carry out experiments, repeat and re-design tests. They also learn how to communicate their findings, present their results, and share their ideas with others.

What next?

Students can carry out some research to find out more about the properties of water that allow the boat to float, and why water has these properties.

Convection current spinning wheel

A design challenge

Background

Convection currents

You will need...

- ✓ Strong copper wire,
- ✓ aluminium cake tin or similar container
- ✓ pin
- ✓ tealight candle.

Follow these steps

1. Bend the copper wire into shape that will support the .
2. Glue the pin to the top of the copper wire.
3. Cut the aluminium cake tin into a circle and then cut into the circle at an angle as in the picture.
4. Bend each edge slightly.
5. Balance the centre of the aluminium cake tin on top of the pin so that it is free to rotate.
6. Light a candle and place it underneath.

So what happened?

As the hot air rises the cake tin spins.

What next?

1. Change the design so the the wheel turns more quickly (or slowly).
2. What is the simplest shape that will turn?

The balancing birdie

Background

Students explore the concept of levers, centre of gravity, weight, mass and equilibrium.

You will need...

- ✓ 1 × balancing bird toy
- ✓ 1 × smooth flat edge
- ✓ 5 × flash cards of key terms
- ✓ 1 × calculator
- ✓ 1 × electronic balance.

So what happened?

The bird balances because it is in a stable equilibrium. There are small weights carefully positioned in the tail and wing tips of the bird. All of the weight of the bird is acting down through the beak of the bird. This is its centre of gravity – the point at which all of the force due to weight is acting. If the bird is given a gentle push, it start to rotate about the fixed point. This fixed point is known as the fulcrum.

What next?

1. The centre of gravity other objects can be determined.
2. The students can calculate their own weight by recording their mass on a bathroom scales and using the formula: weight (in newtons) = mass (in kg) × g (10 m/s^2).
3. Students could research Isaac Newton, who investigated forces in nature.

Follow these steps

1. Position the bird on its beak on a smooth flat point that is visible to all of the students.
2. Rotate and spin the bird around and ask the students how it appears to be flying and balancing.
3. Use flashcards of key terms to introduce the students to the definitions of levers, centre of gravity, weight, mass and equilibrium.
4. Place the bird on the electronic balance and record is mass and convert it into kilograms.
5. Multiply the mass (in kg) by 10 (approximation of the acceleration due to gravity of 9.8m/s^2).

Balancing bird available from Amazon

Magnetism

Background

Magnets have two distinctive properties; they attract certain metals, and when suspended freely they align themselves with the earth's magnetic field, thereby coming to rest pointing north. The fact that iron is not magnetic but may be magnetised can be shown in this demonstarion.

You will need...

- ✓ A compass,
- ✓ bar-magnet, t
- ✓ est tube, i
- ✓ ron filings.

Follow these steps

1. The Dublin physics teacher, David Hobson showed that when a test tube containing iron filings (scattered evenly along its length) is brought near a compass needle, it has no affect. However if one strokes the outside of the tube from one end to the other (a number of times in the same direction) the iron becomes magnetised.

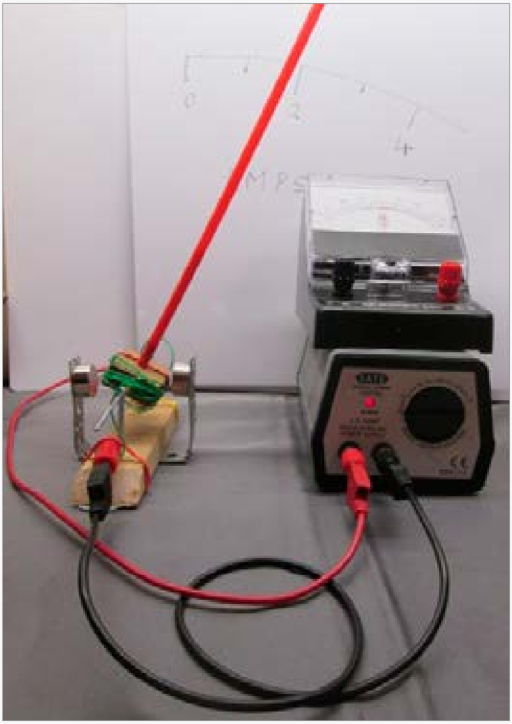
So what happened?

The molecular magnets in the iron were brought into alignment and so the iron became magnetised. When the test tube was brought close to the compass needle, it deflected, indicating that the iron filings were magnetised.

What next?

Shake the test tube, and test it for magnetism by bringing it close to the compass needle again. This time the compass is unaffected, because iron has poor magnetic retentivity, hence the magnetism was lost when the filings were shaken.

Principle of the galvanometer



Background

A galvanometer (seen sitting on top of the power supply in the photograph) is a valuable instrument for detecting if electrical current is flowing. This demonstration looks at what happens to cause a galvanometer's needle to deflect.

You will need...

- ✓ Two strong neodymium magnets,
- ✓ a small rectangle of timber that can pivot about a horizontal axis,
- ✓ 2 m of insulated wire,
- ✓ a pair of leads,
- ✓ a 12V d.c. power supply and
- ✓ a drinking straw.

Follow these steps

1. Wind 2 m of wire around the rectangle of timber in such a way that the first 10 cm and the last 10 cm are free to be coiled into a weak spring.
2. Mount the rectangle so that it can pivot freely about a horizontal axle. Position the coil between two strong magnets.
3. Attach the straw pointer to the rectangle as shown.
4. Connect the ends of the coil to the 12 V d.c. power supply using a pair of leads.

So what happened?

When the power supply was switched on, a current flowed through the coil. This established a magnetic field surrounding the coil which interacted with the magnetic field already in place due to the presence of the pair of magnets. The result of the interaction was that the rectangle rotated on its axle and this caused the needle to defect away from the vertical.

What next?

1. Increase the voltage and observe that the resulting increase in current causes the straw pointer to deflect through a bigger angle.
2. Reverse the polarity of the power supply and observe that the pointer deflects in the opposite direction.

Induction heater to demonstrate the principles of electromagnetic induction

Background

The induction cooker is an everyday application of EM induction. It can be used to demonstrate the principles of electromagnetic induction.

However, a simpler version can be assembled using a cheap induction heater coil and power supply available on the internet; the version used cost about €5.

You will need...

- ✓ plastic tube (e.g. Rubex container)
- ✓ 40 swg enameled copper wire
- ✓ aluminium cooking foil (‘tin foil’)
- ✓ low voltage induction heat-ing power supply module +heater coil (available on the internet)
- ✓ small stainless steel sugar bowl (as a ‘dome’)

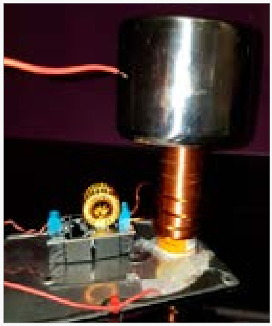
Follow these steps

1. Wind 1000 turns of 40 swg copper wire or similar on a plastic tube such as a Rubex™ tablet container.
2. Connect the top end of the winding to some tin foil stuck to the metal dome.
3. The bottom end of the winding is connected to piece of insulated wire of 30 cm; the end of this wire is left bare.
4. Replace or adjust the supplied heating coil so that you have a coil of 4 or 5 turns that will fit neatly around the 1000 turn coil.
5. Attach the tube with the secondary coil to a suit-able base. The induction heater can be positioned as required.

So what happened?

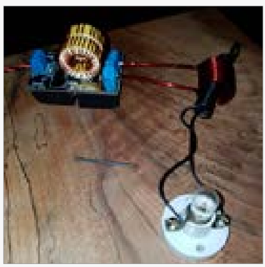
Connect the induction heater to a 12 V d.c. supply and bring the bare end of the insulated wire to the top of the dome, an arc should be seen. This is a simple Tesla coil.

The induction heater cre-ates a high frequency low voltage -high current flow in the primary which in turn induces the high voltage low current flow in the second-ary coil.



What next?

1. Bring a fluorescent bulb or CFL bulb close to the secondary and note that it glows due to induced currents.
2. The induction heater with its original coil can be used to heat an iron nail until it is red hot, demonstrating the use of induction heating.
3. A 6 V bulb connected to a coil of insulated wire of 20 turns or so can be got to light when its coil is placed inside the heating coil showing once again the principle of induction. This can be linked to a discus-sion on the transformer theory etc.



Magnetic Vehicle

Background

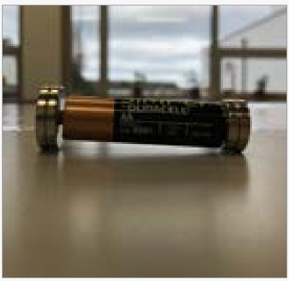
A current-carrying conductor experiences a force in a magnetic field.

You will need...

✓ Aluminium foil, 15 × 4 mm
✓ neodymium magnets
✓ 1.5V AA battery.

Follow these steps

1. Roll out a length of aluminium foil.
2. Attach neodymium magnets to each end of the battery so that the north poles are facing each other.
3. Place on the aluminium foil



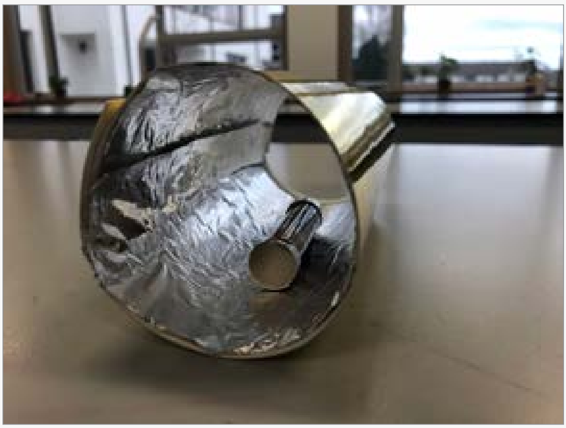
So what happened?

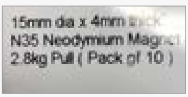
When the battery is placed on the aluminium foil it completes a circuit and current flows. When the same poles are facing each other then the upward current on one side and the downward current on the other experience a force (Lorentz force) in the same direction hence the battery rolls along the aluminium foil in a straight line.

Note: In this demonstration a large current is drawn from the battery.

What next?

1. Try with south and north pole facing each other.
2. Try with south and south pole facing each other.
3. Change one of the neodymium magnets to a one with a larger diameter. The battery will move in a circle this time.
4. Stick aluminium foil to some card and roll the card into a cylinder. Place the battery inside the card on the aluminium foil. The cylinder rolls along the desk.





Electricity & Magnetism

Magnetic Train

Background

A current-carrying conductor experiences a force in a magnetic field.

You will need...

- ✓ 22 gauge bare copper wire,
- ✓ 15 mm × 4 mm neodymium magnets,
- ✓ 1.5V AA battery.

Follow these steps

1. Wind the copper wire around a metal pipe or plastic tube so that the diameter of the coil is only slightly bigger than the diameter of the battery.
2. Attach a neodymium magnet to each end of the battery so that the same poles are facing each other.
3. Place the battery with magnets inside the copper wire and let go.

So what happened?

When the battery is placed inside the copper coil it completes a circuit and current flows through a section of the coil. A magnetic field is produced in that section of the coil which interacts with the magnetic field of the neodymium magnets This creates a force which causes the battery to move through the copper wire.

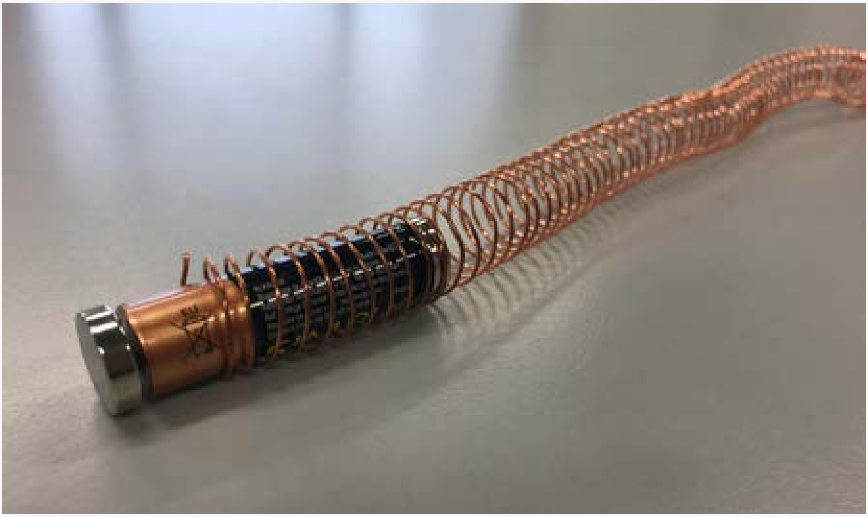
If your battery does not move turn it the other way around.

The direction of the current flowing through the coil will create a north pole (anti-clockwise current) or a south pole (clockwise current) hence the battery needs to be facing the correct direction.

Note: In this demonstration a large current is drawn from the battery.

What next?

1. Try with south and north pole facing each other.
2. Try with south and south pole facing each other.
3. Join the ends of the bare copper coil together to form a circle and watch your ‘train’ continue to move in a circle.



Magnetic piston engine

Background

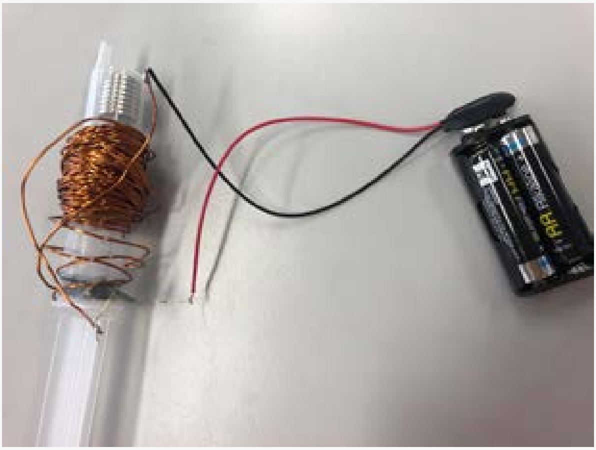
A reed relay is a type of relay that uses an electromagnet to control one or more reed switches. The contacts are of magnetic material and the electromagnet acts directly on them.

You will need...

- ✓ Thin enamelled copper wire
- ✓ 4 neodymium magnets
- ✓ plastic syringe (slightly bigger than the diameter of your magnets),
- ✓ reed relay switch,
- ✓ 1.5V AA battery and battery holder,
- ✓ superglue,
- ✓ solder and soldering iron.

Follow these steps

1. Set up the circuit in the diagram by winding the enamelled copper wire around the syringe and soldering one end of the wire to the reed relay switch and the other end to the battery holder wire. Leave other side of battery holder wire loose or solder to the other side of the reed relay switch to complete the circuit if you have added a push button switch into your circuit.



2. Place 4 neodymium magnets inside the syringe and keep the syringe plunger at the top.
3. Close the switch by touching the loose wire off the reed relay or push the switch button.

So what happened?

As current flows through the copper coil a magnetic field builds up. This pulls the magnets up the syringe away from the reed relay switch. The reed relay switch opens and the current in the coil stops flowing, hence the magnetic field disappears.

The magnets fall back down towards the reed relay switch due to gravity causing the reed relay switch to close. This process repeats causing the magnets to move back and forth inside the syringe like a simple magnetic piston engine or a magnetic oscillator.

What next?

Change the number of turns of the coil or the number of magnets.

Magnetohydronamic Effect

Background

When electricity moves through a conductive fluid in a magnetic field, a force, called the Lorentz Force, is imparted on the fluid, causing it to move.

You will need...

- ✓ Petri dish,
- ✓ aluminium foil,
- ✓ ring magnet,
- ✓ strong copper wire,
- ✓ cracked black pepper,
- ✓ salt,
- ✓ water,
- ✓ low voltage power supply,
- ✓ wire and crocodile clip.

Follow these steps

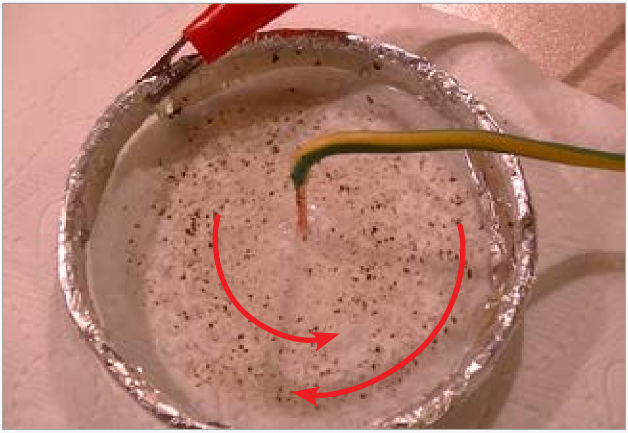
1. Place the aluminium foil around the inside the of the Petri dish as in picture.
2. Sit the Petri dish on top of the ring magnet.
3. Make up a saline solution and pour into the Petri dish.
4. Attach the aluminium foil in the Petri dish to the negative of the low voltage power supply using the wire and crocodile clip.
5. Attach the copper wire to the positive of the low voltage power supply and place the end of the wire in the saline solution so it is in the middle above the hole in the ring magnet.
6. Sprinkle cracked black pepper over the surface of the saline solution.
7. Turn the low voltage power supply on and increase the voltage to 12volts.
8. Observe what happens.

So what happened?

The cracked black pepper moves in two different directions simultaneously showing the forces caused by the current flowing in a magnetic field.

What next?

1. Reverse the polarity of the power supply.
2. Reverse the poles of the magnet.
3. See: https://www.youtube.com/watch?v=s-wrK1qJHUYg



Franklin's Bell

Background

This was the first device that converted electrical energy into mechanical energy in the form of continuous mechanical motion. The bell clapper moves back and forth between two oppositely charged bells.

The invention was attributed to Benjamin Franklin but it was actually invented by Andrew Gordon in Germany in the 18th century.

You will need...

- ✓ Two aluminium cans,
- ✓ aluminium foil,
- ✓ cotton thread,
- ✓ glass rod,
- ✓ string,
- ✓ two wires,
- ✓ two crocodile clips,
- ✓ high voltage supply (can use a Wimshurst machine, electric bug swatter either),
- ✓ insulated metal (scissors with plastic handles).

Follow these steps

1. Place the two cans close to each other.
2. Tie a piece of thread around the middle of the glass rod and attach a ball of aluminium foil to the bottom of the string.
3. Place the glass rod across the top of the two cans as in the picture.
4. Connect the two cans to the high voltage power supply. (If using a bug swatter connect one can to the outer metal layer and the other to the inner metal layer.)
5. Switch on the power supply.
6. Observe what happens.
7. To discharge place an insulated scissors across the two cans.

So what happened?

One of the cans becomes positively charged and the other negatively charged. The aluminium foil ball receives an induced electrostatic charge from one of the cans and is then attracted to it. The ball swings toward the can until they touch and the ball takes on the same charge as the can. Because like charges repel each other, the ball immediately is electrostatically repelled away from the can and, because opposite charges are attracted to each other, the ball is electrostatically attracted to the opposite can. When the ball touches the second can, the ball takes on the charge of the second can, is repelled by it, and then returns to first can. The process keeps repeating creating a ringing effect.

What next?

Try different materials for the ball such as the can tab.

Try different voltages.

Safety notes

1. Take care when using high voltages as you can get an electric shock if you touch the cans!! Take care when discharging!
2. Do not allow students to do this experiment or stand close to this experiment.

Electricity & Magnetism

Running Bug

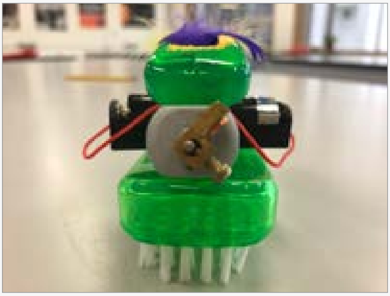
A STEM challenge

Background

This is a nice STEM challenge for students to do. They can design their own ‘bug’ and the best design wins. Nice example for conversion of energy.

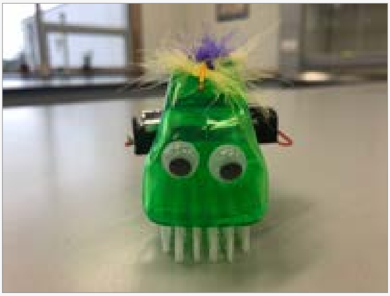
You will need...

- ✓ Nail brush (or similar),
- ✓ motor & motor holder
- ✓ 2 × 1.5 AA batteries & battery holder
- ✓ wire
- ✓ solder &soldering iron (or wires and crocodile clips)
- ✓ some form of metal to cause an imbalance on the motor
(A fuse holder from a mains plug works very well as you can screw it tightly onto the motor axle).



Follow these steps

1. Glue the motor clip to brush.
2. Place the motor in the clip.
3. Screw the fuse holder onto the motor.
4. Attach the motor to the batteries using solder or other means.
5. Switch on and place on the ground.
6. Observe what happens.



So what happened?

When the motor is turned on the eccentric weight attached to the axle causes the motor to vibrate. This causes the brush to move around rapidly.

What next?

1. Change the size of the brush.
2. With the aid of a hair dryer, bend the bristles slightly backwards and see what happens.

Aluminium pie pan electroscope

Background

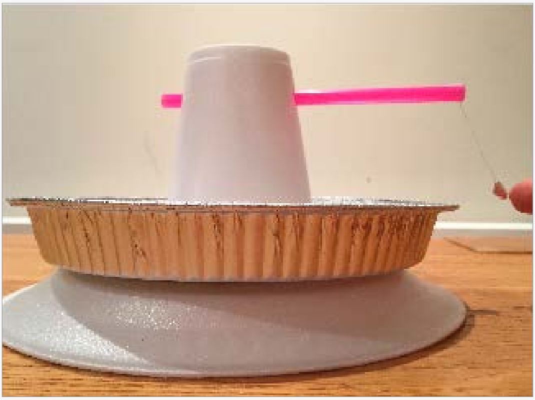
This is a simple experiment that students can easily make themselves in a class. It can be used to demonstrate that like charges repel, using electrostatic charges. It can also demonstrate earthing and can be used to test for humidity and the triboelectric series.

You will need...

- ✓ styrofoam cup
- ✓ styrofoam plate
- ✓ pencil,
- ✓ straw,
- ✓ aluminium pie pan
- ✓ Blu-tack
- ✓ thread,
- ✓ cooking foil
- ✓ balloon,
- ✓ cloth and other materials to test

Follow these steps

1. Take a sharp pencil and make two holes in the bottom of the Styrofoam cup by gently pushing the pencil through the cup.
2. Place the straw through the holes.
3. Use Blu tack to stick the cup to the centre of the aluminium pan.
4. Adjust the position of the straw so that one end is right above the edge of the pan.
5. Cut a very thin slit in the end of the straw and place a long piece of thread through the slit. Cut the length of the thread so it is just below the pan.
6. Take a small piece of tinfoil and wrap it into a ball around the end of the thread. The ball needs to be light, so don't use too much tinfoil. It also needs to be just touching the edge of the pie pan.
7. Tie a few knots in the thread, above the top of the straw, to hold it in place. Your homemade electroscope is now ready for testing.
8. Create static electricity by rubbing a balloon/cloth on a Styrofoam plate.
9. Quickly place the electroscope on top of the plate, holding only the Styrofoam cup when lifting the electroscope.



So what happened?

The ball moves away from the edge of the plate.

What next?

1. Now bring your finger towards the ball. The ball bounces back and forth between your finger and the pan as it charges and discharges.
2. To discharge the electroscope, simply touch the aluminium pie pan with your finger. If left alone it will eventually discharge due to humidity in the room.
3. Try charging different materials and compare the effect on the tinfoil ball to the triboelectric series.

Electricity & Magnetism

Field effect transistor electroscope

A

Background

The MPF102 is an N-channel transistor and is turned off when the movable negative electrons are pushed out of the silicon turning it into an insulator.

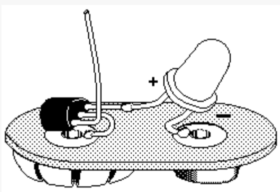
N5460 is a P-channel transistor which will do the reverse.

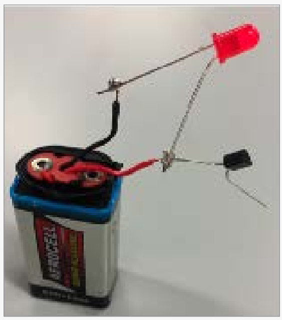
You will need...

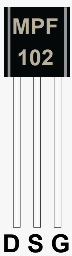
- ✓ MPF102 Field Effect Transistor (F.E.T) (Can be bought online on Amazon)
- ✓ 9-volt battery & 9-volt battery clip
- ✓ red/blue light emitting diode (L.E.D)
- ✓ wire for antenna
- ✓ wire clippers,
- ✓ soldering iron & solder
- ✓ balloon
- ✓ materials to test for static electricity.

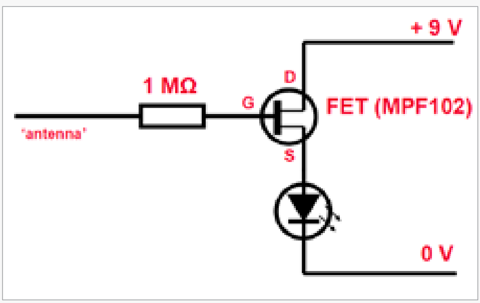
Follow these steps

1. Bend the gate wire of the F.E.T upwards. This acts as the antenna so leave it unconnected.
2. Connect the middle wire, the Source, to the red positive lead on the 9-volt battery clip.
3. Connect the remaining wire, the Drain, to the positive leg of the L.E.D (longer leg).
4. Connect the negative leg of the L.E.D (shorter leg) to the black negative lead of the 9-volt battery clip.
5. Check your circuit is correct and then connect the battery clip to the top of the 9-volt battery. The red L.E.D should light up.
6. To test the circuit rub a balloon on your hair and bring it close to the gate wire. The L.E.D should go dark but will light up again when you remove the balloon.
7. If it doesn't work the humidity may be too high. You can check this using a balloon and rubbing it on your hair. If the hairs on your arm aren't attracted to the balloon then humidity is too high.
8. A wire (0.5m) can be soldered to the gate leg to act as an antenna, increasing the sensitivity to up to nearly 6m!
9. If the L.E.D does not light up touch the gate wire with your finger to reset









(FET electroscope continued)

So what happened?

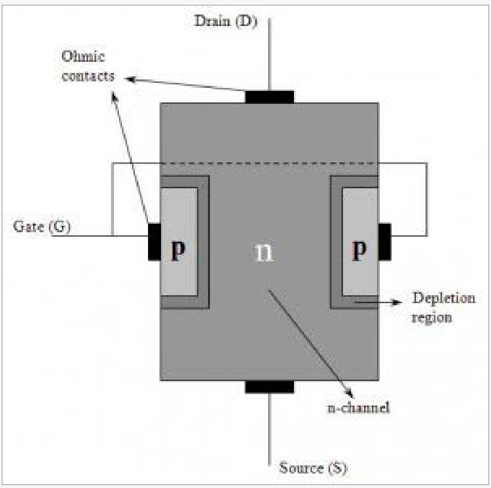
When there is no Gate voltage ($V_G = 0$), and a small voltage (V_{DS}) applied between the Drain and the Source, maximum saturation current (I_{DSS}) will flow through the channel from the Drain to the Source restricted only by the small depletion region around the junctions.

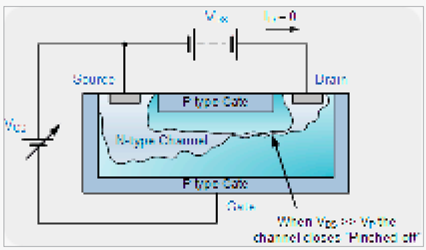
If a small negative voltage ($-V_{GS}$) is now applied to the Gate the size of the depletion region begins to increase reducing the overall effective area of the channel and thus reducing the current flowing through it. So by applying a reverse bias voltage increases the width of the depletion region which in turn reduces the conduction of the channel.

Since the PN-junction is reverse biased, little current will flow into the gate connection. As the Gate voltage ($-V_{GS}$) is made more negative, the width of the channel decreases until no more current flows between the Drain and the Source and the FET is said to be "pinched-off".

What next?

1. Brush your hair with a comb; if it is a very dry day you will see the L.E.D flicker on and off. Bring the comb towards the gate and the L.E.D will go dark, indicating excess negative charge.
2. Rub your feet on a carpet while holding the electroscope and see the L.E.D flicker on and off.
3. Jump up and down on the carpet and see the L.E.D turn on and off.
4. Turn on a Van de Graaff generator and see the electroscope detect the electric field.
5. Hold the electroscope near the aluminium pie pan when you touch your finger of the tinfoil ball and see what happens to the L.E.D.
6. Using a digital hygrometer compare the distance versus humidity with the electroscope and draw a scatter plot and calculate the correlation coefficient.
7. Change the antenna length and compare to the distance and again plot a scatter plot and calculate the correlation coefficient.





Buzzing ball!

(or 'Energy stick')

Background

Students explore the concept of electrical circuits, resistance and current.

You will need...

✓ 1 × Buzzing 'energy ball' or 'Energy stick'

Follow these steps

1. The students are invited up to hold hands. They represent the atoms in a conductor.
2. The first and last students in the line touch the separate conducting strips on the 'energy ball' or 'energy stick'..

So what happened?

Explain that electricity is a flow of electric charge, made up of moving charged particles such as electrons or ions. Substances that allow electricity to travel through them are known as 'conductors'. Examples include metals and solutions of salts. Substances that do not allow electricity to flow through them are known as 'insulators'. Examples include plastic, glass and wood. The ball buzzes and lights up when the circuit is complete. If one of the students breaks the link, the ball does not light or sound.

What next?

1. Simple electric circuits can be built using crocodile clips, batteries, wire, buzzers, light bulbs and switches.

Note

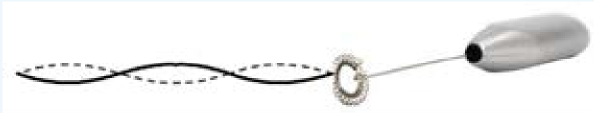
These devices contain a battery and an electronic circuit to amplify the tiny external current in order to drive the buzzer and LEDs. The external current may be a fraction of a microampere while the LED current may be 10 millampere s, i.e. more than 10,000 times greater.

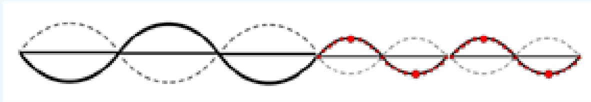
Refraction due to changing wave speed

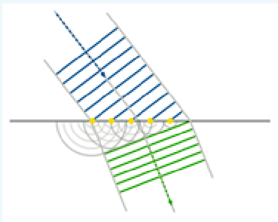
Background

When waves cross a boundary into a more dense medium they are refracted (change direction) due to a reduction in wave speed. In standing waves, two adjacent nodes on are separated by a distance of half a wavelength, $\lambda/2$.

The wave equation $\boldsymbol{v = f \lambda}$ implies that if the frequency, f, stays constant, then a reduction in wavelength, corresponds to a reduction in wave speed.







You will need...

- ✓ A milk frother,
- ✓ elastic cord,
- ✓ bath-chain,
- ✓ an angler's swivel.
- ✓ small cable-ties.

Follow these steps

1. Attach the swivel to the frother by a small cable tie.
2. Attach one end of the elastic cord to the swivel, and the other end to the bath chain.
3. Stretch the chain and chord slightly in a horizontal line and switch on the frother.

So what happened?

A standing wave formed, with greater separation between the nodes in the white elastic cord, than occurred between the nodes on the bath chain. The frequency is constant throughout (determined by the frother). Therefore the closer separation of nodes in the bath chain (denser medium) is indicative of a reduced wave speed in the denser medium, which relates to the resultant change in direction in the top diagram.

What next?

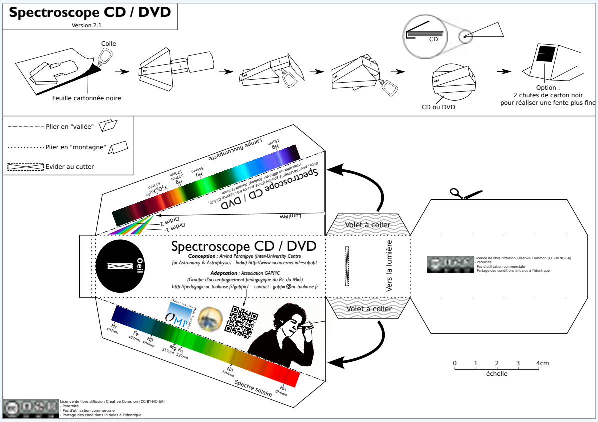
Connect the frother at the opposite end to simulate waves entering a less dense medium.

Spectroscope

(Belgium)

Background

Investigation the spectrum of light is a hugely important technique in many areas of science from astrophysics to chemical analysis. While professional spectrometers are expensive instruments we can make a simple but quite useful and educational one cheaply using old CDs or DVDs. There are various designs for these, but the following is the best I have come across.



You will need...

- ✓ a CD
- ✓ a copy of the spectroscope PDF, available from http://ekladata.com/GMDS2QxvLLAjb-t2o9b-EzwEGOrQ/spectroscope-CD-DVD-version-gappic-omp.pdf

Follow these steps

1. Download the template from the address above or use the dimension's in the diagram.
2. Stick the template on black card and cut out. The black card is needed to block out light from the spectroscope.
3. Cut the slits as indicated in the cardboard. For a sharp slit tinfoil can be used. Two pieces of foil can be folded and placed close together or one piece cut to create a narrow, sharp slit that Is stuck on the cardboard.
4. Glue the data side of the CD/DVD onto the base of the cardboard.
5. Observe the spectrum by placing your eye right up to the eyepiece side while having the inlet side close to the source.

So what happened?

The pattern of narrow lines on the CD face acts as a diffraction grating reflecting and breaking up the light into its spectrum. As we are only using a narrow portion of the CD we get a spectrum very similar to that produced by more expensive diffraction gratings.

What next?

1. Various sources of light can be examined such as fluorescent and filament lamps. Fraunhofer lines can be seen on the solar spectrum taking care not to look directly at the sun) and experiments to look at absorption spectrum in, for example, a solution of copper sulphate can be undertaken.

Anemometer with Coke-can cups

Background

An anemometer is a device used for measuring the speed of wind. Thomas Romney Robinson invented the cup-anemometer which was first erected on the roof of Armagh Observatory in 1846 to measure wind speed.

In this demonstration, the cups are made from Coke cans, and attached to a "paint roller" so that it is light and rotates freely. The rotational energy is converted to electric current in the dynamo which then passes through a galvanometer causing a deflection of the needle.

You will need...

- ✓ Two coke cans and a scissors to cut them.
- ✓ A small electric motor (to be used as a dynamo),
- ✓ two wires,
- ✓ a galvanometer,
- ✓ a paint roller,
- ✓ retort stand (or similar support),
- ✓ an elastic band,
- ✓ a wine cork
- ✓ super-Glue
- ✓ Sellotape.

Follow these steps

1. Attach the galvanometer to the dynamo.
2. Cut the Coke cans in half (vertically) as shown and Sellotape them to the paint roller.
3. Glue the wine cork as shown to the free-end of the roller.
4. Secure the handle of the paint roller to the retort stand.
5. Secure the dynamo to the report stand.
6. Attach the spindle of the dynamo to the wine cork by an elastic band around each.

So what happened?

Air was blown at the Coke cans (anemometer cups) and when they rotated the elastic band transferred the energy of rotation to the dynamo which in turn transformed the rotational energy into electrical energy. The wires joining the dynamo to the galvanometer transferred the electrical current, causing the needle of the galvanometer to deflect.

What next?

Explore if the scale of the galvanometer could be calibrated to indicate the speed of the wind.

A noisy fan

Background

A fan may be made by folding a rectangular sheet of paper in concertina fashion. When moved through the air it may cool you down but it generally doesn't make any noise.

You will need...

- ✓ A large rectangular sheet of card or stiff paper.

Follow these steps

1. Holding the left side of the fan in the photo, slap the right side of the fan sharply against a hard surface.

So what happened?

The energy of the impacts was dissipated to the air as a very loud sound (considering it is essentially a sheet of paper). The "concertina folds" close in rapid succession, making the several sounds merge as one loud sound. The noise was like that which results from striking the flat side of a meter stick against a table, slap a table with the fan, so

What next?

Alter the number and size of the folds and the quality of the paper used to obtain the optimum sound possible.

Musical Triangle

Background

Sound occurs when objects vibrate, or when a collision occurs between objects and some of the energy of the impact is dissipated to the surrounding air. If the object that was struck is held in the hand, much of the energy is absorbed by the hand and only a little sound is heard. If however the object is free to vibrate, the resulting sound can be significantly louder.

You will need...

- ✓ A triangular handle for lifting a manhole cover
- ✓ a steel bolt and
- ✓ a length of string

Follow these steps

1. Tie the string to the straight end of the handle.
2. Hold the straight iron in one hand and strike the triangle with the bolt (held in your other hand. Result; a dull low noise.
3. Now let the triangle dangle from a length of string and strike the triangle again with the bolt. Result; a much louder and booming sound (like a bell) will be heard

So what happened?

When the triangle was held in the hand much of the energy of the impact was absorbed by the hand. When the triangle dangled freely at the end of a string, it could vibrate freely and a “richer” sound was imparted to the air.

What next?

Try other metal objects, e.g. a hollow metal pipe.

Speed of Sound

(Belgium)

Background

Experiments to measure the speed of sound, such as the resonance tube, are based on the fact that we can locate a node or antinode and use a distance measurement to find the wavelength which along with the known frequency of the source allows us to calculate the speed of sound.

This method is similar but uses the visual representation of the wave on an oscilloscope to make the experiment more easily understood by the student.

You will need...

1. a dual beam oscilloscope
2. two dynamic microphones
3. audio signal generator

Follow these steps

1. Set up two microphones connected to a dual beam oscilloscope.
   Note: dynamic microphones are more suitable as electret microphones will need a power supply.
2. Turn on a signal source of known frequency from a signal generator or mobile phone (there are signal generator apps available for smart phones).
3. Display the traces form the microphones on the oscilloscope
4. Move one of the microphones towards or away from the source and note the how the trace changes.
5. Measure the distance between the microphones when the waves are again in phase

So what happened?

When the microphones are at the same distance from the source the waves displayed are in phase. As one microphone is moved the traces move out of phase but eventually come back into phase once the microphone moved is again at the same phase along the wave. The distance moved can be measured and this corresponds to a full wavelength (if the traces are back in phase). The speed of the wave can now be found using the know frequency from the signal generator.

What next?

This arrangement allows for a visual display of what is occurring as we measure the speed of sound. It helps students understand and discuss the principles behind it.

It may also be adjusted to look at interference in sound if the source is connected to two speakers placed some distance apart and one microphone is moved parallel to the line joining the two speakers, a rise and fall in the amplitude of the note displayed will be seen due to the interference occurring.

The speed of sound in air

using a smartphone

Background

The speed of sound in air can be calculated using the formula

$$c = 4\,f\,(\ell + 0.3\,d)$$

when using resonance tubes.

In this experiment you can use a straw which has such a small diameter that we can use the formula $c = f\,\lambda$ instead.

You will need...

✓ Smart phone

✓ a straw

✓ spectrum anaylser app.

Follow these steps

1. Download spectrum anaylser app (free or you can buy one with more features).
2. Open up the spectrum analyser.
3. Place the straw close to the microphone and blow across the top or the straw.
4. Note the frequency on your phone. (You might see the first and the second harmonic).

So what happened?

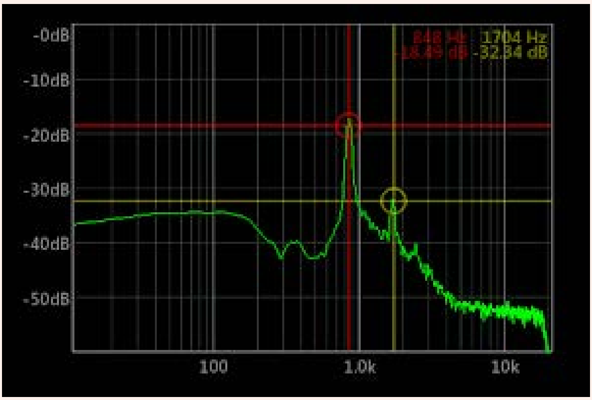
The spectrum anaylser picks up the fundamental frequency of the straw. As the straw is an open pipe then the length of the straw

$$\ell = \lambda / 2.$$

Using $c = f\,\lambda$ you can then calculate the speed of sound in air.

What next?

Change the length of the straw.



Sounds around us

(Slovakia)

Background

The experiments were designed to teach about sound using simple materials. They focus on the concepts of frequency, amplitude, speed of sound and how sound can be ‘seen’.

You will need...

- ✓ tuning forks
- ✓ straws
- ✓ sticky tape
- ✓ scissors
- ✓ empty tin cans
- ✓ balloons
- ✓ rubber bands
- ✓ flip flops
- ✓ 5 cm diameter PVC pipe
- ✓ hacksaw
- ✓ wood
- ✓ nails
- ✓ sound software

Follow these steps

1. Make panpipes using straws of different length, taped together.
2. Drums using tin cans with a balloon stretched over the top, secured with a rubber band.
3. PVC xylophone is made with PVC piping of different length. The flip flops are used to tap the tops of the pipes.

So what happened?

Students get inventive as they make a variety of instruments. They use sound equations to work our what length their piping should be, and use tuning forks and sound analysing software to ensure that they get the length correct for the notes required.

What next?

1. Make another xylophone using a wider pipe. Discuss why it sounds different.
2. Make a guitar, trumpet, cymbals etc. using simple material.
3. See: https://www.youtube.com/watch?v=m3uFWrf-3pIE

What’s that sound?

Background

Students explore the human sensory system (hearing) and sound.

You will need...

- ✓ 1 × Sound tube
- ✓ 1 × anatomical model of the human ear.
- ✓ (a frequency meter)

Follow these steps

1. Ask students to name the five different senses. Get them to match the correct sense organ in the human body with the sense they have mentioned.
2. Show them the sound tube. Start to slowly spin it around above your head. Ask the students to listen to the sound it makes.
3. The frequency of the notes increases

So what happened?

As the tube is spun around standing waves are set up inside it. As the speed is increased the frequency rises, not gradually but in discrete steps. The frequencies of successive notes are simple multiples of the fundamental frequency.

In this case however, the fundamental frequency is rather faint and not easy to hear. You may just hear it if you swing the tube very slowly over and back. Its frequency is about 220 Hz.

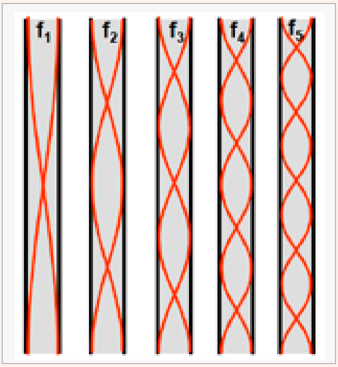
The more obvious harmonics are at around 440 Hz, 660 Hz, 880 Hz and 1100 Hz. These are the expected harmonics for an open tube. (The notes correspond to *d*, *s*, *d*[1], *m*[1] in tonic sol-fa.)

The frequencies can be checked with the aid of a frequency meter (or with some electronic guitar tuners).

The sound tube is flexible and so it can stretch by a few centimetres when spun at high speed. This will cause the high notes to have a slightly lower frequency than would otherwise be expected.

What next?

1. Standing waves in an open tube have an even number of quarter wavelengths. To estimate the speed of sound measure the length of the tube. The lowest easily audible note is the second harmonic (4 quarter waves = 1 full wave) and has a frequency of about 440 Hz. Measure the length of the tube and use $v = f\ \lambda$ to calculate the speed of sound.
2. A diagram of the ear can be given out on a worksheet and labelled.



General

Numeracy with Knitting

Background

Knitting can be used to aid understanding of the concepts of perimeter, area, speed, and pattern. 3D objects can be made, following basic patterns and charts, which require similar skills to those needed in computer programming. Stitches can be used to create illusions, and pieces can be stitched together to make models of organs, puzzles, and much more.

You will need...

- ✓ a ball of yarn with needles of a suitable size
- ✓ a measuring tape
- ✓ scissors
- ✓ a timer
- ✓ a simple charted pattern
- ✓ knitting graph paper

Follow these steps

1. Teach the students to cast on, knit, and bind off.
2. Once they are comfortable, get them to predict how long it will take them to knit one row, five rows, ten rows. Time them. Students should work out their stitch rate.
3. Get students to predict how many rows they need to make a square, get them to accurately measure the cast on edge of their knitting and see if their prediction is correct. Introduce the purl stitch to create texture. Once a square is knitted bind it off. These squares can be sewn together to make blankets for charity donation.
4. Small baby hats can be knitted to introduce shaping using decreases.
5. Introduce a picture of a simple charted pattern, and a knitted representation of the chart. Distribute knitting graph paper and allow students to make their own designs using two colours. Distribute yarn and allow students to reproduce their charts.
6. Illusion knitting is done using a chart, allow student to design a shape or work they would like to have in the illusion. This is achieved by alternating knit and purl stitches across two rows. Allow them to experiment to create their own illusions, and have some to hand to use as examples.

So what happened?

Students understand timing, speed, perimeter and area. They see that a knitted stitch is not a square, so their cast on number is not the same as their rows needed. This introduces the idea of gauging, and can be useful in scaling for garment design.

Creating a chart and reproducing it in their knitting allows students to see input and output, key skills for programming.

What next?

1. Knitted models of body organs, microbes and proteins for Biology
2. Resistors and planets for Physics
3. Periodic table of elements for Chemistry

Solar system fruit basket

Subtitle

Background

This activity is designed to help students visualise the relative sizes of objects in our solar system and the distances between them.

You will need...

- ✓ peas - Mercury
- ✓ white grapes - Venus
- ✓ plums - Earth
- ✓ peppercorns - Moon
- ✓ redcurrants or small blueberries - Mars
- ✓ apples - Uranus
- ✓ water melon - Jupiter
- ✓ galia melon - Saturn
- ✓ peach - Neptune
- ✓ spring onions - Comets
- ✓ a golfing umbrella - Sun
- ✓ a tape measure

Body	Diameter (km)	Diameter in model (mm)	Orbit radius (million km)	Orbit radius in model (m)
Sun	1,391,900	2,200		
Mercury	4,866	8	58	
Venus	12,106	19	108	
Earth	12,742	20	150	
Mars	6,760	11	228	
Jupiter	139,516	220	778	
Saturn	116,438	184	1,427	
Uranus	46,940	74		

Follow these steps

1. Students use the data in the following table to position the fruits appropriate distances from the Sun.

So what happened?

Students understand timing, speed, perimeter and area.

They see that a knit stitch is not a square, so their cast on number is not the same as their rows needed.

This introduces the idea of gauging, and can be useful in scaling for garment design.

Creating a chart and reproducing it in their knitting allows students to see input and output, key skills for programming.

What next?

1. Knitted models of body organs, microbes and proteins for Biology
2. Resistors and planets for Physics
3. Periodic table of elements for Chemistry

ICT in Science – Pulse sensor

(Germany)

Background

The application of ICT in science is huge and this project has students use a pulse sensor connected to an Arduino microcontroller to display a person's pulse on a computer monitor.

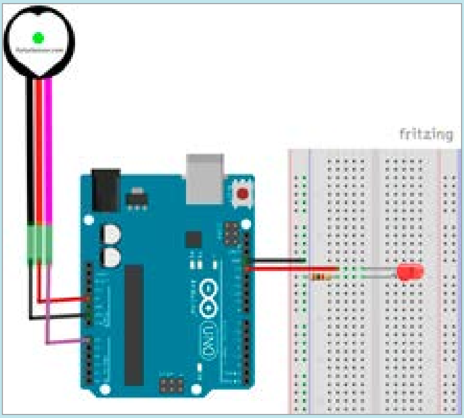
You will need...

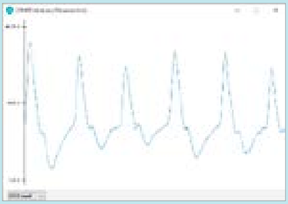
✓ Arduino

✓ pulse sensor

Follow these steps

1. Connect the pulse sensor and Arduino as shown below.
2. Connect the Arduino to the computer with a USB cable.
3. Ensure the Arduino software (IDE - Integrated Development Environment) is on the computer
4. Download the necessary program for the sensor purchased.
5. Upload the software to the Arduino using the IDE.
6. Hold the sensor against the subject's finger and display the trace on the computer using the 'serial plotter' function of the IDE





So what happened?

The trace of the subject's pulse is displayed on the computer monitor, variations in the pulse with exercise etc. can be seen.

What next?

This is only one example of how a microcontroller such as the Arduino can be used to take measurements.

Many other sensors, such as temperature, light, magnetic, motion sensors etc. can be attached and used for an endless range of experiments in the classroom.

The sensors and microcontroller are examples of the appliance of science and understanding how a sensor such as the pulse sensor works is a useful extension of this investigation. The use and understanding of such electronics devices is an essential skill for the scientist of today.

Xico Lopes Eggnaut

A STEM challenge

Background

This can be used as a STEM challenge for students. Students are given a carton of eggs and given a series of egg challenges. Such as can you crack an egg using your thumb and forefinger. Which part of the egg is the strongest? They are then set the challenge of using only paper to create an egg pod and drop the egg from a height. The egg must be visible. This then leads to them designing a water rocket using a bottle (1litre tonic water bottle is the best). They must add an eggpod to it and attach a parachute of their own design. The team that successfully launches their rocket, their pod detaches and their parachute works and safely lands their egg without cracking is the winning team.

You will need...

- ✓ 2 × 1 L soda bottle,
- ✓ rubber bung with hole,
- ✓ bicycle pump,
- ✓ bicycle valve,
- ✓ raw egg,
- ✓ material for wings, parachute and egg pod.
- ✓ (Rokit kit can also be orderd online)

Follow these steps

1. Glue a bicycle valve to a rubber bung.
2. Fill bottle with water about one third of the way.
3. Insert rubber bung and attach to bicycle pump.
4. Place the 'eggnaut' inside the eggpod with parachute attached to the eggpod.
5. Attach egg pod to the top of the bottle (can be made by cutting off the end of another soda bottle).
6. Invert the bottle.
7. Pump air into the bottle and as the pressure builds the rocket will launch.

So what happened?

The rocket launches releasing the eggnaut in the air. Hopefully the parachute opens bringing the eggnaut to a safe landing.

What next?

Build and design launchpads and change angle of launch and measure the maximum range.

Circus Show

(Poland)

Background

Teaching students simple magic tricks and circus acts allows them to physically engage with many aspects of physics. Balance, force, gravity, and motion can all be displayed by the students themselves.

You will need...

- ✓ two skewers
- ✓ elastic band
- ✓ Blu tack
- ✓ scissors
- ✓ sticky tape
- ✓ paper
- ✓ pencil
- ✓ colouring pencils
- ✓ two toothbrushes
- ✓ a piece of plastic gutter pipe (5 cm diameter)
- ✓ heavy bolt

Follow these steps

Balancing act:

1. Connect the two tooth-brushes, bristles facing each other, in a V shape. Secure using the elastic band.
2. Put one skewer down the middle of the bristles, pointed end of the skewer facing down.
3. Design a character that will be your balancing actor, a bear, a ballerina, anything at all. Draw it, colour it, and cut it out.
4. Attach this character to the top of the skewer (the blunt end).
5. Stick a blob of Blu tack to the table and put your oth-er skewer into it, pointed end down. Balance the skewer with the character on top of the skewer in the Blu tack.

Tumbling clown:

1. Design a clown in two pieces. The chest and head piece should be the same width as the pipe (5cm) and 11 cm long, the arms must be outstretched at 10 cm across. The waist and leg section should be the same width, but 30 cm long, 20 cm of waist and 10 cm of leg.
2. Stick the Blu tack to the inside of the tube, and attach the bolt to the Blu tack.
3. Attach the top of the leg section to the outside of the tube, directly above the Blu tack and bolt.
4. Wind the waist section around the tube until you get to the legs (10 cm long).
5. The legs are at the top of the tube.

Circus Show (continued)

6. Attach the chest of the clown to bottom of the tube so that the top and bottom line up.
7. Create an incline and roll your clown down it.

So what happened?

The character position has to be adjusted on the skewer so that equilibrium is achieved and the top skewer balances on the second skewer freely.

The clown propels itself down the incline.

What next?

1. Balance lab equipment
2. Use a mable and two bottle tops instead of the pipe, Blu tack and bolt. Compare the two items as they tumble down the incline.

Ready, Steady, Launch

Fun with Fizzy Rockets

Background

Students explore the concepts of rates of chemical reactions, pressure and forces.

You will need...

- ✓ 3 × Alka Seltzer© tablets of the same mass
- ✓ 1 × wash bottle containing water (equal volume added to each canister)
- ✓ 3 × identical plastic 'film' canisters with lids
- ✓ 3 × glasses

Follow these steps

1. Give each student safety glasses, a film canister, lid and a glass.
2. Start filling each of the film canisters with water from the wash bottle.
3. Next, take one of the alka seltzer tablets and give it to the first student.
4. For the second student, take the tablet and break it in half.
5. For the third, crush the tablet into small pieces.
6. This step happens quickly so explain the instructions to the students in advance so that they all begin at the exact same time. It helps to quickly demonstrate a 'mock' trial procedure for them. Each pupil should add the tablet to the water in the film canister, quickly place the lid on until it 'clicks', then turn it upside down in the glass and then finally stand back quickly! The audience will help to count down from 5,4,3,2,1 before lift off!

So what happened?

The Alka Seltzer tablets release carbon dioxide gas when added to water. Because the gas is enclosed within the plastic film canister, pressure builds up inside. Once it becomes too high, the lid is blown off the canister and it is launched into the air.

What next?

Ask the students to observe the sequence in which the rockets lifted. The student who had the powdered tablet will launch first. This is because it reacts the fastest as it has the smallest particle size and thus the greatest surface area. The next to launch is the tablet that was broken in half. Finally, the 'whole' tablet reacts the slowest and launches last as it has the smallest surface area and largest particle size.

See: https://www.youtube.com/watch?v=C2HPqZFg-M4A

Sweet Diffusion

Background

Students use coloured sweets to demonstrate diffusion.

You will need...

- ✓ 1 × Petri dish
- ✓ 1 × 250 ml beaker of water
- ✓ 2 × plastic spatulas
- ✓ 1 × sheet of white paper
- ✓ 1 × packet of small coloured sweets, e.g. Skittles©

So what happened?

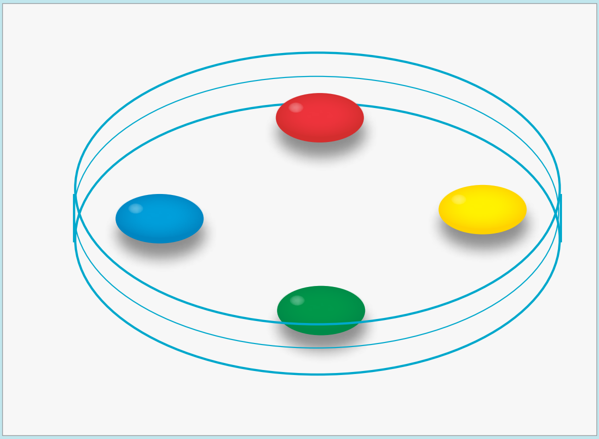
The coloured dye from each of the sweets begins to dissolve in the water and diffuse through it. The colours meet at boundaries, forming an 'X' shape across the dish.

What next?

Experiment with sweets and different solvents and at different temperatures.

Follow these steps

1. Pour some water into a Petri dish until it is almost full.
2. Arrange four different coloured sweets in the 12, 3, 6 and 9 o'clock positions.
3. Observe what happens.



Rainbow Bridge

Background

Students will set up a series of coloured solutions and link them together to demonstrate diffusion.

You will need...

- ✓ 7 × 250 ml beakers of water
- ✓ 7 × coloured dyes (red, orange, yellow, green, blue, indigo, violet)
- ✓ 1 × roll of white paper absorbent tissue paper.

Follow these steps

1. Pour 250 ml of water into each of the beakers and add a coloured dye to each one.
2. Roll up some kitchen paper into a tight roll. Make five of these rolls.
3. Immerse each end of each kitchen paper so that they link up all of the beakers.
4. Wait 15minutes and observe what happens.

So what happened?

The coloured dye from each of the solutions is absorbed up each sheet of paper. A colourful display of linked bridges is formed between each beaker. The colours start to move past each other and into the other beakers after some time, making new coloured solutions.

What next?

Experiment with more dyes and different solvents and at different temperatures.

http://www.incrediblescience.com/

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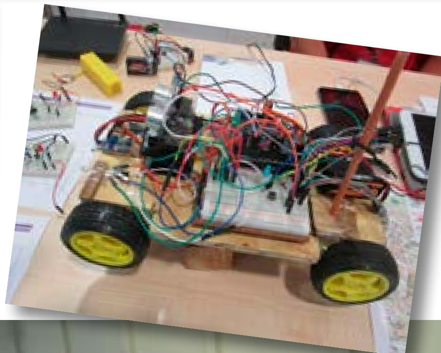
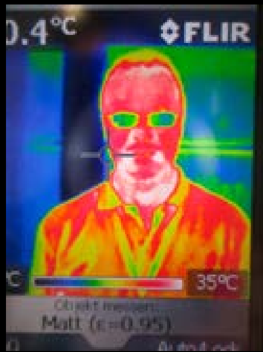
INDEX (continued)


INVENTING THE FUTURE
OF SCIENCE EDUCATION





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