



SSERC Bulletin

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Ideas and Inspiration supporting Science & Technology for all Local Authorities

*Magnetohydrodynamic
Motor*

*Small Scale Demo
of Laboratory
Biodiesel Production*

*Problems Running
Pro/DESKTOP with
Windows Vista*

*Pimp My Trolley
Goes National*

Dry Ice Maker

*Dye-sensitised
solar cell kit*

Darwin 200

*Pimp
our
Trolley*



Following on from the homopolar motor described earlier [1], and inspired by an article by Abdul-Razzaq *et al* in Physics Education magazine [2], we describe an electric motor where the moving conductor is a liquid. The study of the movement of electrically conducting fluids is known as magnetohydrodynamics. Techno-thriller fans may have come across fictional examples of marine propulsion systems using this technology in the novels of Tom Clancy [3] and Clive Cussler [4].

The main parts of the motor are shown in Figure 1. Three Magnadur pole-faced magnets were placed on a piece of board. As the magnets have to be placed side by side with like poles facing upwards, tape had to be used to secure them as the middle magnet would otherwise have flipped over. The inner wall of a polystyrene dish was then lined with foil.

The dish was then placed on top of the magnets. A screw made from a ferromagnetic material was then placed vertically in the centre of the dish, held in place by the magnets below. A saturated or near-saturated salt solution was added to the dish. Connections were then made from two 1.5 V cells in series to the foil and the central screw, as shown in Figure 2.

The solution began to rotate in the dish. Some pepper was sprinkled on the surface to make this easier to see. Reversing the current reversed the flow direction. Bubbles in the solution pointed towards electrolysis taking place. Small amounts of chlorine and hydrogen gas will be produced. Asthmatics will be particularly sensitive to the former.

In the Soup

When this experiment was set up, it prompted us to speculate whether we could stir soup using magnetohydrodynamics. A tin of French Onion soup was duly purchased and its contents emptied into the dish. Sadly, visions of swirling onions were not realised. Only with highly dilute, over-salted soup was any rotary movement seen. Ah well, back to the lang spoon that, apparently, one needs when supping with a Fifer (you'll have had your tea? Ed).



Figure 1 – Parts of a magnetohydrodynamic motor (batteries and leads not shown)

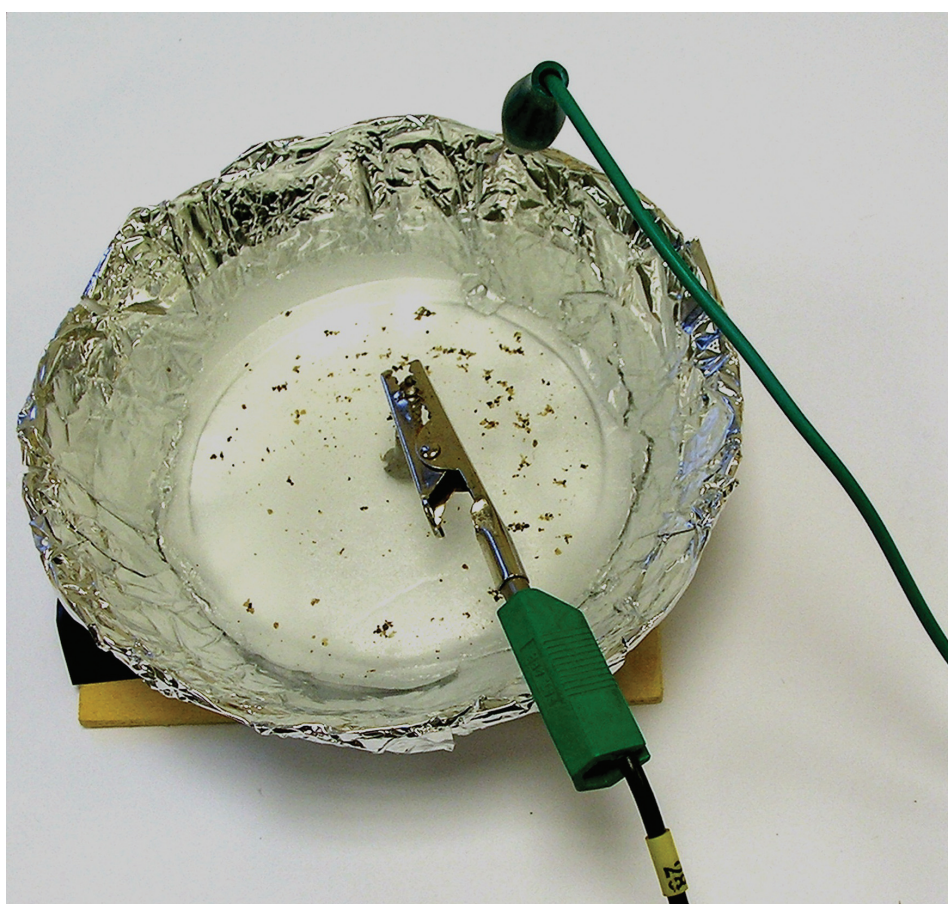


Figure 2– Assembled magnetohydrodynamic motor

References

- [1] Homopolar Motor, SSERC Bulletin 226, http://www.sserc.org.uk/members/SafetyNet/bulls/226/Homopolar_motor.htm
- [2] Physics Education, Creating a d.c. motor using the Lorenz force, Vol. 43, No. 2, p206
- [3] The Hunt for Red October, Tom Clancy (written before he completely lost the right-wing plot)
- [4] Valhalla Rising, Clive Cussler (havers, but enjoyable havers.)

Problems Running Pro/DESKTOP with WINDOWS VISTA

The CAD/CAM in Schools programme, launched in June 1999, was implemented to ensure that all secondary schools in the UK have access to CAD/CAM. As a result of this initiative, Pro/DESKTOP a feature-based solid modeller software for Windows is now used in over 75% of UK secondary school Technology Departments.

The current version is Pro/DESKTOP 8 which was designed to work on the following Windows platforms, 98, Me, NT 4.6 (Service Pack 6 or higher), 2000 (Service Pack 1 or higher) and Windows XP.

When using the *extrude* icon (Figure 1), if an error message is displayed, try the following:

- Close Pro/DESKTOP
- Right click the 'PTC Pro/DESKTOP 8.0' icon on the desktop (Figure 2)
- Select 'Properties'
- Select 'Compatibility' (Figure 3)
- Click check on 'Run this program in compatibility mode for:' and select 'Windows 2000'
- Select 'OK'
- Again, right click the desktop 'PTC Pro/DESKTOP 8.0' icon.
- Select 'Run as administrator'
- Within the 'User Account Control' dialogue, select 'Allow: I trust this program, I know where it's from or I've used it before'
- Now run ProDESKTOP as normal.

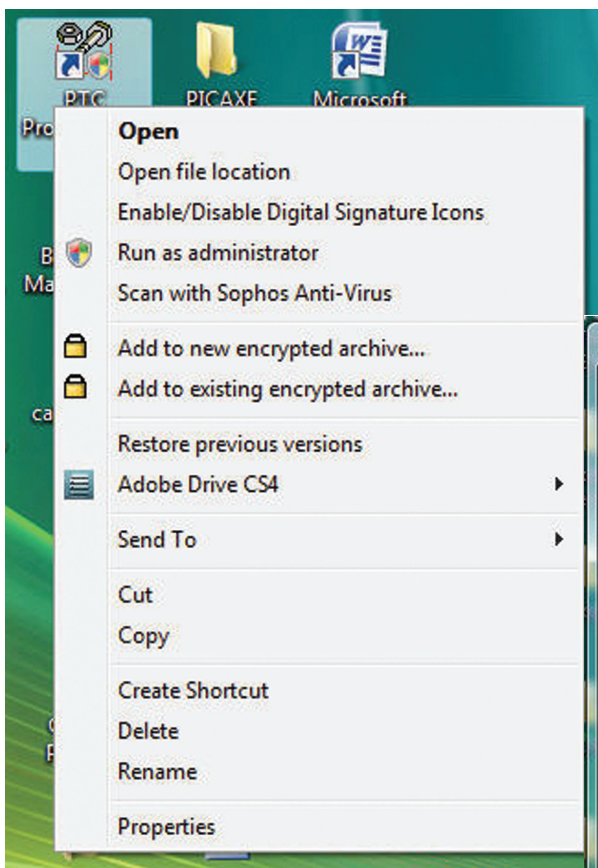


Figure 2 – Right-click on PTC ProDESKTOP 8.0 icon

While Pro/DESKTOP was not designed for use with Windows Vista, it is possible to enable successful running under Vista. One of the most noticeable problems with Pro/DESKTOP and Vista is an immediate error message when trying to create an extrusion.

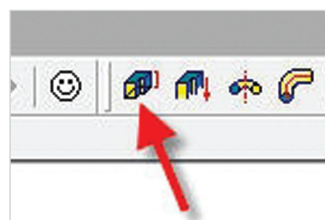


Figure 1 – Extrude icon

It may be possible that there is a display problem when dimensions are imported from the design mode into the engineering drawing mode. The display problem seems to be associated with particular graphics cards. However, printing from either designs or engineering drawings appear to work.

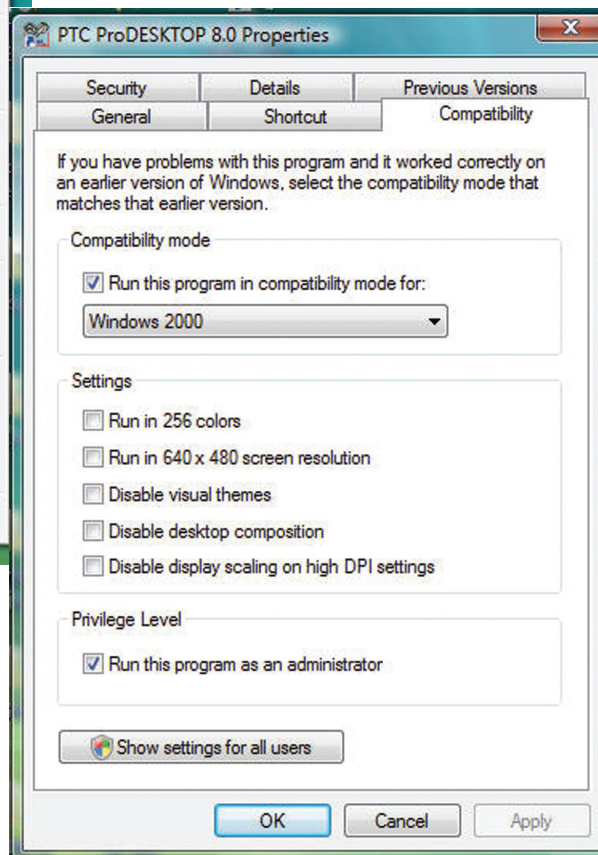


Figure 3 – Compatibility settings



Figure 1 – Biodiesel fuel pump

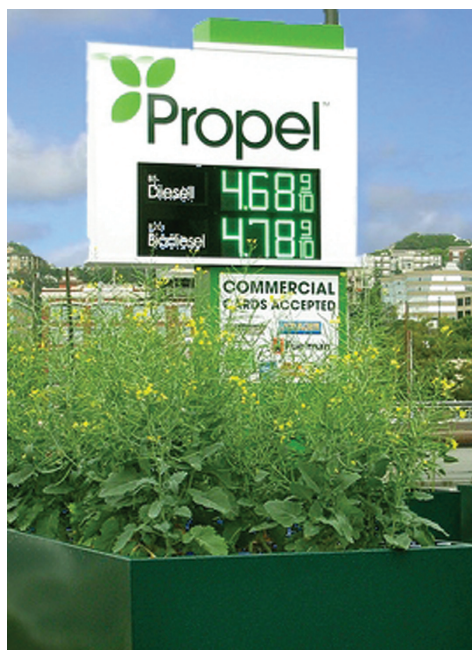


Figure 2 – Biodiesel can be made from oilseed rape

Biodiesel is often in the news, sometimes as a cheap green fuel and saviour of the environment, sometimes as the cause of rising world hunger and a reason for the loss of biodiversity. It is also worth mentioning that every so often someone blows themselves up trying to make it at home in a shed or the garage [1].

With Green Chemistry becoming a set of important principles for industry, making biodiesel allows students to engage with the draft learning outcomes in a Curriculum for Excellence.

We have developed a method which allows students to make biodiesel for themselves quickly and simply. By keeping the scale small and doing the reaction quickly, the exposure to risk is much reduced. The biodiesel can be collected by either leaving the mixture to settle overnight, or by separating them using a centrifuge. The overnight method produces a purer product, but the use of a centrifuge means the entire process can be carried out in about half an hour.

There is plenty of scope to scale the process up and there are many areas in the senior school to look further at the reaction. These include enthalpy of combustion, kinetics, thermo-dynamics, titrations and percentage yield.

Chemicals

- vegetable oil - rapeseed is good as it is high in antioxidant vitamin E.
- potassium methoxide - made from potassium hydroxide and methanol.
- sodium chloride solution, 5%

Equipment

Overnight method:

- eye protection (goggles)
- gloves
- test tubes, 4 per group
- test tube rack, 1 per group
- bungs for test tubes, 2 per group
- beakers, 100 cm³, 3 per group
- syringe, 10 cm³, 1 per group
- Pasteur pipettes - disposable, 3 cm³, 4 per group
- timer/stopclock, 1 per group

Centrifuge method:

- centrifuge
- Equipment as above but replace the 4 test tubes per group with: test tube, polypropylene (or polycarbonate) 13 cm³, 1 per group of a size to fit the centrifuge
- test tubes, 3 per group

The Chemistry

Oils are examples of triglycerides which are esters of three fatty acids (long chain alkyl acids) (which may be the same or different) and glycerol which has three hydroxyl (-OH) groups.

Oils are converted into biodiesel by reacting each triglyceride molecule with three smaller alcohol molecules, usually methanol. Glycerol is also produced. This reaction (called a transesterification reaction) is reversible and can be catalysed by acid or more commonly alkali. An excess of the alcohol is used to drive the equilibrium reaction to the right (the excess can be recovered along with the potassium hydroxide catalyst in the glycerol layer). The overall reaction scheme is shown in Figure 3 below.

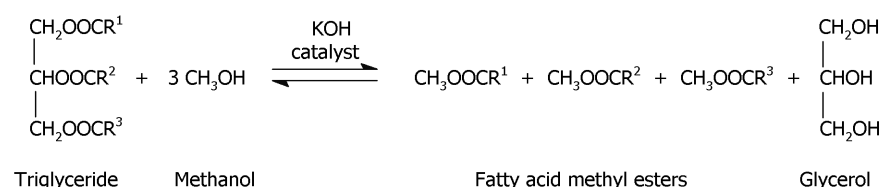


Figure 3 – The transesterification reaction

Experimental method



Figure 4 – Potassium methoxide is added to the vegetable oil using a pipette.

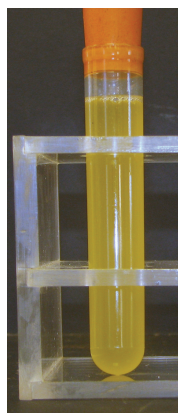


Figure 5 – Vegetable oil and potassium methoxide after having been shaken vigorously and reacted together.

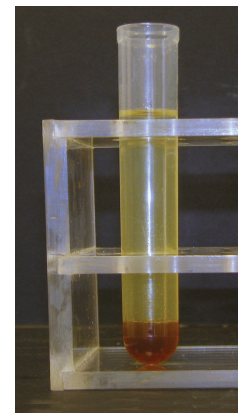


Figure 6 – Products after separating in the test tube either overnight or by using a centrifuge. The brown layer at the bottom of the test tube is the glycerol layer.

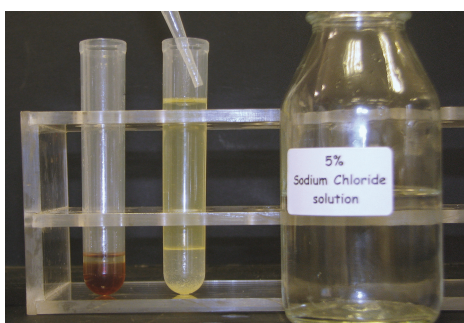


Figure 7 – The biodiesel layer is separated off and washed to remove impurities.

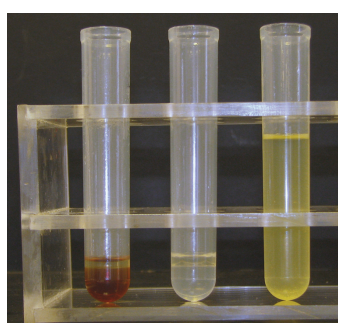


Figure 8 – Finally the top layer of biodiesel is separated off.

The products of this reaction are called fatty acid methyl esters (FAMES). The biodiesel layer is usually washed to remove soaps which can be formed from free fatty acids (FFAs). This is most common for heavily used oils which may already have broken down considerably.

References

[1] http://www.theregister.co.uk/2008/07/28/takeaway_biodiesel_fireball_horror/

Photos credit: amended from <http://www.flickr.com/photos/robseattle/>

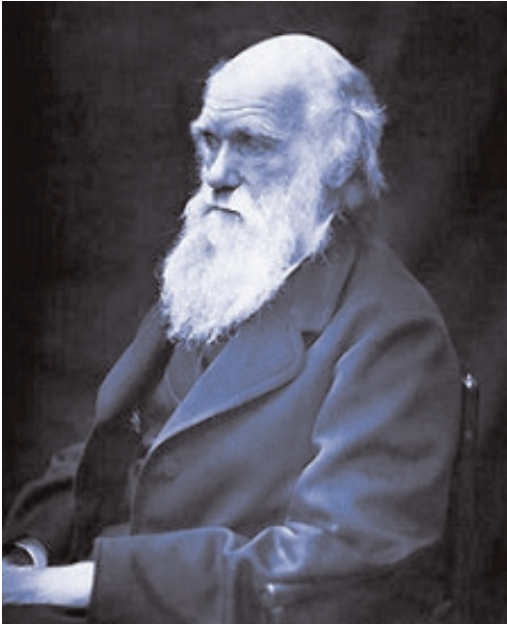
The potassium hydroxide acts as a catalyst in the reaction between the triglyceride and the methanol. In our method, we first produce an intermediate, potassium methoxide, which students then further react with the oil to form the products. The potassium methoxide should be prepared in advance.

A package of teaching and learning materials is now available as a SSERC workshop and will also feature in the 'Bridging the Gap' CPD programme for chemistry teachers. For workshop booking details contact sts@sserc.org.uk

For CPD 2009-10 session check the SSERC website as the courses quickly become oversubscribed.

Chemical	Main Hazard	Control Measures
methanol	Toxic by ingestion, inhalation and skin absorption. Experimental teratogen. Human mutagen. Highly flammable	Use in very well-ventilated area normally but in fume cupboard for large quantities or prolonged working with the compound. Use rubber or plastic gloves and eye protection. Beware repeated exposure. Keep away from flames and all sources of ignition
potassium hydroxide	Strongly corrosive solid	Wear rubber gloves and eye protection. Use goggles to BS EN 166 1 3. (formerly BS 2092C)
potassium methoxide	Toxic and Corrosive	Wear rubber or plastic gloves and eye protection, Use goggles to BS EN 166 1 3. (formerly BS 2092C)
biodiesel	Possible eye Irritant	Use goggles to BS EN 166 1 3. (formerly BS 2092C)

Table 1 – Hazards and Control Measures



Charles Darwin – Picture from Wikipedia

On 12th February 2009 it marks 200 years since the birth of one of Britain's most influential scientists, Charles Darwin. His book *On the Origin of Species by Means of Natural Selection* [1] caused huge controversy on its publication, but went on to form the basis of our understanding of the process of evolution.

Throughout Darwin 200 year there are lots of exhibitions, events and resources. The celebrations began on 1 July 2008, 150 years since Darwin and Wallace announced the theory that rocked science and society, and will continue until 24 November 2009, the 150th anniversary of the publication of *On the Origin of Species*. See the special website at the Natural History Museum (NHM) for details [2].

If **your** school or authority is holding an event for Darwin 200 we would love to know [3], and can help publicise it via our website. Once your event has been held, please send us a report and photos. We will feature a selection in the SSERC Bulletin.

Free resources

The Wellcome Trust is funding a range of national projects throughout the year to engage people of all ages with the legacy of Darwin's scientific ideas. As part of the celebrations they are providing free experiment kits to all state secondary schools across the UK.



Survival Rivals is a series of Darwin-inspired experiments. There are three kits available in the series:

- *I'm a Worm Get Me Out of Here* for 11-14 year olds looks at naturalselection.
- *Brine Date* for 14-16 year olds looks at sexualselection.
- *The X-Bacteria* for post-16 students looks at antibiotic resistance in bacteria.

Each experiment will help young people to see the link between Darwin's ideas and modern evolutionary principles. They are also linked to relevant parts of the Scottish curricula. The kits include experimental materials as well as teacher, technician and student notes and online videos to support their delivery.

Survival Rivals kits are available to pre-order now and will be sent out to schools from Spring 2009. For more information see www.survivalrivals.org.

The kits will also be available for independent schools to purchase. See the Survivalrivals website for details [4].

References

- [1] <http://www.zoo.uib.no/classics/origin.html>
 [2] <http://www.darwin200.org/index.html>
 [3] e-mail - fiona.stewart@sserc.org.uk
 [4] <http://www.survivalrivals.org/>



DARWIN200



SSERC's physics activity on crash testing and crumple zones has attracted attention from the Times Educational Supplement [1], the Institute of Physics (IoP) and Road Safety Scotland. Now schools throughout the country can try trolley pimping for themselves. Brian Redman [2], IoP Teacher Network Coordinator for the South of Scotland has bought a kit to lend to schools in the Borders and Dumfries and Galloway. Kate Wheaton [3] of Road Safety Scotland has worked with SSERC to showcase Pimp My trolley to Road Safety Officers.

The Road Safety Officers felt that the experiments were a good way of engaging pupils in investigating and talking about safety on the roads. As a result, their organisation has bought a further two sets of apparatus to lend to Scottish Schools. The kits consist of a wireless accelerometer, Bluetooth dongle, adapter plate for mounting the accelerometer on a trolley, laptop running all necessary software and all work cards and teachers' guides. The work cards and teachers' guides are based on the CPD material devised by SSERC and are available at www.science3-18.org [4].

Though designed for a proposed CfE outcome, Pimp My Trolley is also relevant to the Standard Grade Physics Transport section and Intermediate 2 and Higher dynamics. Teachers who would like to borrow the equipment should contact Brian or Kate at the addresses below, or email Gregor Steele at SSERC [5] for more information.

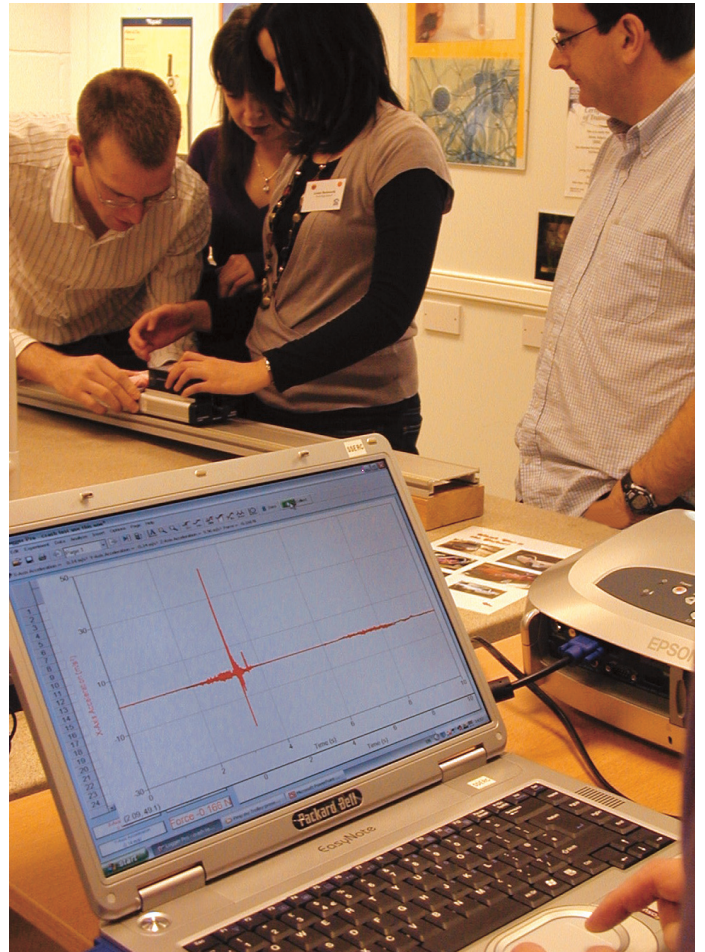


Figure 1 – Crash testing at a recent SSERC course

References

- [1] <http://www.tes.co.uk/article.aspx?storycode=6001956>
- [2] Email: bjred10@aol.com
- [3] Email: Kate.Wheaton@scotland.gsi.gov.uk, Telephone: 0131 472 9204
- [4] http://www.science3-18.org/index.php?option=com_content&view=article&id=765:pimp-my-trolley&catid=325:physics&Itemid=554
- [5] Email: gregor@sserc.org.uk, Telephone 01383 626070

Pimp your Trolley

Figure 2 – A regional slant on trolley pimping



Dye sensitised solar cells (DSSCs) or Grätzel cells were invented in 1991 by Michael Grätzel and his research group at the Swiss Federal Institute of Technology. These cells use a dye which directly converts the energy of sunlight into electrical energy using a process which is similar, in some aspects, to photosynthesis. Various dyes can be used in DSSCs which will have different photon trapping efficiencies, and this could form the basis of interesting student investigations linking biology, chemistry and physics to the aspirations of Curriculum for Excellence at Level 4. It also lends itself to AH Chemistry projects.

Conventional solar cells are rather expensive owing to the cost of producing high-grade silicon. In contrast, DSSCs use a nanocrystalline layer of titanium dioxide. This makes them much cheaper to construct because TiO_2 is a cheap and widely available material which is already used widely in paints, inks and paper, and plastic products.

Dye-sensitised solar cells contain two transparent electrode plates, which are internally connected by an iodine/tri-iodide electrolyte.

The photo-electrode consists of a glass or plastic base which has been made conductive by adding a thin coating of tin oxide doped with fluorine. This is coated by a nanocrystalline layer of titanium dioxide which acts both as a matrix for the dye and as a wide gap semiconductor. It is essential for the photo-electrode to hold more than single layer of dye molecules and that the 'thick' layer of porous titanium dioxide has a high volume-to-surface area ratio, allowing it to hold a large concentration of dye molecules.

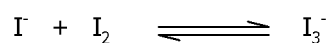
When the dye molecules are exposed to sunlight (photons of light) some of their electrons are lost by photo-excitation and the dye goes into its reduced state. As the titanium dioxide layer has been sintered to make the particles pack more tightly, it acts as a semiconductor. This allows any electrons which have sufficient energy, to move from the low-energy valance band to the high-energy conductance band. The result is a current in the external circuit.

Titanium dioxide has a slightly wider band gap than a conventional silicon photocell, so that although dye-

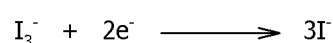
sensitised cells produce photo-excited electrons more effectively, fewer of these electrons have sufficient energy to jump the band gap. Consequently the output current from a typical commercial DSSC is only 20 mA cm^{-2} , compared to the 35 mA cm^{-2} generated by a silicon photocell. However DSSCs are cheaper and will operate at much lower light intensities than silicon photocells. Indeed it has been suggested that some devices could be powered indoors by DSSCs just using normal household lighting.

After flowing through the external circuit, the electrons move through the positive counter electrode, which is coated in graphite, to interact with the electrolyte.

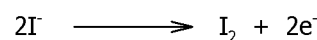
The electrolyte contains an iodine/tri-iodide redox couple which results from the equilibrium set up when iodine is dissolved in a solution of potassium iodide:



At the graphite-covered counter electrode the tri-iodide ion (I_3^-) is reduced by gaining electrons:



The iodide ions, which are formed, move through the electrolyte and two iodide ions regenerate the reduced dye molecule on the photo-electrode by donating electrons to it:



The remaining iodide ion shifts the iodine/tri-iodide equilibrium towards the formation of more tri-iodide ions:

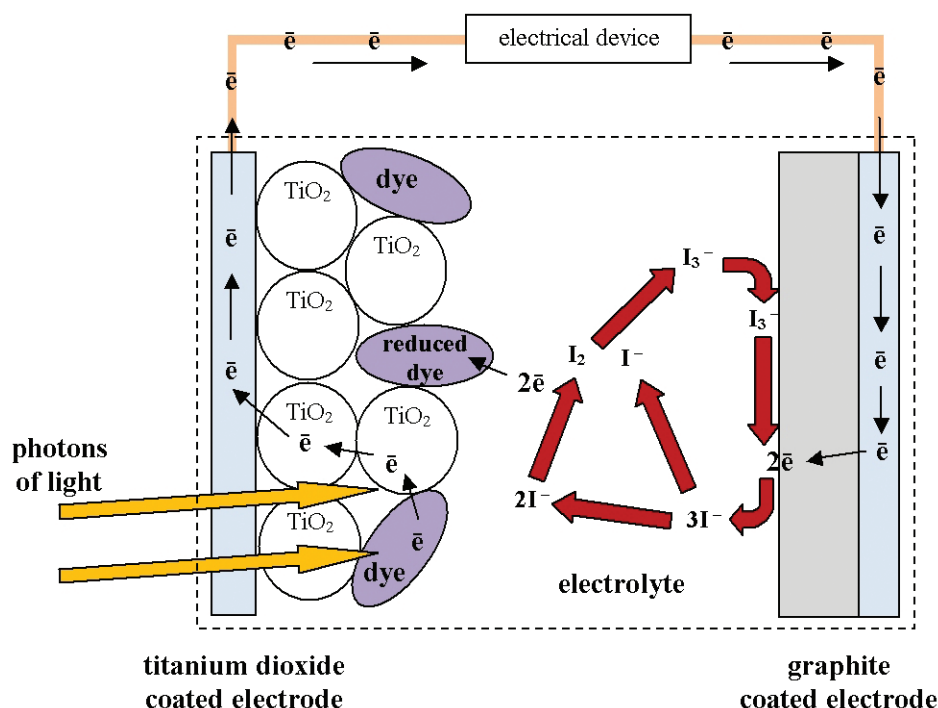
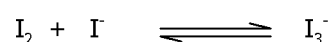


Figure 1 – Dye-sensitised solar cell

Three kits are available from the Dutch company, 'Man Solar' [1] which provide all the basic materials required for students to construct, with ease, a working dye-sensitised solar cell.

The Man Solar 2000 kit contains:

- 6 x titanium dioxide coated conductive glass electrodes
- 6 x uncoated conductive glass electrodes
- 1 x packet of dried hibiscus flowers
- 1 x dropper bottle of electrolyte
- 1 x multimeter with measurement probes
- 1 x pencil
- 10 x crocodile clip cables
- 1 x box of paperclips
- 1 x petri dish
- 1 x set of screwdrivers
- 1 x melody module
- 1 x pocket calculator
- 1 x safety glasses
- 1 x manual

This kit probably does not provide sufficient glass electrodes for a whole class activity. However additional glass electrodes, both coated and uncoated, can be purchased separately from the supplier although a minimum spend is required. It may be worthwhile considering buying only these electrodes and following the instructions given in the rest of the article in order to construct a cell.

Man Solar sell two other solar cell kits: The cheaper Man Solar 1000 kit is similar to the above description except that a titanium dioxide suspension is provided rather than the pre-coated glass electrodes.

Details of how to sinter the electrodes with a furnace or spirit burner are included in the manual. The multimeter and melody module are not included in this kit, but these should not be difficult to obtain locally.

The more expensive Man Solar 3000 kit contains all of the materials provided in the 2000 kit, and in addition contains a fuel stove to sinter the titanium dioxide suspension onto the conductive glass electrodes.



Figure 2– Man Solar Kit

Using the Man Solar DSSC kit:

a) Identifying the conducting side of the glass electrode

As both sides of the uncoated conductive glass electrodes appear to be the same, it is necessary to determine which side of the glass has the conductive coating. This can be done by touching the two ends of the glass electrode plate with the measurement probes of a multimeter, which has its function switch turned to the 200 Ω resistance position.



Figure 3 – The multimeter indicates that this is the non-conducting side of the clear glass electrode.

If the display shows a reading of 1, then this is the non-conducting side (Figure 3). Any other reading means you have the conducting side of the glass electrode (Figure 4).

b) Applying the graphite layer

When applying the graphite layer to the conducting side of the glass electrode it is best to hold the glass by the sides, keeping the surface free of fingerprints, while gently rubbing the side of the pencil lead evenly across the surface. The tip of the pencil should not be used as this can damage the conducting surface. Going over the surface a second time, rubbing the pencil in a different direction, will produce an even layer of graphite (Figure 5).



Figure 4 – The low resistance reading on the multimeter shows that this is the conducting side of the clear glass electrode. ▶

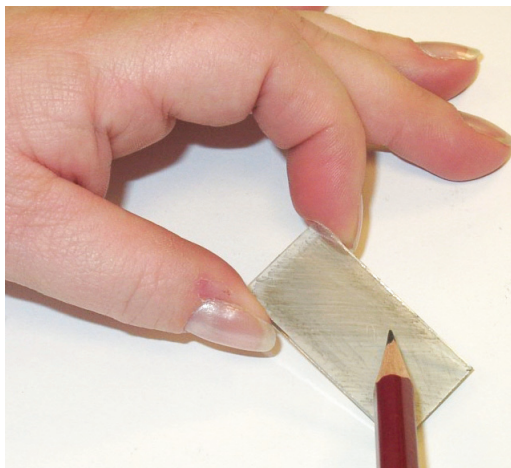


Figure 5 – Using the pencil to apply a graphite layer to the conductive side of the glass electrode.



Figure 6 – Dried Hibiscus 'flowers'.

c) Preparing the dye

The dried Hibiscus 'flowers', which are supplied in the kit (Figure 6), produce a deep red dye when 2 g is added to 50 cm³ of boiling water in a small beaker. These flowers are actually the dried calyces (sepal bits) of the Roselle plant (*Hibiscus sabdariffa*), which is sold as Hibiscus tea or Flor de Jamaica in many health food stores. [2]

The characteristic deep red colour comes from the flavonoid glycosides, such as cyanidin and delphinidin.

d) Dyeing the titanium dioxide coated electrode

The titanium dioxide coated electrode is dyed by placing it face up in a Petri dish, and immersing it in the solution from the cooled dye-bath. The dyeing process only takes about 10 minutes (Figure 7).

After removing the dyed electrode from the dye-bath, being careful not to touch the titanium dioxide surface, it should be gently rinsed by dipping it into distilled water. The dyed electrode can then be dried by either using a hair-drier on the 'cold' setting, or carefully waving it in the air. The surface of the dyed electrode should not be dried by wiping it with paper or a tissue, as this can damage the titanium dioxide layer.

As the electrode dries its titanium dioxide surface changes colour, so that it is easy to know when it is ready for the next stage.

e) Assembling the solar cell

The solar cell is assembled by placing the dye-coated electrode, face up, on a flat surface, adding 2 drops of iodine/ tri-iodide electrolyte (Harmful), and then placing the graphite coated electrode on top, face down. The two electrodes need to be offset by about 5 mm so that crocodile clips can be attached. We suggest that the completed solar cell is held together by 19 mm bulldog clips, which are more reliable than the paperclips supplied in the kit (Figure 8).

f) Measuring the output current

The output current of the solar cell can be measured by attaching a crocodile clip cable to each end of the solar cell, and connecting these to the measurement probes of a multimeter with its function switch turned to the 2 mA position to measure current.

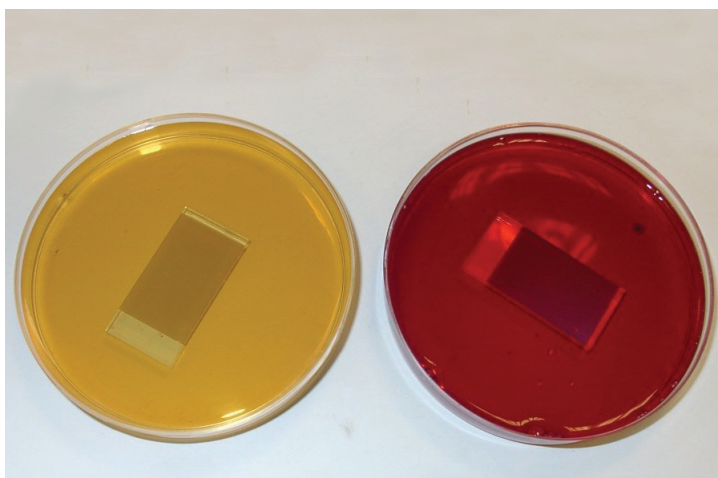


Figure 7 – Dyeing the titanium dioxide coated glass electrodes.

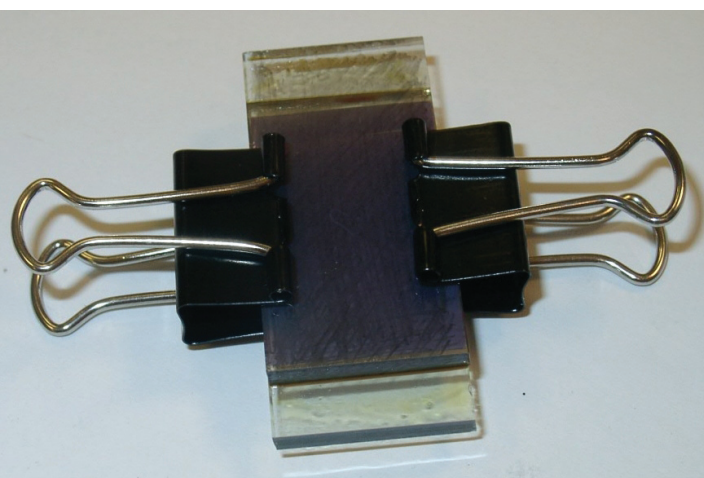


Figure 8 – A completed solar cell, showing the offset electrodes being held together by bulldog clips.

When the solar cell is illuminated by either natural or artificial light, an output current is produced. If a hand is passed over the solar cell, blocking out part of the light, the display reading decreases, proving that the solar cell is transforming light into electrical energy.

Turning the solar cell upside down will result in a different output current. The higher output current is obtained when the titanium dioxide side of the solar cell is illuminated (i.e. the side where the graphite pencil marks are **not** visible).

A constant degree of illumination is required if solar cells containing different dye pigments are to be compared. One way of doing this is by positioning an angle-poise table lamp directly above the solar cell at a distance of approximately 20 cm.

g) Connecting solar cells in series to produce a higher voltage
 Several solar cells can be joined in series (like in a battery) by connecting the positive (graphite coated) electrode of one solar cell to the negative (titanium dioxide coated) electrode of the next solar cell, using a crocodile clip cable. When solar cells are connected in series, their voltages are added together (Table 1).

Arranging the solar cells in series makes it possible to produce a high enough voltage to operate a melody module or a calculator.

The melody module will function when six hibiscus-dyed solar cells are arranged in series, with the terminal graphite electrode connected to the positive (red) wire of the melody module, and the terminal titanium dioxide electrode connected to the negative wire.

By unscrewing the back of a cheap pocket calculator, the wires leading to the battery holder can be detached, and the calculator can be reassemble with the power wires exposed from either side (Figure 11).

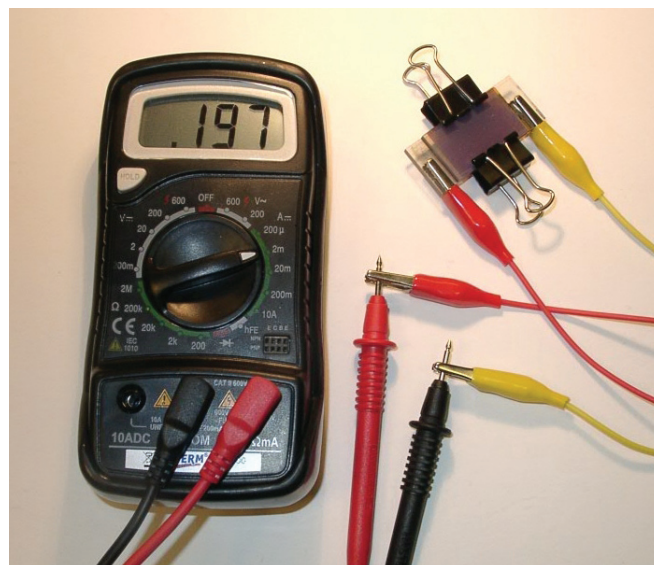


Figure 9 – Measuring the output current from a dye-sensitised solar cell using a multimeter.

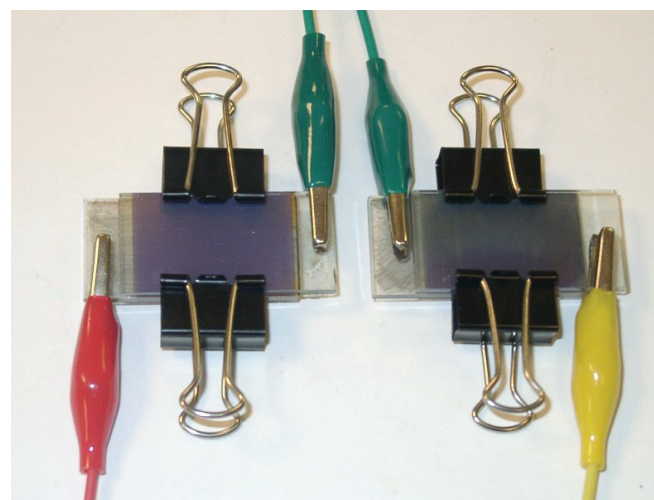


Figure 10 – Solar Cells in series

Number of solar cells in series	Voltage of combined solar cells (V)
1	0.348
2	0.651
3	0.970
4	1.182
5	1.406
6	1.633

Table 1: The effect of increasing the number of solar cells arranged in series.
 (Note: The solar cells are not identical in their photon capturing efficiencies so each will have a unique current and voltage.)

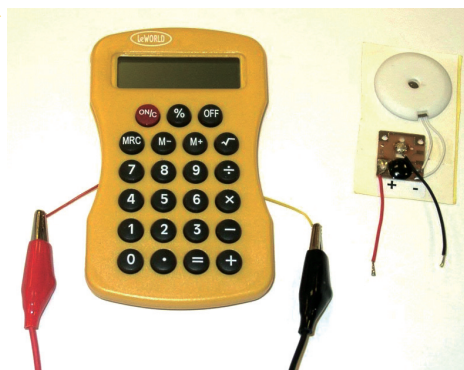


Figure 11 – Both the melody module and the calculator will function using solar cells.

Once again, if the terminal graphite electrode is connected to the positive (red) wire of the calculator, and the terminal titanium dioxide electrode connected to the negative wire, the calculator will function when connected to six hibiscus-dyed solar cells arranged in series and switched on.

A package of teaching and learning materials is now available as a SSERC workshop where delegates extract dyes from plants, test them for their suitability; and then try them in Gratzel cells.

For workshop booking details contact sts@sserc.org.uk

Chemicals & procedures	Main Hazard	Control Measures
Iodine/tri-iodide electrolyte	Harmful indirect vent goggles.	Wear nitrile gloves and
Glass electrodes (assembling solar cell)	May have sharp edges and may break if pressed too hard.	Hold glass electrodes carefully and add bulldog clips gently.
Boiling water for dye-bath	Scalding	Don't touch or move beaker containing the boiling hot dye-bath.

Table 2 – Hazard and Control Measures

Sources of materials:

- [1] MAN SOLAR B.V., Westerduinweg 3, 1755 LE Petten, The Netherlands
E-mail: mansolar@ecm.nl
Internet: <http://www.mansolar.com>
- [2] Hibiscus 'flowers', 'Hibiscus tea' or 'Flor de Jamaica' can be purchased in many health food stores. Alternatively dried Hibiscus flowers can be purchased on the internet for about £2 per 100g (e.g. www.Mexgrocer.co.uk) or MexGrocer.co.uk, 1 Tennyson Rd, Stockport, SK5 6JJ.
Tel : 0800 849 9042 (Information Line Only)



Dry Ice Maker

We have recently had a query about one of these not working. It transpired that the problem could well have been with the type of gas cylinder and not the attachment. Dry ice making attachments will only work with a particular type of CO₂ cylinder. The cylinder must be fitted with a dip tube (this is often referred to as a 'siphon type' cylinder). This allows liquid CO₂ to be siphoned from the bottom of the cylinder.

Therefore, if you are considering purchasing a dry ice maker check if your cylinder is fitted with a siphon tube.[1]

For example, suitable cylinders from B.O.C. are black with two white stripes, diametrically opposite, indicating that it has a siphon tube and is suitable for making dry ice.

Reference

- [1] http://www.practicalphysics.org/go/Guidance_24.html
This site gives further information on types of CO₂ cylinders and links to suppliers of dry ice making attachments, with the catalogue numbers etc.