IOP Institute of Physics
Education *Supporting Teachers*

Classroomphysics

The newsletter for affiliated schools

March 2010 Issue 12

Institute unleashes new resources to empower teachers of physics

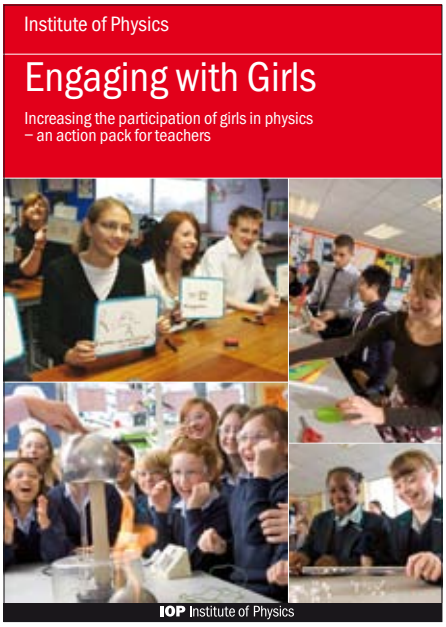
Engaging with Girls – an action pack for teachers
This brand-new resource is now available for anyone interested in encouraging more girls to continue with physics post-16. Whether you are working in a mixed or all-girls setting, you will find this an invaluable pack, both for immediate classroom ideas and for contemplating larger changes in your teaching or department. It is intended to help teachers directly and you should be able to pick it up and get going with some of the ideas very quickly.

In 2006, *Girls in the Physics Classroom – A Review of the Research on the Participation of Girls in Physics* and *A Teachers' Guide for Action* were published. These publications have been widely used by teachers and others to help to inform change in schools and classroom practice and organisation, with benefits for all students in their care. In particular, they were used by teachers in the Girls into Physics Action Research project, run by the National Network of Science Learning Centres, and the Stimulating Physics pilot.

The *Engaging with Girls* action pack contains a suite of resources to complement the previous two publications. The guide to action research is a practical resource for teachers interested in understanding and removing the barriers to girls in physics through a practice-based inquiry process. It is intended for teachers who may be trying out action research for the first time.

The other resources offer more direct suggestions to help teachers to ensure that all students are in tune with the relevance of physics – encouraging use of varied and relevant contexts, using appropriate role models, and making sure all know of the exciting opportunities that a good grounding in physics can lead to.

For more information: to order a pack or to find out more about the Institute's work in this area, visit www.iop.org/education or contact Clare Thomson (e-mail clare.thomson@iop.org).



Left: the action pack focuses on practical, relevant physics teaching. Right: the workshop aims to help teachers to work together to provide timely, accurate and consistent physics-careers information.

Exploring Physics, Uncovering Choice
Do you want to know where to find the most accurate sources of physics-based careers information for your students? Would you like to see more cross-departmental working within your school between science teachers and career co-ordinators? We can help!

Exploring Physics, Uncovering Choice, a brand-new workshop pack of activities and up-to-date information, is written by CRAC, the careers development organisation, and developed by the Institute of Physics. It aims to encourage staff to work together in providing a consistent approach to careers advice and guidance in their school. It will also help teachers to build on their own knowledge of physics-based careers, to help students to make informed choices based on accurate information. We suggest that the workshop should be run by an interested teacher as a way of contributing to the professional development of colleagues, to bring together personal tutors, year heads, subject teachers, career co-ordinators and Connexions personal advisers.

The workshop pack includes: clear instructions on how to lead the workshop along with a CD of presentation slides; a number of activities that enable workshop attendees to explore and share knowledge of physics-based careers (these activities can also be used in the classroom with students); and the tools to start developing an action plan for the whole school. The action plan is to ensure that careers awareness becomes an integral part of a student's education and to decide on each person's role within the school. It is expected that the workshop will take around 90 minutes and it will be most effective with at least five members of staff from at least two departments.

For more information: contact Manchi Chung (e-mail manchi.chung@iop.org). To order the free workshop pack, contact the Institute's education department (e-mail education@iop.org).

Editorial

Welcome to the spring issue of *Classroom Physics*. If you are an affiliated school you should have also received a copy of our education brochure for 2010 – *The Classroom and Beyond* – as well as a copy of our 2009 Schools and Colleges Lecture DVD, *Exploring the Universe*. You will also have a copy of our latest careers resource, a booklet called *Experience*, and some other reminders of online resources that the Institute and others have developed to support your teaching.

Our front page features two new resource packs developed by the Institute, which we hope will become well used. The first is our action pack to help teachers in their efforts to increase the participation of girls in physics. The second pack is a careers workshop that any teacher can use to run a CPD session in their school to help to promote a better understanding of careers both in and from physics. If you would like a copy of either pack, get in touch (e-mail education@iop.org).

Other important Institute initiatives include the extension of membership to the 16–19 age group, which is outlined here on p2, and our new community website *talkphysics.org*. You can find out more details about this significant development on p3. We hope that you will register and find out what the site has to offer, both in terms of help and advice as well as useful resources. There is also news of a recently published report on navigating higher-education requirements in the STEM subjects, with details of how to download the report and the advice to students.

With this edition is a letter about the new Institute Education Forum, put in place since the demise of the Education Group. We hope that this forum will provide a vehicle for those members and affiliated schools who would like to engage with and support the work of the Education department.

Our teaching tips offer advice on the teaching of energy (p7) and modelling feedback with a leaky bottle, from the new SEP resource booklet (p8).

For additional resources, e-mail education@iop.org. Feedback is always appreciated and it could come via the *Classroom Physics* group on *talkphysics*.

Clare Thomson, editor (tel 020 7470 4981, e-mail clare.thomson@iop.org).

‘Experience’ completes the Institute’s new career series

Included with this issue of *Classroom Physics* is the new careers booklet for 16–19-year-olds: *Experience – physics at university*. This new booklet is for students considering physics at degree level, and it includes careers information and advice on choosing a physics course and a university. Along with the *Explore* postcard and the *Expand* leaflet, this completes the new set of career publications for the 11–19 age group.

Additional resources to help integrate the use of this series into lessons are available at www.iop.org/careers.

For more information: To order more copies of the *Experience* booklet or any of the other careers publications, e-mail education@iop.org.

Science Additional Specialism Programme helps to enhance teachers’ physics-specialism skills

The Science Additional Specialism Programme (SASP) will soon be rolling in to its second year. It is designed for teachers without a physics or chemistry degree or a secondary initial teacher training (ITT) specialism in physics or chemistry. It is intended to develop participants’ subject and pedagogical knowledge, and to help them to teach physics or chemistry to learners aged 11–19 with more confidence, expertise and enthusiasm.

On completing and passing the programme teachers will be awarded with a graduate certificate in physics worth 60 H-level credits and they will be eligible for a £5000 bursary.

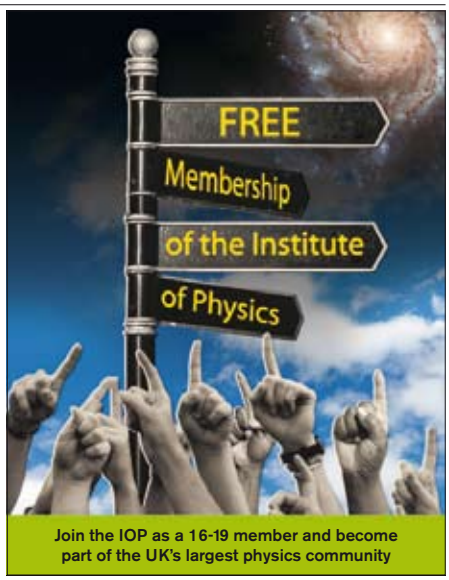
For more information: To find the nearest centre offering this programme, visit the TDA site at www.tda.gov.uk/teachers/continuingprofessionaldevelopment/science_cpd.aspx.

Institute offer targets 16–19s

The Institute is now offering free membership to young people aged between 16 and 19 who are studying physics. As well as the chance to interact with other physics students, 16–19-year-old members will receive the following:

- regular updates on what’s new in physics;
- examination and university guidance;
- information about careers from physics.

For more information: If your students are studying physics at A-level, H-level or the IB, encourage them to sign up for free membership at www.iop.org/16-19.



New community site will get teachers of physics talking

February sees the official launch of *talkphysics.org*, the new community website from the Institute of Physics that brings teachers, resources, ideas, knowledge and mentoring together under one virtual roof.

Designed to enable teachers of physics to communicate and share knowledge and ideas, you can join open discussion groups as a general forum; both for discussions on topics of broad interest and for specific, special interest topics. There are also closed discussion groups for topics that demand less public discussion and for mentoring. *talkphysics.org* has social bookmarking, tagging, blogging, RSS feeds and an events calendar all built in and the site is designed to be quick to engage with and easy to use.

talkphysics.org is the only way to gain access to the Supporting Physics Teaching 11–14 materials – and to participate in and learn from valuable discussions around this set of structured physics resources.

talkphysics.org
Linking teachers of physics

The *talkphysics.org* site is constantly evolving, with more than 1000 registered users already – so why not take a look and join this growing, online physics community? Once you are registered the best place to start is "The Hub", where you can find out about what you can do, where to do it and what the site has to offer.

For more information: To register, visit www.talkphysics.org.

Gatsby offers science teachers and technicians free professional-development support via SEP

The Gatsby Science Enhancement Programme (SEP) now has a team dedicated to offering professional-development support to science teachers and technicians in UK secondary schools and colleges. The SEP Professional Development Leads (PDLs) have already been working with a number of science departments over the past year to support the development of subject knowledge and practical expertise. The topics covered have been wide ranging and the feedback has been extremely encouraging. Examples of sessions include: "Forces with stomp rockets" and "Exploring structure and bonding with smart materials".

The support is bespoke, flexible and free. Each session is tailor-made, designed together with whole science departments to meet the needs and experience of individual teachers and technicians wherever possible. The approach can be completely flexible, arranged to work around busy timetables. Sessions can range from one-day to shorter sessions during the school/college day or they can be twilight sessions. The team often works with science departments on an on-going basis, supporting them over several terms where appropriate.

This support programme is offered free-of-charge, thanks to the generosity of the Gatsby Charitable Foundation.

"This was one of the most enjoyable and interesting CPD sessions that I've ever had. I can't wait to put it in to practice."

"The resources were superb, and they were well explained and delivered."

For more information: visit www.sep.org.uk/cpdsupportfromsep.asp or contact the team directly (e-mail cpd@sep.org.uk).

The competition, run jointly by the Institute of Physics and NESTA, is now being judged nationally rather than regionally.

Degree students are advised to know the SCORE

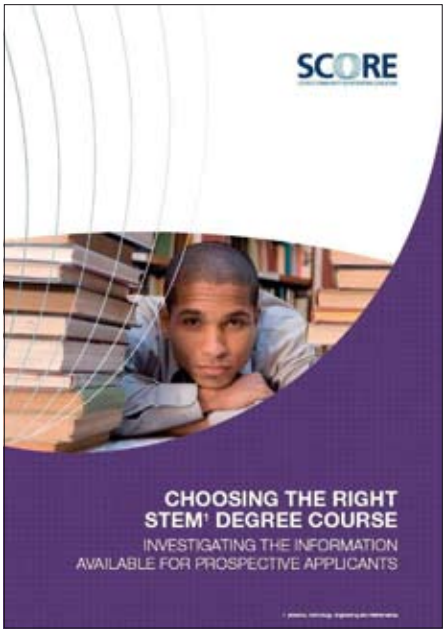
With around 15 000 first-degree courses available in the UK and around 5000 of these requiring STEM qualifications for entry, there is a real need for clear information and advice for young people.

The SCORE partnership, which includes the Institute, has recently published a study looking at the information available to applicants. The report provides evidence for a number of key pieces of advice, including the necessity to check a number of sources of information to gain a full picture of requirements – these sources include the university website, prospectus and contacting the admissions tutor.

SCORE highlights the fact that there can be significant variation in entry requirements between courses within a university and also across universities. The value of mathematics comes through from admission-tutor responses, and students wishing to keep their options open are advised that studying two of biology, chemistry, physics and mathematics will provide the maximum number of STEM degree options.

The study also raises questions about ease of access to entry-requirement information and the transparency of selection criteria. It is recommended that young people and their advisers ask carefully thought-through questions, and the Science Council is producing a guide set of questions to assist those who are in the process of choosing a university course.

For more information: The guide, and advice based on the study, is being made available through the Future Morph STEM careers website at www.futuremorph.org. The SCORE study can be downloaded at www.score-education.org.



The new guide will help STEM degree applicants to navigate higher-education entry requirements.

Researchers in Residence: ready for relaunch

Jad Marrouche, physics researcher at CERN and former RinR.

Researchers in Residence (RinR), is a free, UK-wide scheme, which brings physics researchers into the classroom to support classroom teaching and to inspire students. Funded by Research Councils UK and supported by the Wellcome Trust, the scheme is open to all UK secondary schools. It brings together teachers and leading early-stage university researchers to work together on novel and innovative projects for a period of up to 24 hours' student contact time.

Drawing on their specialist field of knowledge, RinR researchers are able to enrich the curriculum through a range of exciting activities, such as practical classroom demonstrations; after-school clubs; lunchtime talks; careers advice or even by getting involved in PHSE. Using researchers can help to support delivery of some of the more challenging aspects of the curriculum by providing memorable experiences that help to embed knowledge and, over time, encourage deeper learning.

RinR is not just for physics teachers and it can provide schools and teachers with researchers from every subject area. Past placements have seen particle physics likened to a game of chess, history brought to life through archaeological digs, human behaviour examined through dance and crime-scene investigations investigated as an introduction to chemistry.

Commenting on his placement, Jad Marrouche, physics researcher at CERN and former RinR, said: "I got a particularly good response after showing them [the students] some of the images I had brought with me of the giant particle detectors; it really seemed to spark their interest. I think being able to view images related to what I was talking about helped them to better understand the concepts I was trying to get across."

Involvement in RinR requires minimal effort from teaching staff. All researchers are fully vetted, they undergo CRB checks and they are trained in our highly regarded communication training course.

For more information: call 0845 365 7470 or visit www.researchersinresidence.ac.uk. E-mail researchersinresidence@aeat.co.uk.

Earth-physics workshops focus on real-life science

The Earth Science Education Unit (ESEU) launched its three new "Earth physics" workshops at the Association for Science Education Annual Conference in January. The workshops were presented by Chris King, director of ESEU (based at Keele University), supported by OPITO – The Oil and Gas Academy and they were presented in collaboration with the Institute of Physics.

The teacher CPD workshops, aimed at the 14–19 age range, have been designed to show teachers how physics can be presented in Earth-science contexts and to raise confidence and enthusiasm in the active Earth and its application to physics. Each workshop contains a range of practical hands-on activities, real-life applications, career opportunities and career profiles of specialists within the field.

The three workshops are available via the Institute of Physics Network co-ordinators for teachers of science across the UK and they are presented by ESEU's regional facilitators.

- "Tackling climate change through Earth physics": how does climate change work and what can be done about it? Consider the physics behind how climate change could affect the Earth, before investigating different methods of generating power that have low greenhouse-gas emissions. Finally, decide what power source would be most appropriate for your region.
- "The seismology story": how are seismic waves generated and detected and what can this tell us about the Earth? Try a range of activities, including some of those from the Gatsby's Science Enhancement Programme's *Seismology* publication, to investigate how Earth physics can reveal crucial information about Earth processes and structure.
- "The geophys story": try using the "geophys" of *Time Team* to detect things beneath the ground, in the same way as geophysical techniques find archaeological remains, buried infrastructure and natural resources. These activities show how school physics is used in real-world situations.

ESEU

"The geophys story" Earth-physics workshop: investigating soil resistance in the classroom.

For more information: contact your local Institute of Physics Network co-ordinator via www.iop.org/education or contact ESEU direct (e-mail eseu@keele.ac.uk).

CPD trainers aim to encourage practical physics

"This should be a fantastic training opportunity for all [teachers] to take part in – very useful – it will make people think."

"This is a fantastic initiative. It will be very useful to promote a shift in mindset for teachers re effective planning for learning from practical activities."

Comments such as these have come from teachers who are finding the training beneficial in improving the effectiveness of their teaching of practical science.

Getting Practical trainers are based all over England and they are running courses in their local areas. Dates for these CPD sessions are available on the *Getting Practical* website at www.gettingpractical.org.uk and there are still opportunities for teachers to get involved in the programme. The course sessions are free of charge but you must register to attend. The CPD is being offered in a variety of formats, including a full day of training in some areas or two or three twilight sessions in others. Check the listings on the website to see the courses that are available near you.

The *Getting Practical* website is also becoming an excellent place to find practical science resources. You can find out more about two new publications promoting best practice in practical work titled *Analysing Practical Science Activities* and *The Language of Measurement* in the "New Publications" section.

For more information: To register your interest in attending a Getting Practical course, contact Kirstie Hampson (e-mail kirstiehampson@ase.org.uk, tel 01707 283 000).

Summer subject-knowledge booster course gives teachers of physics the chance to shine

This highly successful one-week residential course (now in its fifth year) is scheduled to run twice this year on 12–16 and 19–23 July at Charterhouse in Surrey.

The course is offered free of charge (except for travel costs and insurance cover) to state-school NQTs and it aims to boost subject knowledge and confidence in their teaching of KS3 and KS4 physics. Prospective teacher-training students from five universities in the south are also invited to attend. A chemistry course will run in parallel, and in total, 70 delegates are expected to be resident each week.

Hands-on practical lab work, lectures and group discussions will be used to develop confidence and understanding of physics. Each day will focus on a major part of the physics curriculum and the week will culminate in a practical investigation carried out by delegates in small groups. Each group then reports its findings, giving physics explanations to illuminate results.

The course makes use of the well equipped laboratories at Charterhouse and it is generously staffed with state- and independent-school teachers. The week is highly rated by all who attend. The beautiful surroundings of the school enhance this highly effective educational experience and indoor sports facilities will be available during the week at a small cost.

There are of course limited places, which are awarded on a needs basis.

Steve Hearn demonstrates some hands-on physics to delegates at last year's residential course.

For more information: contact Steve Hearn, e-mail steve.hearm@iop.org.

Weather and climate resource will cause a storm

The Royal Meteorological Society (RMetS) is the learned and professional society for anyone whose profession or interests are connected with weather. *MetLink* (www.metlink.org) is the flagship, dedicated educational website of the society to be launched in early March, with weather and climate resources aimed at primary- and secondary-school teachers, students, teenagers, children and the general public.

On the site you will find a whole range of materials, including informative PowerPoint presentations looking at cloud types; weather hazards and phobias; lesson plans and an indicative guide of where meteorology can link with the curriculum for all key stages; how to book a meteorology ambassador to come to your school; information regarding meteorology careers, courses, qualifications and employers; colouring sheets; puzzles; topical weather articles and more. A whole host of more than 150 meteorology education- and careers-related links can also be found on the *MetLink* site.

Material will be continually uploaded throughout 2010 and beyond. Plans for the future include increasing the number of lesson plans and teaching aids, and producing after-school club material. Any questions, comments on the website or suggestions for materials to be produced would be welcomed and should be directed to the contact listed opposite.

A screenshot of the new MetLink *website.*

For more information: contact education@rmets.org.

Tomorrow's Engineers scheme reaches out

On 7 January, EngineeringUK, the Royal Academy of Engineering and the Lloyd's Register Educational Trust launched Tomorrow's Engineers (TE), a new enhancement and enrichment partnership to improve levels of science and engineering engagement in schools across the UK. The scheme, which was was announced to teachers at the Association for Science Education Conference in Nottingham, will initially support hands-on engineering activities to 30 000 children and young people aged 5–19 in 2010.

Supported by Airbus, E-ON, the IET and Thales, TE will target children who have the potential to do well in maths and science but whose schools are not yet actively engaged in engineering activities. The partnership will bring together programmes provided by the Engineering Development Trust, the Industrial Trust, Primary Engineer, Sentinus, the Smallpeice Trust, STEM Cymru, Young Engineers and Young Engineers & Science Clubs Scotland, and expand them to provide places for an additional 30 000 children in 2010. Tomorrow's Engineers will support these programmes, enabling them to focus on inspiring students with a better appreciation of engineering.

Reaching out to children, teachers and parents alike, TE will address the fact that young people's experiences in their childhood and early teens are a major factor in determining their pursuit of STEM careers, with 28% of practitioners claiming to have started thinking about a career in STEM before the age of 11 and a further 35% between the ages of 12 and 14.

For more information: visit www.tomorrowsengineers.org.uk.

Events

EVENTS FOR TEACHERS

Physics Update
University of Southampton
26–28 March
This three-day residential course will feature an exciting programme of lectures and workshops.
Details and booking: contact Manchi Chung (e-mail manch.chung@iop.org) or visit www.iop.org/update.

Salters Horners Advanced Physics Residential Courses
University of York
21–23 April: A2 preparation, teachers course
22–23 April: technicians course
If you teach the Edexcel A-level specification and you want to explore teaching through engaging contexts, then these courses are for you.
Details and booking: visit www.york.ac.uk/org/seg/salters/physics or contact Sandra Wilmott (e-mail slw5@york.ac.uk).

Physics for Non-Specialists
Science Learning Centre London
21 April, 6 May and 14 July
This three-day course will focus on the physics principles needed to teach physics at KS3 and KS4.
Details and booking: visit www.slcs.ac.uk/network/09069 or e-mail enquiries@london.slcs.ac.uk.

Space Academy Teacher Conference
University of Leicester and National Space Centre
24–26 April
This three-day residential conference will comprise lectures from space scientists and interactive workshops for physics, chemistry, biology and applied science. Further workshops will include using Earth Observation Science to teach science at KS4 and how to use Antarctica Expedition in the classroom.
Details: visit www.ukspaceacademy.org or contact Dr Sarah Hill (e-mail sarahh@spacecentre.co.uk).

Welsh Teachers Conference
Bangor University
8 June
This free conference is open to everyone who teaches physics, including non-specialists. Speakers will include Dame Jocelyn Bell-Burnell and there will be a variety of engaging workshops, including John Nunn demonstrating the VPLab and Andy Newsam from the Astrophysics Research Institute LJMU.
Details and booking: contact Andrea Fesmer (e-mail andrea.fesmer@talk21.com).

Stirling Physics Meeting
University of Stirling
9 June
This day of lectures and workshops will include an exhibition.
Details: contact Claire Garland (e-mail claire.garland@iop.org).

Rugby Physics Meeting
Rugby School, Rugby, Warwickshire
10 June
For all teachers in schools and colleges, this will be a day of information, stimulation and communication. It will include an exhibition and workshops.
Details: contact Manchi Chung (e-mail manchi.chung@iop.org).

North East Physics Teachers Conference
Ogden Centre for Fundamental Physics, Durham University
23 June, 9.30 a.m.
This will be a free day of talks, workshops and displays for teachers, organised by the Institute in conjunction with Durham University and the Science Learning Centre.
Details and booking: visit www.sciencelearningcentres.org.uk/northeast or tel 0191 370 6200.

Merseyside Physics Teacher Network Annual Conference: Physics Can Be Easy!
Chadwick Laboratory, University of Liverpool
24 June
This will be a full day of talks, workshops and discussions for all science teachers and trainee teachers, even those who are not physics specialists. It is aimed primarily (but not exclusively) at KS3 and KS4. There will be amazing ideas to inspire you and materials to take back to the classroom.
Details and booking: contact Lucas Hayhurst (e-mail lht@blueyonder.co.uk).

Manchester Teachers Conference
Manchester Metropolitan University, Oxford Road, Manchester
24 June
This conference aims to share the vision and enthusiasm for teaching physics and science and it is directed at teachers working at KS4. There will be free entry for secondary-education delegates and exhibitors.
Details and booking: contact Dr Vladimir Vishnyakov (e-mail v.vishnyakov@mmu.ac.uk).

South West Physics Teachers Conference
St Luke's Campus, University of Exeter
25 June
This will be a free day of talks, workshops and displays, organised by teachers for teachers.
Details and booking: visit www.tinyurl.com/PhysicsExeter or contact Alison Alexander (e-mail alisonalexander@aol.com).

Liverpool Physics Teachers Conference
Chadwick Laboratory, University of Liverpool
1 July
This annual conference is for specialist teachers of physics and it is aimed at GCSE and A-level. Organised jointly by the University of Liverpool and the Institute's Merseyside Branch, there will be free entry for all participants. There will be new ideas and activities to try. For information about last year's conference, visit www.liv.ac.uk/~iop/PTC/index.html.
Details: contact Steve Barrett (e-mail s.d.barrett@liv.ac.uk).

Physics Update
University of Sheffield
9–11 July
This three-day residential course will feature an exciting programme of lectures and workshops.
Details and booking: visit www.iop.org/update or contact Manchi Chung (e-mail manchi.chung@iop.org).

Physics Subject-Knowledge Booster Course
Charterhouse, Surrey
12–16 and 19–23 July
See p5 for full details.

EVENTS FOR STUDENTS

Institute of Physics 2010 Schools and Colleges Lecture: Powering the Future – the Physics of Fusion
This free lecture for 14–16-year-olds, given by Dr Melanie Windridge, continues its tour.
Details and booking: visit www.iop.org/education and click on "Events" or contact Clare Mills (e-mail clare.mills@iop.org).

National Particle Physics Masterclasses 2010
March–May
This popular series of one-day events for sixth-form students and their teachers, run by practising particle-physics researchers at various institutes all over the country, will be held throughout March and May.
Details: visit www.particlephysics.ac.uk/teach.html.

Teaching energy

The idea of energy runs throughout the teaching of physics. It would be nice to think that it is a unifying concept – but often this is not the case – it can be a hot topic. What follows is a suggestion for one way of introducing ideas about energy in the lower school. The general approach relies on identifying "energy stores" and thinking of the "pathways" that allow one store to empty and another one to fill.

It is worth remembering why we introduce ideas about energy: it is so that we, our students and scientists can do calculations. Ideas about energy don't explain why things happen but they are are fantastically powerful at predicting whether they will happen and what the outcomes might be. This power comes from the knowledge that energy is conserved and our ability to quantify the energy associated with energy stores.

Energy stores

Imagine stretching a spring. You do work to make it longer and, when it relaxes, it will do work back for you. In the stretched state, there is an energy store associated with the spring (because it is elastic and it will return to its original shape). Let's call this an elastic store.

To fill up the elastic store, you emptied (or part emptied) a chemical store. To analyse this system, we can take snapshots in time (looking at the start and end states rather than what happened in-between). Before: the chemical store is full; after: the chemical store is empty and the elastic store is full. You can use beakers (with orange-coloured water) to represent the stores in discussions with students – this leads nicely towards Sankey diagrams.

We can analyse most situations using a small number of stores:

- chemical (e.g. fuel and oxygen);
- kinetic (for a moving object);
- gravitational (due to the position of an object in a gravitational field);
- elastic (e.g. in a stretched or compressed spring);
- thermal (for a warm object);
- electric/magnetic (for two separated magnets or charges);
- vibrational (for a system that is oscillating);
- nuclear (for nuclei that are radioactive, fuse or undergo fission).

You will notice that light and sound are not listed. This is because, in this scheme, we will think of them as pathways rather than stores.

Energy pathways

Pathways carry energy from one store to another. For example, shining a torch at a wall empties a chemical store and it fills a thermal store, using a beam of light. The light is transient, as are all pathways.

Similarly, doing mechanical work is a pathway. In the spring example, it was by doing mechanical work that we emptied the chemical store and filled the elastic store.

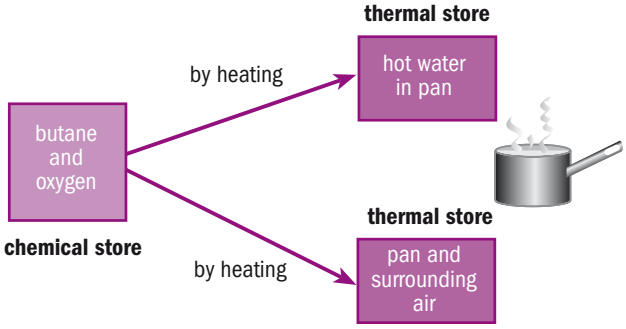
To complete our picture we need to add a pathway for electric circuits, which do electrical work, and pathways for what happens when one body heats another body (either by radiation or by the movement of particles).

So our energy pathways can be summarised as:

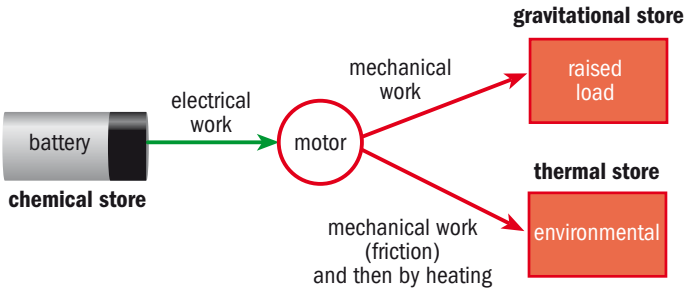
- mechanical work (when a force moves through a distance);
- electrical work (when a charge moves through a potential difference);
- heating by particles (conduction and convection);
- heating by radiation (e.g. light, microwaves, sound).

The amount of energy carried by a pathway depends on time (unlike the amount of energy in a store). We would tend to calulate their power rather than their energy. The diagrams below show some other examples.

1. Using a camping gas stove to boil water in a pan.



2. A battery connected to a motor that is raising a load.



In summary

You can use this scheme to introduce ideas of energy. It is not a physical model, nor is it a fundamental law of physics that should be learned for examinations – like the "nine types of energy". Rather, we hope it is an approach that will initiate discussions and help students' understanding by being clear, consistent and unambiguous.

For more information: see "Teaching energy: thoughts from the SPT11–14 project", I Lawrence 2007 *Phys. Educ.* **42(4)** 402–409 or visit www.iop.org/spt and download the Supporting Physics Teaching (SPT) energy resources and suggested approaches for teaching energy.

Modelling climate change with a leaky bottle

The steady-state (leaky) bottle kit was designed as part of the resources that SEP has been developing on modelling climate change. The Earth can be modelled as a steady-state system, and the leaky bottle can be used to illustrate how negative and positive feedbacks affect the temperature of the Earth.

The Earth and a centrally heated house stay at the same temperature because they are in dynamic equilibrium. The house is at a higher temperature than the surroundings. There is a thermal store associated with the house. Without any internal heating, this thermal store will empty and fill up a thermal store associated with the surroundings. The house needs to be actively maintained at its temperature by, for example, burning gas in a central heating boiler. A chemical store is emptying and filling the house's thermal store. A **steady state** is achieved when the house's thermal store is being filled at the same rate that it is emptying.

A useful model for explaining the concept of a steady state is a "leaky bottle", which represents the house's thermal store – an inverted plastic bottle with the bottom cut off and a rubber tube attached to the neck. Water is used to show the thermal store filling up; the level of water in the bottle represents temperature (you could discuss bigger houses using wider bottles). Adding water to the bottle (with the clip on the tubing closed) represents the chemical store being emptied and the thermal store being filled – the water level rises. Then we switch the central heating off and let the house cool. Releasing the clip at the bottom allows water to flow out, representing the house's thermal store being emptied; as it empties the water runs into a sink with the plug in – you can discuss that the water never gets very deep in the sink (the temperature of the surroundings hardly changes). It is important to notice that the flow of water **decreases** as the level of the water in the bottle **decreases**. This is key to understanding the nature of **feedback**.

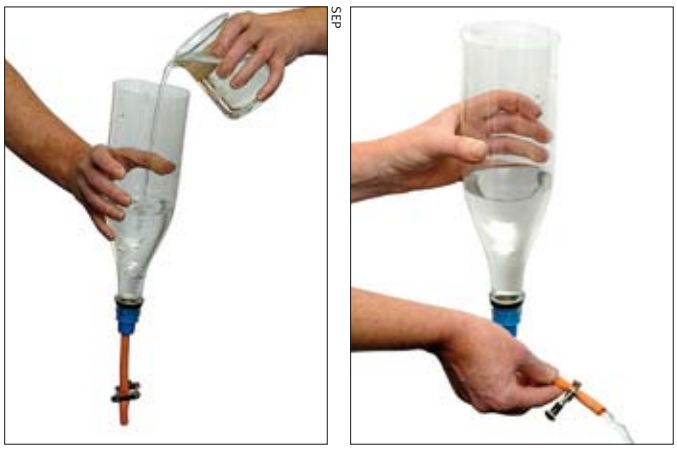
Negative feedback

The bottle can now be set up so that water can be run into it from a tap, while at the same time water can flow out of it into the sink. Starting with an empty bottle, pupils could be asked to predict what will happen if the tap is turned on a little. The bottle starts to fill up but it does not overflow because, as the water level rises, the output of water increases. Eventually the water reaches a steady level at which the input balances the output. Changing the rate of flow from the tap or altering the clip on the outflow alters the level of the water in the bottle but it will eventually lead to a new steady state because of the **negative feedback** in this system – the rate of outflow depends on the height of the water. The idea that needs some discussion with pupils is that we do not have to carefully adjust the input until it balances a fixed output – the **system will adjust itself** until the height of water produces exactly the output to balance the input.

You can ask students to think about what it is in this model that represents the power of the central heating system, and the quality of insulation and the size of the house. (These ideas are discussed at more length in an article in *Physics Education*: R Boohan 1996 "Keeping moving to stay where you are: energy flows and temperature differences" *Phys. Educ.* **31(1)** 20–23).

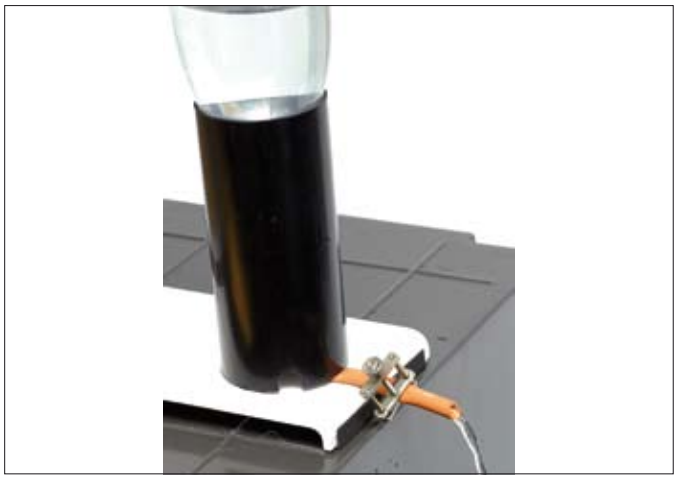
Positive feedback

We can go further with this bottle and model **positive feedback**. It could now represent the thermal store associated with the Earth once it goes past its "tipping point". By turning the collar on which the bottle stands, the weight of the bottle can be made to press down on the rubber tubing. As the water level **increases**, the rate of flow out of the bottle **decreases**. The flow eventually stops and the bottle overflows.



Filling the leaky bottle with water and then allowing it to drain out can be used to represent the heating and cooling of an object.

A steady state is achieved when the rates of flow into and out of the bottle become equal.



Resting the bottle on the rubber tubing leads to positive feedback.

For more information: about the booklet *Modelling climate change*, visit the *SEP* website (www.sep.org.uk). The "Steady-state bottle kit" is available for purchase (£3.90) from Middlesex University Teaching Resources (www.mutr.co.uk).

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