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Volume 27 No 3 March 2014

EDUCATION

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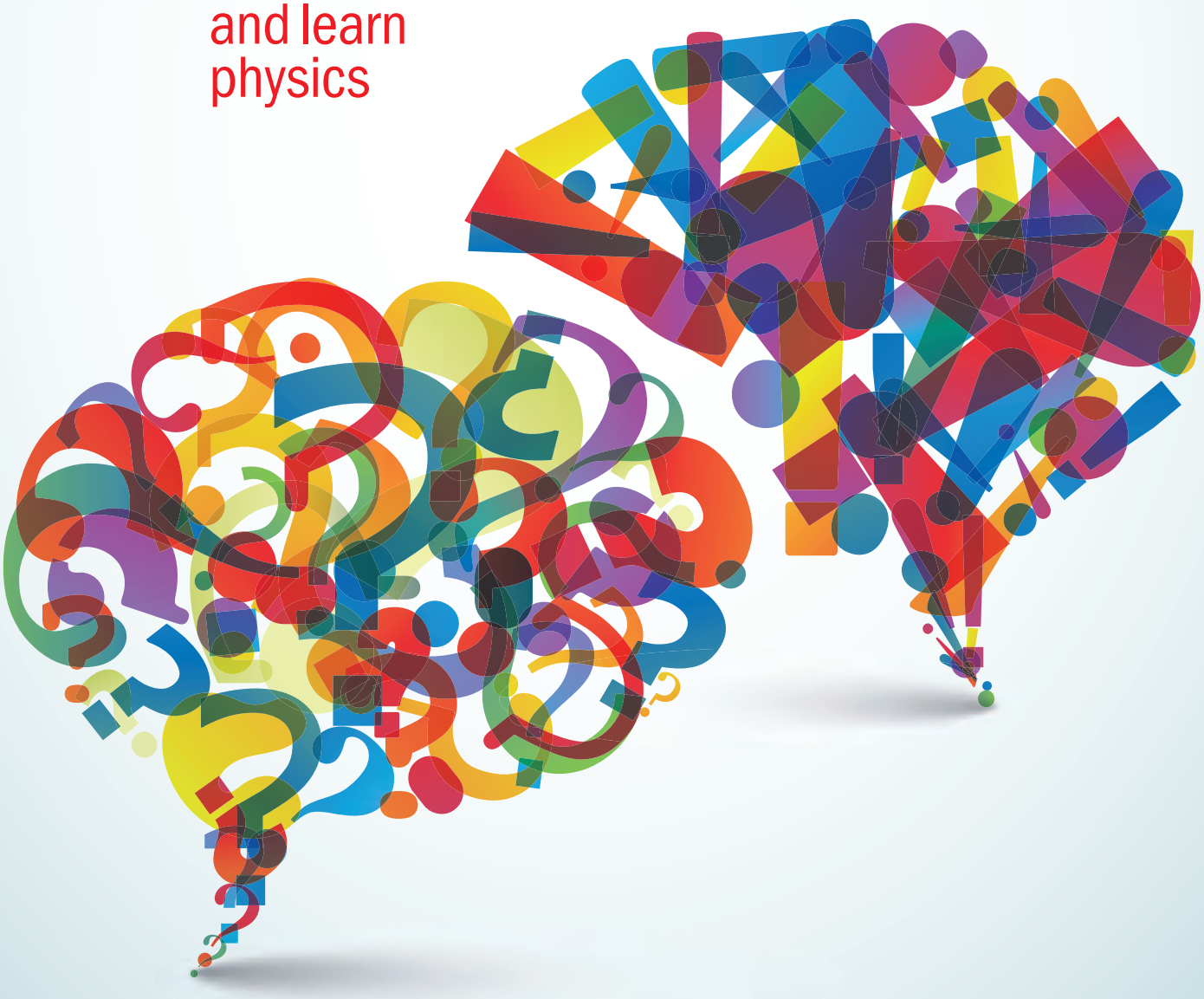

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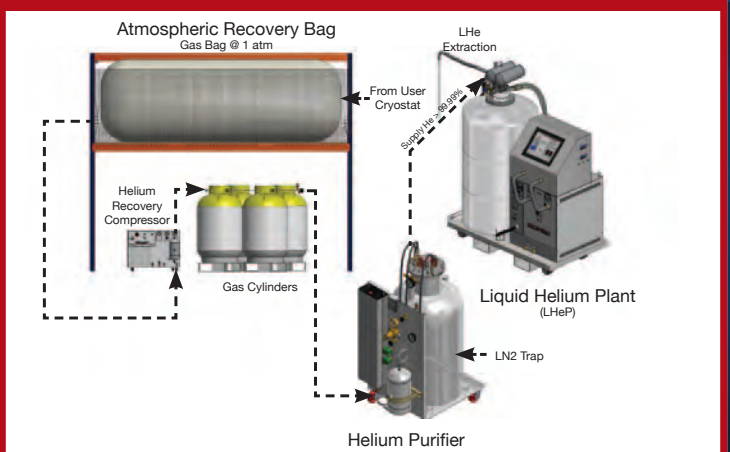

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physicsworld

Working abroad Graduate careers special 61–65

Get em young Why coding is vital to physics 27–29

Open learning The pros and cons of MOOCs 43–46

On the cover
Education: new ways to teach and learn physics 19–51
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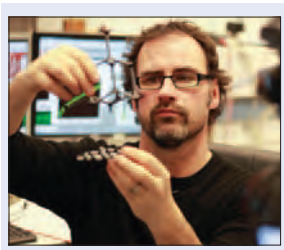
Physics World is published monthly as 12 issues per annual volume by IOP Publishing Ltd, Temple Circus, Temple Way, Bristol BS1 6HG, UK

United States Postal Identification Statement
Physics World (ISSN 0953-8585) is published monthly by IOP Publishing Ltd, Temple Circus, Temple Way, Bristol BS1 6HG, UK. Air freight and mailing in the USA by Sheridan Press. 450 Fame Avenue, Hanover PA 17331. US Postmaster: send address changes to *Physics World*, IOP Publishing, PO Box 320, Congers, NY 10920-0320, USA.

Brady Haran



Multimedia

Check out the digital version of *Physics World* for videos on:
- The power of MOOCs (p43)
- Explaining science on *YouTube* (p31)
- Richard Feynman in action (p40)

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For the record

It is baffling that in our modern world we have such blind trust in science

Prince Charles *quoted in the* Guardian

The first in line to the British throne says that people widely accept what science tells them – except when it comes to climate change, adding that climate deniers belong to the "headless chicken brigade".

It would be worse than trying to reconstruct a book that you burned from its ashes

Physicist **Don Page** *from the University of Alberta quoted in* Nature

In a new paper, Stephen Hawking suggests that matter that gets sucked into a black hole could be held behind the event horizon, with the information not being destroyed but rather scrambled and then released back out through Hawking radiation.

I now know the size of the universe better than I know the size of my house

Physicist **David Schlegel** *from the Lawrence Berkeley National Laboratory quoted on the BBC*

Astronomers working at the Baryon Oscillation Spectroscopic Survey announced that they had measured the distance between galaxies in the universe to an accuracy of 1%.

I've heard it described as playing battleship

Physicist **Gray Rybka** *from the University of Washington quoted on KPLU news*

Rybka says that hunting for dark-matter particles has similarities to playing the famous two-player game.

It's a wonderful opportunity, but with a bit of fear and trepidation as well

Space scientist **Maggie Aderin-Pocock** *quoted in the* Guardian

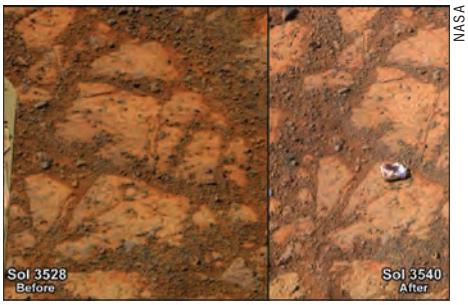
Aderin-Pocock is taking over as a main presenter of the long-running BBC TV series *The Sky at Night*.

One minute we're eating pizza then five minutes later we've helped to discover a supernova

Student **Tom Wright** *from University College London quoted on the BBC*

During an evening telescope class at the university, undergraduates spotted the exploding star, which occurred in the Messier 82 galaxy.

Seen and heard



NASA

Mushrooms on Mars?

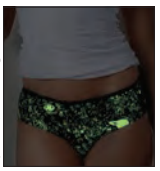
You may remember the story of Walter Wagner, the Hawaii resident who went to court to try to stop CERN's Large Hadron Collider (LHC) from starting, before a judge threw out the case. Well, now another science-themed lawsuit has been filed, this time to force NASA to investigate a strange white-coloured object that its Opportunity rover spotted on Mars. NASA released a photo of the weird-looking entity, which was not visible on 26 December 2013 but appeared in an image taken of the same spot on 8 January (see above). Despite wild speculation on the Internet, NASA concluded that it was "clearly a rock". But that was not enough for "scientist and astrobiologist" Rhawn Joseph, who is so sure that the rock is in fact a living organism, more closely resembling "a mushroom-like fungus", that he has filed an 11-page lawsuit in California to make NASA examine the object in more detail. He has also apparently attempted to contact NASA boss Charles Bolden and other senior staff at the agency to persuade them to examine the object more fully, so far to no avail. If the object is indeed biological, Joseph also wants NASA to acknowledge that he made the discovery and that he appears as first author on and has "final editorial approval" of the first six scientific articles published by NASA on this discovery. Any guesses how long it will be before Joseph's writ follows that of Wagner?

Cold leech

All *Physics World* readers must have at some point in their lives dipped a banana into liquid nitrogen and then shattered the frozen object into pieces. And if you haven't, you've probably wanted to. Well think again before putting an East Asian leech into a bath of liquid nitrogen as the little creature will come back out alive. In fact, researchers in Japan have shown that *Ozobranchus jantseanus* can survive in liquid nitrogen at –196 °C for up to 24 hours. The findings have, however, left the scientists puzzled because this type of leech never normally experiences temperatures less than a few degrees below 0 °C. The leech also smashes the previous record for a living object surviving a dunking, which was held by tiny, eight-legged "water bears" and the larvae of one type of *drosophilid* fly, both of which lasted for just an hour.

The designated survivor

The nuclear physicist and current US energy secretary Ernest Moniz may be 14th in the US presidential line of succession, but if something really terrible had happened in late January, he might have found himself leading the world's biggest economy. That is because Moniz was appointed "designated survivor" while US president Barack Obama delivered his State of the Union address. The speech, which is attended by the country's top leaders, including the vice-president, members of the US cabinet and Supreme Court justices, is where US presidents outline their legislative agenda for the coming year. A designated survivor is a member of the cabinet who stays at a distant, secure and undisclosed location during the address to maintain continuity of government in the event of a natural disaster or terrorist attack that ends up killing officials in the presidential line of succession. Of course, nothing untoward happened, so Moniz did not find himself as leader of the world's richest nation. The question remains, however, where was Moniz during the speech? Having emerged with his trademarks flowing grey hair intact, at least we know Moniz wasn't at the hairdressers.



etsy.com/makeitgoodpdx

Star panties

How about getting yourself a nice pair of glow-in-the-dark solar system underwear? The online shop "makeitgoodpdx", which is based in Oregon, US, is selling the garments for £11.34 through *Etsy*. Available in sizes ranging from XS to XL, the solar system print was hand-drawn by artist Nate Crane and features planets, moons, galaxies, shooting stars and asteroids, and is printed in "glow-in-the-dark ink". According to the seller, the underwear, which is made from 92% organic cotton and 8% spandex, is a "cut above" with a "tweaked and tested" style. "Rock 'em and feel out of this world," the description states.

Frontiers

In brief

Ballistic electrons go far in nanoribbons
An international group of researchers has shown that electrons can travel more than 10 μm in graphene nanoribbons without scattering – which is much further than predicted by theory. Graphene is an extremely good conductor of electricity as its electrons can travel very close to the speed of light. But the presence of imperfections means that an electron in a freestanding flake of graphene barely travels about 10 nm before scattering, increasing the material's electrical resistance. The researchers created pristine ribbons of epitaxial graphene just 40 nm wide and found that electrons can travel along the edge of the ribbon without scattering. Even more surprising, the team spotted a large jump in the electrical resistance of sections of nanoribbon that are longer than about 16 μm (*Nature* 10.1038/nature12952).

Novel dual-pumping fibre laser built
A new type of fibre laser that operates in the mid-infrared range has been designed by researchers in Australia. The device uses a dual-wavelength pumping approach that makes it 25 times more powerful than existing fibre lasers operating at mid-infrared wavelengths. The team's laser produces more than 0.25 W, with a significant peak in emissions at wavelengths of 3.6 μm. Many common hydrocarbon molecules absorb light in the mid-infrared range, and so a cheap and convenient source of laser light in this part of the spectrum could have a variety of practical applications, from atmospheric analysis to non-invasive medical diagnosis (*Optics Letters* **39** 493).

Cloudy skies on nearby dwarf star mapped
The weather forecast for a brown dwarf located just 6.6 light-years from Earth includes periods of patchy clouds, according to astronomers in Germany, the UK and France. They applied a technique called Doppler imaging, which exploits a star's spin, to map the distribution of bright and dark areas. Using data from NASA's Wide-field Infrared Survey Explorer, they saw, for the first time, features geographically localized in 2D across the globe of the brown dwarf, noticing patchy features all across the surface, which are consistent with partial cloud cover. These clouds are made of silicate rocks and molten-iron droplets kept aloft by vigorous atmospheric motions. The discovery lends insight into weather on "hot Jupiters" – giant planets that orbit so close to their star that they are lost in its glare, usually making them difficult to observe (*Nature* 10.1038/nature12955).

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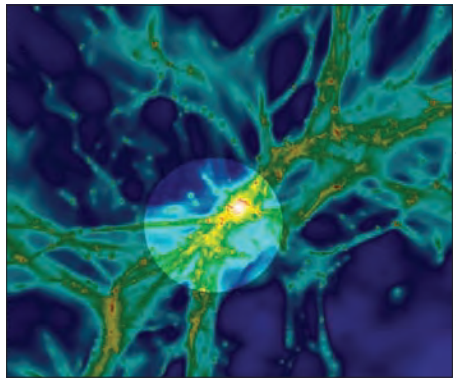
Quasar shines a light on cosmic web



Anatoly Klypin and Joel Primack, Sebastiano Cantalupo

Shine on Quasar UM 287 illuminates its surroundings.

The first view of part of a filament of the "cosmic web" might have been glimpsed by astronomers, thanks to a quasar acting like a torch to illuminate the gas. The observations, made by an international team of researchers, could be the first evidence of the long-predicted large-scale structure of matter in our universe – a network of filaments thought to connect all matter, including galaxies and gas clouds.

Matter in the universe is not uniformly distributed, but exists instead as filamentary structures with intervening voids. Normal matter and dark matter are thought to co-exist in this cosmic web, as scientists believe that the gas "feels" the gravitational force of the dark matter and traces it out across the cosmos.

A small fraction of this gas is dense enough to produce stars and galaxies, but most is too diffuse and cold to produce stars or emit its own light, making the web difficult to observe. To get round this problem, Sebastiano Cantalupo of the University of California, Santa Cruz in the US, along with colleagues in the US and Germany, began looking for cosmic gas that is lit by one of the brightest sources in the universe – a quasar. When lit by the ultraviolet light from a quasar, the cosmic gas emits radiation at a particular wavelength of hydrogen, which the team detected with a specially built narrow-band filter.

Using the 10 m Keck I Telescope at the W M Keck Observatory in Hawaii, the team detected the presence of a long filament of gas or a nebula. It has a projected length of about 460 kiloparsecs (about 1.5 billion light-years) and was illuminated by the distant, radio-quiet quasar UM 287.

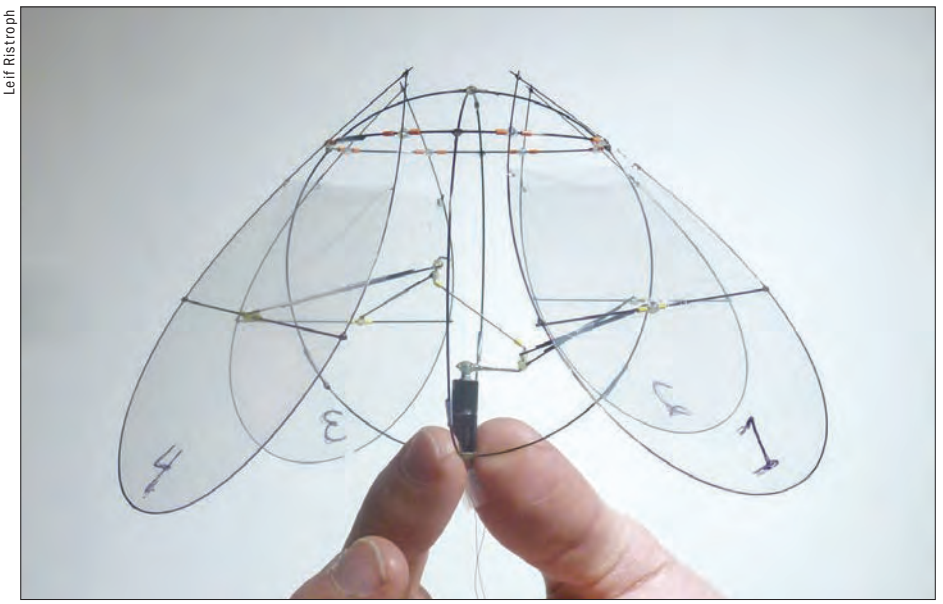
As the amount of radiation emitted by the filament depends on how much hydrogen is illuminated, as well as its density and distribution, the astronomers can infer the mass and physical properties of a cosmic web filament, which is otherwise extremely difficult to do without a direct image. While the filament's morphology was in good agreement with predictions from simulations, the filament itself appeared too bright given the typical density and distribution of hydrogen gas in the simulated web, suggesting that the gas is actually much denser and has a much clumpier distribution than predicted (*Nature* 10.1038/nature12898).

Monopoles seen in lab

An analogue of a long-sought-after particle comprising an isolated magnetic pole has been observed by physicists in the US and Finland. This latest work does not prove whether or not the unusual particles exist, rather it shows that a physical system described by the underlying mathematics can be created in the lab.

Physicists have tried to create magnetic monopoles – first predicted by Paul Dirac in 1931 – inside particle accelerators, and have searched pristine environments, such as the Antarctic ice, but have come up empty-handed. The approach of David Hall and colleagues at Amherst College in Massachusetts and collaborators in Finland is to produce an analogue of what is known as a "Dirac monopole" – the generalized quantum-mechanical form of a magnetic monopole, which Dirac said would, when naturally occurring, require electric charge to come in discrete units. Dirac considered what happens when a monopole interacts with an electron and found that a monopole passing through an electron cloud would leave a vortex in its wake.

Hall's group has reproduced that vortex in a Bose–Einstein condensate of ultracold rubidium atoms. The condensate is a single matter wave and stands in for the electron cloud in Dirac's formulation. To reproduce the monopole, the researchers applied a real, external magnetic field to the condensate to orient its atoms in such a way that they create a "synthetic" magnetic field inside the condensate. To show that they really had produced a Dirac monopole, the researchers shone a laser beam through the condensate, which created a "shadowgraph" – the shadow cast by the atoms was pierced by a narrow strip of light, which, the team concluded, was the vortex created by an isolated north pole (*Nature* **505** 657).


Leif Ristroph

On the wings of a...jellyfish?

A jellyfish-like flying machine that hovers and stabilizes itself with no feedback control has been unveiled by researchers in the US. This degree of self control is unique among such flapping-wing "ornithopters", and its developers hope that their prototype – pictured above – could be developed into a toy. Made of carbon-fibre loops and Mylar film, the ornithopter is the latest result in the drive to develop small autonomous flying machines for a variety of uses ranging from environmental monitoring to military reconnaissance. It was designed and built by Leif Ristroph and Stephen Childress of New York University. While the two applied mathematicians did not set out to create a jellyfish, similarities soon become apparent on construction. The ornithopter is 10 cm wide and has a mass of 2.1 g. It flaps its four downward-pointing wings in and out, bobbing like a jellyfish as it ascends and hovers. Making such a functional ornithopter has proved to be a challenge in the past because flapping flight is inherently unstable, unless you are a flying insect. Robotic flying machines usually have to manage their flight continuously, sensing small perturbations and compensating for them with changes in wing motion (*J. R. Soc. Interface* **11** 20130992). (See also p15.)

Physicists figure out why wet skin wrinkles

If you have ever sat in the bath and wondered why your fingers go wrinkly when wet, it is because the dead outer layer of your skin is made up of matrix-like structures called corneocytes. Physicists in Germany have now modelled a corneocyte and carried out calculations to see how its volume changes as it takes up water.

The outer layer of a mammal's skin – known as the stratum corneum – is the body's first line of defence against toxins in the environment, and also helps to control the water content of our body. When ambient conditions are dry, the stratum corneum forms a barrier to evaporation to prevent the skin from drying out and vice versa when it is wet. The stratum corneum is made mostly from keratin – a fibrous protein– which is arranged to form the corneocytes.

In a previous study, Myfanwy Evans of the Friedrich-Alexander-Universität Erlangen-Nürnberg and Stephen Hyde of the Australian National University showed that the structure of corneocytes is based on a cubic unit cell made from criss-crossing filaments of keratin that are not normally straight, but instead resemble helical springs. The volume of the unit cell can therefore increase by a factor of five until the filaments have essentially straightened out.

In this latest research, Evans has teamed up with Roland Roth of the University of Tübingen to study the thermodynamics of the expansion process. In their calculations, the two researchers quantified the corneocyte's tendency to expand in terms of the energy released as a filament absorbs water. They calculated the free energy of the unit cell over a range of sizes, plotting the free energy as a function of the length of a unit cell and the radius of curvature of the helical filaments. This "3D energy landscape" revealed a distinctive valley-like structure that contains a region of low free energy where it is thermodynamically favourable for the unit cell to exist (*Phys. Rev. Lett.* **112** 038102).

Innovation

Quantum dots power polarizing light source

A new way of generating linearly polarized photons using quantum dots has been developed by an international team of researchers. The novel source of polarized light could be used to develop energy-saving computers and mobile-phone screens, as well as secure communications. Researchers have long studied quantum dots and their many possible applications, but getting them to emit photons that have a predefined polarization has proved difficult and this is an essential requirement for many applications.

Most devices that create polarized light do so by sending unpolarized light through a polarizing filter. However, at least half of the light (and so an equal amount of energy as heat) is lost in the process, making them rather inefficient. To avoid such losses, a better method would directly generate polarized light from the source itself. While researchers have known that this is possible with quantum dots, until now the polarization has been weak, hard to control and the methods to do it are complex.

But now, Per Olof Holtz of Linköping University in Sweden and colleagues, along with other researchers in Thailand, have come up with an alternative method where asymmetrical quantum dots of indium gallium nitride (InGaN) are grown at the apex of elongated microscopic six-sided gallium-nitride pyramids. The team can control the precise elongation of the micropyramid, which in turn determines the polarization of the emitted photons. They then used a continuous-wave ultraviolet laser operating at 266 nm to excite the dots and found that photons are emitted with a well-defined wavelength and are highly linearly polarized, on average 84%.

Holtz told *Physics World* that nitride-based semiconductors are good for generating polarized light because of their valence-band structure. While the quantum dots that the team used emit violet light with a wavelength of 415 nm, the photons can, in principle, take on any colour within the visible spectrum by simply varying the amount of the indium used. The researchers' method should let them build ultracompact arrays of photon emitters, with a controlled polarization direction for each individual emitter. The method also has other advantages – the quantum dots can be used at high temperatures and produce a higher degree of polarization than is possible with other semiconductors. It is also compatible with current electronic-processing techniques (*Light: Sci. & Apps.* 10.1038/lsa.2014.20).

News & Analysis

Controversial journal relaunches

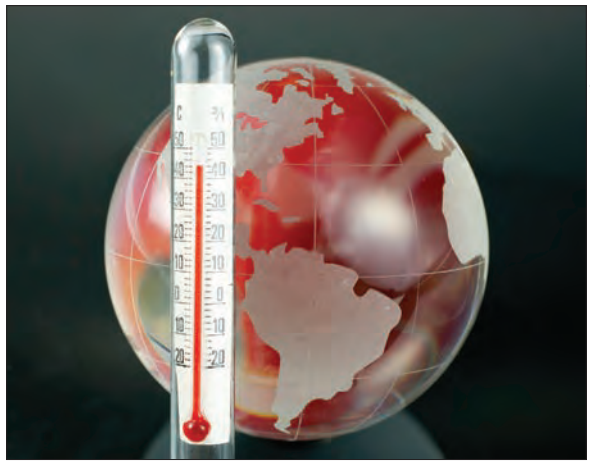
A journal that shut after allegations of malpractice has been reopened, as **Andy Extance** reports

A physics journal shut by its founding publisher due to "nepotistic reviewing and malpractice" has been relaunched by its editor-in-chief, Sid-Ali Ouadfeul from the Algerian Petroleum Institute. *Pattern Recognition in Physics* (*PRP*) was closed by Copernicus Publishing, which is based in Göttingen, Germany, following a special issue on solar variability that the journal published in January 2014, the concluding paper in which cast doubt on global warming. Ouadfeul has now launched the journal independently and is again inviting submissions.

Copernicus publishes 36 journals on an open-access basis, including 16 titles on behalf of the European Geosciences Union. It also holds funding deals with Germany's Max Planck Society and Helmholtz Association, and additionally invites ideas for new journals. In a statement published on its website, Martin Rasmussen, Copernicus's managing director, said that it had closed *PRP* because "the editors selected the referees on a nepotistic basis, which we regard as malpractice in scientific publishing and not in accordance with our publication ethics we expect to be followed by the editors".

Rasmussen told *Physics World* that in 2012 Ouadfeul suggested Copernicus should launch a journal on pattern analysis that would cover the theoretical, experimental and applied aspects of the subject in all branches and disciplines of physics. As Rasmussen felt Ouadfeul was "not yet well known in the international scientific community", the firm asked him to look for a second editor-in-chief.

Ouadfeul suggested Nils-Axel Mörner, a retired ex-head of the paleogeophysics and geodynamics department at Stockholm University, who was appointed as co-editor-in-chief before the journal's first papers were published in March 2013. Although Mörner is critical of the Intergovernmental Panel on Climate Change and the idea that sea levels are rising, Rasmussen insists that Mörner's viewpoint on climate change "did not play a role, since the journal was never meant to publish climate-change-related research".



iStock/oonal

The heat is on
An open-access journal that closed after it published a special issue casting doubt on global warming has been relaunched by its editor-in-chief.

In July 2013 Jeffrey Beall, a librarian from the University of Colorado, who runs the watchdog blog *Scholarly Open Access*, alleged that Ouadfeul self-plagiarized in *PRP*'s very first paper. He also noted that Ouadfeul edited two of the remaining four papers published up to that point and said that climate-change sceptics had been named as the editors for the other two.

Mörner then proposed a special issue of the journal entitled "Patterns in solar variability, their planetary origin and terrestrial impact", which featured 14 papers on the topic published between November 2013 and January 2014. "Obviously, we are on our way into a new grand solar minimum," all the issue's authors wrote together in the special issue's "general conclusions" paper in December. "This sheds serious doubts on the issue of a continued, even accelerated, warming as claimed by the IPCC project."

But in January, when Copernicus was about to issue a press release to publicize the special issue, it saw this comment and recognized what it called "a major problem with misuse of the journal's topic". The firm then noticed that most referees were also authors on the issue's main papers, which drove it to close *PRP*. Further investigation revealed that the only three other referees for the special issue were also authors on the concluding paper. "The authors stated relatively bold implications," says Rasmussen. "This is free speech and welcome in scientific discourse. However, the review showed clear malpractice. The journal was being misused for publishing work from a different topic than agreed: climate change, or its denial."

I don't know why Copernicus closed it down but now we have reopened it

The closure has riled *PRP*'s supporters, with Mörner calling the situation "twisted". "Nepotism is to favour friends and relatives without respect to qualifications," he told *Physics World*. "We did the opposite. The reviewers were all specialists. It is true they primarily were chosen among authors of the special issue, with some additionally from outside. We achieved a wonderful collection of papers that elevate an old hypothesis into a firm theory: that solar variability is driven by the 'planetary beat'. It is ironic that I am accused of upsetting normal reviewing. My whole life, I have been keen on 'fair play'. We had internal quarrels within *PRP*, and I was fighting for decent reviewing."

The shutdown also surprised Ouadfeul. "It was normal peer review, like other journals," he told *Physics World*. "I don't know why Copernicus closed it down, but now we have reopened it. No problem." *PRP* now appears on a new website with the relaunch driven exclusively and independently by Ouadfeul.

Indeed, Rasmussen regrets that *PRP* did not use the public peer-review system Copernicus promotes, where referee comments are discussed publicly, which he felt would have helped to "avoid or at least uncover such malpractice". Although he calls the affair "unfortunate", he denies that it reflects poorly on Copernicus or open access. "Different approaches including public, open or closed peer review have shown that the vast majority of open-access journals are reliable, professional and highly reputable."

Publishing

Concerns voiced over Dutch open-access drive

Researchers and institutions in the Netherlands are scrambling to implement new publishing rules after the Dutch education ministry announced plans late last year to speed up the transition from subscription-based scientific publishing to open access. Speaking at the annual European conference on academic publishing in Berlin in January, Dutch education secretary Sander Dekker said that free access to scientific information is essential to healthy science and that "publicly funded research should be publicly available". However, critics warn that the move could hurt physicists' attempts to publish in the top journals.

Open-access publishing usually comes in two forms – "gold" in which an article is free for all to read as soon as it is published if the author pays an article processing charge, or "green" where the paper is embargoed for a certain period after which it is free to read online. In November 2013 Dekker told parliament that all scientific publications that were "made in Holland" would be open access in 10 years' time – via either the gold or green route – with at least 60% being so in 2019.

Dekker, a member of the Dutch liberal VVD party, has now urged researchers, libraries, publishing houses and funders to address the issues of such a transition to fully open-access publishing, calling on academia to meet the potential extra costs. Dekker, who was involved in the implementation of the open-access policy for the EU's Horizon 2020 programme, even warns that if the Dutch five-year goal is not met, he will pass a law to restrict public funding of research to open-access publishing researchers only.

Opening up research
Sander Dekker, Dutch education secretary, has vowed to speed up the transition from subscription-based scientific publishing to open access.

Dekker's appeal has led to strong reactions in the Dutch scientific community, many of whom doubt the feasibility of the plans, including the possibility that they cannot publish in journals that do not offer open access. "The incentive to aim for the highest-impact titles will be undermined. Dutch science will lose", economist Roel Beetsma of the University of Amsterdam wrote in an open letter to Dekker late last year, in which he stated doubts that the cost of scientific publishing would come down following a move to open access.

Beetsma's concern over the lack of access to top journals is backed up by astronomer Ed van den Heuvel, also at Amsterdam. "Denying Dutch researchers the ability to publish in subscription journals such as *Science* and *Nature* is scientific hara-kiri," Van den Heuvel told *Physics World*. "Scientific quality is the only issue, all the rest is secondary."

However, Amsterdam-based scientific-publishing house Elsevier formally welcomed the initiative, stressing it has already opened up several hundred of its titles. "We will be happy to work out a system that fits all," the company said in a statement. Yet particle physicist Jos Engelen, current president of the Dutch funding agency, the Netherlands Organisation for Scientific Research (NWO), and a former CERN chief scientific director, told *Physics World* that giving power to commercial publishers has "turned out to be a mistake". "Their interests are also in selling events and advertisements that are not necessarily in the interest of a public funding agency such as the NWO, which is trying to foster the national interest of good Dutch research," he says.

Yet Engelen adds that Dutch physics will be relatively unhurt by Dekker's plans. "We already have a relatively open culture, with repositories such as *arXiv*," he says. "There the scientific debate takes place. And we all know how to handle the drawbacks of the system as I am sure responsible scientists in other fields will learn just as well."

Martijn van Calmthout
Amsterdam

Publishers open journal content to UK public library users

Library users in the UK now have access to hundreds of thousands of journal articles following a new initiative called Access to Research, which was rolled out last month. The two-year pilot programme will allow public-library users in the UK to freely access 8000 journals from 17 publishers including IOP Publishing, which publishes *Physics World*, as well as Elsevier, Nature Publishing Group and Wiley.

The new initiative is being spearheaded by the Publishers Licensing Society (PLS), a not-for-profit firm that oversees licensing in the UK for book, journal, magazine and website copying. Last year, about 250 libraries from 10 local authorities, the majority of which are in southern England, were involved in testing the programme, with the initiative now being launched nationwide. Access to Research is in response to one of the main recommendations of the Finch report, which was published in June 2012 and aimed to reach a consensus on an open-access policy among universities, libraries, researchers, learned societies and publishers in the UK. The recommendation stated that major academic publishers should grant public libraries a licence to provide free access to academic articles.

To browse a journal, users must go into a library that has signed up for the initiative and then use a registered computer in the library to access a specially built Web-based search platform. "The programme will now give the public free access to research around the world through our public libraries," says UK science minister David Willetts. "This will connect people, including students and small businesses, to a wealth of global knowledge – maximizing its impact and value." Richard Mollet, head of the Publishers Association, adds that the pilot will be "hugely valuable for publishers, libraries and their patrons".

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Access all areas
Library users in the UK will now have access to more than 8000 journals from 17 scientific publishers.

Michael Banks

Italy

Space chief quits following corruption probe

Italy's space activities have been thrown into uncertainty following the resignation of Enrico Saggese as president of the Italian Space Agency (ASI). Saggese stepped down in the wake of investigations by prosecutors regarding possible fraudulent contracting, expenses-paid holidays and questionable consultancies awarded by the agency. The organization, which has an annual budget of around €500m, will now be run by a government-appointed commissioner until a new president is nominated.

The presidency of Saggese, an electronics engineer, was controversial from the start. He took over as a commissioner in 2008, after the then government of Silvio Berlusconi removed the existing president, astronomer Giovanni Bignami. Saggese's arrival angered many scientists, not only for the treatment handed out to his predecessor but also because of question marks over the new chief's independence. Saggese was vice-president for space activities at one of the ASI's biggest contractors – aerospace and defence giant Finmeccanica. Doubts notwithstanding, however, he was appointed president of the agency a year later.

According to the newspaper *La Stampa*, the latest investigations were sparked by a whistle-blowing ASI manager who told prosecutors in Rome that he had noticed "irregularities" in the agency's operations, including "invoices for non-existent transactions", and who said that Saggese had threatened to ruin his career when he brought the matters to light. The prosecutors subsequently put Saggese and six other individuals under investigation for their alleged involvement in bribery, the offices and homes of whom were raided by police on 6 February.

ESA

Stepping down Enrico Saggese, president of the Italian Space Agency, has resigned in the wake of investigations into contracts, hirings and expenses.

Investigators are also studying documents relating to a lavish trip to California that Saggese is alleged to have laid on for 33 guests using mainly public money. The visit, which cost a reported €930 000, is said to have involved business-class flights and nine days' worth of luxury accommodation in order to watch a rocket launch that in the end did not take place.

In his letter of resignation, which he sent to research minister Maria Chiara Carrozza the day after police searched his offices, and which was accepted a few hours later, Saggese claims he is innocent of any wrongdoing, asserting his "complete extraneousness to the alleged actions". He explains that he decided to quit "in the interest of the ASI's international prestige" and in order to "better defend my uprightness, respectability and prestige".

According to Rodolfo Guzzi, a former ASI director, the agency essentially stopped funding basic research during Saggese's presidency. He says that of the agency's €100m budget for domestic activities, all bar a few million was awarded to commercial enterprises, whereas previously a substantial fraction of the money had supported projects at research institutes and universities.

That funding will now remain blocked until a new president is appointed, Guzzi adds. Although that should not lead to any of the ASI's roughly 200 employees being laid off, it might, he points out, cause industry to cut back on personnel. Aldo Sandulli, a professor of administrative law from Suor Orsola Benincasa University of Naples, was appointed ASI commissioner – a temporary position – on 12 February. Carrozza has set up a selection committee to provide her with a short list of candidates for the presidency.

Edwin Cartlidge
Rome

Energy

India plans world's biggest solar power plant

India has unveiled ambitious plans to build the world's largest solar-energy park. Dubbed the Ultra Mega Solar Power Project and located about 550 km south-west of New Delhi in the state of Rajasthan, the plant is projected to generate 4000 MW. When complete it would be 16 times bigger than the 250 MW Agua Caliente Solar Project located in Arizona, US, which is currently the biggest such facility.

India is proposing to construct the plant on an empty salt pan in the Thar Desert in western India. Having an area of about 10 km^2, it will be set on the banks of a highly saline natural inland lake. The first phase of the project will involve the installation of 1000 MW and is likely to be finished by 2016. When fully commissioned a decade from now, the Indian government estimates that the plant will supply enough energy to light up more than 40 000 typical Indian homes.

Pallava Bagla

Power from the Sun The next step in India's National Solar Energy Plan is the 4000 MW Ultra Mega Solar Power Project.

According to the Indian Ministry of New and Renewable Energy, the plant is estimated to cost around $1bn but the government is hoping it can source $500m of subsidized green funding from the World Bank. The project is being spearheaded by the Solar Energy Corporation of India and is being supported by six public-sector companies that specialize in power, electronics and construction.

The idea for the plant stems from 2009 when India released its ambitious National Solar Energy Plan that set a target of generating 20 000 MW of solar power by 2022 at a cost of $20bn. In 2013 India's installed capacity for solar stood at 2100 MW (with the highest being Germany at 32 000 MW).

Speaking at the Delhi Sustainable Development Summit in New Delhi last month, Rajendra K Pachauri, chairman of the Intergovernmental Panel on Climate Change and director-general of the Energy and Resources Institute in New Delhi, emphasized the need to embrace clean energy, adding that "a large proportion of human society remains totally outside modern energy systems".

Pallava Bagla
New Delhi

Funding

Physics gains ground in US budget

After years of suffering budget cuts, the 2014 US budget, signed by US president Barack Obama in mid-January, contains promising news for physics researchers. The Office of Science at the Department of Energy (DOE) receives $5.07bn – an increase of 9.7% over last year's figure – while its Advanced Research Projects Agency–Energy stands to obtain $280m, worth an extra 11.2%. NASA's science programme receives $5.15bn – a rise of 7.7% – and the National Science Foundation will get $7.17bn, up 4.2%.

Much of the current year's increases merely make up lost ground following sequestration in 2013 – which saw a 5% cut in all government agencies' budgets following a failure to solve political disagreements in 2011 – and the fact that Congress failed to pass budgets in financial years 2012 and 2013. In those two years it voted on "continuing resolutions" that maintained the budgets at the previous years' levels.

"While it wasn't perfect, I was pleased that the bill preserves essential funding for scientific research and development," says Bill Foster, a physicist who is a Democratic Representative for Illinois. Yet Rush Holt of New Jersey, a fellow physicist and Democratic Congressman, takes a less optimistic view. While lauding the budget's inclusion of $508m that he sought for the DOE's Office of Fusion Energy Sciences, he laments that the budget is premised on "the deep, deep cuts" of the sequester. "Even over the next two years, more than three-fourths of the sequestration cuts remain in place – cuts that gut research, education, healthcare, infrastructure and other investments necessary for a vibrant economy," he says.

CC-BY Martin Falbisoner

Spending splurge
The 2014 US budget contains steep rises for science including a 9.7% increase for the Department of Energy's Office of Science.

Indeed, the sequester and last October's two-week government shutdown continue to cast a shadow over the research community, with telescopes in Arizona, California, Hawaii and West Virginia facing possible closure. Equally disturbing, research universities report delays in existing research projects, reductions in the numbers of new research grants and cuts in staff – effects that could permanently reduce the productivity of research. Patricia Dehmer, DOE acting director, warns that her department will still award fewer grants over the next three to five years, because the budget now requires it to fund them in full at the time they are awarded, instead of paying them out in three- to five-year increments.

"Sequestration is a very damaging budgeting approach when it comes to scientific research," says Michael Lubell, director of public affairs at the American Physical Society. "The approach of making temporary cuts and then restoring funds works if you are paving roads. But it doesn't work so well with scientific research; people leave the country or go into other fields."

Peter Gwynne
Boston, MA

China

PandaX heats up the race for dark matter

A new $8m Chinese experiment has begun taking data in the search for dark matter. The Particle and Astrophysical Xenon (PandaX) experiment has opened at the China Jinping Underground Lab, which is located under some 2.4 km of rock in Sichuan province. PandaX will use its 120 kg tank of liquid xenon to search for weakly interacting massive particles – a leading dark-matter candidate – and its first data are expected later this year.

Dark matter accounts for around 26.8% of the total mass-energy of the universe, with dark energy making up 78.3% and ordinary matter the rest. PandaX was first mooted in 2009 by researchers at Shanghai Jiao Tong University (SJTU) together with support from China's science and technology ministry and the National Natural Science Foundation of China. Six other institutes in China and the US are also involved in PandaX, including the Shanghai Institute of Applied Physics, the universities of Shandong, Peking, Michigan and Maryland as well as the Yalong River Hydropower Development Company.

Xiangdong Ji

Going underground
PandaX will use a 120 kg tank of liquid xenon to search for weakly interacting massive particles – a leading dark-matter candidate.

When a dark-matter particle hits a xenon atom in the tank, it transfers energy to the atom, which recoils in the liquid, producing radiation. The radiation is then picked up using photomultiplier tubes. PandaX is now the fourth major experiment to hunt for dark matter using xenon following the XMASS Dark Matter Experiment in Japan, XENON100 in Italy and the Large Underground Xenon experiment in the US. While these facilities are bigger in terms of the amount of liquid xenon they hold, there are plans to scale up PandaX.

"Results depend on the scale of the experiment, which means the usable amount of xenon," says PandaX spokesperson Xiangdong Ji from the SJTU and the University of Maryland. "We are considering scaling up to nearly half a tonne of xenon later this year." Indeed, PandaX was originally designed to operate more than a tonne of liquid xenon but when it will be upgraded has yet to be decided. "We haven't set a timetable," says Ji. "It depends on the funds, which depends on the results."

Jiao Li
Beijing

Research

Military lab move sparks controversy

A money-saving proposal from the US Air Force to move its Office of Scientific Research (AFOSR) from Virginia to Ohio has come up against strong protests from politicians and researchers. The American Physical Society (APS) – along with a group of 15 universities that receive funds from the AFOSR – argues that the relocation could damage the Air Force's commitment to fundamental research, with APS president Malcolm Beasley warning that it could "cripple" the Air Force's basic research programme.

With a budget of $525m in 2013, the AFOSR has about 170 employees. It invests in basic research – from controls for air and space flight to energy technologies and materials development – that is carried out by academic and non-profit research organizations across the country. The lab's current location near Washington, DC, is close to the headquarters of other government agencies responsible for funding basic research, including the National Science Foundation, the Department of Energy, NASA and the Defense Advanced Research Projects Agency.

US Air Force/Abhishek Yadav

Relocation, relocation
Plans to move the Air Force Office of Scientific Research from Virginia to Ohio has met strong opposition over fears that it could "cripple" its research programme.

Sparked by the US military's need to cut costs as its budget declines following the end of its wars in Iraq and Afghanistan, the proposal would move the AFOSR to the Wright-Patterson Air Force Base in Dayton, Ohio, the current home of its Air Force Research Laboratory (AFRL), which focuses on applied research. "There's always a competition for funds between the AFOSR and the AFRL," Michael Lubell, the APS's director of public affairs, told *Physics World*. "The concern is that moving the AFOSR to Wright-Patterson will give the AFRL at least a bit of a boost."

Dayton's lack of proximity to other research organizations could result in the AFOSR's researchers and support staff refusing to move out of the Washington area – a phenomenon that has happened in past military relocations. Virginia senators Tim Kaine and Mark Warner, along with Representative Jim Moran, have written a letter to General Janet Wolfenbarger, commander of the Air Force Material Command at Wright-Patterson, warning against the move. They add that the AFOSR's current location provides "fertile ground for the cultivation of collaborative research".

The proposed relocation came to light when the Institute of Electrical and Electronics Engineers released a letter it wrote to Wolfenbarger in mid-January, stating that the move would be "high risk" and would result in "significant attrition of talent and disruption of that important research enterprise". In response, the Air Force asked for comments from the research community, but gave just five days to respond. Yet the issue is not likely to be settled soon. Owing to red tape, the Air Force might not decide whether or not to make the move until October 2015.

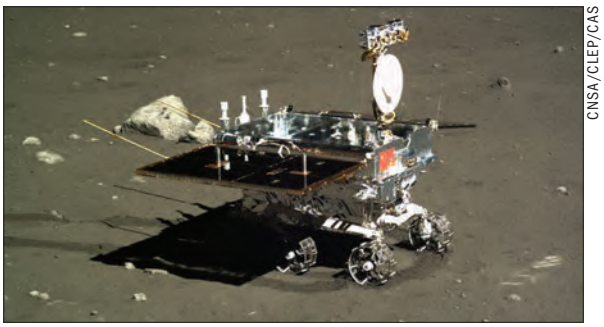
Peter Gwynne
Boston, MA

Space

Jade Rabbit wakes up from lunar sleep

China's first lunar rover, Jade Rabbit, woke up last month after a two-week shutdown, but problems remained to get the probe fully operational as *Physics World* went to press. There were, however, initially conflicting reports about the status of the mission after the English-language website of the state-owned China News Service reported that Jade Rabbit "could not be restored to full function as expected". However, China's official Xinhua news agency later said that mission control was still working to fix "control abnormalities", and that the rover "can be saved".

Jade Rabbit was launched on the Chang'e-3 probe on 2 December 2013 from the Xichang Satellite Launch Center in Sichuan province. The rover, which is expected to travel around 10 km over the surface of the Moon for a period of three months, is around 1.5 m long, 1 m wide, 1.1 m high and weighs 140 kg. In ancient Chinese mythology, Chang'e is the Chinese goddess of the Moon and Jade Rabbit was her pet. Chang'e-3 follows on from China's two successful lunar orbiters – Chang'e-1 and Chang'e-2 – which launched in 2007 and 2010, respectively.



CNSA/CLEP/CAS

Staying alive
China's Jade Rabbit has come out of hibernation but is still having technical troubles.

Jade Rabbit carries a camera, radar and infrared and X-ray spectrometers. The main mission of the rover is to survey the Moon's surface and geological structure, looking for natural resources and taking 3D images as well as taking infrared spectra and analysing the lunar soil. The probe is also carrying a telescope and an ultraviolet camera to observe the universe and the plasma sphere around the Earth.

However, after initially taking some images of the Moon's surface, on 25 January Jade Rabbit experienced mechanical problems. The problems were apparently related to the probe's process for shutting down for the lunar night, which lasts more than two weeks and during which temperatures plummet to –180 °C.

However, upon waking up last month Xinhua said that the probe was "alive" and receiving signals from Earth. "It's awake. We have a signal," China National Radio quoted Pei Zhaoyu, a spokesman for the lunar probe programme. "But the problem still hasn't been resolved." As *Physics World* went to press it is was unclear how long it would take to resolve the problems and whether the probe would be fully operational again.

Michael Banks

Research

Number of papers read by researchers levels off

A study of US academics has discovered that the number of papers that researchers are reading is no longer going up but has levelled off. The study, led by Carol Tenopir from the Center for Information and Communication Studies at the University of Tennessee in Knoxville, finds that researchers read on average 264 academic articles per year in 2012, about the same as they read back in 2005. It also shows that scientists spend around half an hour reading each paper (*Learned Publishing*, in press).

The annual survey of reading habits began in 1977 and is based on a questionnaire sent to about 800 academics at five US universities. Scientists are asked to give details of the number of papers they read – beyond just the title or abstract – as well as answer questions about the time spent reading and the purpose, value and the format of the papers.

When the survey first started, scientists used to read 12–13 articles per month, spending an average of 48 minutes on each. But during the following two decades the number of manuscripts consumed increased steadily, while each got less attention.

Shutterstock/Matushchak Anton

Reading matters
A survey has unveiled that researchers read on average 264 academic articles in 2012 – about the same as in 2005.

In 2005 a significant surge in the numbers of articles read was recorded by the survey, coupled with a marked decrease in the time researchers spent with each article to just 32 minutes, but the most recent survey shows that the number of papers read now seems to be stabilizing. "Academics still spend many hours each year reading scholarly articles, but perhaps their upper capacity has been reached," says Tenopir.

The survey also indicates that academics aged 60 or older are more likely to read a printed article, while younger researchers prefer a digital format. "Readings from all ages are now overwhelmingly from e-sources, and a growing percentage of those readings are read on screen rather than printed out on paper" adds Tenopir.

Hazel Hall, a social scientist from Edinburgh Napier University who was not involved in the study, says that despite the levelling off in the number of papers read, this does not necessarily mean that researchers are reading less overall. "Their awareness of new research is actually greater than in the past because meta-knowledge about newly published research is so much easier to access, for example through online contents page services [such as] *Twitter* feeds," she says.

Katia Moskvitch

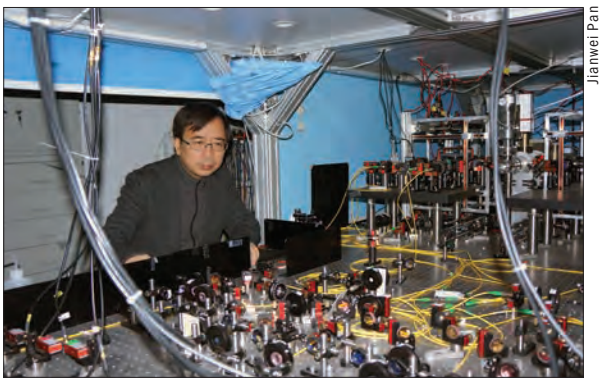
Research

China establishes five innovation centres

After nearly a year of planning, the Chinese Academy of Sciences (CAS) has created its first batch of Centres for Excellence and Innovation (CEI). Focusing on quantum information and technology, particle physics, the Earth system, brain science and thorium molten-salt reactors, the centres have been given management autonomy so they can set their own research direction and introduce performance incentives for staff.

The CEI in Quantum Information and Quantum Physics will be based at the University of Science and Technology of China (USTC) in Hefei and will receive around 60 million yuan ($10m) each year to buy new equipment and fund researchers. Chunli Bai, the president of the CAS, hopes that the centre can achieve a "comprehensive leading position" in quantum information, which will include the construction of a "secure and scalable" fibre-optic quantum network between Beijing and Shanghai by 2016.

"We hope that the CEI will improve the situation of competitive funding in China," says Jianwei Pan, a quantum physicist from USTC and the director of the centre. "The fields with hopeful major breakthroughs need stable funding to support scientists to devote more time and energy into research, similar to what happens at the Max Planck Institutes in Germany."



Jianwei Pan

Leading light
Quantum physicist Jianwei Pan will be director of the Centre for Excellence and Innovation in Quantum Information and Quantum Physics based at the University of Science and Technology of China in Hefei.

The CEI in Particle Physics, which is based at the CAS's Institute of High Energy Physics (IHEP) in Beijing, will be used to integrate particle physics in China. "It will play an important role for the development of particle physics in China by identifying the objectives and ideas for development, and promote talents," says Yifang Wang, the director of IHEP, who has been appointed head of the new centre. Although its budget had not yet been approved as *Physics World* went to press, Wang estimates it will be no more than $1.6m annually.

The other three centres are the CEI in Tibetan Plateau Earth System Sciences, based in Beijing, the CEI in Brain Science, located at the Institute of Neuroscience in Shanghai, and the CEI in Thorium Molten Salt Reactors Energy System, which is based at the Shanghai Institute of Applied Physics. The CEIs will each receive independent assessments every two or three years, which will be carried out by a panel of international researchers. After five years a more comprehensive assessment will be conducted to determine whether or not each CEI will continue.

Jiao Li
Beijing

Sidebands

First neutrinos for US experiment

One of the world's longest-distance neutrino experiments has detected its first neutrino. The NuMI Off-Axis Electron Neutrino Appearance (NOvA) experiment in the US is designed to study neutrinos created at Fermilab near Chicago that are then – after passing through a "near" detector at Fermilab –sent some 800 km towards NOvA's main detector at Ash River, Minnesota. Both detectors are supposed to be complete later this year with the experiment expected to run for six years. Neutrinos come in three "flavours" – electron, muon and tau – and the goal of the NOvA experiment is to determine the order of the neutrino masses, known as the mass hierarchy. NOvA is made up of more than 200 scientists from 38 institutions in Brazil, the Czech Republic, Greece, India, Russia, the UK and the US.

Asia catches up in R&D stakes

Europe and the US no longer dominate research and development, according to a report published by the National Science Board (NSB) – the policy-making body of the US National Science Foundation. The NSB's biennial report – *Science and Engineering Indicators* – concludes that countries in Asia are catching up with their western counterparts. Since 2001, the share of the world's R&D performed in the US has fallen from 37% to 30%, while it has dropped from 26% to 22% in Europe. In the same period Asia has seen its share increase from 25% to 34%. Fuelling this increase has been China, which has grown from 4% to 15% since 2001. The report also states that China is investing heavily in clean energy, spending nearly $61bn in 2012 – double that of the US.

Ireland pushes photonics

The Irish government has established a new €30m Irish Photonic Integration Centre. Led by the Tyndall National Institute together with University College Cork, Cork Institute of Technology and Dublin City University, the centre brings together more than 100 researchers to develop new light-enabled technologies in the hope that it will grow Ireland's share of Europe's €58bn photonics market. The centre will receive €20m from the government with an additional €10m from industry and it will work with 18 industry partners including hi-tech start-ups such as X-Celeprint. The firm has already agreed to base its headquarters at Tyndall and create up to 20 jobs over the next two years.

Particle physics

CERN kicks off plans for LHC successor

The CERN particle-physics lab near Geneva is putting plans in place to build a successor to its Large Hadron Collider (LHC). At a meeting held at the University of Geneva last month, some 300 physicists and engineers – including current CERN boss Rolf-Dieter Heuer – discussed a range of options for a possible future collider. This includes plans for a massive next-generation circular collider – with a circumference of 80–100 km – that would accelerate protons to energies of about 100 TeV.

While the 27 km-circumference LHC has been colliding protons at energies of up to 7 TeV in the hunt for new particles since it first switched on in 2008, for more than 30 years physicists have been carrying out R&D on linear colliders that could one day be the LHC's successor. One leading design effort is the International Linear Collider (ILC), which would accelerate electrons and positrons to about 250 GeV and smash them together at a rate of five times per second. Funding for the $8bn, 31 km-long collider has yet to be found, but Japanese particle physicists are already making moves to host this next-generation particle smasher.

Meanwhile, a design for a higher-energy machine – the Compact Linear Collider (CLIC) – that could operate at 3 TeV is being developed by a team at CERN. Construction of the ILC and CLIC could begin in the coming decade and they would, if built, study the Higgs boson in great detail through the "clean" collisions that can be made from colliding electrons and positrons rather than smashing protons together.

Yet it remains unclear whether these machines will be built and physicists have recently been coming up with other proposals that involve circular colliders similar to the LHC. "We need to keep our options open about what the next particle collider will be," says John Ellis of Kings College London, who has been involved in designs for particle colliders beyond the LHC and spoke at the meeting. "A bigger, more ambitious machine could offer us more capabilities."

One leading design for a next-generation circular collider is TLEP, which would be housed in an enormous new 80–100 km-circumference tunnel that would most likely be built in Geneva. It could initially collide electrons and positrons at energies of about 350–500 GeV. Most of the cost of such a machine would be in excavating the tunnel, with the accelerator itself only accounting for about one-third of the total. Yet that same 100 km tunnel could then be used well into the future, eventually housing a proton–proton machine that could operate at an energy of up to 100 TeV. Researchers are planning to complete a conceptual design study for TLEP by 2017 as an input to the next review of the European strategy for particle physics.

Blueprint for the future
An outline plan for a future tunnel in Geneva that could house a 80–100 km particle collider.

CERN

We need to keep our options open about what the next particle collider will be

Although Ellis admits that the 100 km tunnel would involve an "enormous investment", he thinks that the advantages would outweigh such concerns. Indeed, the 100 km tunnel could even be built so that it could allow two machines – one electron–positron and one proton–proton – to operate simultaneously, if needed. Ellis says that a preliminary engineering report has already been done on the 100 km tunnel and it threw up no "major show-stoppers", even if parts of it would be built underneath Lake Geneva. "The geology in the region is quite good for digging," adds Ellis.

Yet Lyn Evans, who masterminded the construction of the LHC and is now responsible for overseeing the development of the ILC and CLIC, says that, for the moment, the top priority for CERN is the full exploitation of the LHC and its luminosity and energy upgrade programme. "A machine of [TLEP's] size will have a very high cost, so there must be a very strong scientific justification and international support," he told *Physics World*.

Michael Banks

Feedback

Letters and comments that appear here may have been edited.
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Debating dark matter and modified gravity

In reply to Catherine Heymans' article "What is the nature of the dark universe?" (Features, October 2013 pp33–34).

Catherine Heymans' article assumes that dark matter exists. But until astrophysicists actually identify dark-matter particles, it is surely premature to declare that this is the case. The article also fails to mention alternative schemes, such as Modified Newtonian Dynamics (MOND), that do not require dark matter.

MOND was invented by Mordehai Milgrom, but he is only one of several authors who have criticized today's Standard Model of cosmology (known as the LCDM). Their criticisms include:

1. The Milky Way and Andromeda galaxies are accompanied by 24 and 28 satellite galaxies (give or take one or two each) all of which fall within thin discs. However, Benoît Famaey and Stacy McGaugh, astronomers from the Université de Strasbourg in France and Case Western Reserve University in the US, point out that the LCDM predicts 200–600 satellites, in a roughly isotropic distribution (arXiv:1301.0623).

2. Robert Sanders of the University of California, Berkeley remarks in a recent paper (arXiv:1311.1744) that the LCDM fails to account for the fact that the radii of galaxies vary as the fourth power of their mass. In contrast, this ratio follows naturally from MOND: Brent Tully and Richard Fisher found this relation in 1977, and MOND uses the Tully–Fisher relation to fit all galaxies using just one parameter known to 20% accuracy.

3. Pavel Kroupa and collaborators comment that the LCDM fails completely to explain polar ring galaxies (arXiv:1304.4931). Most galaxies appear as discs or spheres, but polar galaxies have two discs nearly at right angles to one another. These discs exert Coriolis forces on one another, like forces responsible for cyclones on the Earth. MOND fits polar ring galaxies accurately, but the LCDM predicts a spherical distribution.

4. I have published a model based on MOND that concludes that galaxies are controlled by quantum mechanics (arXiv:1304.7483; see also *Canadian Journal of Physics* **91** 668), and this scheme also makes a connection with dark energy. The conclusion is that galaxies are organized systems, and the pattern of their organization follows identical equations to those used in particle physics to describe mixing between the three known flavours of neutrinos and also mixing between quarks.

It is my understanding that there are many experiments currently being funded to look for dark matter, at a cost of roughly $200m each. In view of the large amounts of money being spent, a balanced view of the facts is essential. It would be valuable if astrophysicists and particle physicists could get together amicably to discuss these issues.

David Bugg
Queen Mary, University of London (emeritus)
david.bugg@stfc.ac.uk

Fergus Simpson (University of Barcelona, fergus2@icc.ub.edu) and Catherine Heymans (University of Edinburgh, heymans@roe.ac.uk) reply:

The points that Bugg raises primarily focus on issues relating to the nature of galaxies. The LCDM model, however, makes no concrete predictions regarding the properties of individual galaxies. To do so would require additional assumptions on galaxy formation, and this is an active area of research where a great deal of uncertainty remains due to the highly nonlinear processes involved.

If we wish to test cosmological theories of gravity, as we have done in a recent publication (*MNRAS* **429** 2249), it is essential to look on much larger scales. The smooth conditions of the early universe provide an ideal environment where precise theoretical predictions can be made, thereby providing a stern observational test for cosmological models. Exquisite measurements of the cosmic microwave background by the Planck satellite (arXiv:1303.5076) have provided us with strong corroborating evidence supporting the picture of a photon-baryon fluid oscillating in the gravitational wells of an inert dark fluid, which we call dark matter.

Further evidence of a distinct matter-like component comes from the aftermath of a collision between two clusters of galaxies (D Clowe *et al.* 2006 *Astrophysical J.* **648** L109). Their gravitational wells were found to be displaced from the bulk of the conventional matter. This is difficult to explain with simple modifications to gravity, yet is a natural consequence of a

More on that jellyfish

Leif Ristroph

This jellyfish-like flying machine (built by Leif Ristroph and Stephen Childress of New York University) can hover and stabilize itself in flight with no feedback control ("Flying 'jellyfish' is self-stabilizing", 16 January http://ow.ly/tl63X; see also p5).

Why use this to make a toy for kids? How about using it in real-world applications? How about using the energy created by its flying wings to generate wind for air ventilation for homes or to power up a small device? Start an idea-generating contest among kids and I am sure they will come up with a tonne of cool things.

Lucky Pataky
via *Facebook*

Most flying creatures have an active control system (the brain). This little prototype has no control system. It demonstrates one of the possibilities for living creatures to fly in an environment such as Jupiter's atmosphere – it would not have to be a "balloon creature", as has been proposed before. This is an amazing little achievement. I'd love to see if it could scale to something large enough for human flight.

edprochack
via *physicsworld.com*

collisionless dark-matter particle.

While we agree that a fair representation of scientific research and viewpoints is important, equally it would be misleading to suggest that a viable alternative to the dark-matter paradigm currently exists. Alternatives are indeed being investigated and developed, but they must be tested against a variety of observations before they can be considered to be on even terms. In itself, MOND is not widely regarded as a competing model, as it is incompatible with Einstein's relativity. Its relativistic extension, TeVeS, shows greater promise, but is a substantially more complex model with many free parameters. In contrast, the sheer simplicity of the LCDM model – which uses a single particle and a small cosmological constant to explain the geometry and large scale structure of our universe – is unrivalled.

As Bugg points out, a number of experiments such as SuperCDMS and LUX are currently attempting to directly detect dark matter as it passes through the Earth. Whether this strategy is viable hinges on whether the constituent quanta of dark matter are weakly interacting massive particles (WIMPs). While we cannot be sure that dark matter takes this form, the potential reward of discovering a new fundamental particle makes the decision to search an irresistible one. Failure to make a detection would represent a failure of the WIMP conjecture and not dark matter as a whole. To demand direct detection as a necessary requirement would be to deny a number of great scientific discoveries, from planets orbiting other stars (M Mayor and D Queloz 1995 *Nature* **378** 355) to the existence of gravitational waves (R A Hulse and J H Taylor 1975 *Astrophysical J.* **195** L51).

A case for quantum parallelism

In reply to Philip Ball's article "Questioning quantum speed" (Features, January pp38–41).

I was surprised to read Ball's article on the possible ways in which quantum computers achieve their vaunted processing speeds. Whether the reason is quantum parallelism, entanglement or contextuality, we can be certain of one thing: classical computation processes proceed in our familiar 3D space, whereas quantum computation takes place in the much higher dimensional configuration space or state space.

There is now no doubt that the quantum wavefunction is an objective physical entity (M F Pusey *et al.* 2012 *Nature Phys.* **8** 475). In other words, the wavefunction is "ontic", and for any object that is known to be ontic, logic dictates that we can make the same claim for the space in which it resides – in this case the configuration space. As any physicist knows, the dimensionality of multi-particle configuration spaces can be vast. And by definition the simultaneous eigenstates of any quantum algorithm exist at different locations within that configuration space.

I believe that David Deutsch (whose views were mentioned in Ball's article) is generally correct in his claim that quantum parallelism is real. Once we accept this broader view, only then do we need to worry about such finer details as entanglement and contextuality.

Jim Austin
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Impressive ice spikes

In reply to David Appell's article "When ice grows up" (Lateral Thoughts, February p52).

I was fascinated by this article, especially as it seems to explain a phenomenon that occurred in our bird bath a few years ago, and which had everyone baffled (see photo, right). The bird bath's internal diameter is 33 cm, so the length of the "sculpture" is about 16 cm. I assume the weird shape of the spike was caused by the wind?

David Briers
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David Briers

Spiked David Briers' bird-bath phenomenon.

However, the ellipse can be accurately approximated by a parabola near its turning point.

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Watt an imagination

In reply to Francis Farley's letter on "Imagination in science" (Feedback, February p20).

I agree with Farley's comments on the importance of imagination in science. However, it is interesting that the first name he quotes in order to justify them is that of James Watt. It is not clear that Watt's achievements were any more revolutionary than those of his predecessors or his successors. Surely the greatest breakthrough was that of Thomas Savery in conceiving of a steam engine in the first place, closely followed by Thomas Newcomen's injection of cold water to condense the steam, thereby speeding up the cycle. Watt, in contrast, only made incremental improvements to Newcomen's engine, such as the introduction of the separate condenser.

It is true that the "expansive principle" was Watt's idea, though apparently he made little use of it. And most tellingly of all, the "imaginative" Watt shied away from the next great breakthrough – making the steam engine small enough to be put on wheels by using high-pressure steam, thus ushering in the age of railways. It is a travesty that Richard Trevithick, who did embrace this revolutionary idea, was rewarded with relative obscurity.

Jim Grozier
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Approximately correct

In reply to Max Tegmark's article "It's all just mathematics" (Features, February pp22–27).

Tegmark is wrong to state (in the caption to figure 1) that the trajectory of something thrown in the air is an upside-down parabola. It is an ellipse – the same as an object in a gravitational orbit.

Great balls of fire

In reply to the *physicsworld.com* news article "Burning soil fuels ball lightning" (9 January, http://ow.ly/tl8aO) on evidence that a burning core of soil acts as an energy source for ball lightning.

This mechanism does not readily explain reports of ball lightning that claim it is formed within enclosed spaces such as aircraft or buildings.

Mark Stenhoff
via *physicsworld.com*

Is it possible for nuclear fusion to occur with the energy of lightning?

reader01
via *physicsworld.com*

The idea has been suggested, for example by J R Roth (*Fusion Science and Technology* **27** 255). The current level of knowledge on the subject is insufficient, though. It would be important to be able to produce long-lifetime ball lightning at will in the laboratory, and then see if the necessary temperature and density for thermonuclear reactions can be reached. Then, we must also remember that it isn't enough to prove you can get fusion reactions – you also need to produce more power from them than you put into the system.

On the other hand, the idea of producing fusion reactions in discharges on high-pressure gases was explored in the 1980s. It was called the "gas embedded pinch", and was followed by discharges on solid fibres. In both cases, instabilities didn't allow the necessary conditions for thermonuclear reactions to be reached, although the results were quite interesting.

jjeherrera
via *physicsworld.com*

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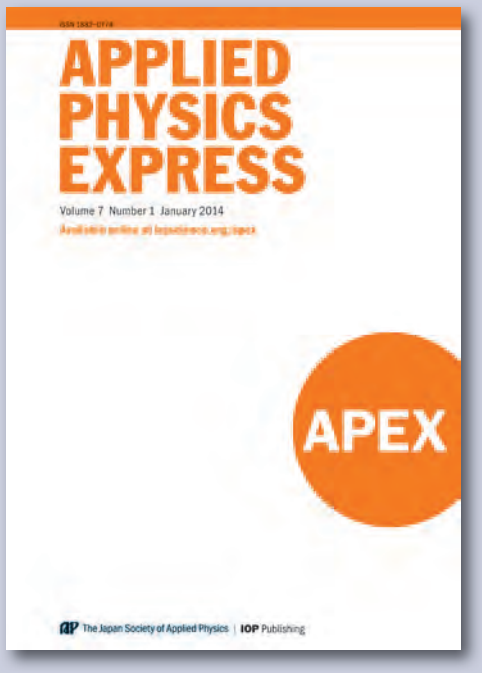

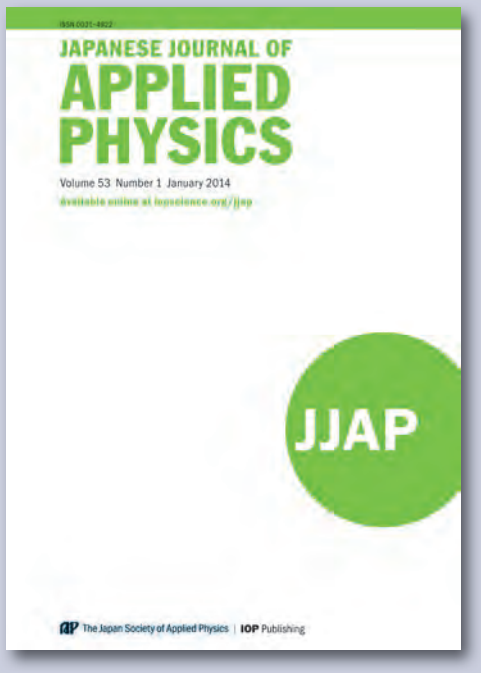

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Subscription information 2014 volume
The subscription rate for institutions is £355 per annum for the magazine, £674 per annum for the archive. Single issues are £34. US orders to: IOP Publishing, PO Box 320, Congers NY 10920-0320, USA (tel: 800 358 4677 (toll free) or 845 267 3018; fax: 845 267 3478; e-mail: ioppublishing@cambeywest.com). Rest of world orders to: Subscriptions Dept, IOP Publishing, Temple Circus, Temple Way, Bristol, BS1 6HG, UK (tel: +44 (0)117 929 7481; fax: +44 (0)117 929 4318; e-mail: custserv@iop.org). *Physics World* is available on an individual basis, worldwide, through membership of the Institute of Physics

Bibliographic codes ISSN: 0953-8585
CODEN: PHWOEW
Printed in the UK by Warners (Midlands) plc, The Maltings, West Street, Bourne, Lincolnshire PE10 9PH

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Lessons for learning

This special issue looks at some innovative ways to teach and learn physics

"Why don't scientists behave more like scientists when it comes to education?"

It's an interesting rhetorical question that was put to me when I caught up recently with a senior figure from the world of physics education. The comment reminded me just how easy it is for us to ignore the evidence of how people best learn physics, despite physicists undoubtedly being proponents of evidence-based reasoning. The temptation, particularly at university level, is to teach the way one was taught, even if those methods weren't particularly good.

There are, though, some amazingly effective educators, and this special issue of *Physics World* offers a snapshot of just some of the many innovative ideas that exist for learning and teaching physics. It's not an exhaustive selection, but includes topics that we simply felt were interesting or novel. For example, we examine the huge growth of "massive open online courses", or MOOCs, in which universities make their lectures freely available in video form on the Internet (pp43–45), while Philip Moriarty, a condensed-matter physicist at the University of Nottingham, describes his experiences as one of the stars of the Sixty Symbols series of *YouTube* science videos (pp31–34).

Elsewhere, we look at the importance of giving children computer-programming skills from an early age (pp27–29). There's also a great feature by BBC science presenter Fran Scott, who reveals her golden rules for engaging children with science (pp36–39), while Eugenia Etkina and Gorazd Planinšič examine the implications for teachers of the fact that learning involves physical changes in the brain (pp48–51).

And if you're a student who's tired of writing notes in lectures, then how about drawing pictures instead? It's a technique that professional "doodler" Perrin Ireland uses, and to show you how it works, we asked her to "doodle" notes for the video of a lecture given by the inspirational Richard Feynman in 1964 (pp40–41). We'll never know but my bet is he would have been amused.

Matin Durrani
Editor, *Physics World*

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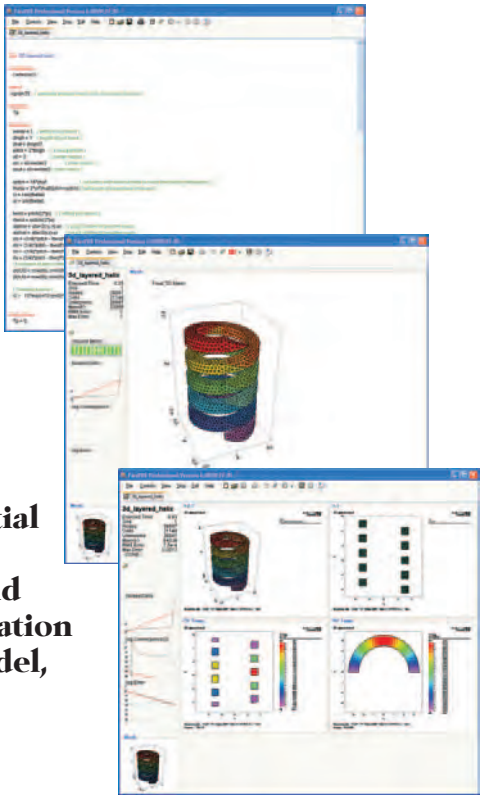

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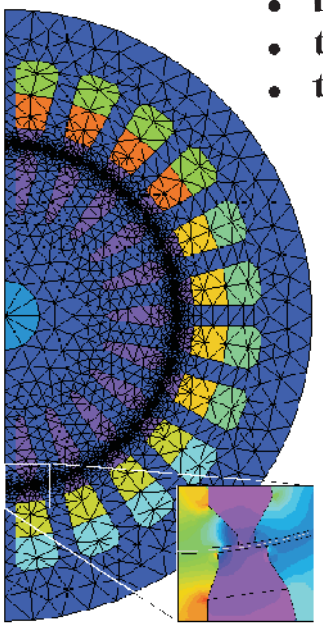

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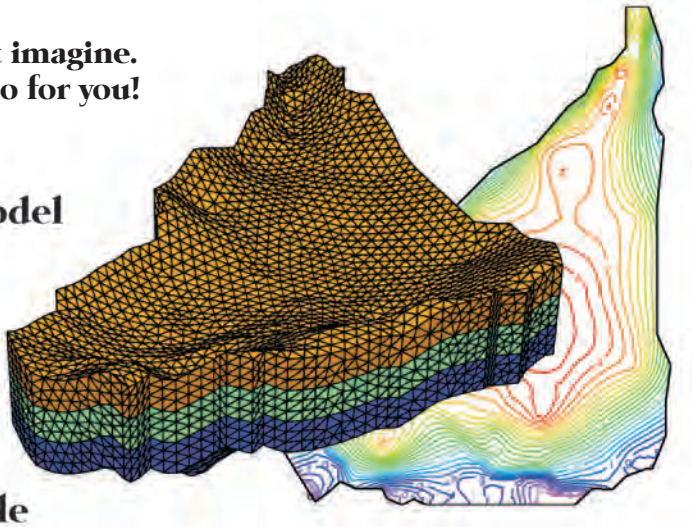

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Taking modern physics into schools

Having helped to introduce a new curriculum in Scottish schools that showcases the latest physics research, **Martin Hendry** describes the lessons learned in bringing cutting-edge physics into the classroom

Jesse Karjalainen

Prisms to particles The new Scottish physics curriculum incorporates hot topics such as the Higgs boson.

We are living through an exciting time for physics, especially in the "big science" fields of cosmology and particle physics. There was last year's exquisite mapping of the cosmic microwave background radiation by the Planck satellite, which came hot on the heels of the ground-breaking discovery of the Higgs boson at CERN's Large Hadron Collider in 2012 and the 2011 Nobel Prize for Physics for the discovery that the expansion of the universe is accelerating.

Yet contemporary ideas such as dark energy, which was invoked to explain the accelerated cosmic expansion, present something of a dilemma for physics educators. On the one hand these concepts are intriguing and thought-provoking, inspiring pupils to study physics beyond high school (and maybe even pursue a career in the subject). On the other hand, even the most passionate advocate of modern cosmology would surely not argue that our ideas about dark energy are as well founded and fully established as, for example, Newton's laws of motion (even if Newtonian physics is itself an approximation to reality – albeit a remarkably successful one). So where do you draw the line in designing the school syllabus? Should there be a place for contemporary research – however speculative – in the physics curriculum?

From dark energy to transiting exoplanets

Significant developments in school education in Scotland over the past few years have given me the opportunity to look at how best to showcase modern physics research in the classroom. This work has resulted in the new "Curriculum for Excellence" which will be fully introduced in Scottish schools over the next couple of years. Although the curriculum is a Scottish initiative, I believe there are some important universal lessons that those in all nations can learn.

In the words of Education Scotland, the curriculum "aims to achieve a transformation in education in Scotland by providing a coherent, more flexible and enriched curriculum from three to 18". In the sciences the enriched curriculum should enable pupils to demonstrate a knowledge and understanding of the big ideas and concepts in physics, develop the skills of scientific enquiry and investigation using practical techniques, and recognize the role of creativity and inventiveness in the development of the sciences.

My personal involvement in the new curriculum has focused on trying to put these lofty goals into practice, particularly for the senior phase of school education: the Higher and Advanced Higher syllabus that is normally studied by pupils in their fifth and sixth years of secondary school. This has not yet been fully implemented because the pupils undertaking the new programme are still working their way through the lower secondary stages. But for several years a revised Higher and Advanced Higher physics syllabus, based on some of the concepts from the Curriculum for Excellence, has been available to "early adopter" schools (nearly 10% of all physics pupils taking these exams in Scotland in 2013). This has provided a vital test bed for some key elements of what will shortly become the Curriculum for Excellence Higher and Advanced Higher physics syllabus adopted by all schools.

For example, in the revised Higher and Advanced Higher curriculum, pupils now study a unit entitled "Our dynamic universe". This incorporates elements of cosmology including a review of evidence for the Big Bang, dark matter and dark energy, as well as a look into the Standard Model of particle physics, the astrophysics of stars, and an introduction to special and general relativity. The material concentrates on the big picture rather than lots of details. The aim is to challenge and enthuse pupils, giving them a sense of how our understanding of these fields has changed and continues to change – and to highlight the deep, philosophical questions about the origin of the cosmos and our place within it that these fields are seeking to address.

Another key element of the revised Higher physics syllabus is the "Researching physics" unit. This is a 20-hour module where pupils research the physics underlying a topical issue, which involves planning and carrying out their own practical investigations, and preparing a communication (usually, but by no means always, a written report) that summarizes their findings. Among the topics that have proven popular for this unit is the search for extrasolar planets. Alongside Internet research and the use of simulation software from the website of NASA's Kepler satellite, for example, pupils in a number of schools

have built their own classroom-based planet-transiting experiments using nothing more hi-tech than a household lamp, a simulated cardboard "planet" and a simple digital lightmeter.

Of course, the accommodation of this new material has required some reorganization of the current syllabus, with some topics being moved to the lower secondary years and others (such as analogue electronics) removed altogether. However, the number of topics in the latter category is very small owing to a general "decluttering" of the syllabus, shifting the focus from specific pieces of factual knowledge to more emphasis on method and the scientific process.

Should there be a place for contemporary research – however speculative – in the physics curriculum?

Enthusing students

To date, the results of these changes – in terms of pupil engagement and enthusiasm – appear to be very encouraging. The introduction of the new curriculum has prompted a subtle shift in science teaching from focusing on what we know to how we know it. By learning something about the latest discoveries in fields such as cosmology and particle physics, pupils are gaining valuable insight into the process of science, and how contemporary theories are being tested by observation and experiment.

Indeed, in the past three years I have visited many of the schools whose pupils are undertaking the revised syllabus, and have held numerous workshops and Q&A sessions with their teachers. From secondary schools in the Hebridean islands to inner-city schools in Glasgow and Edinburgh, I have seen first-hand the tremendous enthusiasm and ingenuity of these early adopters, and the practical activities that they have introduced to support the new syllabus. I have also witnessed the enthusiasm of the pupils as they engage in the classroom with the same cutting-edge physics topics they see featured on television and the Internet – from the Higgs discovery to the mysteries of dark energy. They seem to be entirely comfortable with a physics landscape in which there are more questions than answers.

The implementation of the new curriculum has been far from smooth and serious concerns remain among Scottish physics teachers about assessment arrangements for the new national qualifications, and the degree of guidance and support that is provided by the education authorities. However, my overall impression is that the content and ethos of the new syllabus – and in particular the "Researching physics" module and the revised elements of "Our dynamic universe" – have been very popular with the early-adopter schools. As the Curriculum for Excellence Higher and Advanced Higher physics syllabus rolls out across all schools in the next few years I hope that this trend will continue and a new generation of budding physicists will be inspired as they explore the very latest contemporary discoveries.

Martin Hendry is a cosmologist at the University of Glasgow, UK, where he is also head of the school of physics and astronomy, e-mail martin.hendry@glasgow.ac.uk

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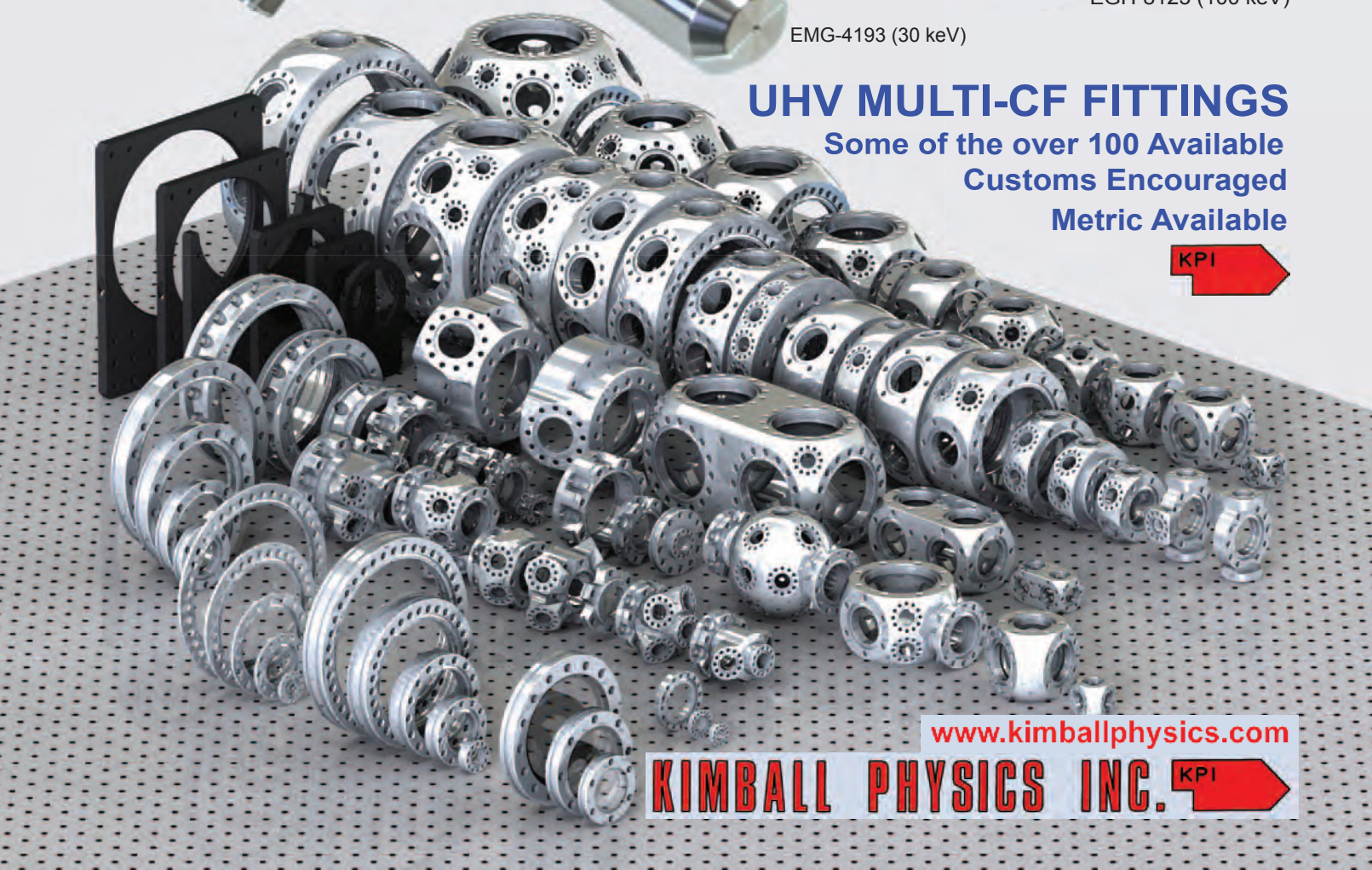

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Critical Point Feynman's failings

They were never successful as a textbook. So why, a half-century after their publication, do so many physicists keep Richard Feynman's three volumes within reach? **Robert P Crease** has a theory

Richard Feynman's *Lectures on Physics* were the centrepiece of an innovative experiment in physics education half a century ago at the California Institute of Technology. Rapid changes in physics, and improvements in high-school science and mathematics education following Sputnik, made Caltech's educators aim high. They wanted to stop using textbooks as the primary material for the first two years of college physics and instead teach it through a series of original lectures. While the initial idea was for all faculty to share the lectures, Feynman was eventually chosen to deliver them entirely himself, which he did in 1961–1962 and 1962–1963. Audio (but not video) recordings were made, and other faculty transcribed the lectures, intending to edit them into a new textbook.

Things did not go as planned. The editing process was gruelling and required, as the editors reported in their foreword, "the close attention of a professional physicist for from 10 to 20 hours per lecture". Even then, the editors were dissatisfied with the "completeness, smoothness, or logical organization" of their product. But they decided to publish anyway.

Finding a publisher was easy. Feynman's Nobel prize was still a few years off (1965), but his reputation as a teacher was already established. The *Lectures* – with their classic red covers – were published by Addison–Wesley in 1964 and have never gone out of print, selling hundreds of thousands of copies. The original audio versions are also available.

For several years after the *Lectures* were published, a few people tried to use them as a textbook, including Caltech physicist David Goodstein. "It didn't work," he recalls. "I tried hard. But they're too sophisticated." Goodstein came up with his own undergraduate course instead, and co-authored *The Mechanical Universe* (1986) – a textbook that was not only used successfully but turned into an educational TV series.

So why does everyone still have and consult the *Lectures* if they failed at their original purpose?

Steve Trevett

Encapsulated genius Feynman's original set of lectures have stayed in print for 50 years.

Magician's secrets

I asked Daniel Kleppner, an emeritus professor of physics at the Massachusetts Institute of Technology (MIT), who once tried to incorporate several of Feynman's lectures into a course on mechanics. Kleppner didn't use Feynman's original lectures, which had only been audio recorded, but films of a later series he gave at Cornell University in 1964. Things didn't work out. "It went over like a lead balloon," Kleppner says. "The students needed the personal relationship. Even though it was an old-fashioned lecture format, they preferred me in person to Feynman in a movie."

Inspired by Feynman's example but tapping his own experiences, Kleppner then wrote a textbook with his colleague at the time Robert Kolenkow. Entitled *An Introduction to Mechanics* (1973), it really was, and still is, used to teach MIT undergraduates; a second edition is being reissued this year. And that's the point. As Kleppner explains, the Feynman books are a major contribution to physics education – but for faculty, not students. "He was a magician and his lectures are a handbook of magician's secrets," he says. "They are not too difficult for undergraduates like Feynman – except there are none!"

In 2009 Microsoft Research put Feynman's Cornell lectures (entitled *The Character of Physical Law*) on a special video platform together with commentary by MIT professor Robert Jaffe. These lectures are shown at MIT every January and attract a healthy student audience. But Jaffe finds these lectures are even more valuable as a model for teachers. "It's one of the great physics personalities at his best – a stunning theatre performance," Jaffe told me. "We see how Feynman uses his body, and brings the audience along with him. If all of us could stand before students with Feynman's personality and dynamism, we'd all be better teachers!" Jaffe has tried to channel some of that energy in a forthcoming text of his own, *The Physics of Energy*.

The critical point

Still curious about why Feynman's *Lectures* had managed to fail as a textbook yet inspire so many others, I asked people if they had ever heard of criticisms. Most were stumped. Several recalled hearing that the historian of science Paul Forman had criticized Feynman for being "too much fun". Forman was amused when I mentioned this to him, and sent me a copy of the 1991 article containing the brief remark that had evidently triggered that memory (*Isis* **82** 71).

Forman's article is about what he called "transcendence", or the temptation of some scientists and other scholars to see themselves as beyond ordinary morality just because they work in a "transcendent world of intellectual or aesthetic ideas and ideals" – in other words, as if they had reached a higher plane of existence. Almost as an aside, he mentioned Feynman, who though "avowedly deficient in his sense of social and personal responsibility", was still able to be "regarded by his fellow physicists as an eminently moral character" for the simple reason that he was so "manifestly devoted to physics, indubitably getting 'fun' out of it."

Forman's provocative article is about something different – but his off-hand remark about fun is revealing, and a clue to what makes Feynman's *Lectures* so compelling and inspiring. Getting fun out of explaining and doing your work is not just a pose that teachers put on to charm students, but a sign of mastery of the material. The trouble is that Feynman's conceptual engagement was a notch above the undergraduate audience. The strength of the Feynman *Lectures* – their conceptual sophistication and ability to draw imaginative connections between topics in physics – is also their weakness for undergraduates, who need to understand those topics first. That's why, though written as an undergraduate textbook, the *Lectures* turned out to be more useful for teachers.

Robert P Crease is a professor in the Department of Philosophy, Stony Brook University, US, and co-editor-in-chief of *Physics in Perspective*, e-mail robert.crease@stonybrook.edu

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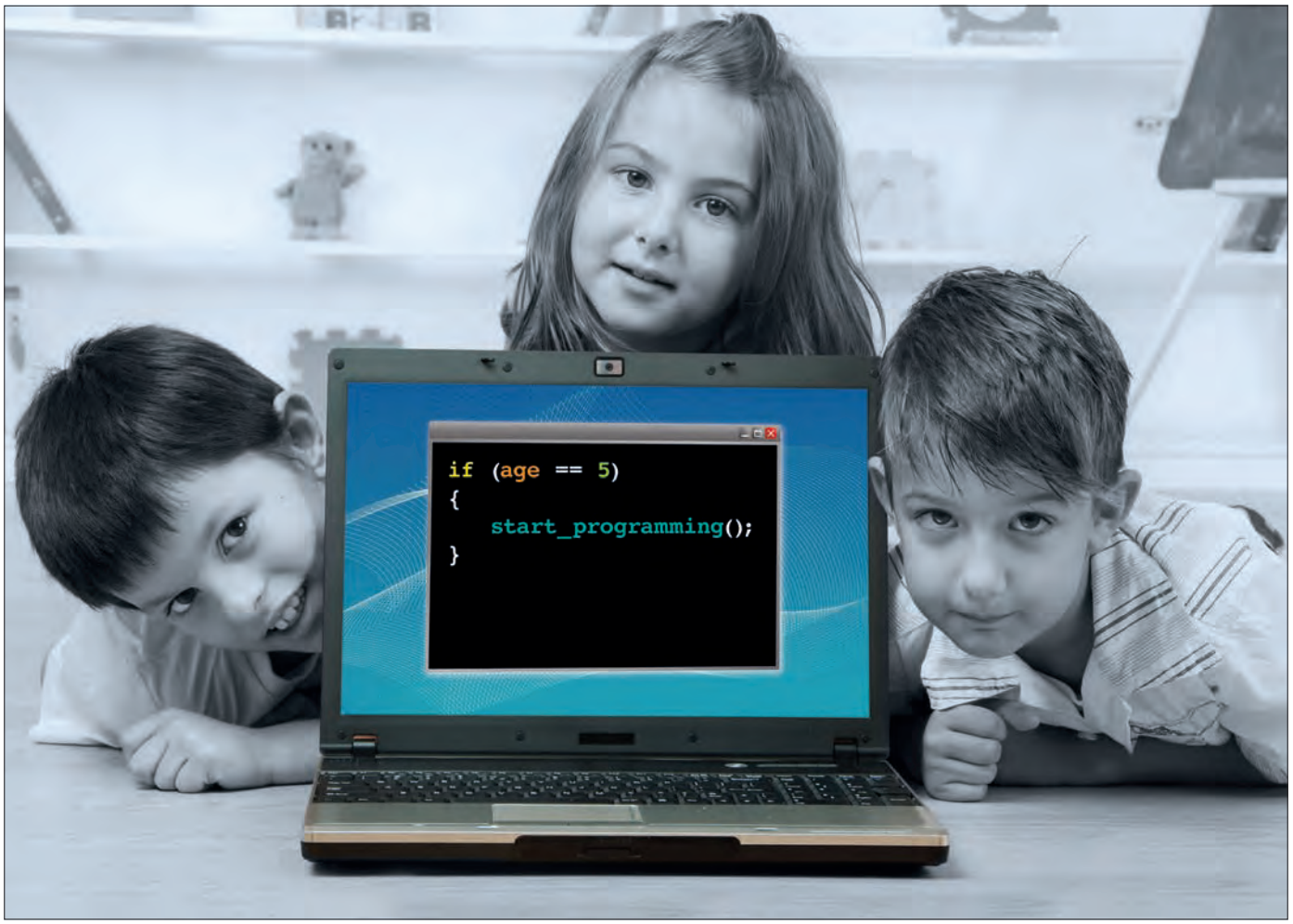

Computing in the classroom

Computer science is essential for modern physics, yet students come little prepared for it. That may soon change, says **Jon Cartwright**

Particle physics 40 years ago was a slow process. Collisions had to be recorded on black-and-white photographs, which were then pored over by hundreds of technical assistants. This was true even of (for the time) cutting-edge accelerators such as CERN's Big European Bubble Chamber, which took images every three seconds.

Today it is a very different story. Inside the Large Hadron Collider (LHC) at CERN, for instance, collisions occur every 25 nanoseconds. Data generated at such rates have to be processed by a network of powerful computers around the world. But particle physics is far from being the only field within physics that makes use of high-level computing. From simulating the behaviour of cold atoms to designing control systems for complex equipment, computing has become not an optional but a necessary activity.

"Physicists have always been fairly technically savvy, always been keen to use computers," says Joel Goldstein, a particle physicist at the University of Bristol in the UK who works on the Compact Muon Solenoid experiment at the LHC. "As computers have evolved, it's become almost impossible to design any experiment now that doesn't use a computer. Even our simple undergraduate lab experiments have computers to do the hard chores, such as data logging. You're taking data every few seconds. Why not get a computer to do that, so you can have a cup of tea?"

Yet despite the thorough dependence of modern science on computing, few physics students gain any proper understanding of it before university. Indeed, many undergraduates are unaware that computing is a part of daily research, or that almost all working physicists are fluent in at least one programming language. Goldstein, who used to teach undergraduate programming at Bristol, says that many new phys-

Jon Cartwright is a freelance journalist based in Bristol, UK, http://jcartwright.co.uk

Allen Heard

Learning through play Lincoln, four-year-old son of Allen Heard (head of computing/IT at Ysgol Bryn Elian in North Wales), working on using his Raspberry Pi as a webcam server for an insect habitat.

ics students are "taken a little bit by surprise" by what is in store. "We teach them from the ground up," he says. "And we have to, because the range of abilities is huge. We get some people who have done programming as hobbyists and can code in their sleep, but there are others who have barely written a Word document."

Students do not have only themselves to blame. While some countries have long had computer science on the school curriculum, others give students little if any teaching in the subject. In the UK, for example, the vast majority of teaching about computers has focused on information and communication technology (ICT), a relatively lightweight subject that focuses on consumer-level applications of computing, such as communication, e-commerce and office software. ICT has for many years been a mandatory part of the UK National Curriculum, with very few students opting to take GCSEs or A-levels in actual computer science, or "computing" as the subject is known to UK exam boards.

Educators have been putting increasing pressure on governments to treat computer science as a unique subject discipline – one, like physics and maths, that can improve problem-solving skills

But the disparity in computer-science education is changing. Educators have been putting increasing pressure on governments to treat computer science as a unique subject discipline – one, like physics and maths, that can improve problem-solving skills. If these educators are successful, undergraduate physics students will be better prepared for their physics courses – and may become better physicists as a result. "It will save us time and effort in the basic computer courses," says Goldstein. "We'll be able to start from a higher level, and go to a higher level."

A new discipline

Computer science is the science of how computers work, how they are programmed, and what they can and cannot do. It goes back to the earliest computers – arguably as far back as the early 19th century and the work of the British polymath Charles Babbage, who invented the first mechanical computer. As an academic discipline, however, computer science only began to emerge in the 1950s. In 1953 the University of Cambridge in the UK began offering the world's first year-long course in computer science, which ran until 2008. In 1962 the first computer-science degree programme in the US was offered by Purdue University in Indiana – although even at this time there was still scepticism among academics that computing was a science.

No such scepticism exists today, but while computer science is widely read at university, and included in many degree courses such as physics, it is still little-taught at school. Perhaps the most prominent exception is Israel, which took an educational review at the turn of the century and now teaches computing as a fully fledged scientific subject, focusing on the key concepts and foundations of the field. Indeed, it has the most rigorous computer-science high-school programme in the world, according to a 2011 report by Microsoft Research UK that compared the international teaching of computer science. Israel's programme comes in short or long versions, which are both elective. Still, even the long version is taken annually by 7000 students – the same number who opt for physics. "Israel has been the model country for many years," says Chris Stephenson, executive director of the US Computer Science Teachers Association.

Stephenson says that a few other countries, such as Estonia, New Zealand and China, are beginning to take computer science more seriously. But in Stephenson's own country – the US – the situation is mixed. Part of the problem in the US is that education is largely controlled not by federal government but by individual states, or sometimes even by individual districts. Some states, such as Texas, have been rated highly for their computer-science standards, teaching and assessment. But many others are lagging behind. "The biggest challenge for the US is access to rigorous computer-science courses," says Stephenson. "Far too many schools offer no computer science or low-level 'point and click' applications courses. This is especially true in high-poverty schools."

Many educators in the US are trying to even the playing field. The non-profit organization Code.org

recently launched a video featuring celebrities such as Shakira, Ashton Kutcher and Barack Obama, encouraging people to attempt one hour of programming using tutorials on its website. Meanwhile Code.org's sister organization, the advocacy group Computing in the Core (CinC), has introduced bills into the House and Senate that will make computer science a core subject, like physics, in the hope that this will make it easier for schools to introduce computer science on their curricula. It has also persuaded more US states to recognize computer-science credits as counting towards high-school graduation. "Computer science hasn't always counted in the same way as maths or science," says Della Cronin, a spokesperson for CinC. "We feel that has diminished demand among students, and made it difficult to invest in computer-science teachers."

Pressure from non-governmental organizations can pay off. Last year, the UK government announced that from September, computer science proper, including programming and the theory of computing, will form a mandatory part of the National Curriculum, taught from Key Stage 1 (pupils aged five) onwards. It was a breakthrough due in no small part to input from societies such as Computing at School and the British Computing Society (BCS). "I believe that Britain's move from an ICT-focused curriculum to a computer-science curriculum is quickly moving Britain to the front of the pack," says Stephenson.

Starting young

Pupils learning computer science from age five, when previously they may never have learnt it at all, is a radical step. But it is both achievable and welcome, according to Bill Mitchell, the director of the BCS Academy of Computing, which promotes computing as an academic discipline. Mitchell says that young children can learn the basics of programming visually using software such as Scratch, which is produced by developers at the Massachusetts Institute of Technology in the US. In Scratch a pupil can, for instance, create a cartoon fish, rotate it and make it avoid other objects, using simple commands and without directly executing any actual code. "We were told [by primary school teachers] that when they teach programming to pupils aged 5 to 11, they are actually very good at it," says Mitchell. "What's more, if you do it in the right creative way, they really enjoy it, and it helps them develop intellectually. It's a win–win situation."

All this bodes well for physics, which increasingly depends on technology. "Physics certainly relies on computer science quite heavily these days, particularly when you consider particle physics, where the search for elusive particles would be impossible without the use of high-performance supercomputers," says Dennis Frailey, vice-chair of the Institute of Electrical and Electronics Engineers (IEEE) Computer Society Educational Activities Board. "And it's certainly true that advances in meteorology, such as weather reporting and climate modelling, have been substantial in the last few decades, mostly due to computers."

If there is one development that has truly highlighted the desire for greater computer-science teaching, however, it is the Raspberry Pi. Inspired by the BBC Micro, a teaching computer that graced many British school classrooms in the 1980s and 1990s, the Raspberry Pi is a credit-card-sized computer designed to encourage the learning of computer science the world over. Its developer, the UK Raspberry Pi Foundation, first started selling its units in 2012 for $35, and since then has sold more than two million.

The Raspberry Pi has led many people to rediscover programming who played with it in their youth. More importantly, it has led to an upsurge in programming among young people, including those planning to study physics (see box above).

Back at Bristol, Goldstein reveals that his 13-year-old nephew is also a "huge Pi fan". "He is making Raspberry-Pi-controlled cars and things like that," he says. "He's picking up all these skills. And if we get a good core of highly interested students with these skills, these are people who are going to have a massive head start when they get to university." ■

The power of the Raspberry Pi

Samuel Bancroft

The power of the tiny Raspberry Pi computer to encourage programming is obvious from the story of three sixth-form students at William Howard School in Cumbria, UK, who in June 2013 launched a helium-filled weather balloon with a payload of scientific instruments, all of which were controlled by this device.

The students – Samuel Bancroft, Ben Bancroft and Jake Greenwood – say their school does not offer computer science as a subject, and that they did not receive any help for their experiment. Nevertheless, they say they had interests in both physics and computer science, which the Raspberry Pi allowed them to pursue creatively.

In an e-mail to *Physics World*, the students described their experiment, which reached an altitude of more than 31 500 m. "The measurements we obtained certainly gave us an idea of the hostile conditions present at such a height," they wrote. "The pressure was as low as 0.88% of ground-level pressure at peak altitude. Temperature also fluctuated dramatically. We took especial interest in our ionizing radiation readings, which we took using a Geiger–Müller tube. The measurement for our radiation (measured in counts per ~20 seconds) increased dramatically beyond 4 km, before reaching a peak at 24 km. Beyond this point it then decreased with increasing altitude. It was these data that we found fascinating."

The data were so great, in fact, that they will be published in the journal *Physics Education* this month.

The power of *YouTube*

Brady Haran

As one of the presenters of the hugely successful Sixty Symbols series of *YouTube* science videos, **Philip Moriarty** describes his experiences in front of the camera and how they have transformed his ideas about bringing physics to wider audiences

"No, put the pen down. No equations."

"But. But. But…"

Asking a physicist to forgo mathematics when explaining a particularly challenging concept is always going to lead to some consternation – as is obvious from my response above to film-maker Brady Haran's request. And this wasn't the first time that we'd argued this point. Haran put down his camera and made his point. Again.

"Start writing equations and you might as well speak in a completely different language – you're going to lose most of the viewers."

Sighing, I countered that explaining physics without including at least a sprinkling of maths was selling the viewer short. "Brady, it's like the difference between listening to a guitarist playing alone compared to the music they create as a member of a band," I argued. The interplay of the instruments completely changes the perception and impact of the song, I reasoned, adding that maths similarly adds that extra dimension to the physics. (I'm rather keen on the links between music and physics and maths – see box on p32.)

But Haran was having none of it. "No, it's like explaining Shakespeare to a non-English speaker," he replied. "Sure, they miss out on the true beauty and cleverness, but at least you can tell them the story and why it's so important. Stubbornly reading them *Hamlet* in English will achieve nothing."

This type of exchange is par for the course when making videos with Haran – the exceptionally talented and remarkably prolific film-maker and journalist behind a slew of very successful science-related *YouTube* channels. His films include the physics-focused Sixty Symbols series, Periodic Videos (covering all 118 known elements), Numberphile and Computerphile (about mathematics and computing, obviously) and the forerunner of them all – TestTube

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The picture above shows the author making a video with Brady Haran for *Physics World*, which you can watch in our digital edition

Where heavy metal meets maths (and physics)

Jeremy Kalgreen, available at monstersofgrok.com

If there is one thing I have learned from the last 15 years of teaching undergraduates, supervising PhD students and co-ordinating physics postdocs, it's that a Venn diagram of physicists and fans of heavy-metal music (and its plethora of sub-genres) has quite a large overlap. I'm certainly not the first to have noticed the link – just visit the excellent *Monsters of Grok* website to see the huge range of T-shirt designs that rather niftily combine the names of famous physicists and the logos of popular rock and metal bands. I particularly like the Gauss/Kiss design, the Newton/Iron Maiden hybrid and the Sagan/Slayer crossover (see above).

Given this connection, I regularly try to brow-beat Brady Haran into doing videos that incorporate some aspect of metal into our descriptions of maths and physics. For example, we have made a music video on the Numberphile channel with the multi-talented Dave Brown, which involved writing and recording a "math metal" song whose riffs, rhythms, lyrics and "sound effects" have been derived from the digits of the golden ratio, ϕ. Meanwhile, Sixty Symbols has videos on the physics of mosh pits, and the relationship between the wah-wah pedal used in rock guitar and Fourier analysis.

Another idea that we are developing (and which the UK's Engineering and Physical Sciences Research Council has agreed to fund) is a song and video based on the Schrödinger equation: what better *aide-mémoire* for students studying quantum physics than to have it as part of the lyrics to a metal song? In fact, the response to the metal–physics theme has been extremely encouraging: our videos have so far attracted almost half a million views and the comments on them have been overwhelmingly positive. Their aim is not just to preach to the converted, but to encourage an interest in maths or physics among those who may not have thought about the subject before.

We've certainly made at least one convert who posted this comment under the golden-ratio video: "I think you just tricked me into liking math. Clever bastards."

("videos behind the scenes in the world of science").

Haran's motivation for making videos has always been to connect viewers with scientists much more naturally than is the norm with traditional media – to provide a "window" into a scientist's world. His videos are raw, honest and direct, lacking the "corporate sheen" that so many science films veer towards. It is an approach that has proved incredibly popular: at the time of writing, the subscriber base for all of Haran's channels is over two million, and his videos have been viewed a total of 155 million times – and rising fast. Haran has the uncanny ability to know exactly what will work, and what won't, in the videos he makes. (And he almost always wins in spats like the above.)

Daunting and rewarding

Having worked with Haran since 2009 and featured in some 45 of his videos, the experience has transformed my ideas on public engagement and outreach. A big challenge when communicating physics concepts and ideas via *YouTube* is the diversity of the audience, which ranges from academics, subject experts and teachers to students, school pupils and those with no background in science at all but an intense interest in it. And from comments left beneath the videos – as well as via social media, e-mails and face-to-face conversations – we know that viewers range in age from five to at least 75.

This wide spread in backgrounds and ages, which is very different from that in a typical university lecture theatre, means that making *YouTube* videos is extremely rewarding but also rather daunting. Just how should we pitch our explanations? To make matters worse, the first time my colleagues or I get to see the final video is generally only once it has been uploaded to *YouTube*. Our lack of involvement in the editing process makes some sense – it lets Haran get his films out quickly and give them a tighter focus than if we were constantly sticking our noses in. But because the subscriber base for each of Haran's channels runs into the hundreds of thousands, once we watch the video it can easily have already picked up thousands of views and hundreds of comments. Any verbal slip-ups, perceived or actual, can be rapidly subjected to intense scrutiny by the *YouTube* audience. And they take no prisoners.

But as Haran and my colleagues at the University of Nottingham describe (see box on p34), the benefits of communicating physics via *YouTube* generally far outweigh the occasional discomfort of a small number of negative viewer comments. They also compensate for the irritations of the "trolls" who populate any online forum, and the many e-mails we receive written in various weird and wacky fonts – almost always with a liberal smattering of BLOCK CAPITALS – which claim that the correspondent has discovered a new and astounding grand theory of everything and that [insert world-renowned physicist of choice] had got it all wrong.

Nagging reservations

Yet in spite of the benefits it brings, I do have some nagging reservations about online education, both via *YouTube* channels and through massive open online courses (or MOOCs) (see "the MOOC point" pp43–46). I think we need to temper our enthusiasm for online education with some healthy scepticism about the extent to which actual learning is taking place. Enthusing and engaging viewers is exceptionally important (and fun), but learning is a complex and messy business that needs at least as much effort from the student as from the teacher. Indeed, Frank Noschese – a physics teacher at John Jay High School in New York – has gone as far as describing education via video (including the work of the extremely popular Khan Academy channel) as "pseudoteaching" because students do not actively engage with the material.

This is obviously a deeply contentious issue, particularly among the growing *YouTube* education community (and I'll return to it later). But what's interesting is that when I asked Haran about his approach to video-making, he said he did not label his online videos as education, entertainment or even as "edutainment". According to Haran, his main mission is simply to "find out interesting stuff and tell

other people about it". In other words, Haran sees his videos as essentially a form of journalism, which is not surprising given that he worked as a journalist both for the BBC and the *Adelaide Advertiser* in his native Australia before moving to Nottingham in 2002.

This journalistic bent gives rise to a none-too-subtle tension when making *YouTube* videos in the Haran style. As academics, our approach to explaining a concept is arguably the polar opposite of what journalists like to do: we prefer to painstakingly lay the groundwork, carefully building up an explanation in as precise a fashion as possible, with a sometimes rather too intense focus on the minutiae of the science. Journalists instead want to get to the headline as quickly as possible – to grab the audience from the start and compel them to read, watch or listen to their story via a strong "hook". It took me some time to get used to this approach, and it can still be uncomfortable to let go of the detail, particularly when you know that at least some of the Sixty Symbols audience will call you out for it in the comments section under the video.

Indeed, the ability of viewers to give instant feedback to *YouTube* videos is both a blessing and a curse. You're glad that people have responded to your videos and want to read what they have to say, but you have to be braced for the worst. The universal advice regarding *YouTube* videos, which is to ignore the comments entirely, can be pretty well impossible to follow. I too usually disregard the wise counsel of PhD students and postdocs in my research group, many of whom think *YouTube* comments are nothing more than the condensed collective stupidity of humanity.

Haran's channels tend to buck this trend: the comments can often prompt a well-informed and, at times, quite erudite discussion. Still, you do have to learn to put up with some unpleasant stuff. My astronomy colleague Meghan Gray, who has featured in many of Haran's videos, points out that there is an infuriating gender bias that often taints the comment threads, with the comments she gets often being far more focused on her appearance than those received by male colleagues. "Whether the intention is to flatter or be nasty, it can be uncomfortable and unpleasant, and the scientific message becomes secondary," she says. "Fortunately, other viewers will tend to quickly censure those who express views of this type, which is heartening – we do have some lovely fans."

Getting the balance right

Although Haran is not a scientist by training, and has no formal education in physics, chemistry or mathematics beyond secondary school level, he has an abiding interest in – and passion for – science and mathematics. This plays a pivotal role when it comes to engaging the audience. "Perhaps my most important role is to represent the viewers," he says. "I try to think about what they'd ask if they were in the room. Not necessarily what the scientists want to say, but what do the viewers want to know? Nothing makes me happier than when a viewer writes to say 'Thank you Brady – that was just the question I was hoping you would ask next!'"

Let me edutain you
Some of the science channels created by film-maker Brady Haran – but do they really help students to learn?

For us academics on the other side of the camera, however, this aspect of film-making can be daunting: whatever "narrative" we may have developed for a particular topic can be shot down in flames by a single unanticipated and perceptive question from Haran within seconds of the record button being pressed. "We don't know what Brady is going to ask, and he asks some really good, pertinent and challenging questions that can leave you a bit flummoxed," says my Nottingham colleague Ed Copeland, a cosmologist whose appearances in Sixty Symbols and Numberphile have rightfully won him a dedicated following on *Facebook* and *Twitter*.

Copeland admits getting the balance right is "very challenging" – to make explanations neither too verbose and technical nor too short and shallow. "Brady plays a crucial role there, pulling me back from getting too technical but giving me enough leash to discuss some technical aspects," he says. Even Roger Bowley, an emeritus professor in physics and astronomy at Nottingham who's been a member of the Sixty Symbols team right from the start, admits that "simplifying complex ideas into a single, logical storyline that can be understood by the general public" is the most challenging aspect of the process.

Powerful impact

The key to a successful *YouTube* video, according to Mike Merrifield, an astronomer at Nottingham, is to put yourself in the position of the viewer and avoid confusing or jargon-filled explanations. "You need to simplify things to a point where they are understandable in this format without compromising the underlying science", he says. Yet keeping things simple without fundamentally compromising the description of the science is an exceptionally difficult balancing act. Indeed, last year I decided I wasn't getting this balance right and grew ever more concerned about the perception we were creating by trying to put across physics in easy-to-digest, video clips lasting just a few minutes. Physics is not easy and we shouldn't pretend it is – it needs hard work

YouTube science – from those who've taken part

Laurence Eaves, semiconductor physicist
Appears in: Sixty Symbols, Numberphile
It's rewarding that people come up to me in a railway station, museum or cinema foyer and tell me that they are fans of our videos. It's like Alvy Singer being recognized by a fan in Woody Allen's *Annie Hall*!

Meghan Gray, astronomer
Appears in: Sixty Symbols, Deep Sky Videos
It's wonderful that by chatting to Brady Haran for half an hour in my office, I can reach tens of thousands of people around the world, many of whom kindly take the time to get in touch and express their appreciation.

Mike Merrifield, astronomer
Appears in: Sixty Symbols, Deep Sky Videos, Backstage Science
A rewarding aspect of the *YouTube* experience is when the DHL delivery man says "Nice videos, by the way" as he's leaving.

Tony Padilla, cosmologist
Appears in: Sixty Symbols, Numberphile
Making videos about stuff you aren't as expert on as you'd like to be is challenging. When you really stray away from home, you have to put in much more preparation time, and it can be a bit like revising for an exam. And the examiners are the viewers. They don't miss a trick.

but the rewards are great if you put the effort in.

When the great physicist Richard Feynman was asked to describe how magnets work, he made an exceptionally important point about explaining physics to a general audience. Feynman believed that not everything can be, or should be, reduced to an explanation of just a few minutes and a simple, but potentially misleading, real-world analogy. As he famously said when asked to briefly explain his Nobel-prize-winning work on quantum electrodynamics: "Listen, buddy, if I could explain it to you in a minute, it wouldn't be worth the Nobel prize."

To me, Feynman's comments illustrate the inherent tension between the journalistic and academic approaches to science communication – and it is a point that I have debated at length with Haran and a number of other colleagues involved in Sixty Symbols. Indeed, so concerned was I at having misrepresented important physics in a couple of videos that last year I decided I would bow out of contributing to Sixty Symbols. What changed my mind was a message from a 16 year old in Dublin who said that the Sixty Symbols videos are what had inspired him to pursue a career in science. Since watching them, he had ended up getting an A in his Junior Certificate exam, having previously scraped Bs and Cs.

Perhaps it's the Irish connection (I did my undergraduate degree and PhD at Dublin City University) but I found that message affecting and humbling. When Sixty Symbols has that type of influence, I can live with a few qualms about the nature of *YouTube* edutainment. ■

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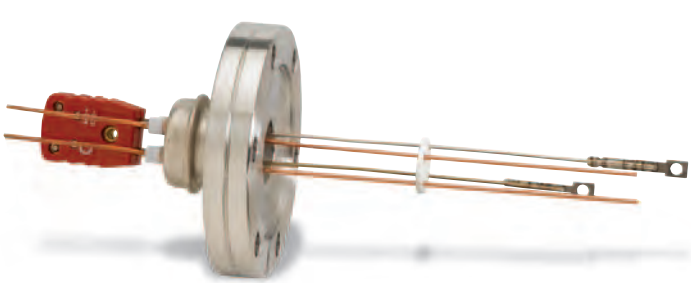

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Rules of engagement

Empowering children to look at the world around them with curious, questioning eyes is the goal of **Fran Scott**, who describes the golden rules she follows to do just that

Most recently working for Children's BBC and BBC Learning, **Fran Scott** uses her expertise within the field alongside her neuroscience knowledge to convey seemingly complex scientific ideas to children in novel and entertaining ways, e-mail fransfacts@gmail.com, www.franscott.co.uk

Ever hear a child say "Yeah, I get it!"? Well, if you do, they're lying. They're only saying those words because you're boring them and they don't want to listen anymore. Instead they want to move on to that dancing robot exhibit, go and play with their friends, or for everyone to just stop staring at them. Sounds harsh, but if they truly understood then they would be questioning you about the phenomenon or sharing it with their friends. In short, they'd be too engrossed in further curiosity to bother to give you an update on their knowledge level.

This is just one of the many idiosyncrasies I have learnt over the past nine years of being involved in informal children's science education. Over those years I have gained a reputation for not only understanding the science, but also being able to explain it, and well. I am involved in many arms of science outreach: I scientifically review and advise on science books and also consult on and present children's science on the BBC.

I chose this avenue because I find nothing more frustrating than the lazy communication of science to children. After all, it is during their primary-school years (ages 5–11) that children are forming their initial opinions of the subject – finding out if it's right for them or not. I strongly believe that we, as scientists, as physicists, have a responsibility not to intimidate them with our over-use of jargon, or our inability to break things down, and instead show children the basic ideas. We need to empower them to use these foundations as a base from which they can look at the world around them with curious, questioning eyes.

Yes, I *chose* this avenue. Explaining science to children is not an easy process; it's not a wimp-out. It takes time, a clear understanding of the concepts and a *lot* of thinking. Do not think that you can simply hand the children branded pens and then talk *at* them about your area of expertise. Do not think that all you need to know is the level of the science you are explaining to the children. Both these approaches are purely lazy. But I still see them – and too often.

So, having said what *not* to do when explaining science to children – trivialize the task at hand – what is it you *can* do to improve your science interactions with children? I have a set of four "golden rules" that can be remembered using the acronym REAP – and indeed they do reap great results. I like rules; they make you put the seemingly obvious into practice. So, if the following seem obvious, it's because they are; however, they're not *so* obvious that everyone is adhering to them.

Rule 1: Research – know the whole concept

Only by knowing the whole of the story can you interpret it and summarize it as a whole, rather than as a fragment. And "the whole" is important. People don't remember fragments so well. We're not interested in *bits* of a story, we want to know the *whole*, we want to know *why*. So if you can't explain the whole of the story it's just not going to "go in". Or, as Einstein reputedly, and rather more concisely, put it: "If you can't explain it to a six year old, you don't

British Science Association

The power of fun
Fran Scott adjudicates a tug-of-war at the British Science Festival in which children discover friction by trying to pull apart two interleaved telephone directories.

understand it yourself."

Whenever I'm asked to explain a concept, this is my first port of call. I absorb myself in it. I read – a lot. I also talk to people – a lot. I talk through what I think the theory is. I talk to experts. No one person can be an expert in everything, so don't be embarrassed to ask. I see my goal as being able to *help* children understand a theory. It is not about me being the sole person involved in doing this; it is a matter of using the knowledge that's out there, and me then translating this into something that children can understand.

Rule 2: Extraction – select the key ideas

These usually constitute four to six bullet-pointed aspects, ideas or stories that together explain the whole of the principle you have researched. These ideas don't always have to be connected, or even fully formed right away.

For example, when I was advising on the principle of floating for the Archimedes episode of the Children's BBC programme *Absolute Genius with Dick and Dom*, the main ideas I extracted were:

- The volume of water displaced by an object when fully submerged is equal to the volume of the object.
- An object will float if the weight of the water displaced by the object is equal to or greater than the weight of the object.
- An object will float if it is less dense than or equally as dense as the fluid it is trying to float on.
- An object will float if the buoyant force is equal to or greater than the weight of the object.

Reading those ideas, they may seem, at first glance, to be saying the exact same thing. They're not. Yes, they all explain Archimedes' principle in their own


BBC Science

Attention grabbing
The author puts her four golden rules into practice for BBC Science.

way, but none of them *fully* explains it. At least not to a person who doesn't yet know the words "displaced" or "density" – i.e. not to your average six year old. And so to rule 3….

Rule 3: Assimilate – boil down the ideas to one "learning outcome"

During this process I aim to fully understand the main messages in the points I have extracted in rule 2 and then collate these messages into one main idea that highlights the basis of all these principles. This should be a maximum of three sentences long. I do this by becoming somewhat of a six year old myself. I ask "Why?". I probe "What is density?". I ask "So what?". Let me explain…

Fran: The volume of water displaced by an object when fully submerged is equal to the volume of the object.
Child Fran: So what?
Fran: Well, this is what Archimedes actually came up with while he was sat in the bath. It was his "Eureka!" moment. It's pretty important stuff.
Child Fran: Why?
Fran: Because it allowed him to be able to measure the volume of the king of Syracuse's crown, and work out if it was made of pure gold or not.
Child Fran: So what? Surely that's not *that* important, is it?
Fran: Well, no. But finding this out allowed Archimedes to apply mathematics and a theory to why boats float, which previously had just been done by trial and error.
Child Fran: Eh? How did he get from sitting in the bath to boats?
Fran: He realized that for a boat to float it had to displace an amount of water that weighs the same as, or more than, it does.
Child Fran: What does displace mean?
Fran: Push aside.
Child Fran: So if it could push aside more water it was more likely to float?
Fran: Yep. And the bigger the object is the more water it pushes aside.
Child Fran: So bigger things float better?
Fran: Yes, but there's more to it. It's about density really….
Child Fran: What's density?

…you get the picture. Admittedly, this conversation is usually internal.

One important phrase I always refer to during this process is "You're only ignorant once" – i.e. once you know something, it is difficult to remember what it's like *not* knowing it. So, do your best to empty your head of all the familiar jargon and the complex ideas that you now currently and willingly accept as the norm.

So after all the internal questioning, what did I come up with?

For objects of the same weight, the bigger the object is, the more likely it is to float.

I know what you're thinking: that's simple. Yes, but tied up in this simple phrase are the ideas of density, water displacement and upthrust, as all of these, at their core, are dependent on size.

Rule 4: Present – make your learning outcome engaging

How you present your carefully constructed idea depends on where you are presenting it, obviously, but there are some key elements that are transferable to all situations.

First, *make it entertaining*. This is perhaps controversial – surely education is mutually exclusive to entertainment? Not in my eyes; without attention in the first place, no learning can actually occur. And don't think that just because it's physics, it can't be entertaining.

But entertaining doesn't necessarily mean using big, loud, "wow" moments; it covers a multitude of attention devices, from the use of narrative through to cleverly used humour. As educational consultant Sai Pathmanathan so elegantly puts it in a summary of her research on "edutainment", "the cognitive processes involved in understanding humour are the same as those involved in problem-solving. Humour can therefore reinforce these processes so that meaningful learning takes place".

Second, *know what is familiar to your audience and build on it*. No child is an empty vessel. Every child has already come across physics in many, many everyday situations. Yes, they may not yet know *why* objects act a certain way, but they know that they *do* act a certain way.

So, don't presume your audience knows nothing. Everybody knows *something*. Building on that something they already know will make your audience comfortable and therefore more confident. It will also, through the intricacies of how memories are formed – memory by association – allow that new knowledge to stick.

Finally, *do not use jargon, unless you first explain it*. Yes, jargon can be useful; it can allow you to communicate your theory or idea in a concise manner, using one word instead of several. But always remember that phrase: "You're only ignorant once". What may seem just normal use of English to you may be

Talk to the hand Making science entertaining for children doesn't necessarily mean "wow" moments; it may mean interacting with a CBBC puppet.

gobbledegook to a child. By all means use jargon, but precede that jargon with its meaning. And always precede, not follow.

It's a peculiar thing, jargon; one that requires a balance. When evaluating presentations, I find that jargon, just like extensive vocabulary, is used by the presenter as a marker of their intellect. A balance is needed; you need to use enough (explained) jargon to gain the trust of your audience, but not so much that you lose them. Never use unexplained jargon as a quick route to being perceived as intelligent; that's just an ego-trip, and won't help your audience.

Also consider this: "jargon" may include more words than you might think. Words such as density, displace and buoyancy would all be foreign to a six year old and so do need to be explained, if used at all.

With these key elements in mind, it is up to you to devise a demonstration/scene/workshop/game that encapsulates your one learning outcome. This may be something that doesn't, at first, seem connected to the concept you are conveying, but think outside the box; think more about your learning outcome than your initial concept. And keep thinking. Talk it through with adults and children and, of course, yourself. Ensure that you are perfectly happy that the take-home message of your demo/scene/workshop matches your carefully selected learning outcome.

Sweetshops and rubber rings

So, yes, there is an art to explaining the facts. But by being armed with these golden rules, hopefully now the somewhat daunting task of explaining physics well to six year olds, in a way they'll understand forever, seems a whole lot more manageable. And next time you see clips on children's television of people "playing" with sweets in a sweetshop, discovering that although the bags all weigh the same, some float better than others – or perhaps presenters swimming in a pool, sinking without flotation aids, but then floating perfectly after armbands and rubber rings are attached – you'll know that every scene has been thoughtfully considered and carefully crafted so that the one desired learning outcome is indeed the one the children take away.

Learning by doodling

Do your reams of written lecture notes ever really sink in? **Louise Mayor** investigates how visual methods can help you process and remember information

Louise Mayor is features editor of *Physics World*, e-mail louise.mayor@iop.org

Commissioned by *Physics World*, this colourful image is based on a lecture by Richard Feynman called "The Great Conservation Principles". It is one of seven Messenger Lectures he gave at Cornell University in the US in 1964 and can be watched online at http://ow.ly/to2xE or in the digital version of this magazine. (See p25 for more on the impact of Feynman's teaching.)

The drawing's creator is professional "science doodler" Perrin Ireland, who describes herself as "a learner who needs to visualize concepts in order to understand them". Her doodling began while she was doing a degree in human biology at Brown University in the US. Ireland's illustrated notes were so helpful that her coursemates began asking for copies. Quite simply, for many people, thinking visually or in a story-like way helps them to recall facts and explanations – which can come in very useful when trying to learn something new.

Doodling has also entered the world of academics, with some conference organizers commissioning a professional doodler, such as Ireland, to "live-scribe" at their event. As well as adding interest and helping delegates to process information, the drawings make a nice record of the meeting.

Ireland is not alone in her vocation; there is a growing movement of "information visualizers" who bring their methods to businesses to foster innovation and productivity. Disney, for example, has used SB Ink – a creative consultancy run by "Infodoodler-in-chief" Sunni Brown – to "ideate" on a project in 2009 (the exact topic of which was kept under wraps). The participants were asked to "visually play" with ideas for how they wanted the project to turn out, and Brown recorded the resulting ideas and decisions in a style similar to Ireland's.

Everyone's brain contains different memories and associations, so the best way to take advantage of these techniques is to do them yourself – because when you convert the information you're trying to learn into images, associations and analogies, you are forced to relate them to the images and concepts already stored in your mind. We'd love to see your efforts – please send them to pwld@iop.org. ■

• For more on how learning depends on building connections to prior knowledge, see pp48–51

N: T CONSERVATION PRINCIPLES

A physicist uses all the ORDINARY WORDS in an UNUSUAL MANNER:

YOU CAN CALCULATE A NUMBER, ACCORDING TO A RULE
COMES OUT THE SAME AFTER, NO MATTER WHAT

ANGULAR MOMENTUM

Law of conservation of ENERGY

number of blocks seen (+) weight of box − 16 oz / 3 oz = 28

abstract calculation

NICE ROUND BALL
ITE COMPLICATED DETAIL...

boulder → a bumpy business made out of balls.
→ ATOMS LEFT BEHIND STILL SHAKING IN THE FLOOR.

THERMAL ENERGY

THE BANKER & EVERYONE ELSE: I have 20 shillings to a pound.

VS.

PHYSICISTS & their IRRATIONAL RATIOS: I have 1.6183178 shillings to a pound.

	CHARGE	BARYON #	STRANGENESS	
CONSERVED	YES	YES	NEARLY	y
COMES IN UNITS	YES	YES	NEARLY	y
SOURCE OF A FIELD	YES	?	?	

We make these tables because it's a TRICK WAY of GUESSING at NATURE

THE ONLY UTILITY of THE SCIENCE IS TO GO ON AND MAKE GUESSES.
WHAT WE DO ALWAYS IS TO STICK YOUR NECK OUT & THAT of COURSE MEANS THAT SCIENCE IS UNCERTAIN.
WE HAVE TO PROPOSE LAWS BEYOND THEIR RANGE.

IF YOU THOUGHT BEFORE THAT SCIENCE WAS CERTAIN, WELL THAT'S JUST AN ERROR ON YOUR PART.

Discovering the laws of physics is like trying to put the pieces together of a JIGSAW PUZZLE.

How do we know they're all part of ONE, AT PRESENT INCOMPLETE, picture?
WE'RE NOT SURE, but we get ENCOURAGEMENT from the common characteristics of several pieces – they all show BLUE SKY, or they're all made out of the same kind OF WOOD.

by Perrin RIreland

FORTHCOMING INSTITUTE CONFERENCES
APRIL 2014 – JULY 2016

2014

7–8 April
Magnetism 2014
University of Manchester, Manchester, UK
Organised by the IOP Magnetism Group and IEEE UK & ROI Magnetics Chapter

7–9 April
IOP Nuclear Physics Group Conference
Selsdon Park, Surrey, UK
Organised by the IOP Nuclear Physics Group

7–9 April
Pressure, Energy, Temperature and Extreme Rates (PETER 2014)
Grand Connaught Rooms, London, UK
Organised by the IOP Shock Wave and Extreme Conditions Group

7–10 April
Advanced Materials for Demanding Applications
Glyndwr University, North Wales, UK
Organised by the IOP Nanoscale Physics and Technology Group

11–14 April
Advanced School in Soft Condensed Matter "Solutions in the Spring"
Homerton College, Cambridge, UK
Organised by the IOP Liquids and Complex Fluids Group

14–16 April
The Physics of Soft and Biological Matter
Homerton College, Cambridge, UK
Organised by the IOP Biological Physics, Liquids and Complex Fluids, Molecular Physics, and Polymer Physics Groups

14–17 April
41st IOP Plasma Physics Conference
Grand Connaught Rooms, London, UK
Organised by the IOP Plasma Physics Group

19–24 May
9th International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region: NuInt14
Selsdon Park Hotel, Surrey, UK
Organised by the IOP High Energy Particle Physics Group

9–11 July
3rd Superconductivity Summer School
University of Oxford, Oxford, UK
Organised by the IOP Superconductivity Group

14–15 July
Colloidal Quantum Dots and Nanocrystals
Chancellors Hotel and Conference Centre, Manchester, UK
Organised by the IOP Quantum Electronics and Photonics Group

15–17 July
"Innovative Instrumentation for EURISOL" 5th EURISOL Topical Meeting 2014
University of York, York, UK
Organised by the IOP Nuclear Physics Group

21–25 July
ICSOS'11: 11th International Conference on the Structure of Surfaces
University of Warwick, Coventry, UK
Organised by the IOP Thin Films and Surfaces Group

26–28 August
IPTA 2014: Inverse Problems from Theory to Application
At-Bristol, Bristol, UK
Organised by IOP Publishing

1–4 September
Photon14
Imperial College London, London, UK
Organised by the IOP Computational Physics, Instrument Science and Technology, Optical, Quantum Electronics and Photonics and Quantum Information, Quantum Optics and Quantum Control Groups

3–5 September
Physics meets Biology
University of Oxford, Oxford, UK
Organised by the IOP Biological Physics Group

4–5 September
International Conference on the History of Physics
University of Cambridge, Cambridge, UK
Organised by the IOP History of Physics Group

15–19 September
Quantum, Atomic, Molecular and Plasma Physics (QuAMP) Summer School
Durham University, Durham, UK
Organised by the IOP Atomic and Molecular Interactions, Molecular Physics, Plasma Physics, Quantum Electronics and Photonics, and Quantum Optics, Quantum Information and Quantum Control Groups

16–18 December
Topical Research Meeting on Hybrid Quantum Systems
National College for Teaching and Leadership, Nottingham, UK
Organised by the IOP Quantum Optics, Quantum Information and Quantum Control Group

2015

12–16 April
Electrostatics 2015
Southampton Solent University, Southampton, UK
Organised by the IOP Electrostatics Group

18–22 May
Nuclear Physics in Astrophysics VII: 28th EPS Nuclear Physics Divisional Conference
The Royal York Hotel & Events Centre, York, UK
Organised by the Institute of Physics

2016

3–9 July
The XXVII International Conference on Neutrino Physics and Astrophysics
Royal Geographical Society, London, UK
Organised by the Institute of Physics

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The MOOC point

Massive open online courses give students free access to some of the world's top educators. **James Dacey** explores the benefits and drawbacks of these courses compared with those traditionally offered by universities

Walter Lewin is a very rare breed – one of the handful of academics who have made it their mission to transform the way their students look at the world around them. Rather than seeing teaching as a chore that's taking precious time away from research, he approaches the lecture hall as if it were a stage, having carefully crafted interactive lectures that can have students hanging on to his every word. "The class has to see, and smell, and feel in their hands, that you love physics," says Lewin, an emeritus professor of physics at the Massachusetts Institute of Technology (MIT), whose teaching talents have been recognized through numerous prizes and awards. "You must somehow at times make them laugh. I can make them cry. I have them so in my hands that I can make them sit on the edge of their seats."

If students could learn free of charge from a hand-picked selection of *über* teachers such as Lewin – in their own time and from the comfort of their own home – why would they make do with uninspiring lecturers at their own university department?

It's a question that's become more common over the past few years, which have seen the rise of massive open online courses, commonly known as MOOCs. These are short courses usually mixing online teaching with assignments such as problem sets and extended projects. While the concept of online private study has been around for as long as the Web, the novelty with MOOCs is that these courses are freely available and the providers take full advantage of the

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Breaking down barriers

One inspiring example of the power of MOOCs to break down global barriers to education is the story of a boy called Battushig Myanganbayar from Ulan Bator in Mongolia. In 2012, aged just 15, he took the edX "Circuits and electronics" MOOC, a subject he had no prior experience with through his state education, and achieved a perfect score. Myanganbayar has since moved to the US where he has started an undergraduate degree at the Massachusetts Institute of Technology, and is so far taking courses in electronics, solid-state chemistry and biology.

As if his personal achievements weren't impressive enough, Myanganbayar has also created a series of videos on *YouTube* in which he explains some of the more difficult concepts from the MOOC in Mongolian, having translated them from the original English versions. "Every time when I learn new stuff, every time when I'm working on a new project, I think about how it could bring happiness for people in the future and that gave me a lot of energy," he explains.

latest Web technology, such as online video and interactive virtual labs. Indeed, MOOC evangelists claim that these courses are a key step in the global democratization of education, given that anyone with good enough Internet access can take them.

But could an online course ever provide the same complete learning experience as that gained from attending a university in person? After all, students can't simply stick their hand up mid-lecture if they are lost, or wait behind at the end to ask for something to be clarified. And surely doing a MOOC from home can never match the social aspect of attending a university, which is just as valuable in a student's university experience as is personal academic study.

Flipping the tunnel

Lewin is the instructor for two physics MOOCs offered by MIT via edX – a large, US-based MOOC provider – on the subjects of classical mechanics and electricity and magnetism. In addition, many of his colourful lectures, which often include dramatic demonstrations such as Lewin swinging across the front of a lecture hall to illustrate pendulum motion, have been recorded and made available through MIT's OpenCourseWare project (OCW), which was launched in 2002 and is often thought of as the precursor to the current MOOC initiatives. But despite his high profile in MIT's Web education, Lewin recognizes that taking one of his online courses could never reproduce the experience of attending one of his lectures in person. He views the edX and OCW initiatives purely as ways of extending his reach and a means to inspire viewers around the world to consider studying physics full-time at a university.

However, the president of edX, Anant Agarwal, believes that MOOCs can offer advantages over traditional learning and that there is no reason why the social aspects of learning have to be compromised in taking these Web courses. Agarwal points out that the students taking edX MOOCs can access discussion forums where they can get a response from fellow students within minutes. "In an on-campus class, often students have to wait a couple of days or a week to find 10 minutes with a professor or a teaching assistant," he says. Indeed, several "meet-up groups" have emerged around the world in which students get together to work on studying the edX MOOCs.

Agarwal says the MOOC model is "flipping the funnel" in the student-recruitment process, giving people opportunities at a university that they may never have received otherwise. "In a typical university, say Harvard University or MIT, they admit less than 10% of students that apply. [With edX] anybody can come in and take the course, however a smaller number passes the course." As an example, Agarwal says that the first time edX ran its "Circuits and electronics" MOOC, 155 000 students from 162 countries signed up for the course, and of these 7200 students passed. Even with the high drop-out rate, this figure is substantially higher than the number of students passing the campus-based course.

But there are others who question the idea that MOOCs have transformed the status quo in education. They argue that cases such as that of Battushig Myanganbayar – a 15 year old from Mongolia who took a MOOC and ended up winning a place at MIT (see box above left) – are the rare exceptions rather than the rule. It's a view backed up by a recent survey described in the online repository *Social Science Research Network*, which found that most students completing courses from one particular MOOC provider already hold a degree from a real-world university. Sent to people enrolled in MOOCs offered by Coursera, it found that 83% of the 34 779 students who replied already had an undergraduate degree, with 44.2% reporting education beyond a bachelor's degree. The authors, led by Gayle Christensen of the University of Pennsylvania, wrote that the student population tends to be "young, well educated and employed, with a majority from developed countries".

A blended approach

Another interesting development is the incorporation of MOOCs into existing degree programmes. One example of this "blended learning" has taken place at MIT, which has seen a major revamp of a module known as Junior Lab. This long-standing practical course is usually taken by third-year students specializing in physics, and has been described by Krishna Rajagopal – MIT's associate head of physics education – as "the centrepiece" of the undergraduate physics programme at MIT. In the traditional incarnation of Junior Lab, students attend a series of introductory lectures and are given a selection of reading assignments before they begin the practical work. Rajagopal and his colleagues have been running a trial where they have replaced this pre-course activity with a suite of online activities and resources, including videos and interactive exercises, based on the edX technology. The idea is that students can access the information as and when they require it throughout the course, freeing up more time for focused discussions with lab instructors when working on practical projects.

The MIT physics department is pleased with the outcome of the trial and is planning to officially launch the revamped Junior Lab for the 2014 spring semester. Rajagopal says he will be looking at how

students perform in the online activities to get an idea of the concepts that students find particularly challenging. "Every class I've ever taught, at the end you wish you had 10 or 15 minutes more, so you could do the one last thing that you wished you had time for. So I'm hoping I'll get time for a lot of those things, by actually knowing what my students have done before they come into class."

While it is too early to assess whether the new-look Junior Lab is doing better at preparing undergraduates for a career in physics, students who have taken part in the trial seem to have enjoyed the format. "Junior Lab has the reputation of essentially making one's life a living hell for about a semester and consuming all of their time," says undergraduate student Isaac Yandow. "The [online] pre-labs are good. We have to do them before every lab and they make me a lot more confident than I was before".

This style of blended learning is gaining in popularity in the US, according to Agarwal. He says it is also being used at university and high-school level for course instructors to cherry-pick the best online resources to incorporate into their on-campus course, just as they might have done in the past with textbooks. edX has already been involved in pilot programmes at two Massachusetts community colleges and at San José State University (funded by a grant from the Bill & Melinda Gates Foundation), to deliver "Circuits and electronics" as a blended course. "Initial results for the San José State pilot show a dramatic decrease in failure rates from previous semesters," says Agarwal. He claims the percentage of students required to retake the course dropped from 41% under the traditional format to 9% for those taking the edX blended course.

Plethora of platforms

MOOCs are courting so much attention at the moment because of the sheer pace at which new courses are appearing. Between them, the large US-based MOOC providers Udacity, Coursera and edX are already offering hundreds of courses in a wide selection of fields, particularly in STEM subjects (science, technology, engineering and maths) and computer science. The normal model has so far been for major universities to create and deliver the MOOC courses, with the online platforms being created and maintained by MOOC providers. The provider edX, for instance, was launched in 2012 after Harvard and MIT each invested $30m, and the organization has since teamed up with several other leading US universities.

In September 2013 the first UK-based MOOC provider FutureLearn, wholly owned by the Open University, opened registration for its first batch of courses, including one called "The discovery of the Higgs boson". FutureLearn's partners include 26 universities – 23 of which are in the UK, with the remaining three in Ireland, New Zealand and Australia, as well as the British Library and the British Museum.

The scope and scale of how universities are engaging with MOOCs seems to suggest that the courses are destined to become much more than the latest educational fad. As Mike Sharples, a researcher in educational technology at the Open University who is the academic leader of FutureLearn, explains, institutions see "huge opportunity to engage learners around the world in high-quality education at higher level [as well as] major strategic opportunities: to promote their brand and display the quality of their teaching content worldwide, and to recruit some students from MOOCs onto degree courses". In other words, universities may well see MOOCs as an opportunity to expand their real estate. By building attractive new campuses online populated with superstar teachers, they may entice more students back to their real-world headquarters.

MIT's Junior Lab
As of this semester, students taking the MIT physics department's key experimental module, Junior Lab, will have access to a suite of online resources alongside their practical assignments.

In addition to creating FutureLearn, the Open University has also recently launched the *OpenScience Laboratory*, thanks to a £1m grant from the Wolfson Foundation. This website is a resource for science undergraduates who have free access to virtual laboratories, including microscopes and a spectrometer, and remotely control real-world equipment including telescopes and bench-top experiments. Nicholas Braithwaite, an engineering physicist who is *OpenScience Laboratory* director, says that the lab has already signed up users in 84 countries. "Although we began on our home territory of undergraduate science, we recognize the potential contribution that the *OpenScience Laboratory* might make to primary, secondary and further education; we are actively seeking partners in these sectors," he says.

Down to business

Despite the potential of MOOCs, there is a lot of uncertainty about their economic sustainability. A report by the UK Department for Business Innovation and Skills released in September 2013 noted that "the Burning Issue in the MOOCosphere is the search for business models". Online education initiatives do not come cheap and the report also highlighted fears among smaller and less prestigious institutions that they may lose market share as a result of MOOCs bankrolled by big elite universities fighting for students in the increasingly com-

Caught on camera

MOOC master Walter Lewin has his microphone attached, ready for filming.

In a special filming trip to MIT, *Physics World* interviewed several people quoted in this article. Members of the Institute of Physics accessing *Physics World* in digital format through our apps or via myiop.org can enjoy a short film about blended learning initiatives at MIT and an extended interview with Battushig Myanganbayar.

petitive global market. Whereas the likes of Harvard and MIT can use MOOCs as a shop window for their much-lauded campus courses, the worry is that smaller institutions may struggle to attract recruits. Some of them have also pointed out that MOOCs are unable to serve learners with more complex learning needs.

One way that MOOC providers have sought to diversify their business is to seek partnerships with external organizations. For example, the "Secret power of brands" course, offered to the public free of charge by FutureLearn, was developed by the University of East Anglia in association with the international brand consultants Wolff Olins. Fittingly, both parties stand to benefit from the association with each other's brand, as well as producing some good PR through embracing modern technologies and business models. Similarly, the Khan Academy, a not-for-profit online education platform in the US, has joined forces with the Bank of America to create the website *BetterMoneyHabits* to provide people with tips and advice for personal finance. Meanwhile, many MOOC providers have started charging for add-ons such as final examinations, university certificates and even official university credit, prompting some to question the "open" aspect of MOOCs.

In the near future, this model of MOOC providers working with academic and industry partners is likely to become more common, although some leading universities, such as Oxford and Cambridge, have been noticeable by their absence, not yet offering any MOOCs. For the short term, individual universities will no doubt continue to grapple with the financial implications of MOOCs; for many it appears to be a risk worth taking. It looks like, for now at least, both online and offline education are here to stay.

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Thinking like a scientist

Eugenia Etkina and **Gorazd Planinšič** describe how research into how people learn – plus the desire to help all students develop scientific "habits of mind" – is reshaping the way they teach physics

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An essential question for every teacher is "What will my students remember a year after they have taken the final exam?" This question is significant for students specializing in physics, since each course they take will contribute to their understanding of what it means to do physics. But it is perhaps even more critical for students in introductory physics courses, since most will not go on to become professional physicists and are thus unlikely to encounter pure physics in the future.

Traditionally, we, as physics educators, have focused on teaching fundamental physics concepts and the ways that such concepts apply to real-world problems. But in recent years, this focus has shifted. Numerous studies of what makes people successful in the workplace have shown that while understanding scientific concepts is important, the ability to think like a scientist while solving complex problems is equally vital (see, for example, *International Journal of Science Education* **24** 661). Specifically, students need to know how to formulate a problem; collect and analyse data; and identify patterns. They also need to know how to test ideas; how to evaluate assumptions and solutions; how to distinguish evidence from inference; how to argue scientifically; and so forth.

Science educators around the world have begun incorporating this new focus into their curricula. For example, the Next Generation Science Standards in the US place scientific "habits of mind" (sometimes called science practices or science competencies) at the centre of science education for all students from kindergarten to the end of high school (http://ow.ly/sZCbr). On the other side of the Atlantic, a multinational group of physicists involved in a project called Tuning Educational Structures in Europe found that the competencies ranked most highly by physics graduates and employers include problem solving, teamwork and the ability to apply knowledge in practice. With this in mind, the group has produced a guide for academics involved in planning or revising physics degree courses as part of the Bologna process, along with a platform for establishing communication between employers and universities (materials are available at http://ow.ly/sZCkZ).

Another factor driving the shift in physics education relates to changes in our understanding of how people learn. We now recognize that learning is a process of physical change that occurs in the brain, and possibly in the whole body. A more complete explanation of this "embodied cognition" can be found in the work of Margaret Wilson, a psychologist at the University of California, Santa Cruz. In essence, learning involves rewiring paths to the neuronal connections that students already have when they enter our classrooms, and this process is enhanced when students interact bodily with their environments. This new understanding has important implications for how physics is – or should be – taught.

We now recognize that learning is a process of physical change that occurs in the brain, and possibly in the whole body

Rewiring minds

To understand how the "rewiring" process works, let us consider a simple example. Suppose a child sees something new – a pile of dirt, for example. She wonders what it is, so she searches her brain for existing knowledge that might be relevant. This process produces another question: is dirt like chocolate? If it is, then it should taste like chocolate – and so we see the child putting dirt in her mouth.

Although the result of this "experiment" is that dirt is not like chocolate, this does not mean that the child did not learn anything. On the contrary: she completed what is called a brain learning cycle. Such cycles begin with concrete experiences and simple observations and then proceed to reflections that connect such observations to things they already know. The next step is to produce a hypothesis about this connection, followed by the immediate testing of this hypothesis through an active movement. As James Zull – a biologist at Case Western Reserve University and founder of its University Center for Innovation in Teaching and Education – put it in his book *The Art of Changing the Brain* (2002), learning takes place when someone is continuously building connections to prior knowledge through interactions with the world and reflective thinking.

More recently, in his book *From Brain to Mind: Using Neuroscience to Guide Change in Education*, Zull also showed that imagery plays an important role in the learning cycle. Think of an apple. Your understanding of what an apple is will be an amalgam of your perceptual experiences: you may remember the feel of biting into it, the taste, the smell and so on. Even if you have never eaten an apple, you may be able to draw on photographs or other illustrations you have seen. Together, these experiences form a "per-

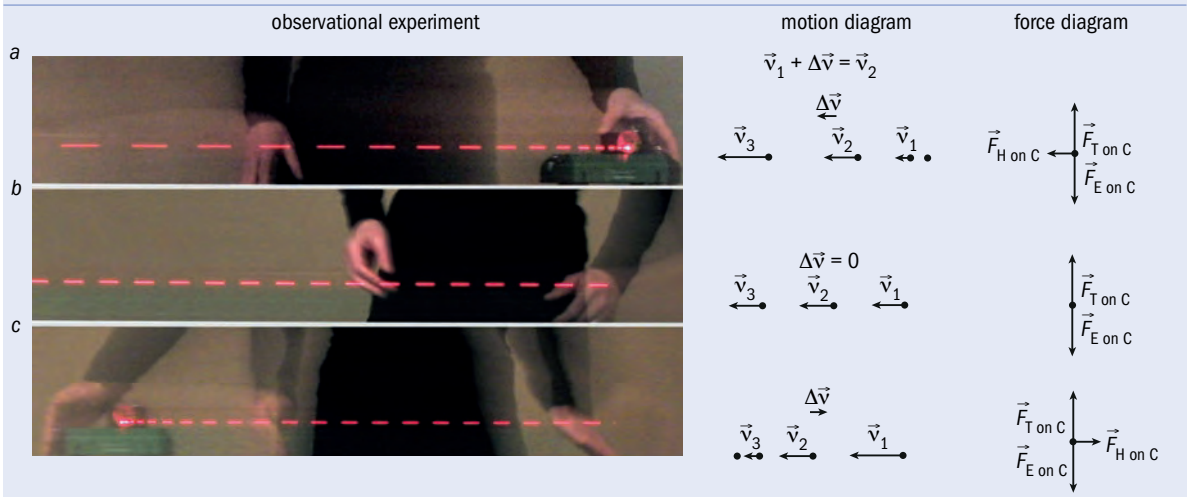
iStock/esenkartal

ceptual symbol" that we can then call "apple". Shorn of this underlying experience, however, the word "apple" will mean nothing to you, even if you are presented with some kind of textbook definition of it.

Finally, because learning is inherently social, the rewiring process is enhanced when a learner interacts with other people. Interactions with peers allow learners to benefit from each other's different expertise and encounter different points of view, and they also encourage them to speak about the ideas that they are working on. The mere act of speaking also involves the motor function, which is extremely important for learning.

These ideas – that learning is a physical change;

1 Learning in motion



Photos taken with a blinking LED, motion diagrams and force diagrams for a cart that is (*a*) speeding up, (*b*) moving at constant velocity and (*c*) slowing down. On the motion diagrams the dots represent the positions of the cart at equal time intervals, the $\vec{v}$ vectors represent the cart's velocity and $\Delta\vec{v}$ vectors represent the change in the velocity. On the force diagrams each force exerted on the cart is labelled with two subscripts that indicate two interacting objects: $\vec{F}_{E\,on\,C}$ is the force exerted by Earth on the cart, $\vec{F}_{T\,on\,C}$ is the force exerted by the track on the cart and $\vec{F}_{H\,on\,C}$ is the force that the hand exerts on the cart.

that it takes place in cycles; that images need to precede formal definitions; and that it is a social process – are by no means exhaustive. For us, however, they are the major building blocks in our understanding of how people learn, and they have some important implications for how we teach physics.

One implication is that for rewiring to take place in the brain, learners need to be actively engaged in the instructional process. In other words, passively listening to good explanations – as often happens in traditional physics lecture courses – will not produce the needed change. The rewiring approach to learning also suggests that we should view the knowledge that students bring to our classrooms as a productive resource to build on, rather than as an impediment to future learning. This is true even though students' prior physics knowledge consists of ideas that often contradict each other. Finally, physical interaction with the world is extremely important.

Another lesson is that learners need opportunities to conduct observations and try to explain them using their existing knowledge – for example, by creating analogies. This process enables learners to extend their knowledge and to test new ideas by doing experiments or by discussing their thoughts with peers. A final lesson is that learners need a perceptual symbol of a concept before a teacher introduces a formal definition. This perceptual symbol could be a real phenomenon with which they have some physical experience, but it could also be a picture or a statement in which they describe the phenomenon in their own words – or even some combination of the three.

Oof! A person catches a 5 kg medicine ball dropped from about 1 m. A blinking LED shows the time interval of the catch.

Ideas in motion

If the discussion so far seems rather abstract, here is an example of a lesson that is both consistent with the ideas above and also geared towards helping students develop scientific habits of mind. The example may seem trivial, but it addresses one of the most difficult concepts in introductory mechanics: when a non-zero sum of forces is exerted on an object, it is the *change* in the object's velocity vector ($\Delta\vec{v}$) that is aligned with the sum of all forces, rather than the velocity vector itself ($\vec{v}$). This idea forms the qualitative foundation for understanding Newton's second law. However, the most common experience students have of this law is of an object that is initially at rest and then starts to move. In this case, both $\Delta\vec{v}$ and $\vec{v}$ point in the same direction. Because people usually focus on the velocity, this may lead them to think – erroneously – that an object always moves in the direction of the force.

In the lesson described below, we assume the students have already learned that in physics, the word "force" stands for a physical quantity that characterizes the interaction of two objects. We will also assume that they have some experience with the forces most common in mechanics and that they know how to add them as vectors. Note also that the activities we describe will be much more successful if students work together in small groups and present results of the consensus of this group work to the class. Using small boards for students to show their work to the rest of the class is very helpful.

Step 1. Provide students with simple concrete experiences. Use a heavy cart with small wheels on a smooth track. Ask students to push the cart (it is important that the students are pushing, not the teacher), exerting a constant force on it. Students will observe that the cart moves faster and faster. The next experiment is to set the cart in motion and let it coast without touching it. If the surface is smooth, the cart will move at a constant velocity. Finally, when the cart is moving, ask students to exert a force on it in the direction opposite to the direction of motion. The students will observe the cart slowing down in the direction of motion. The heavier the cart, the easier

The rewiring approach to learning suggests that we should view the knowledge that students bring to our classrooms as a productive resource to build on, rather than as an impediment

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Interaction Encourage groups of students to present their findings back to the class.

it is for them to see that it does not stop instantly. To increase the perceptual aspect of the three experiments, the students can use a bowling ball instead of the cart and push it with a mallet.

Step 2. Help students construct images of the concept and connect new ideas to what they already know. After doing the experiments described above, students will have a physical feeling for the situation. The next task is to help them build on this. One way is to take a flashing LED light, attach it to the cart and take photos (see figure 1). Independently of the availability of such photos, though, you should ask the students to create graphical images that represent each experiment with a motion diagram and force diagram for the cart (remember, we assume that the students have already learned how to make such diagrams). They should create drawings similar to those in figure 1. The two-subscript notation for the forces addresses the difficulty of identifying forces exerted on an object.

Step 3. Encourage students to identify patterns. Let students discuss the patterns that they see in the sets of diagrams. They will notice that on each diagram the sum of the forces vector is in the same direction as $\Delta\vec{v}$. You can help them formulate a provisional rule: when the sum of the forces exerted on an object is not zero, the object changes its velocity and the velocity change is in the same direction as the sum of the forces.

Step 4. Engage students in active testing of the rule. Invite students to propose new experiments for which the outcomes can be predicted using the new rule (after doing these activities a few times you will know what equipment your students will request). Here the perceptual aspect of learning can be emphasized again. In addition to trying the experiments that they propose, ask the students to use the new rule to predict what they will feel when catching a heavy medicine ball dropped from above as opposed to holding it. They need to use the motion diagrams and force diagrams to make the prediction and then physically experience how much harder they need to push on the ball to catch it compared to holding it still (the photo below left allows students to infer that the person exerts the stopping force over the substantial difference). Thus the experiment also helps the students realize that it is impossible to stop a moving object instantly.

Step 5. Help students reconcile the new rule with their previous experiences. Does this rule make intuitive sense? Encourage students here to come up with examples of different moving objects (such as a ball thrown upwards, a parachutist doing a sky-dive or a sledge coming to a stop after the end of a slope) and analyse them by making motion and force diagrams and co-ordinating between them. Ask the students to come up with three examples when the rule is true in everyday life and three examples when it is not. This discussion will pave the path to the concept of non-inertial reference frames.

Habits for success

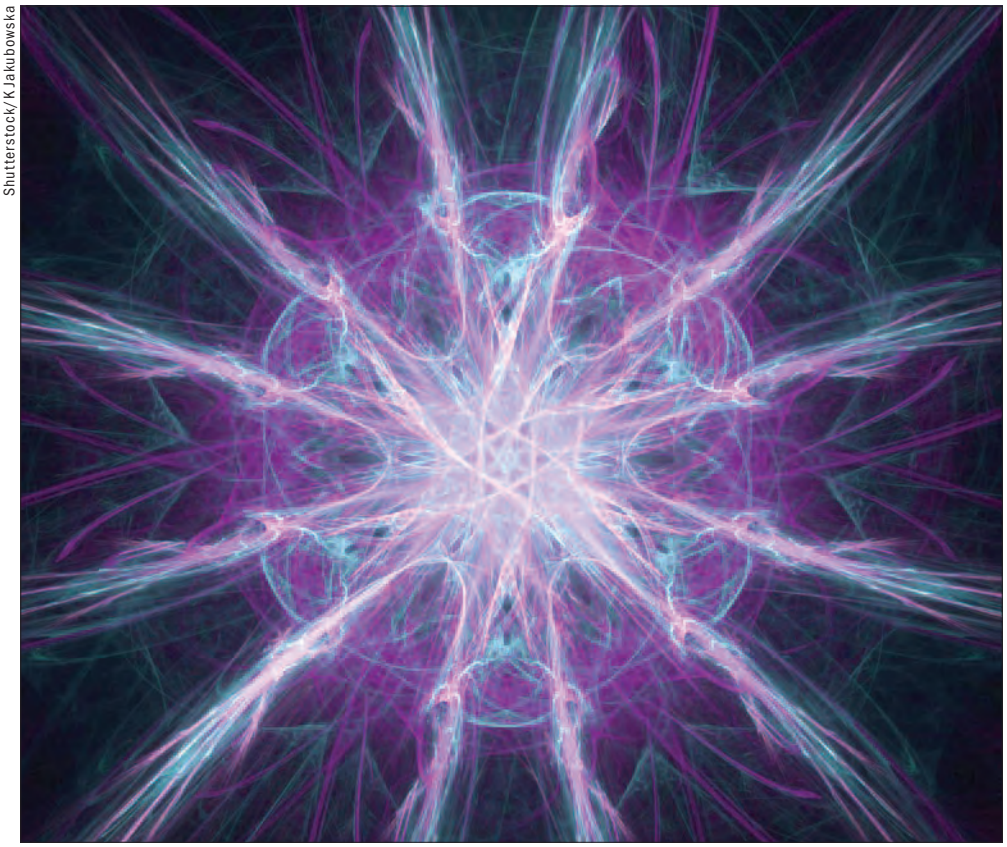
This example shows how to help students construct one of the most complex concepts of Newtonian dynamics using our knowledge of how people learn. Specifically, it focuses on a learning sequence in which students start with very simple concrete experiences and construct representations to analyse them. Afterwards, they progress to identifying patterns (and explaining them when possible), actively testing the patterns (or explanations) in new experiments and reconciling them with prior experiences.

This path is non-threatening and gives all students the opportunity to be successful at different points. The new knowledge they gain has not been handed down from an authority figure; instead, it is the result of the students' own carefully constructed learning experiences, including their analysis of simple experiments. Repeating this path many times during the instruction will allow the students to form the scientific "habits of mind" they need to be successful in the future. We believe this is important because such habits do more than just help our students to succeed in a world that demands creative problem solving; they also make the world a better place, as more of its citizens become capable of making informed decisions. ■

Reviews

Matthew R Francis

We are bound by symmetry



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Guiding light
The link between physics and symmetry is familiar but Dave Goldberg's book aims to explain it in an accessible way to laypeople.

The Universe in the Rearview Mirror: How Hidden Symmetries Shape Reality
Dave Goldberg
2013 Dutton Books
£16.88/$27.95hb
352pp

As in art, symmetry is often a guiding principle in science. Physicists in particular seek patterns that highlight underlying principles that can, in turn, be translated into sleek mathematical form. It's not merely an aesthetic choice. Many, perhaps most, of the accomplishments of modern theoretical physics have exploited symmetry and its exceptions to describe and predict the results of experiments. The 2012 discovery of the Higgs boson and the development of superconductors are just two of the success stories arising from symmetry.

This is old hat to professional physicists, but perhaps less widely known to laypeople. For that reason, Dave Goldberg's book *The Universe in the Rearview Mirror* strives to explain in an accessible way how symmetry affects…well, pretty much every major topic in quantum physics, gravitation and cosmology. In just over 300 pages, the book provides an engaging whirlwind tour of much that constitutes modern physics. Condensed-matter physics is a notable large omission – but then again, a discussion of symmetry in that branch of physics could fill an entire book in itself.

Goldberg, who is a physicist at Drexel University in Pennsylvania, US, takes a very conversational tone, with many jokes of a type I'd describe as "professorial": they're the kind of quick hit-or-miss asides one might make in a lecture to keep the students listening. His book begins with the basics – what is symmetry in a mathematical sense? – before delving into the matter–antimatter asymmetry in the book's first numbered chapter. (A structural quibble: the "Introduction" is actually an essential chapter of the book, as it introduces many of the major concepts needed to understand the subsequent material.) Later chapters discuss entropy and the arrow of time; relativity and the isotropy of the universe; and a number of topics in particle physics. These include the quantum property known as spin, electroweak theory, the Standard Model of particles and interactions, and of course the Higgs boson, which is practically a mandatory subject in any popular-physics book now.

Inevitably, Goldberg's explanations vary in quality. I found his discussion of the Casimir and Unruh effects (weird quantum phenomena in the vacuum) to be very good introductions for non-specialists. He also provides an excellent summary of the problems facing attempts to unify the different forces of nature, and specifically the question of proton decay. On the other hand, his explanation of Lagrangians and the principle of least action (both essential topics in a mathematical sense) falls short, since it requires him to define a lot of new terminology in just a few pages, most of it barely mentioned again. The book also misses an opportunity to explain how specific symmetries shaped the development of the Standard Model; while it outlines a few of the important symmetries (including parity or reflection symmetry, time-reversal, time-translation, and exchange of matter and antimatter) early on, it fails to bring them back into the picture when the Standard Model is discussed.

Goldberg sometimes indulges in the bad habit of parroting conventional narratives when they are wrong or misleading. For example, he admits that it's unfair to bring up the luminiferous aether – the hypothetical substance permeating space to provide a medium through which light can travel – only to point out that it was superseded by relativity. He even writes, "I feel a little bit dirty right now" (though that doesn't stop him). But the true unfairness of the standard narrative is that it ignores the complex reasoning behind the aether theory.

Some of the brightest minds of 19th-century physics worked on it, and the fact that they were ultimately wrong does not reflect poorly on them. We might as well call Isaac Newton an idiot for not coming up with quantum physics.

Of course, Goldberg is not alone in that brand of writerly laziness. He is also not the only one to repeat the trope that the "twin paradox" – the mismatch in age between a twin who travels to a distant star and one that stays on Earth – can only be resolved with general relativity. Even so, one hopes for better, particularly since these stories are repeated in practically every popular-physics book.

The Universe in the Rearview Mirror also contains a few odd errors of fact. Goldberg erroneously lists the prominent experimentalist Chien-Shiung Wu as "C-S Yu" – a particularly galling insult to a great scientist who has often been overlooked, in part because of her gender and ethnicity. This error seems to be one of carelessness rather than misogyny,

The book provides an engaging whirlwind tour of much that constitutes modern physics

though, since another chapter is devoted to the mathematician Emmy Noether, who is rightly lauded as a pioneer in the study of symmetry in physics. (By my count, only two other women are named in the book: the Australian particle physicist Helen Quinn and the ubiquitous Marie Curie.) In a similarly careless error, Goldberg refers to Paul Dirac as French, even though Dirac was born in Bristol and lived most of his life in the UK (his Francophone father was Swiss, not French).

Such mistakes are small but embarrassing. Putting them aside, though, the book as a whole is sound on its subject matter, and Goldberg's conversational jokes keep his narrative light. Whether readers find his jokes amusing likely depends on personal taste, though, so here's a slightly goofy metaphor that gives a flavour of the book while also encapsulating what it's about. "There's a proverb: a Persian rug is perfectly imperfect, and precisely imprecise. Traditional rugs have a small imperfection, a break in the symmetry that gives the whole thing more character. So it will be with the laws of nature, and a good thing because a perfectly symmetric universe would be staggeringly boring. Our universe is anything but."

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Alexei Kojevnikov

Plutopia forever

Reuters/Denis Sinyakov

Inhospitable zone
The area around the Techa river in Russia remains radioactively contaminated decades after the nearby Maiak Combine's radioactive-waste facility overflowed.

Plutopia: Nuclear Families, Atomic Cities, and the Great Soviet and American Plutonium Disasters
Kate Brown
2013 Oxford University Press
£16.88/$27.95hb
416pp 528pp

Kate Brown does research in places where most of her colleagues prefer not to travel. Her wonderful first book, *A Biography of No Place* (2005), explored the pre-Second-World-War history of the westernmost borderland of the Soviet Union, which was then home to a mix of ethnic minorities, including Polish, German, Ukrainian and Jewish. For her new book *Plutopia*, Brown visited two of the world's most radioactively contaminated regions: the areas near the Hanford Nuclear Reservation in Washington State and the Maiak Combine in the Ural Mountains, once the centres of plutonium production for the American and Soviet nuclear industries. Her primary interest lies in exposing the dark underside of their military-economic activities: the history of environmental pollution and the development of segregated "atomic cities" that provided privilege and better protection for the plants' permanent staff, but not for the "commoners" who lived and farmed just outside the fence.

Brown, a historian at the University of Maryland, Baltimore County, invented the word "plutopia" to characterize these cities, whose citizens were compensated for their risky work and diminished liberties with an abundantly consumerist lifestyle designed to ensure their loyalty and conformity. The city of Richland, near the Hanford site, began as an outpost of the Manhattan Project, housing workers from the US plutonium-production facility in a racially segregated settlement. After the end of the Second World War, it evolved into a futuristic city that provided its residents – predominantly blue-collar workers – with privileged middle-class salaries and standards of living, including better housing, schools, policing and special health-care services.

In the early years, Richland's Soviet counterpart, Ozersk, segregated its permanent civilian workforce from conscripted soldiers and prisoners, but motivated them with the sense of duty and self-sacrifice that came directly out of the wartime effort of saving the country from foreign invasion. Not only the rank-and-file, but also top scientists and generals, exposed themselves to high levels of radiation during work emergencies. By 1960, when the Soviet Union had achieved a modicum of security through nuclear deterrence, the city made a transition to a more peacetime mode and followed Richland in adopting a consumerist strategy. The concept of the "middle class" is not in a literal sense applicable to Soviet society, which did not permit the development of a truly rich, upper class. However, its elites were allowed a lifestyle that reminds Western observers of their own middle classes; just as in Richland, blue-collar workers in Ozersk received salaries and perks that would have been appropriate for white-collar professionals in the rest of the country.

The litany of environmental crimes at both plutopia sites extends over decades. During the early years, in a hurry to produce plutonium, the plants often processed irradiated fuel without letting it cool down long enough for the most radioactive, short-lived isotopes to decay. And when the Maiak Combine's waste-storage facility overfilled in 1949, Soviet managers did not dare interrupt production. Instead, they decided to release radioactive liquids into the river Techa, contaminating its basin forever. That same year, their American counterparts ordered the so-called "Green Run" – a release of highly radioactive waste into the Columbia River that was, they claimed, a scientific experiment.

The waste facilities at both sites leaked and released isotopes into the air. Originally meant to be temporary, they were constructed upon a wishful assumption that science would eventually figure out how to dispose of radioactive garbage. In 1957 a storage container at Maiak overheated and exploded, producing Chernobyl-scale contamination in the Urals. Soviet authorities ordered the resettlement of villages from the most dangerous area along the Techa, but the resettlement took several years and was not even completed, leaving some inhabitants within the heavily polluted zone. In the US, special interests of land speculators ensured that areas near the Hanford site were irrigated and sold to aspiring farmers who were not informed of the risks.

Plant supervisors – whether appointed by Soviet atomic agencies or by corporate subcontractors such as General Electric or Westinghouse – established similarly styled regimes of corporate loyalty, secrecy, public assurances of safety and intimidation of whistle-blowers. In *Plutopia*, Brown gives voice to critics of the cover-up practices as she describes her travels to the polluted areas, interviews those who challenged the atomic establishment or were victimized by it, and reports stories of accidents, illnesses and genetic deformities possibly related to radioactive exposure.

Brown is aware that her informants are not always reliable sources. Indeed, many are prone to the sorts of rumours and conspiracy theories that are abundantly generated around all closed sites that place strict control over information. But at the same

time, they are also bearers and collectors of unique information that has often been ignored or overlooked. Overall, Brown does a careful and convincing job as a sceptical investigator. She reports personal stories and tries to independently verify and separate reliable from unconfirmed parts, while admitting that many questions remain unresolved.

One such unresolved problem concerns health risks associated with long-term exposure to radiation in relatively low average doses. In the early years, when radiation monitoring was restricted primarily to high-intensity gamma rays, workers at certain stages of plutonium production were often overexposed to other dangers. Having observed deteriorating health and some terminal cases among employees, Soviet doctors coined the term "chronic radiation sickness" and imposed limits on the overall time workers could spend in dangerous areas. Over the years, they treated about 1000 patients suffering from this disease, but their American colleagues have been reluctant to accept the diagnosis.

In the meantime, some medical crimes were also committed. During the late 1960s, US researchers used prisoners in Walla Walla, near the Hanford site, as experimental subjects and exposed their testicles to high doses of radiation. Soviet doctors did not deliberately set up conditions for human experimentation, but they still engaged in what Brown calls "a crime of opportunity" by studying diseases and genetic disorders among villagers who had been left to live along the banks of the radioactive Techa for two generations. For the more dangerous work of cleaning up and containing accidents, both sites used so-called "jumpers" – workers conscripted or hired on a limited-term basis who were subsequently transferred elsewhere and no longer monitored for health effects.

Brown visited contaminated villages on the Techa and talked to their residents, but could not get inside the security zone encircling Maiak and Ozersk. This leaves the Soviet side of her story somewhat lacking in primary accounts, especially for the chapters describing the early years of construction. To fill the gap, she uses narratives from the secondary literature about atomic spies. However, such literature is neither very reliable (when writing about spies, many authors feel entitled to embellish stories beyond reason), nor especially relevant to the topic (unlike Los Alamos, Hanford is not known to have leaked classified information to the Soviet side). At the same time, some very appropriate sources are missing. I was surprised to find no mention of Zhores Medvedev, who blew the cover of secrecy over the 1957 radioactive disaster in the Urals, or of Mikhail Grabovsky's *Plutonievaia Zona* (2002) and other quasi-autobiographical books. Vladislav Larin's *Kombinat Maiak* (2005), the most detailed existing account of the zone's ecological problems, is used in a limited way. Insiders – residents of plutopia – could have provided more information, both in writing and in possible interviews.

The winding down of the Cold War left plutopia's managers worried: what would happen to their cities and employees once plutonium was no longer a top priority for the government? As it turned out, pollution is a profitable business and cleaning it up guarantees an even more perpetual source of spending than the initial production of radioactive materials. Thus, even in the post-Cold-War world, grants continue to pour into the military-industrial complex of the atomic cities, and to the haves rather than the have-nots. In her conclusion, Brown hints cryptically that "We are all citizens of plutopia." Her core metaphor may indeed be extendable to our increasingly segregated societies, to those living in gated communities or in states heavily guarded against immigration, and for whom the existence of such freedom-restricting boundaries is justified by the sense of entitlement, privilege and hierarchy created by the boundaries themselves.

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Web life: *AstroEDU*

URL: http://astroedu.iau.org

So what is the site about?

In the past few years, we've used this column to publicize many excellent teaching resources on the Web, including repositories for experiments on earth science (*Earth Exploration Toolbook*, March 2012, p65), quantum physics (*The Quantum Exchange*, March 2013, p61) and general science (*Science Buddies*, June 2011, p39). *AstroEDU* is a newcomer to the "online science activity database" category, having posted its first tranche of astronomy-themed projects in autumn 2013. But aside from its novelty and its focus on astronomy, what sets it apart is its commitment to peer review. In fact, all of the activities on the site have been vetted and approved by two reviewers – one astronomer and one educator.

Who is behind it?

AstroEDU is managed by Edward Gomez of the Las Cumbres Observatory Global Telescope and Pedro Russo of Leiden University in the Netherlands, with support from the International Astronomy Union's Office for Development. Both Gomez and Russo are also on the site's 10-strong editorial board, which includes astronomers from Brazil, Nigeria, Japan, Australia, Canada and Europe.

Can you describe some of the activities?

At the moment, *AstroEDU* is still a prototype, with only around a dozen projects in total. However, they are off to a promising start, with a pleasing range of activities suited to children of all ages and abilities. "Meet our neighbour: Sun", for example, is designed to help mixed classes of sighted and visually-impaired primary-school children build and explore tactile maps of the Sun, complete with flares and sunspots. At the other end of the scale, an interactive Web app called "Star in a box" gives advanced students the chance to explore what happens as stars of various masses get older and age out of the Hertzsprung–Russell diagram's "main sequence".

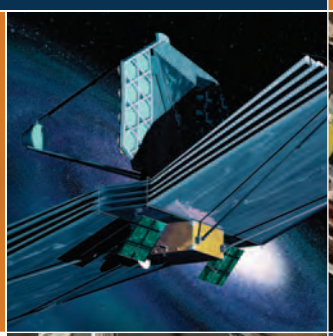
Anything else I should know?

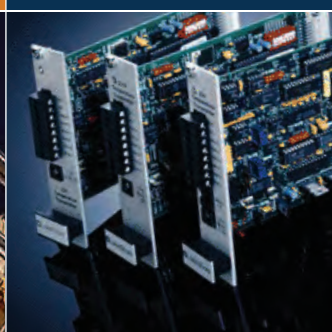
Each activity comes with extensive documentation for teachers. Some also give information on how the activity could fit into particular science curricula; for example, "Model of a black hole" is judged appropriate for a UK year 5 unit on forces.

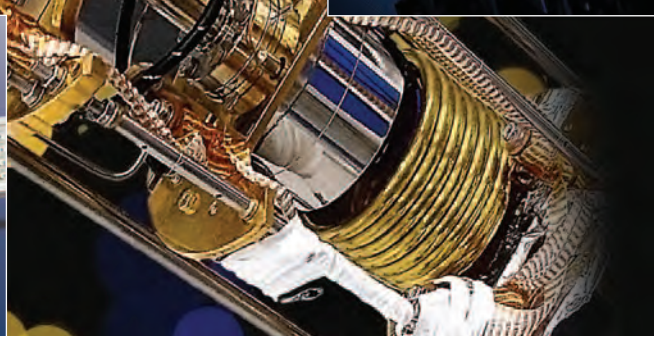
How can I get involved?

Educators, astronomers and interested members of the public are welcome to upload their own astro-themed activities to the site and/or volunteer to act as peer reviewers for others' submissions. Before doing so, however, *AstroEDU*'s managers recommend you read the site's submission guidelines and notes on activity preparation, which contain advice on how to craft resources that teach scientific skills and attitudes, not just concepts. They also advise you to "Think about what you want your students to be able to do at the end of your resources" and urge you to incorporate elements of guided, enquiry-based learning into your activities. If that sounds like a lot of work, well, yes, it probably is. Did you think teaching was easy?

Advancing Cryogenics







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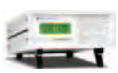

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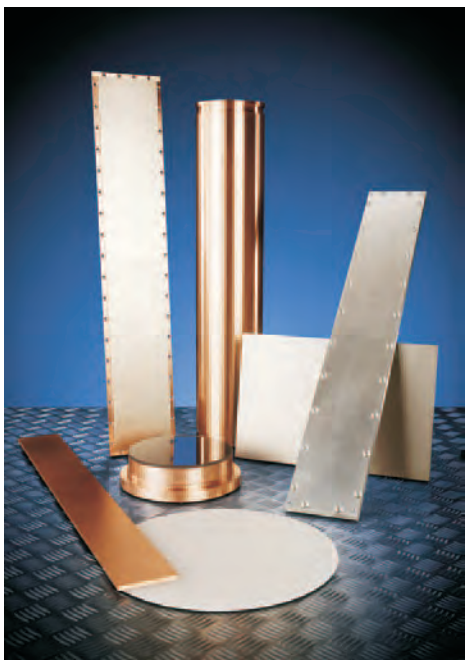

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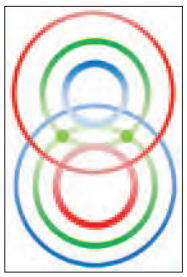
Between the lines



Different approach
Superstar teacher Leonard Susskind's new book aims to explain to quantum mechanics, but it's not one for newcomers to the subject.

Mastering quantum mechanics

Leonard Susskind's book *The Theoretical Minimum* was a surprise bestseller in 2013, defying conventional wisdom about the perils of mixing equations and popular science. Its sequel, *Quantum Mechanics: the Theoretical Minimum*, is similar in many ways. Both books are based on Susskind's popular continuing-education course at Stanford University. Both were co-written with one of his students in that course, although this time around, Art Friedman, a data consultant and former software engineer, has taken over the co-author role from science educator George Hrabovsky. And of course, the new book is just as mathematical as its predecessor. But there are also some differences. As Susskind and Friedman point out, quantum mechanics is "technically much easier" than its classical predecessor, but it is famously hard to get one's head around. Their book also takes a different approach from that of many undergraduate quantum-mechanics courses, covering entanglement, quantum information and even tensor products before encountering that old standby, the simple harmonic oscillator, in the 10th and final lecture. Readers who have seen such material before, even if in the distant past, will probably get more out of *Quantum Mechanics* than complete newcomers will. Indeed, Friedman himself qualifies as a lapsed quantum mechanic, having earned an undergraduate degree in physics before switching to computer science. As he puts it, "the world seems filled with people who are genuinely, deeply, interested in physics but whose lives have taken them in different directions. This book is for all of us".

- 2014 Allen Lane/Basic Books £20.00/$26.99hb 384pp

Now try writing about it

Tendencies towards over-formality and obfuscation in written communications by scientific practitioners have been shown to inhibit reader comprehension. Fortunately, as Anne Greene demonstrates in her book *Writing Science in Plain English*, such problems are not inevitable. Greene teaches scientific writing at the University of Montana, and her book offers solutions to many common faults, including wordy phrases, passive voice and poor sentence structure. She also digs into topics such as the "register", or tone, of a piece of writing. In casual conversations, most people employ an informal register ("How the heck do porcupines manage to mate with all those spines everywhere?"), but authors of journal articles tend to use the abstract register ("The assessment of strong direction tendencies of the North American porcupine was made…"). In Greene's view, neither register is appropriate for scientific writing. Instead, she recommends the "conventional register", where the author tells a story with identifiable characters in a formal and emotionally neutral way ("Male porcupines are polygamous and defend several females, and I hypothesized that competitively dominant males would have larger home ranges"). The book's numerous exercises give readers the chance to practise their writing and editing skills, while excerpts from well-written papers in a variety of disciplines (including astronomy and genetics as well as wildlife biology) offer inspiration. Slim enough to read on a short-haul flight and small enough to tuck into a laptop case, this book makes a good travelling companion for physicists who want to improve their professional communication skills. After all, education doesn't stop when you graduate.

- 2013 University of Chicago Press £9.00/$13.00pb 136pp

Fun and educational

When the list of children waiting to join Caroline Alliston's UK-based science club grew longer than the club's actual membership roll, she knew that she was doing something right. However, the engineer and mother of two also knew that she couldn't be in three places at once. Her solution was to collect some of her club's most successful experiments and publish them for others to use. Alliston's latest collection, *Physics for Fun*, follows two that were nominally devoted to technology and features 30 all-new projects. The book gives roughly equal space to mechanical projects (such as a miniature trebuchet) and electrical ones (including a hydrogen generator and a model house with working doorbell, lights and fan). Most experiments require only common household items, and tweens and young teens should be able to build them without much adult guidance. However, the physics behind some is rather complex, and Alliston's short, child-friendly scientific explanations do not always do it justice. The second project in the book, for example, is a spectroscope made from an old compact disc. Although the spectroscope is fairly easy to construct, a proper explanation of how it actually works would challenge A-level students, never mind the book's target audience of children aged 7–14 years. Long on fun but perhaps a little short on physics, *Physics for Fun* nevertheless makes a good source of ideas for parents, teachers and would-be science-club founders.

- 2013 Alliston Publishing £5.00pb 60pp

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Abstract Submission Opens May 19, 2014

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- A Organic Bioelectronics
- B Multifunctional Polymeric and Hybrid Materials
- C Medical Applications of Noble Metal Nanoparticles (NMNPs)
- D Materials and Concepts for Biomedical Sensing
- E Hard-Soft Interfaces in Biological and Bioinspired Materials—Bridging the Gap between Theory and Experiment
- F Reverse Engineering of Bioinspired Nanomaterials
- G Plasma Processing and Diagnostics for Life Sciences
- H Micro/Nano Engineering and Devices for Molecular and Cellular Manipulation, Stimulation and Analysis
- I Emerging 1D and 2D Nanomaterials in Health Care

ELECTRONICS AND PHOTONICS

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- K Graphene and Graphene Nanocomposites
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- O Oxide Semiconductors
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- Y Technologies for Grid-Scale Energy Storage
- Z Materials Challenges for Energy Storage across Multiple Scales
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- BB Molecular, Polymer and Hybrid Materials for Thermoelectrics
- CC Advanced Materials and Devices for Thermoelectric Energy Conversion
- DD Materials for Advanced Nuclear Technologies
- EE Scientific Basis for Nuclear Waste Management XXXVIII
- FF Materials as Tools for Sustainability

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- HH Flame and High-Temperature Synthesis of Functional Nanomaterials—Fundamentals and Applications
- II Semiconductor Nanocrystals, Plasmonic Metal Nanoparticles, and Metal-Hybrid Structures
- JJ 3D Mesoscale Architectures—Synthesis, Assembly, Properties and Applications
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- TT Advanced Materials Exploration with Neutrons and X-Rays—The State-of-the-Art in the International Year of Crystallography

GENERAL

- UU Structure-Property Relations in Amorphous Solids
- VV Reactive Materials—Past, Present and Future
- WW Defects and Radiation Effects in Advanced Materials
- XX Bridging Scales in Heterogeneous Materials
- YY Advanced Structural and Functional Intermetallic-Based Alloys
- ZZ Hierarchical, High-Rate, Hybrid and Roll-to-Roll Manufacturing
- AAA Undergraduate Research in Materials Science—Impacts and Benefits

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GraduateCareers

March 2014

Working abroad

The ups and downs of travelling the globe for your career

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GraduateCareers

Navigating new cultures

Working overseas is a common career step for physics graduates, but moving countries can produce a culture shock. **Sharon Ann Holgate** explains how to manage the effects of cultural differences

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Many physicists will study or work overseas at some point during their careers. Indeed, the field's international nature means that even those who remain in their home countries will regularly interact with colleagues from around the globe. While being exposed to new cultures can be enriching, cultural differences can also create challenges for physics graduates who choose to do further study overseas, accept a short-term secondment or research post in another country, or even just attend a foreign conference. Fortunately, the downsides can be minimized with some planning and insider knowledge.

Consider Clive Alabaster, a Norway-based British physicist who is a co-director and consultant at White Horse Radar. His work has taken him to a wide range of countries, including Australia, Canada, Germany, Malaysia, South Korea and – while in his former role as a lecturer at the UK's Cranfield University – Saudi Arabia. Alabaster says that he read up on all of these countries before travelling, but before his Saudi trip, he also sought advice from the university's international-affairs office and an Arabic-speaking colleague who had previously worked there. From them, he says, "I learned if somebody passes you something, you must accept it in your right hand and pass it right hand to right hand". At mealtimes, Alabaster adds, you will keep being offered food in Saudi Arabia until you decline it. "It's perfectly okay to decline, but if you have accepted it onto your plate you should finish it," he says.

Speaking the language

Alabaster also recommends learning at least some of the local language when working abroad, even if your working language is English. "If you can say 'please', 'yes' and 'thank you', people will look very kindly on that," he explains. But as with most things, the more you put into studying a language, the more you will get out. Erik Lucero, an American-born physicist who is now a research scientist at HRL Laboratories in the US, served as the "international ambassador" for his PhD research group at the University of California, Santa Barbara. He says that as well as boosting his language skills, classes in basic Japanese "helped prime me for the culture" before he travelled to Japan to promote the group's research at the country's RIKEN institute. By talking to colleagues who had worked in Japan, Lucero also discovered that having business cards is "a big deal" there because that is how people exchange details. In the US, he adds, "I wouldn't have ever thought of needing them, especially as a graduate student."

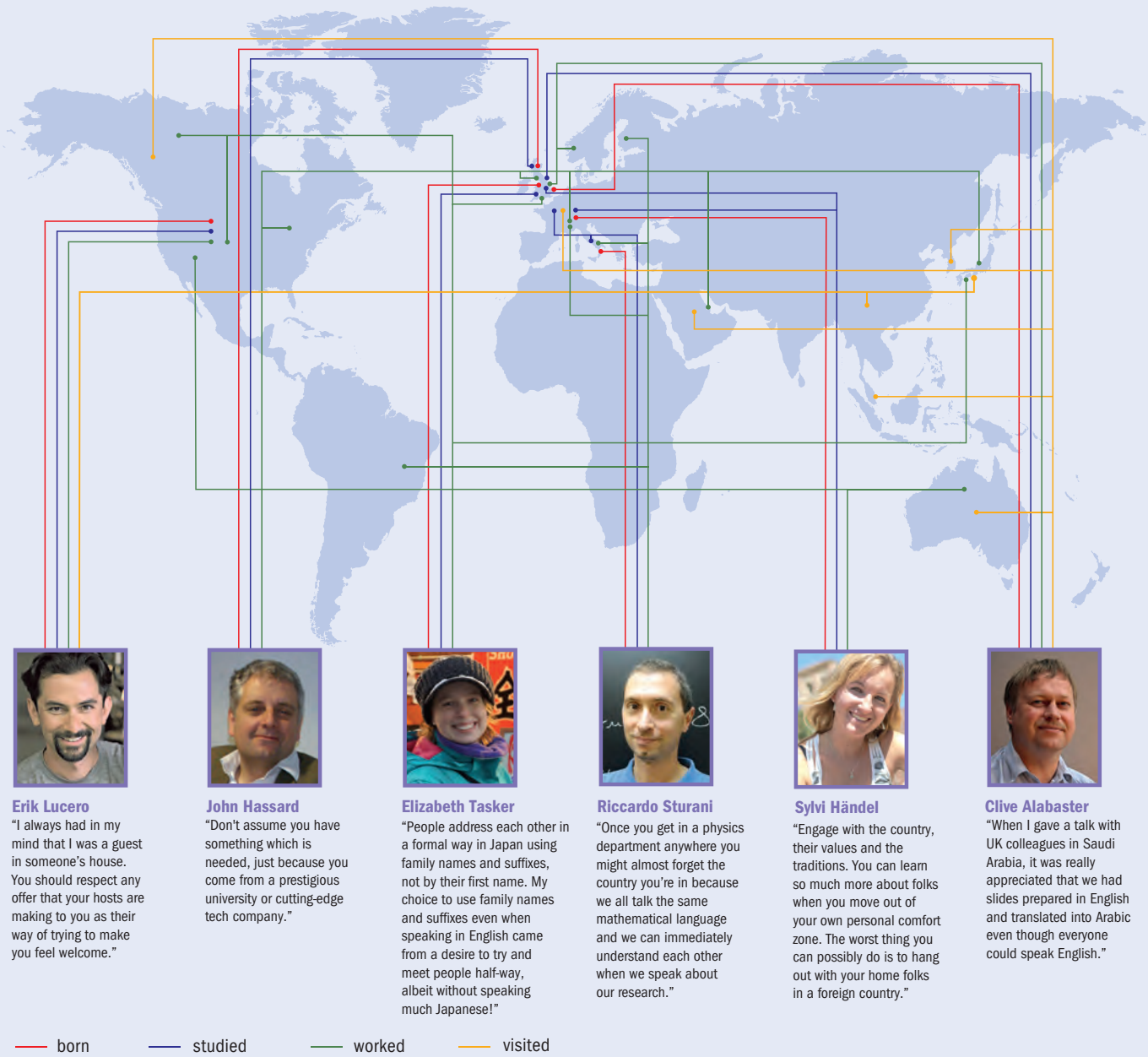
Some communication differences are less easily dealt with. Elizabeth Tasker is a physicist at Hokkaido University in Japan, and has previously worked in Canada and the US after studying in her native UK. In contrast to people in these other countries, who typically nod their heads to signal agreement and understanding, Tasker notes that "Japanese people nod and smile to show they are listening, but they may not be understanding anything. This leads to many misunderstandings and strange conversations." She advises that anyone who comes to work in Japan from overseas should "be prepared to roll with the mistakes", adding,"You will be misunderstood so you always need a plan B!"

> If you can say 'please', 'yes' and 'thank you', people will look very kindly on that

When in Rome...

Another way to maximize your effectiveness is to look out for, and adapt to, differences in working practices. For example, after discovering that Norway's working hours are shorter than the UK's, Alabaster says that he now avoids arranging meetings there before 10 a.m. or after 4 p.m. Management styles can also differ widely. Sylvi Händel, a postdoctoral researcher in physics at the University of California, Los Angeles, who has previously worked in Australia and studied in the UK, has experienced this first-hand. In her native Germany, she says, "When you have done something wrong or not completed a task…people are very direct and will tell you. In the UK, people will rather suggest

Globetrotters: six physicists who have worked abroad



Erik Lucero
"I always had in my mind that I was a guest in someone's house. You should respect any offer that your hosts are making to you as their way of trying to make you feel welcome."

John Hassard
"Don't assume you have something which is needed, just because you come from a prestigious university or cutting-edge tech company."

Elizabeth Tasker
"People address each other in a formal way in Japan using family names and suffixes, not by their first name. My choice to use family names and suffixes even when speaking in English came from a desire to try and meet people half-way, albeit without speaking much Japanese!"

Riccardo Sturani
"Once you get in a physics department anywhere you might almost forget the country you're in because we all talk the same mathematical language and we can immediately understand each other when we speak about our research."

Sylvi Händel
"Engage with the country, their values and the traditions. You can learn so much more about folks when you move out of your own personal comfort zone. The worst thing you can possibly do is to hang out with your home folks in a foreign country."

Clive Alabaster
"When I gave a talk with UK colleagues in Saudi Arabia, it was really appreciated that we had slides prepared in English and translated into Arabic even though everyone could speak English."

an alternative idea to you, so it is a totally different approach."

Keep in mind though that some differences that you encounter will be personal rather than cultural. When it comes to business negotiations, "Aggressive, passive, hard-working, lazy, selfish, constructive, honest and devious approaches exist everywhere," says John Hassard, a UK-born physicist at Imperial College London, who has founded companies in Qatar and Bahrain. Hassard, who is currently based in Qatar, but has also worked in the US, Japan and Switzerland, advises finding out about any specific procedures relevant to the country you are working in before starting business negotiations. Otherwise, though, he recommends treating everyone the same.

Social interactions

For Händel, the biggest cultural challenge of working abroad is meeting and making friends with people outside of the work environment. "I usually deal with the problem by joining a local sport or hobby group," she says, adding that it is "helpful to engage in watching the 'national sport' with colleagues, just to get in touch with people". Similarly, Lucero connected with colleagues in the physics lab he visited at China's Zhejiang University by inviting them to play the tile game mah-jong, which is, he explains, "very culturally relevant to the Chinese".

Social differences are more numerous than professional ones, according to Riccardo Sturani, an Italian-born physicist who is currently on a four-year research contract at the Universidade Estadual Paulista in São Paulo, Brazil. A veteran observer of cultural differences, Sturani

has studied in Italy and France, and worked as a postdoc in Finland, Switzerland and Italy before moving to Brazil. He says that Finland gave him the biggest cultural shock because it took more time to get to know people there. "In Finland, people tend to interact less with you on a human level because they don't want to invade your privacy," he says. "It's because of their natural shyness and their way to show respect and consideration for you."

As challenging as working overseas can be, many physicists find it well worth the effort. "Of course it's hard to jump-start a new life in a new city," Sturani says. "You don't even know where to shop for food, let alone who to go out with at the weekend. But you usually know your colleagues already because you've met them at conferences, and I like the challenge and excitement of learning new languages and being part of a different culture." There can be professional advantages as well. Although he has never lived outside the US, Lucero says that he feels "very fortunate to have been able to go abroad and see how other people in the world do great physics". He adds "For my own growth as a scientist, seeing the slight differences in their approach to the work was very important for me to reflect on and I've tried to integrate these different approaches into how I work now."

Sharon Ann Holgate is a freelance science writer and broadcaster with a DPhil in physics, www.sharonannholgate.com

Making the right move

Your first steps into the world of work after graduation are an adventure and working abroad can seem like an especially exciting way to begin. But is it right for you? **Marcia Malory** investigates

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Working in a foreign country can be rewarding. "It strengthens the CV to do some international time, learning about different cultures and acquiring language skills," says Gordon Chesterman, careers-service director at the University of Cambridge, UK. Employers may regard foreign experience as a sign of "a little bit more independence and maturity in someone", he adds, because it inevitably involves "being removed from the protection of friends and family".

On the other hand, expat life can be stressful. On a bad day, homesickness can strike anyone, even the most emotionally hardy. After you've had an argument with a close friend or been criticized unfairly by your manager, the inability to find your favourite comfort food can seem intolerable. And even if you love being in a new environment, there will be times when cultural differences seem overwhelming (see pp62–64). So what can you do to minimize these problems and make the most of your time in a new place?

Do your research

When deciding where to work, Chesterman suggests that you begin by considering your motives for moving abroad. For example, are you moving to experience a new culture? If so, he says, "The bigger the cultural differences, the more you're going to gain." But if your reasons are related to career or research opportunities, it is probably more important that the country you're moving to has prestigious academic institutions or companies that will enhance your CV.

Once you have decided where you want to go, you can minimize stress by finding out in advance what to expect once you're there. Learn about all the regulations that will affect you, from immigration laws to foreign tax rules, and try to foresee any problems that could arise (see box opposite). For example, a bank might require proof of residence, while a landlord might want you to have a bank account. Remember: once you've graduated you won't have an adviser to teach you how to find a place to live or get your electricity turned on. How will you deal with such matters independently?

When deciding where to work, begin by considering your motives for moving abroad

Then there's the financial side. "We encourage students to look at the cost of living," says Chesterman. "It can be astronomical in some cities and much less in others." Can you be sure that your earnings will cover your expenses? Have you thought about exchange rates? You should also consider ways that being a foreigner could affect your job prospects. Some employers might be reluctant to hire you and University of London career adviser Deena Lamela-Panthaky recommends that you study a country's work culture before making an application. "What kind of application processes are they used to? What does a CV look like there? Does everybody go to an agency?" Little things, such as using the expected e-mail format, can affect how prospective employers perceive you.

Delayed reactions

Other challenges associated with working abroad may not become apparent until

after you move. For example, your non-citizen status could cause you problems at work. Kirsten Cooper, head of physics at Bootham School in York, UK, is originally from South Africa and she observes that class trips to other EU countries were a real pain before she obtained UK citizenship. "You have to take a train down to London and apply for a visa. You have to have all of your accommodation sorted out. You have to have an invitation. It's expensive."

If you move to another country for short-term work or study (as an international student or postdoc, for example) and then decide to stay permanently, you may face a fresh set of issues. Universities are often much more culturally diverse than their surrounding communities; after graduation you might be the only person from your country living in your area or working at your organization. Cooper recalls that after she left the University of York, where she received her Master's degree, someone assumed that she didn't know how to use a mobile phone. Primary-school students at her first teaching job mistook her South African accent for a speech impediment.

It's okay to go home

Most expats feel lonely or lost sometimes. However, if you're constantly feeling angry, sad or frustrated, it might be best for you to return home. If this happens, don't be disappointed with yourself. Settling in a foreign country is extremely challenging and not everyone is cut out for it.

But regardless of whether your time abroad proves to be a learning experience or an exciting adventure (or both), you should expect to feel some reverse culture shock when you return to your home country. Living abroad will have changed you. At first you might feel as out of place back home as you once did when you were away. Give yourself time to reacquaint yourself with your former surroundings, and give your family and friends a chance to get used to the new you. You will adjust. After all, when you spend time abroad you develop the skills required to cope with change wherever you are.

Marcia Malory is a freelance science writer, www.marciamalory.com

Dos and don'ts when working abroad

Do take care of your visa
Find out what visa you need to live and work in the country, and how to get yours approved. Visas can be expensive so make sure you can afford to pay for yours. If you have a spouse or children who are moving with you, they will need visas too.

Do pay your taxes
Learn your home country's rules on how expats are taxed as well as your adopted country's rules on the taxation of immigrants. Find out if there's a tax treaty between the two countries.

Don't leave your housing search too late
You might need to show proof of accommodation to obtain your visa, but finding a landlord who will rent to someone who can't yet live in the country legally and has no credit history there could be difficult. Give yourself time to resolve such possible catch-22s.

Don't stick to your own kind
The best way to avoid homesickness and get used to your new culture is to interact with local people. Go out with your colleagues. Join a club or a community group. Become a volunteer.

Do be kind to yourself
Simple things, such as paying for groceries or using public transport, can become difficult when you haven't yet learned exactly how the system works. Learn from your mistakes; don't punish yourself for making them.

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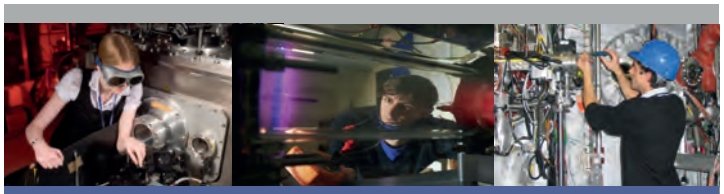

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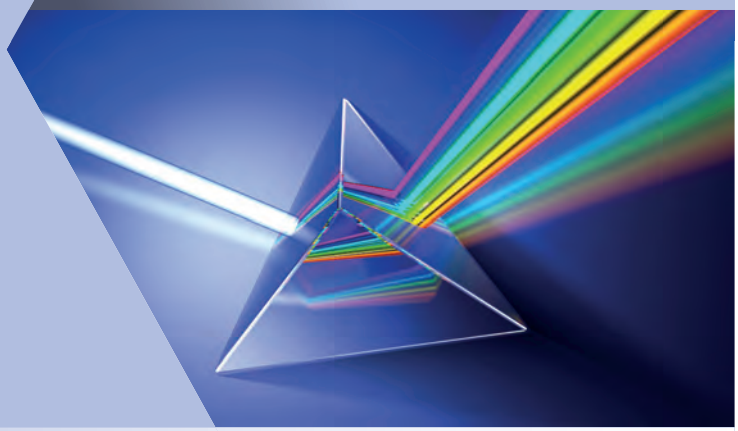

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Closing Date March 21, 2014

UNIVERSITY OF CAMBRIDGE

THE WINTON PROGRAMME FOR THE Physics of Sustainability

Winton Advanced Research Fellowships in the Physics of Sustainability

University of Cambridge – Department of Physics

Fixed-term: The funds for this post are available for 5 years in the first instance.

The Fund Managers of the Winton Programme invite applications for up to two Advanced Research Fellowships. Fellowships will be of 5 years' duration and will provide salary comparable to junior university faculty positions (on the scale currently £37,756–£47,787 per annum) and appropriate support for equipment, graduate students, travel and operating expenses. Proposed projects should be in new areas or take new approaches in established areas related to research in the broad field of the application of physics to sustainability.

For application details and further information see: http://www.winton.phy.cam.ac.uk/jobs

Quote reference: KA02722

Closing Date: 31 March 2014

The University values diversity and is committed to equality of opportunity.

Magnox

Radiological Protection Engineers – Chapelcross (Dumfriesshire)

Circa – £39k-£61k, dependent on experience plus excellent benefits

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In promoting equal opportunities, we welcome applicants from all sections of the community. We select people according to their abilities and our needs.

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

The Faculty of Physics, Mathematics, and Computer Science at the Johannes Gutenberg University of Mainz (JGU) invites applications for an appointment at the level of

University Professor (W2 with tenure) in Experimental Physics

in the area of Electronic and Magnetic Properties of Condensed Matter Systems. The professorship will become available in 2014.

We are looking for a scientist with an internationally visible research record in the fields of electronic and magnetic properties (such as magnetism, superconductivity, topological insulators etc.) of new correlated materials. Possible research topics are static and dynamical properties of nanostructures, inorganic/molecular hybrid systems and the interaction of spin, charge and orbital degrees of freedom.

The position is embedded in the Graduate School of Excellence Materials Science in Mainz (MAINZ) and intense collaboration with existing experimental and theoretical groups at the Institute of Physics is expected. Candidates have the possibility to participate in coordinated research activities, in the Center for Innovative and Emerging Materials (CINEMA), and will have access to state-of-the-art lithography and microscopy tools.

Applicants are expected to have a Ph.D. in physics, a proven first rate research record and to possess the required pedagogical skills for teaching. Undergraduate courses are usually given in German. JGU promotes a concept of intensive tutoring and expects a high rate of presence at the university. The appointment requires participation in teaching activities and in the duties of academic administration.

JGU aims at increasing the percentage of women in academic positions and encourages in particular the application of women.

JGU is an equal opportunity employer and particularly welcomes applications from persons with disabilities.

JGU is a leading research university with a focus on Physics and Materials Sciences and is regularly ranked top 10 in Germany. At the Institute of Physics a number of large scale research activities are coordinated including the Graduate School of Excellence Materials Science in Mainz (www.mainz.uni-mainz.de) and the Excellence Research Cluster "Precision Physics, Fundamental Interactions and Structure of Matter" as part of the German Federal Excellence Initiative.

Qualified candidates are asked to submit their applications **by March 31, 2014**, including the usual documents (CV; list of publications; copies of three key publications; research proposal) as a single PDF file via the portal **http://www.phmi.uni-mainz.de/stellen**.

Applications should be addressed to

"Dekan des Fachbereichs 08, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz".

National Taiwan University

Postdoctoral Position in Atomic, Molecular, and Optical Physics, National Taiwan University

Applicants are invited for a postdoctoral position in theoretical and computational atomic, molecular, and optical physics or chemical physics. The candidate should have strong background in high performance computing. The successful candidate will conduct research in one or more of the following forefront areas: atomic and molecular multiphoton processes in intense laser fields, attosecond science, time-dependent density functional theory, coherent control, Quantum computing / information, etc.

Applications including a cv, list of publications, and at least three recommendation letters should be sent to:

Professor S. I. Chu,
Center for Quantum Science and Engineering,
Department of Physics, National Taiwan University,
E-mail: **sichu2010@gmail.com**

LANCASTER UNIVERSITY DEPARTMENT OF PHYSICS

Chair in Physics

Salary: Professorial Band 2 (minimum £83,011)
Closing Date: Thursday 01 May 2014
Reference: A908

Lancaster's Department of Physics was ranked first and equal-first in the 2008 and 2001 UK Research Assessment Exercises respectively and is seeking to further enhance its scientific standing.

Lancaster University wishes to appoint an outstanding physicist at the level of Professor (equivalent to a Full Professor), to join an existing research group or create a new research group in any area of experimental or theoretical physics which complements and enhances the existing research programme of the Physics Department. At Lancaster there are 3 professorial pay bands and Band 2 is just below the Distinguished Professor grade (Band 3).

The post is permanent and tenable from 1 October 2014. In addition to your research activities, you will also be involved with undergraduate and postgraduate teaching.

If you are an ambitious scientist with an international reputation for excellence in research, please contact Professor Peter Ratoff (Head of Department) for an informal discussion.
Email: p.ratoff@lancaster.ac.uk Tel: +44 1524 593639.

The Lancaster University Department of Physics is strongly committed to fostering diversity within its community as a source of excellence, cultural enrichment, and social strength. We welcome those who would contribute to the further diversification of our department.

The Cockcroft Institute of Accelerator Science and Technology

LANCASTER UNIVERSITY DEPARTMENT OF PHYSICS

Chair in Accelerator Physics (Associate Director of the Cockcroft Institute)
Salary: Professorial (minimum £60,266)
Reference: A907

And

Lecturer in Accelerator Physics
Salary: £37,756 to £45,053
Reference: A909

Closing date: Thursday 1st May 2014

As a founding member of the Cockroft Institute and with the UK's highest ranking physics department in the 2008 Research Assessment Exercise, Lancaster University is seeking to appoint a Chair in Accelerator Physics (Associate Director of the Cockcroft Institute) and Lecturer (Assistant Professor) in Accelerator Physics to further consolidate the Institute's international profile. The successful applicants will be expected to advance experimental research in accelerator physics in close collaboration with Institute members in the Physics & Engineering Departments, other universities, and Daresbury and Rutherford Appleton Laboratories.

You must have a Ph.D. in accelerator physics, particle physics, electrical engineering or a related discipline, with an outstanding research and publications record and a high level appreciation and grasp of potential future international accelerator developments.

Informal inquiries about the institute may be made to Professor Swapan Chattopadhyay, **swapan@cockcroft.ac.uk**. For information about the Lancaster University Physics Department: Professor Peter Ratoff, **p.ratoff@lancaster.ac.uk**.

The Lancaster University Department of Physics is strongly committed to fostering diversity within its community as a source of excellence, cultural enrichment, and social strength. We welcome those who would contribute to the further diversification of our department.

But it's obvious!

In *Through the Looking Glass*, Humpty Dumpty tells Alice, rather scornfully, "When I use a word it means just what I choose it to mean – neither more nor less." Well, fine, but it would still be a good idea to make clear to others what that meaning is. This is often done informally by means of "conventions", which are defined as "established usage". But who does the establishing? Questions related to definitions are often regarded as pedantic – nowadays a pejorative term – because the answer is "obvious". But is it? A few examples illustrate some possible pitfalls.

The direction of linear polarization of light is generally set by that of the electrical vector, or *e*-vector. Thus light reflected from a horizontal shiny surface is horizontally polarized. But once, when laying out a practical class in remedial physics for biology students, I found that the Polaroid sheets had all been marked the "wrong" way. Upon querying this, I was told that "physicists refer to the *magnetic* vector", and under this convention, light reflected from a horizontal shiny surface is vertically polarized. Maybe some physicists do use this convention, but even back in the early 1900s, such usage was regarded by R W Wood (author of *Physical Optics*, first published in 1905) as "rather unfortunate". By the time the third edition was published in 1934, Wood had firmly rejected it, and the *e*-vector convention is also used in all the later physics textbooks I own.

When linearly polarized light passes through an optically active medium, such as a solution of natural sugars, its direction of polarization rotates progressively. If the rotation is seen to be clockwise, it is said to be right-handed or dextrorotatory – as with sucrose or glucose (also known as dextrose). If the rotation is anticlockwise, it is left-handed or laevorotatory, as with fructose (aka laevulose). This convention is universally accepted because it is "obvious" – the light passing through the solution is always observed as it comes towards one's self, and no other interpretation seems sensible. (Although it does raise the question of why clockwise is considered "right handed", since the hands go *left* at the bottom of the dial!)

But things are not so clear when the polarization is circular. In this case the vector(s) rotate, following a helical course, and there is no widely accepted interpretation of the handedness of movement along a helix. True, a normal corkscrew and the thread of a right-handed screw are seen to rotate clockwise as they recede from the observer, and the screw advances (tightens) when rotated clockwise. So far, so good; it's *obvious*. But a botanist looking down at the seedling of a climbing plant will say that it rotates clockwise if it twines to the right – that is, coming *towards* the observer. The right-handed hop plant twines "round its poales…always according to the course of the sunne" (Reynolde Scot, *A Perfite Platform of a Hoppe Garden*, 1574), while bindweed and runner beans twine the other way – anticlockwise. That usage is *obvious* too, although if viewed from soil level (as by an ant) it would look otherwise.

With radiated signals, the convention used depends on whether one considers the transmitter or the receiver. It is said that the very poor initial reception of signals from the Telstar satellite by the Goonhilly Down facility in south-west England was due to different conventions regarding circular polarization between US and UK radio engineers: one team had considered the handedness of signals as they were transmitted, while the other team looked at their being received.

Shutterstock/TwilightArtPictures

There is no widely accepted interpretation of the handedness of movement along a helix

Finally, a difference of usage is now appearing in relation to circularly polarizing optical filters. To me, it would seem logical for a left-handed filter to be one that allows left-handed circularly polarized light to pass through it, and can therefore be used to create such light from unpolarized light. This seems to be a natural and *obvious* usage. But recently some authors have adopted the opposite convention: to them, a left-handed filter is one that blocks left-handed circularly polarized light. They claim this is the convention "used by physicists". Is it really? To me, this convention appears unnatural and potentially misleading. (And my suppliers do not use it – so take care when ordering!)

Of course, any usage is acceptable provided one makes clear what it is. A good example is electronic filters, which are usually (and helpfully) specified as either "bandpass" or "bandstop" for particular frequencies. But in photography, a "UV filter" can either be a filter used to block UV or the exact opposite: a "blacklight" filter used to take pictures by UV alone. Here the sense is usually clear only from the context.

Pedantry can sometimes be overly fussy. It would be plain pernickety, for example, to make every botanical reference define its convention on twining handedness, since the usage is universal within that field. But where different usages are known to exist, then a definition should certainly be given. Otherwise, serious misunderstandings can and will arise. The signal-reception problem at Goonhilly Down was quickly corrected by rewinding a helical antenna, and is now forgotten. However, a few decades later, the Mars Climate Orbiter burned up while entering the planet's atmosphere because its two teams were using different unit systems – and the choice of units would seem even more "obvious" than different definitions of terms.

David Pye is emeritus professor of zoology at Queen Mary, University of London, UK, and author of *Polarised Light in Science and Nature* (Institute of Physics Publishing, 2001), e-mail dpye6@aol.com

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