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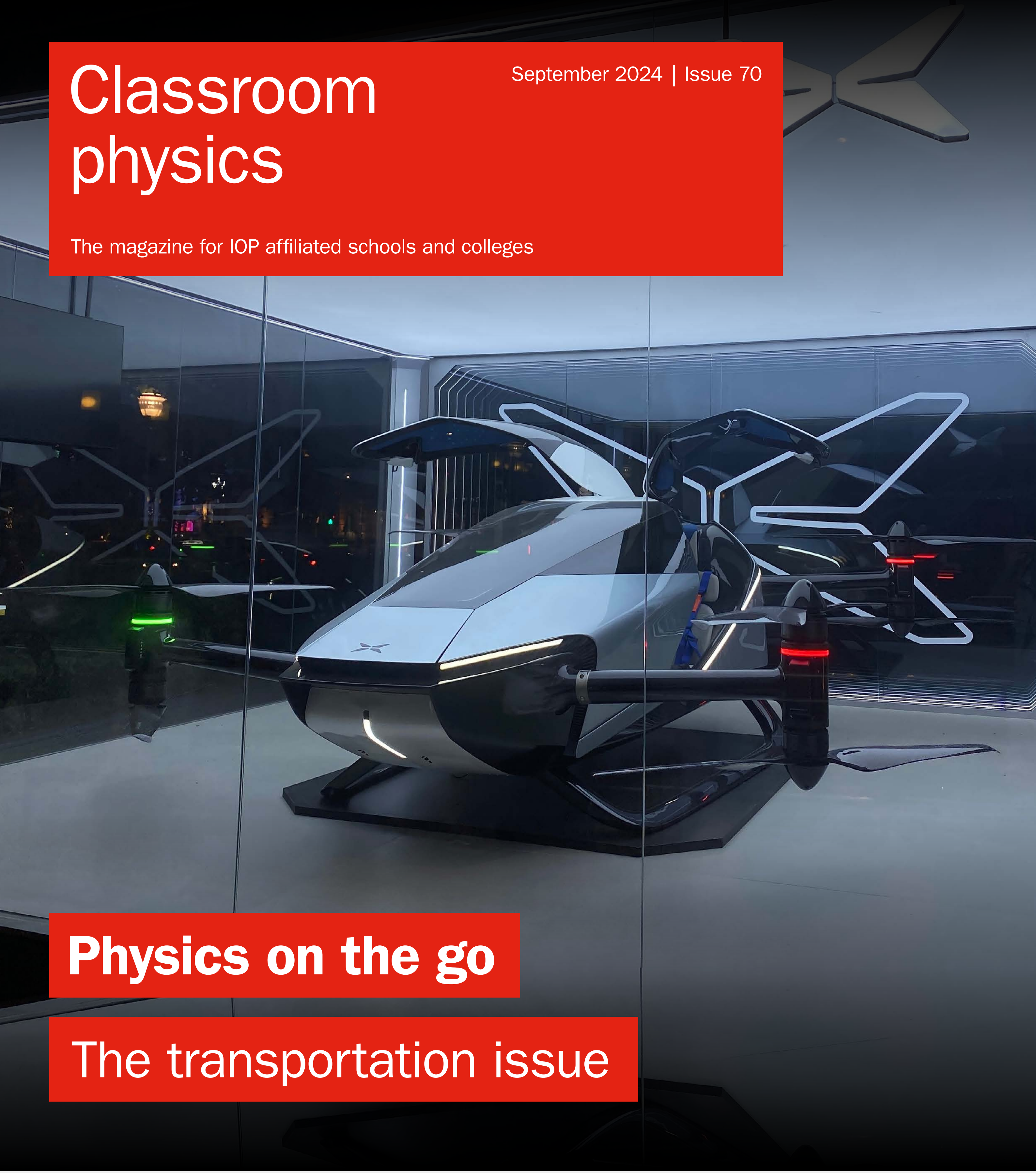
Classroom physics

The magazine for IOP affiliated schools and colleges



Physics on the go

The transportation issue

Focus on electric flight with activities on batteries, motors and propellers

Alternative answers to powering electric vehicles

How the kingfisher shaped the bullet train

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IOP Institute of Physics

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Editors' note

We hope you had a great end to the academic year and enjoyed a well-earned summer break.

We're pleased to be back with our transportation issue, where we look at the technologies that move people and things – by road, rail, air or sea.

We've particularly focused on green transport, and what's happening with various modes of transportation as they look to transition away from fossil fuels. In our lead feature (page 6–7), guest writer Averil MacDonald makes the case for hydrogen as part of the future energy mix to decarbonise transport. In our regular slot with items from Physics World (page 16) are two interesting takes on the steps being taken to reduce the carbon footprint of shipping and aviation.

Another theme in this issue is electric flight. Here we've looked at the growing use of drones for delivery services (page 7) and, in our teaching resources pull-out section (pages 9–12), the physics underpinning flying cars.

We're grateful to all the partner organisations who have shared content, resources and links on the transport theme. Look out for those alongside all our regular features.

Be sure also to check pages 19 and 20 for information on upcoming events and opportunities – there's quite a full few months ahead.

Have a great term!

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IOP affiliated schools and colleges will receive with this issue...

A copy of the new IOP teacher subject knowledge framework. Find out more on page 4.

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Read Classroom Physics online and access previous editions at **spark.iop.org/classroom-physics**

IOP activities round-up

The IOP's annual celebration of physics, held in June at Silverstone welcomed guests from across IOP's membership, as well as several of the 2023 IOP Awards recipients and over 150 pupils from local schools.

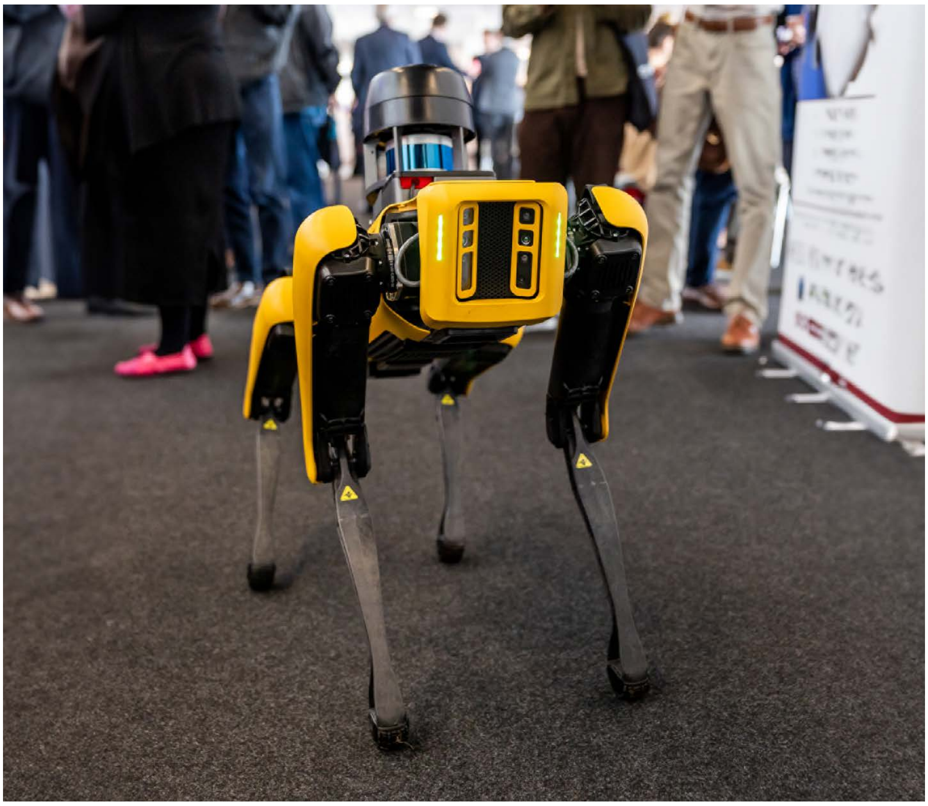
Among those to receive IOP Awards in 2023 were a group of teachers and technicians from schools and universities around the UK, and a young recipient of the Apprenticeship Award. Keen readers of Classroom Physics may recall us featuring content from Saskia Burke (apprentice) and Razika Berboucha (technician) in March, and we're delighted to include an article from IOP Technician Award winner Andres Tretiakov in this issue.

Other event highlights included Elizabeth Cunningham, IOP's Vice-President for Membership, speaking to local schoolchildren about physics-based career opportunities. Guests also heard about IOP's five-year strategy and a new IOP Inclusion Award, designed to support university departments to be welcoming and inclusive to all. Among the many speakers and demonstrators on aspects of physics research, highlights included an AI robot dog (pictured).

Early in July, IOP's Claudia Gipson, Influencing & Engagement Manager, delivered a session at The Ogden Trust's 25th anniversary conference. This focused on technical education including physics related apprenticeships and T levels, as well as sharing findings from the 'Solving skills' report and case studies from the follow-up 'Solving Skills One Year On' report, published this year.

Practical support in Wales

In Wales, the 'Experimental Extravaganza' events at the beginning of July marked their third year with conferences at Coleg Merthyr and Bangor University. These events were in partnership with the Royal Society of Chemistry



Credit: IOP

An AI dog at the Silverstone event in June

and benefited from guest speakers from Cardiff University and Bangor University School of Ocean Sciences.

In total almost 100 physics, chemistry, biology and non-subject specialist teachers and technicians, signed up for the events, which this year focused on practical work and how to overcome the challenges in this crucial component of science education.

The events also featured Gary Williams from Physics Education (see pages 14–15) who introduced research papers, as a stepping stone to teachers conducting their own action research – something strongly encouraged by the Welsh Government as part of a teacher's Professional Learning Passport (PLP).

Summer holiday engagement and outreach

Through the summer holidays, IOP hosted events around the UK and Ireland for young children and families, based on 'Mimi's Space Adventure'. Exhibitions and weekend family activity days were held at the IOP headquarters in London and Dublin, as well as a special appearance at the Inverkeithing Highland Games.

'Mimi's Space Adventure' was developed with funding from the UK Space Agency as part of its Space for All project. It followed on from 'Mimi's Rainbow Adventure', published last year as part of the Limit Less campaign.

Credit: IOP

Guests at 'Mimi's Space Adventure' in London

IOP intervenes after A level physics paper leaves pupils "shaken"

IOP Chief Executive Tom Grinyer has written to the AQA exam board after reports that students were left distressed and disheartened by an A level physics paper.

The IOP had already raised concerns in 2023 that the AQA A level physics paper 2 was too challenging – as was evidenced by the grade boundary for an A being set at 49%. While ultimately the number of A grades awarded was unaffected, the fact that even the best students were not able to answer half of the questions in the exam had serious impacts. As well as creating anxiety for individual students, setting papers that are too difficult feeds into the damaging and unwarranted reputation among young people that physics, as a discipline, is harder than other subjects.

Worryingly, similar reports emerged after this summer's exam. Comments from online forums, and messages sent to the IOP team directly from teachers and parents, indicated that pupils "felt shaken by the experience, worried about the results and, in some cases, unsure whether to stick with physics beyond 18", according to the letter.

Charles Tracy, Senior Adviser for Learning and Skills at the IOP, commented: "In effect, the reputation of physics is in the hands of a small number of examiners at AQA. Amongst other things, we are calling for greater scrutiny of papers and questions before they go out."

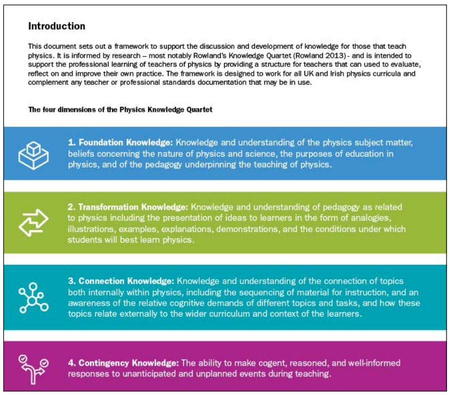
IOP are currently involved in discussions with AQA about the issue.

Physics subject knowledge framework

The IOP has published a new subject knowledge framework to support teachers of physics in their professional learning.

The framework is built around the 'knowledge quartet', based on the research of Tim Rowland and others, and provides a structure for focusing on four different dimensions of a teacher's professional capability. These are foundation knowledge (their underpinning substantive knowledge of physics), transformation knowledge (how they represent ideas to students), connection knowledge (knowing how ideas relate to each other and how to sequence them), and contingency knowledge (being ready for the unexpected).

The framework is designed to work for teachers across the UK and Ireland and will complement any teacher or professional standards documentation that they use.



Introduction

This document sets out a framework to support the discussion and development of knowledge for those that teach physics. It is informed by research – most notably Rowland's Knowledge Quartet (Rowland 2013) - and is intended to support the professional learning of teachers of physics by providing a structure for teachers that can used to evaluate, reflect on and improve their own practice. The framework is designed to work for all UK and Irish physics curricula and complement any teacher or professional standards documentation that may be in use.

The four dimensions of the Physics Knowledge Quartet

1. Foundation Knowledge: Knowledge and understanding of the physics subject matter, beliefs concerning the nature of physics and science, the purposes of education in physics, and of the pedagogy underpinning the teaching of physics.

2. Transformation Knowledge: Knowledge and understanding of pedagogy as related to physics including the presentation of ideas to learners in the form of analogies, illustrations, examples, explanations, demonstrations, and the conditions under which students will best learn physics.

3. Connection Knowledge: Knowledge and understanding of the connection of topics both internally within physics, including the sequencing of material for instruction, and an awareness of the relative cognitive demands of different topics and tasks, and how these topics relate externally to the wider curriculum and context of the learners.

4. Contingency Knowledge: The ability to make cogent, reasoned, and well-informed responses to unanticipated and unplanned events during teaching.

For each dimension, the framework provides a series of detailed examples of teaching approaches that would demonstrate knowledge and understanding. The document is intentionally not a tick sheet. Instead it is designed to provide prompts to help teachers consider what it means to be a great teacher of physics and identify their own development needs.

A copy of the framework for teachers is included as a supplement with this issue of Classroom Physics. It is also available online, along with a version for physics teacher educators, at **spark.iop.org/framework**

The winning entry

Eurekas winner explores the mystery of the atom

Twelve-year-old David Majowicz, from Chellaston Academy in Derby, has been awarded overall first prize in the IOP's Eurekas competition.

His entry was a time capsule containing letters from eight physicists whose work increased our understanding of the atom. Starting with the ancient Greek philosopher Democritus, and taking in JJ Thomson, Ernest Rutherford, Niels Bohr and others, each physicist's letter explains what they discovered and is followed up with activities to understand their work better.

Sarah Bakewell, IOP's Head of Diversity and Inclusion, and one of the competition judges, commented: "It was an astonishing entry, incredibly detailed and it is amazing that one of our youngest entrants came up with something so thoughtful and engaging.

"David's box could be turned into a teaching tool in its own right – the thought and attention to detail that went into it was remarkable."

This year's Eurekas attracted 212 entries from young people aged 11–16 across the UK and Ireland. Entrants were asked to explore how physics can help us solve mysteries, resulting in a diverse array of submissions that showcased creativity and ingenuity. Entries were in a wide range of formats, from film and music to presentations.

Other entries looked at topics including the science behind Iron Man's suit, the mysteries of time travel and a DIY telescope project.

To see all the entries, visit **theeurekas.co.uk**

New data on perceptions of school physics

New polling for the Ogden Trust suggests physics is among the best taught subjects at A level, but that poor experiences at GCSE are preventing students from continuing post-16.

Of those surveyed who have taken A level physics, three quarters (76%) said they had enjoyed it, and 85% thought it was well taught. Nearly seven in ten of all undergraduates surveyed (68%), including those who didn't take physics A level, thought physics made a positive contribution to a student's prospects, with only maths, chemistry and economics scoring higher on this measure.

The survey also sought to determine why students chose not to continue with physics past the age of 16. Of those surveyed who hadn't continued with physics after GCSE, 42% cited lack of enjoyment, 24% said they could have taken physics further had it been better taught at GCSE level, and 19% felt they could have continued with more encouragement.

This disparity between GCSE and A level experience may be attributable to a lack of specialist teachers. Clare Harvey, Chief Executive of The Ogden Trust, said: "It is unsurprising to see that those who do take physics further have a positive experience at A level – this just serves to highlight the value of excellent teachers. If students are to continue studying physics beyond GCSE, teachers – especially the growing number having to teach the subject when it is not their main specialism – must be given up-to-date resources and the professional support that will allow them to deliver lessons confidently and accurately."

The research was conducted as part of work to mark the Ogden Trust's 25th anniversary. Polling firm Savanta surveyed 1004 current UK undergraduates about their views on physics teaching in schools. All had taken A levels in England, and the sample was split evenly between people taking STEM and non-STEM subjects at university.

more...

Read the full report at **bit.ly/OgdenTrustReport**

Teaching resources survey

IOP's recent survey on physics teaching resources found IOPSpark and the IOP-funded Best Evidence Science Teaching (BEST) resources ranked highly, as did PhET, TES and BBC Bitesize.

The survey indicated that most teachers are looking for exam-style questions, classroom experiments and demonstrations. Those with coaching responsibilities are also searching for information on pedagogical approaches and common misconceptions.

Taj Bhutta, Strategic Lead for Curriculum and Content at the IOP, said: "We will be using the results to inform our next steps in our continuing work to ensure that all educators across the UK and Ireland have the tools they need to teach physics. Based in teachers' feedback, we have also updated the IOPSpark homepage. We hope you like it, and thank you to all those that contributed."

more...

The BEST resources are available at **stem.org.uk/best-evidence-science-teaching** and you can visit IOPSpark at **spark.iop.org**

Physics project supported with Royal Society grant

A school STEM club project to evaluate different types of thermometer has been inspiring pupils at Aylesford School in Warwick.

The project aims to evaluate thermometers by completing standard science practicals with different ranges, expansion materials, thermocouple temperature probes, data loggers and IR cameras, to determine how they compare to a traditional mercury expansion thermometer.

Mercury thermometers, which have traditionally been widely used because of their large temperature range (–37 to 356°C) and sensitivity to small changes, are being replaced in settings such as hospitals, where new machines and storage operate at lower temperatures.

Sam Holyman, science teacher and STEM coordinator at Aylesford, said: "Our project is operating across the secondary phase with a dedicated group of STEM Clubbers who are core to our project. These students have completed required practicals which focus on temperature and then we have been led by their curiosity, investigating other experiments which require the use of temperature monitoring."

The work is funded by a Royal Society Partnership Grant, which supports collaboration between schools and STEM professionals. Aylesford has worked with a team at Oxford University that focuses on brain imaging with MRI scanners. This has created opportunities for pupils to meet early-career researchers and established scientists with virtual and in-person visits.

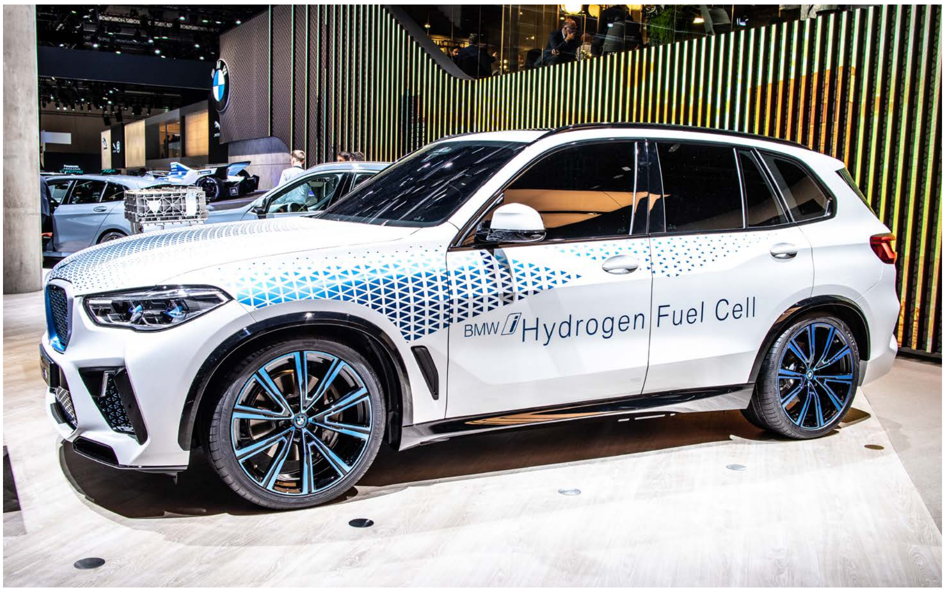
Sam commented: "Science budgets are always stretched, so the Royal Society grant has been a lifeline as we carefully choose experiments which would allow us to not only undertake a meaningful and engaging investigative project, but also provide modern equipment to be used across the school."

more...

The Royal Society's Partnership Grants provide up to £3000 for schools and colleges to partner with professionals from academia and industry on an investigative STEM project. Find out more at **royalsociety.org/partnership**

Hydrogen – the other part of the electric vehicle revolution

Battery-powered cars connected to public charging points are increasingly common in towns across the UK and Ireland as we move towards a greener transport system. But energy expert Averil MacDonald, Emeritus Professor at Reading University and a former physics teacher, thinks battery power is only part of the solution, and we should be embracing hydrogen fuel as well.



Credit: Shutterstock

Hydrogen fuel cell cars offer green transport without putting additional strain on the grid

Decarbonising our transport system is one of the biggest and most exciting changes we need to make as we work towards a net-zero future. Currently, there are strong moves towards battery-powered vehicles, as governments seek to phase out petrol and diesel cars. But for this to work, there are some serious obstacles to overcome, particularly around electricity capacity and storage. I believe we should also be focusing on hydrogen fuel, which avoids some of these problems.

There are many myths out there about the decarbonisation of transport. Scientists and students should exercise enquiring minds, so here I look at some key claims and counter-arguments for your students to consider.

Much of our focus at the moment is geared towards increasing the manufacture and use of battery-powered vehicles. It's important we recognise the limitations of this as a solution to how we create clean transport.

In the UK, for example, we're currently capable of generating an absolute maximum of 75 GW of electrical power, assuming it's sunny and windy and all nuclear, gas and coal-fired power stations are turned up fully. At times, particularly when it's cold and dark, and especially when there's no wind, the UK population uses almost the full amount of electricity being generated. Our electricity has to be generated at the instant it's used – it can't yet be stored. So, the more battery-powered cars there are, the greater the likelihood that generation won't meet demand. For this reason, most charging points are now 'smart' which means they'll switch off if demand starts to outstrip supply. Research has shown that, with its current infrastructure, the UK can only sensibly support about 13% of our 32 million cars being battery-powered.

Italy can generate twice as much electricity per person as the UK while Germany can generate three times as much. The UK needs to increase the amount of electricity it generates.

This means there are many opportunities for people to work on new types of electricity generation, to ensure that the UK has the power it needs all around the country. There's also an important role for energy advisers supporting businesses to reduce their energy use, or helping homeowners improve the energy efficiency of their homes.

It would be a great leap forward if we could develop huge batteries or another way to store energy at large scale, such as compressed air. Imagination is needed to come up with ideas to solve this problem.

In the UK, the national grid is the infrastructure that allows electrical transmission at high voltage using overhead powerlines and then, for the 'final mile', via underground cables into local substations where it's 'stepped down' by transformers before arriving at our homes at 230 volts. The 'final mile' and the local substations were, mostly, installed well before anyone thought of battery-powered vehicles. The cables and transformers weren't designed to withstand high-power operation. If there's just one battery car on charge in a neighbourhood, then the infrastructure will probably cope, but as more and more neighbours connect to the system, there's a risk that the local transformer will blow.

Town planners of the future will need to understand electricity and electrical charging to allow them to design systems to ensure people have access to electricity and charging points in car parks and around towns for people who don't have off-street parking. There will be a lot of work for people to install electricity infrastructure – everything from power lines to new transformers to charging points.

While electric battery-powered vehicles have a place in the green transport plans of the future, we should also be looking at alternatives such as hydrogen fuel cell electric vehicles (HFCEV). Using hydrogen gas in a fuel cell generates electricity without the need to recharge a battery. The driver simply goes to a hydrogen filling station and clips a pipe onto their fuel tank, waits a few minutes while 5 kg of hydrogen flows into the tank, and then can drive for up to 300 miles.

A common myth is that hydrogen is too explosive to be used safely. In fact, hydrogen is no more explosive than petrol vapour and there are no flames in a FCEV car (we deliberately set fire to petrol in an internal combustion engine!). Conversely, when a battery catches fire it takes 40 times as much water to put it out as a petrol fire – and the car has to be allowed to burn out completely.

For a long time, we thought that hydrogen could only be stored at low temperature and under high pressure, but recent developments have shown that metal hydrides are a very safe way to store hydrogen. Aluminium hydride in the form of a powder fills the fuel tank and hydrogen is introduced. The hydrogen molecules sit in the interstitial spaces amongst the aluminium hydride. The hydrogen is inert as its molecules can't 'see' each other, and because they are relatively close together the density is about seven times what it is in liquid hydrogen – but without the need for high pressure and low temperatures.

Hydrogen can be transported around the world in huge tankers as liquid ammonia (NH3), then 'cracked' to release the nitrogen and retain the hydrogen. There are plans in the UK that the hydrogen will then be fed into our gas pipe network (replacing the methane) and, potentially used as a zero-carbon fuel for heating our homes.

While still a young industry, hydrogen has the potential to be a global market in the way the oil industry is today. There are already hydrogen fuel cell cars, taxis, buses, vans, trucks and trains, and work is underway to look at hydrogen-powered flight. I think hydrogen offers solutions to lots of the challenges we face in creating a clean transport network – as well as great opportunities for people with physics skills.

Delivering the future

Drones are playing an increasingly active role in delivery services. Whether transporting the mail or vital health supplies, drone technology seems set to continue to expand.

Postal services first began in England under Henry VIII, and Royal Mail will have seen more than its fair share of modes of transportation, from horses and carts, to the night train, to the fleet of cars, vans, bicycles and trolleys we see today. Last summer, it embarked on a new method, with the first drone postal service launched in Orkney, enabling letters and parcels to be delivered efficiently between islands.

The system reduces the need for ferry crossings to move post around the archipelago, saving time and cost. The drones can carry up to 6 kg at a time and make the short hops between islands from the main post office in the capital, Kirkwall, out to the islands of Hoy and Graemsay. For these remote communities the service greatly speeds up deliveries and provides a stronger connection to the outside world.

Drones are being used in other contexts where geographic challenges make traditional forms of transport less than ideal. Zipline, an American firm, began delivering medical supplies in remote areas of African countries in 2016. In regions where road quality can be very poor, deliveries by road can take days, compared with the hours made possible by drone technology. For products such as blood plasma, speed is of the essence. The company has built medical distribution centres in countries including Rwanda, Ghana, Nigeria and Cote d'Ivoire, but is also operating in the US and Japan. Recently, an NHS trust in Northumbria has been working with Zipline and logistics firm Apian to create a delivery service to move medications between hospitals, care homes and GP surgeries.

The potential for the drone industry is huge. Financial services firm PwC, in a report on the sector updated in 2022, predicted the number of commercial drones operating in the skies above the UK could reach 900,000 by 2030, in an industry sector worth £45 billion to the UK economy. Besides deliveries, other important applications include the use of drones to inspect large-scale facilities such as solar farms, or to provide safe access to otherwise dangerous areas in an

Credit: Shutterstock

emergency such as a gas leak. And as we see on our screens every day, drone footage from photographers and filmmakers is increasingly used in journalism and the creative industries.

Jobs with drones include pilots, engineers and designers, but as the technology is being used in more industries, it's touching on all sorts of other roles. All of this could support as many as 650,000 jobs by 2030, according to PwC – so it's an area with great potential for young people with appropriate skills.

more...

Book an experience, order posters and explore careers profiles for transport engineering at **neonfutures.org.uk**

In this column,
James de Winter
(University of Cambridge and University of Uppsala)
and **Richard Brock**
(King's College London)
highlight publications and resources from physics education research and suggest how they may be used to inform classroom teaching.

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Physics and maths: separated by a common language?

You say equation, I say formula
You say variable, I say quantity
Let's call the whole thing off…

It's common for some students to struggle to use the skills and techniques learned in maths lessons in physics. The concept of transfer, where knowledge and skills from one domain are not always easily translated to another, is a problem in multiple contexts. In his paper, "Using math in physics: Overview" Joe (E.F.) Redish suggests one reason why transfer may be an issue between maths and physics:

> *"The key difference between math as math and math in science is that in science we blend our physical knowledge with our knowledge of math. This blending changes the way we put meaning to math and even to the way we interpret mathematical equations."*

The blending of conceptual knowledge with mathematical symbols and formalisation is a key consideration for physics teachers. The letters in a formula in physics represent real-life quantities and bring some additional assumptions that mathematicians may not concern themselves with in a similar-looking equation.

When a physicist sees $a = \frac{v-u}{t}$, they know that a, v and u may be positive or negative, but also that, whilst unstated, $t \geq 0$. Redish notes that in mathematics, equations are used to calculate and solve, whereas in physics, they're often used to explain. He suggests we should explicitly highlight the explanatory power of mathematics in physics lessons, reminding students that the derivation of an equation is more than just a symbolic operation as the equations carry conceptual meaning. An example might be the way that some prefer to express Newton's second law as $\frac{F}{m} = a$ to highlight how the a is a consequence of an F acting upon an *m*.

Maths courses might teach the difference between a formula as a relationship between two or more variables that is always true (e.g. Area of Triangle = $\frac{bh}{2}$) and an equation that only works for certain values and is not always true (e.g. 3x+9=33). Perhaps physics teachers can help students by being more precise with their language. Distinguishing between terms such as variable and quantity may support our insistence that students always include a unit in their answers. Without the unit, it's a number; the unit helps it become a quantity.

Redish adds some further considerations concerning the term constant:

> *"Math in math seems so clean. A variable is a variable. A constant is a constant. In physics, our constants can be universal constants, parameters, initial conditions; and we might choose to differentiate with respect to them."*

Other issues in the paper, each with a seperate follow-up article, include 'Dimensional analysis', 'Estimation', 'Functional dependence' and 'Reading the physics in a graph'. Some are more suited to teaching older students, but all are worth reading for those interested in this area. They form part of what Redish calls the 'mathematical toolbelt', which he encourages teachers to help students develop.

One of us (James) has researched how school experiences of pre-service teachers can cause physics graduates to reconceptualise the role of mathematics in physics teaching and learning (de Winter & Airey, 2022). As experienced users of mathematics, it's easy to forget the challenges that the mathematical aspects of physics can pose for students. Redish's work acts as a useful reminder of some pitfalls, including suggestions to support students to become fluent in transferring between the domains.

References

Joe Redish's site with links to papers: **bit.ly/JoeRedish**

Redish, E. F. (2021). Using Math in Physics: Overview. The Physics Teacher, 59(5), 314–318. **bit.ly/RedishMathsInPhysics**

de Winter, J., & Airey, J. (2022). Pre-service physics teachers' developing views on the role of mathematics in the teaching and learning of physics. Physics Education, 57(6), 065007. **bit.ly/3WVEPku**

Pull out and keep!

Electricity & magnetism, forces & motion

Electric aircraft

Inside this pull-out:

- **Activity 1: Rechargeable cell**
- **Activity 2: Simple motor**
- **Science club activity: Investigating propellers**
- **Student activity sheet: Investigating propellers**

Credit: Shutterstock

Electric cars take to the skies

Vertical take-off and landing passenger vehicles (eVTOLs) are predicted to transform how we make short journeys around cities.

Popularly known as electric flying cars or air taxis, eVTOLs produce minimal noise and zero emissions which, combined with their ability to take-off and land vertically, makes them ideal for short passenger flights in urban environments.

As well as an interesting context to add to your teaching, eVTOLs also provide an opportunity to discuss science and engineering careers. With hundreds of prototype versions in development, the global industry is predicted to be worth up to $1 trillion by 2040 and those with the skills to design the next generation of this technology will increasingly be in demand.

The activities in this pull-out focus on the core components of this future mode of transport: rechargeable batteries, motors and propellers. In the first activity, students make an electrical cell and investigate how voltage depends on charging time. In the second, they build a simple motor to see how current from a cell combined with a magnet produces motion. And in our final activity, they make a propellers and investigate how blade angle affects thrust. On this page are some ideas on recharging, motors and propellers for eVTOLs that you may want to include in your teaching.

Recharging

Flight times for the first generation of eVTOLs are predicted to be an hour or two. To make them viable as air taxis, a network of fast charging ports will be needed. For example, the X2 flying car shown in the photo has a 66 kWh battery and so:

- Battery capacity: E = 66 kWh x 60 x 60 s = 238,000 kJ

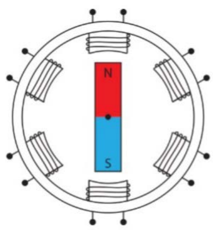
If it's charged from empty using a fast-charging station which operates at 750 V, 320 A:

- Electrical power: P = IV = 320 A x 750 V = 240 kW
- Charging time t = E/P = 238,000 kJ / 240 kW = 991 s = 992/60 mins = 17 mins

Repeating the calculation for a charging station that operates at 230V, 13A shows it would take over 22 hours using a domestic power supply.

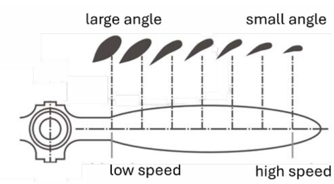
Motors

Electric aircraft use brushless motors that are quieter, more efficient and have longer lifetimes than conventional motors. For student-friendly explanations and diagrams see: **bit.ly/brushlessDC**



Propellers

Like all aircraft, eVTOLs have propellers whose outer part rotates faster than the inner part. To spread the stresses more evenly, they're designed to have blade angles that decrease with distance from the hub. The plastic propellers in our science club activity (page 11) have a profile that varies in a similar way.



Inclusive teaching tip

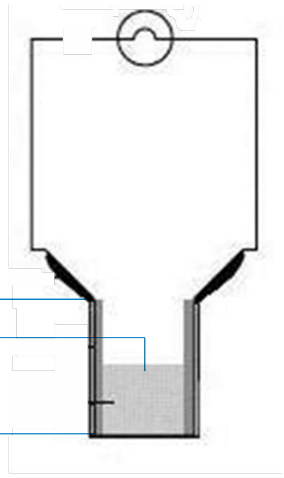
Be careful not to assume all members of your class have been on an aircraft or there's a car at home.

Activity 1: Rechargeable cell

In this activity, students make a rechargeable cell to explore how cell voltage depends on charging time.

Apparatus

- Eye protection
- 100 ml beaker
- 3 V DC supply
- Voltmeter
- Switch
- 1.5 V torch bulb in holder
- Six connecting leads
- Two crocodile clips
- Stopwatch
- 100 ml of 0.5 M dilute sulfuric acid
- Two lead foil electrodes (about 2 cm x 8 cm), folded over the rim of the beaker



Safety and preparation

The lead foil electrodes and lead(IV) oxide deposited on the positive electrode in this experiment are toxic and dangerous for the environment (see CLEAPSS Hazcard HC056). Dilute sulfuric acid, H2 SO4 (aq) is an irritant – see CLEAPSS Hazcard HC098a and CLEAPSS Recipe Book RB098.

Wear eye protection throughout. Once the cell is assembled, don't allow the electrodes to touch and keep electrolyte level low enough so that it isn't bought into contact with the crocodile clips.

Procedure

1. Assemble the cell and connect it to the DC source. The sulfuric acid in the cell should be within 1 cm of the crocodile clips.
2. Switch on the DC source and adjust the voltage to 3 V. Supply current for 1 minute.
3. Disconnect the power supply from the cell and build the circuit shown in the diagram. Note the reading on the voltmeter.
4. Close the switch to discharge the cell. If the bulb glows, wait for it to fade.
5. Keeping the voltage setting of the DC source the same, repeat for charging times of 2, 3, 4 and 5 minutes.
6. Disconnect the power supply from the cell.
7. Plot a graph of cell voltage (V) against charging time (seconds).

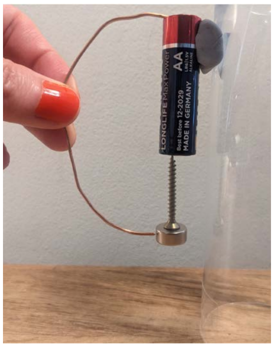
Teaching notes

With a 3 V supply, we found that the cell was fully charged after 10–15 minutes. For a period of up to 5 minutes, students should find that the cell voltage increases linearly with charging time.

With thanks to the Royal Society of Chemistry for permission to adapt their activity. **rsc.li/45yxex0**

Activity 2: Simple motor

In this activity, students build a simple motor and determine the direction of a magnetic field.



Equipment

Each group of students will need:

- Neodymium magnet
- Woodscrew
- Short length of cable with two bare ends
- 1.5 V cell
- Beaker
- A small blob of Blu Tack

Safety

Rare-earth magnets are brittle and shatter easily. Students should not lift the magnet too high off the bench.

Procedure

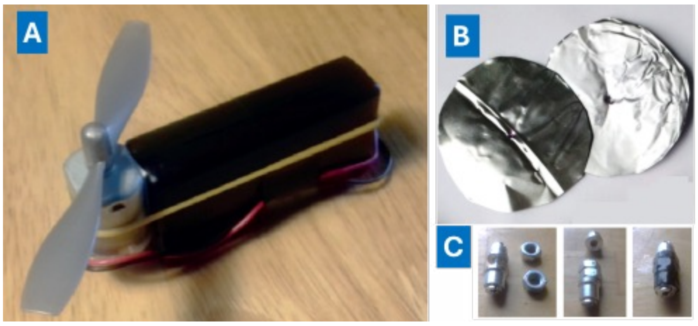
1. Use Blu Tack to attach a cell to the vertical edge of an upside-down beaker so that the positive terminal of the cell points towards the ceiling.
2. Put the head of the screw onto the magnet so that they attach to each other.
3. Attach the sharp end of the screw to the bottom (negative) terminal of the cell.
4. Hold one end of the cable onto the top of the cell and touch the other end to the edge of the magnet. The magnet and screw should start to spin.
5. Identify the direction of the current, force and field inside the magnet.
6. Predict, explain and test what will happen if they turn the cell the other way around.

Teaching notes

Inside the magnet, the current flows radially along a line from the point where the wire makes contact to the centre. If students struggle to identify whether the current is inwards or outwards, remind them it flows from the positive to the negative terminals of the cell. They can work out the direction of the force by looking at whether their magnet spins clockwise or anticlockwise and the direction of the magnetic field using Fleming's left-hand rule.

Science club activity: Investigating propellers

In this activity, students measure the thrust produced by different propeller shapes and then design their own.



Equipment

- Motor MM10 from Mindsets Online (EW2-008)
- Switched battery box from Mindsets Online (EC1-035)
- Two-bladed plastic propeller from Mindsets Online (131-001)
- Three-bladed plastic propeller from Mindsets Online (CP2-002)
- Propeller adapter to fit 2mm shaft (collet version) – e.g. available from rclife.co.uk
- 2 x AA cells
- Two small nuts
- Double-sided sticky tape and pads
- Top-pan balance capable of reading to 0.1 g or better
- Disposable aluminium baking tray
- Rubber band

Preparation and safety

Each group of students will need: a motor mounted on the battery box (A); two aluminium propeller templates (B); and a connector converted for use with thin aluminium propellers (C). See 'Technician notes'.

The propellers used in this activity rotate at high speed. Remind students to wear safety goggles to protect eyes and warn them not to touch the tips of spinning blades to avoid cuts and bruises.

Procedure

Students should follow the instructions on their activity sheet to:

- Set up a propeller test station
- Compare the performance of two- and three-bladed plastic propellers
- Make a two-bladed aluminium propeller and investigate how thrust depends on blade angle
- Develop and test their own aluminium propeller design

Teacher notes

Any downward travelling air from the propeller that hits the top of the balance will affect the accuracy of students' readings. To minimise this effect, they should place the battery box with the propeller overhanging the edge of the balance (as illustrated on the student activity sheet).

When making aluminium foil propellers, students will need to leave the central part of the disc intact to form a hub. Have spare discs of aluminium available in case they accidently cut their propellers in half.

When investigating blade angles, students will find that maximum thrust occurs for an angle of between 40^0 and 50^0. This is because propellers with low blade angles don't deflect enough air downwards to produce a significant thrust and those blades with large angles suffer more from drag forces which slow the motor.

Although not needed for this activity, students can calculate the thrust in Newtons using:

Thrust (N) = change in reading (g) ÷ 100

Technician notes

For each group of students:

A) Mount a motor to a battery box and add a propeller:
- Put two AA cells into the battery box.
- Cut a piece of the sticky tab to the same size as the flat side of the motor.
- Attach the side of the motor without electrical contacts to the short end of the battery box using the sticky tab so that the top of the motor is level with the top of the box.
- Switch on the battery box and touch the two wires to the contacts on the motor. Looking down on the motor, the shaft should rotate anticlockwise. If it rotates clockwise, reverse the two wires. Solder wires in place.
- Attach the dangling battery box wires to the side of the box that does not have the switch, using sticky tape.
- Add a rubber band around the motor and box to help hold the motor in position.
- Attach the two-bladed grey plastic propeller to the shaft and switch the motor on to check everything works.

B) Make two aluminium propeller templates:
- Draw two 8 cm diameter discs on a disposable baking tray and cut them out.
- Locate the centre of the discs and, placing them on cork or Blu Tack, poke a small hole through the centre using the tip of a pen.

C) Convert the propeller adaptor for use with the aluminium propeller:
- Take the dome off the propeller adaptor shaft and add one or two nuts to act as spacers.
- Wrap tape around the collet and nut(s) only. Trim any excess tape.
- Put the dome back on the adaptor shaft.

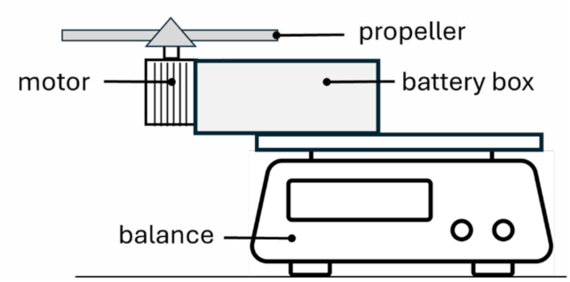
Student activity sheet

Investigating propellers

1. Set up a propeller test station

You have been provided with a motor with propeller mounted to a battery box and a top pan balance.

a. Switch on your balance, zero it and check that it is measuring in grammes (g).
b. Place the battery box on the balance with the propeller overhanging the edge of the balance as shown (right). Attach a loop of sticky tape between the two to hold in place.
c. Check your testing station is working properly by switching on the motor. The reading on the balance should reduce.



2. Compare performance of plastic propellers

The plastic propeller attached to the motor has two blades. You have also been provided with a three-bladed propeller.

a. Copy the table.

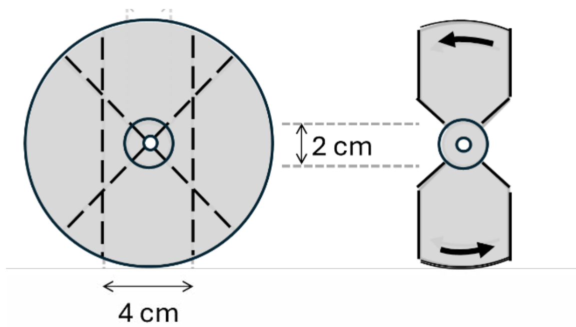
	reading on balance (g)		
	motor off	**motor on**	**change**
two-bladed plastic propeller			
three-bladed plastic propeller			

b. Take measurements with motor on and off for the two-bladed propeller. Record your results in the table and find the difference between your two readings.
c. Switch the motor off and remove the two-bladed propeller. Replace it with the three-bladed propeller.
d. Place it back on the balance and take measurements with the motor off and on. Record your results in the table and find the difference between your two readings. Which propeller gives the greatest thrust?

3. Make and test a two-bladed aluminium propeller

You have been provided with aluminium discs with a hole at their centres and a propeller adaptor.

a. Draw the pattern shown in the diagram (right) on one of the discs and cut out to make the two-bladed shape shown.
b. Remove the dome from the propeller adaptor, push the aluminium foil propeller onto the top of the adaptor and the bottom of the adaptor onto the motor. Screw the dome down to hold everything firmly in place.
c. The blades will rotate anticlockwise when you connect them to the motor. Draw arrows to show the direction of rotation.
d. Use the top pan balance to find how much thrust the flat blades produce.
e. Twist the blades so that both leading edges (tip of arrows) face upwards and both trailing edges (tail of arrows) point downwards.
f. Use a protractor to set the blade angles to 10^0 and take readings using the top pan balance with the motor off and on.
g. Increase blade angle from 0 to 70^0, at 10^0 intervals, and take measurements to determine how thrust varies with blade angle. Which angle produces the most thrust?



4. Design your own aluminium propeller

Can you get more thrust than the two-bladed design?

Physics and transport

A crash course in physics

JD Bernal is perhaps best known for his contributions to X-ray crystallography, was a founding figure of molecular biology, and contributed to mapping the beaches prior to the D-Day landings. His scientific flair, however, was stronger than his driving. Bernal drove an Austin 10, with the back doors held closed by a rope across the back seat. Whilst driving in London, his biographer relates, he was involved in a crash with a black cab. When Bernal's butler, chauffeur and mechanic, Benton, came to collect the car, he arrived to find the cab driver staring in bemusement at equations Bernal had written in the dust in the side of the damaged vehicle. Bernal was attempting to show, using Newton's laws, how the accident wasn't his fault. The cabbie told an attendant policeman he would never wash his taxi again.

Of birds and bullet trains

The natural world has often been a source of inspiration for designers. When choosing the shape of the nose of the Japanese Shinkansen bullet train, engineers looked to the kingfisher. Initial versions of the train would create a shockwave upon entering a tunnel, causing an undesirable loud noise and potential structural damage. Kingfishers have evolved to overcome a similar problem: when they dive into water, the shape of their beaks reduces shockwaves and allows for a 'silent' dive – creating the minimum of disturbance to avoid scaring off prey. Adding a nose inspired by the kingfisher's beak to the Shinkansen reduced energy consumption by 10–15% and solved the noise issue when entering tunnels.

The physics of flying carpets

A paper in Physical Review Letters, on the dynamics of flexible foils in fluids, has relevant guidance for Aladdin: the authors consider whether flying carpets are physically possible. The authors note some analogies for flying carpets in the natural world, such as skates and rays which glide through the sea using enlarged pectoral fins that act as wings. However, they also note that flying carpets, whilst 'within the realm of possibilities in nature and in technology', face the problem of developing a sufficiently powerful engine. Sadly, they conclude the magic carpet 'will remain in the magical, mystical, and virtual realm as it has existed for millennia'.

Kelvin's balls

When ironclad ships were introduced in the second half of the 19th century, compasses experienced deviations because of the ships' iron hulls. Engineers proposed a solution to the deviation by placing lumps of iron or magnets near the binnacle (the compass stand). John Gray developed a system in which correcting magnets on the binnacle could be adjusted with screws to change the degree of deviation. Kelvin subsequently improved on the design, and the two iron spheres seen on either side of a ship's compass were referred to as Kelvin's balls. Examples of Kelvin's balls can be seen at the Royal Maritime Museum in Greenwich, London.

spark.iop.org/stories-physics

Compiled by Richard Brock.

Follow him on X (Twitter) at **@RBrockPhysics**

Download more Marvin and Milo activities at iop.org/marvinandmilo

Physics*education*

Physics Education is our international online journal for everyone involved with the teaching of physics in schools and colleges.

Editor-in-chief Gary Williams highlights his favourite papers on **transportation** from the archive and shares some highlights from the current volume.

Access over 50 years of articles at **iopscience.org/physed**

Affiliated schools have free access – email **affiliation@iop.org** for a reminder of your log-in details.

Credit: IOP

A LEGO superconducting train

History is written by the victors, but it's also written by the living, and in science those who have gone before don't always get their fair share of the spoils. Before Oxford and Paris became the intellectual centres of Western Europe, the Wye and Severn Valleys were important centres for maths and science. Around the year 1100, Walcher of Malvern, near Worcester, was the first person in Western Europe to write about using an astrolabe, having learnt about Arabic science in Spain. Fast forward a few hundred years and we have the Merton Calculators, a group of scholars linked to Merton College, Oxford, who worked out the mean speed formula in the 14th century and hence paved the way for our equations of motion. In the paper "Galileo's speedometer: an approach to the concept of instantaneous velocity", the authors use the chain of ideas that came from Merton and went on to Galileo as a vehicle for teaching about instantaneous velocity.

Walcher of Malvern doesn't seem to have had too many problems with transportation as he wrote that he "happened to be" in Italy at one point during a lunar eclipse as well as having been to Spain before moving to Malvern. Contrast this with possible travel of the future! In "Demonstration of a superconducting train with LEGO® Mindstorms", we have all the details of a fantastic levitating train. The trains are cooled with liquid nitrogen by riding on a conveyor that takes them through a bath of the super cold liquid. Superconductivity brings with it plenty of chances for discussion about electricity and efficiency, conduction and resistance, but with this model the main concern might be what happens to the passengers when the train gets frozen…

Traffic flow is an issue that seems to provoke a lot of emotion. Students are often surprised that traffic jams can be caused purely by differences in speed. If vehicles arrive at a stretch of road faster than they leave, there will be a build-up of traffic. This can be quite a fruitful area for discussion, leading to ideas of group velocity. In the Frontline article "Road capacity with a steady flow traffic", a simple one-lane road is modelled and results compared with real-world data. The authors note that colleagues tended to estimate much higher optimum speeds than the model predicted!

"Galileo's speedometer…"
bit.ly/PEGalileoSpeedo

"Demonstration of a superconducting train…"
bit.ly/PESuperconductingTrain

"Road capacity with a steady flow traffic"
bit.ly/PETrafficFlow

From the archive

The title of "Modeling mousetrap car motion with polynomial functions of time" shouldn't stop you taking a look, as the basic idea of a mousetrap car is useful and mousetraps are available at low cost, even if you don't want to get involved with polynomial functions. A sturdy car is built with an accessible axle. A mousetrap with a long arm and a length of string attached is fastened to the car. The long arm is pulled back and the string wrapped around the axle. As the spring on the mousetrap returns to its normal position the long arm pulls the string, turns the axle and away the car goes. An alternative is the compressed air dragster launcher as shown here: **bit.ly/PEDragsters**

Bicycles are the most efficient form of transport and generally the only one students get to control themselves. If it wasn't for air resistance, bicycles would be able to reach speeds of 200 mph. This idea has been explored on television with Guy Martin riding a bike behind a lorry at 112 mph. Denise Mueller-Korenek is the fastest cyclist in the world at the moment, having reached over 180 mph. "Exploring the aerodynamic drag of a moving cyclist" looks at a series of models and bike-on experiments that proved to be very popular with students.

It's not always easy getting the data you want, even when you know it exists. In "Speedometer app videos to provide real-world velocity–time graph data 1: rail travel", Julien King takes a video camera, an egg timer and a tablet and gets some real-world data for students to plot describing the train journey.

"Modeling mousetrap car motion…"
bit.ly/PEMousetrapCar

"Exploring the aerodynamic drag of a moving cyclist"
bit.ly/PEMovingCyclist

"Speedometer app videos…"
bit.ly/PESpeedoAppVideos

Recent articles

Using the conducting property of pencil lead is an idea that has appeared in Physics Education before, but the Open Access paper "Pencil and paper electronics: an accessible approach to teaching basic physics concepts" takes the idea a step further. Not only do the authors have a very neat method for looking at resistance vs length and type of pencil, using masking tape to give a uniform width of track, but they also make a strain gauge and a thermal sensor using the same ideas. This paper provides a very cost-effective method for students to get hands-on with electric circuits and a quick search of the Physics Education archive will produce further information on this method.

Fed up of finding Nerf gun darts in the garden, under the dresser and down the back of the sofa? Take them and their launchers to work! In the Open Access paper "The physics of nerf guns", the author provides some simple ideas on how to use these toys in your teaching. There is probably more to be done with them, and given that they can be bought quite inexpensively in charity shops, this is well worth considering for including in your scheme of work.

Returning to the theme of transportation, and looking again to the future, what about a little teleportation? "A Christmas story about quantum teleportation", an Open Access paper, is quite advanced, but it covers some of the basic ideas of quantum teleportation and gives food for thought. As the paper points out, teleportation of matter isn't possible according to our current understanding of physics; but teleportation of information is. The authors think that quantum teleportation will play a key role in the setting up of secure, quantum networks for communication. All of these ideas are wrapped up in a Christmas story with Santa delivering presents and looking in his "Ledger of Good Nature"!

"Pencil and paper electronics…"
bit.ly/PEPencilPaperElectronics

"The physics of nerf guns"
bit.ly/PENerfGuns

"A Christmas story about quantum teleportation"
bit.ly/PEQuantumTeleportation

Physics*education*

Quick Links

"Cloud chamber using Peltier cooling"
Make your own cloud chamber without dry ice

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"Human electrical circuits: interactive learning with plasma ball"
Are friends electric?
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Learn what students want to learn about

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"Sliding down an inclined plane: a new method for measuring gravitational acceleration and kinetic friction in upper-secondary school"
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Flight from the escape room

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Green challenge: can the shipping industry clean up its act?

In this article from July, James McKenzie, a Physics World journalist specialising in physics in industry, looks at the steps being taken to decarbonise global shipping.

About 90% of world trade depends on transportation by sea. But shipping contributes 2–3% of global carbon emissions, and the 90,000 or so ships plying the world's oceans are also belching out vast quantities of poisonous gases that endanger health. It's extremely important that solutions are found to clean this industry up.

This article examines various alternative options, including liquid natural gas, batteries, ammonia and hydrogen, and some of the ships already afloat using these technologies.

While the industry is moving in the right direction, McKenzie concludes, big questions remain about whether it will be possible to roll out the new technologies fast enough.

bit.ly/PWGreenShipping

Physics challenges for green aviation

American aerospace physicist Brian Tillotson wrote this informative article in 2020, which charts the past and future development of aircraft.

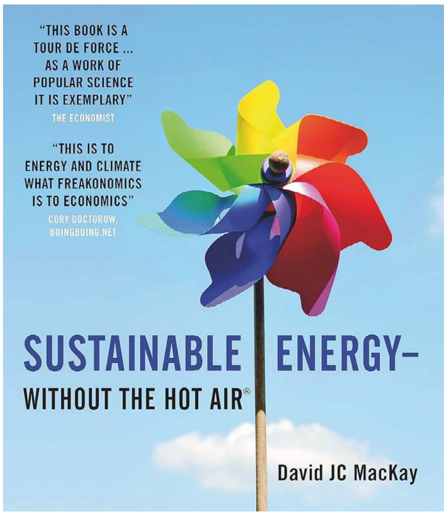
His starting point is the increasing efficiency of air travel over time, with a journey across the continental United States today using, per passenger, less than half the fuel of a car making the same journey.

The article goes on to explain various aspects of aircraft design that have evolved to increase efficiency, such as wing shape, the size and positioning of jet engines, lighter construction materials, and the different approaches taken to dealing with lightning strikes that new materials have necessitated.

Looking to the future, Tillotson explains how new wing designs and technical innovations, such as the use of batteries in a hybrid model and hydrogen fuel for hypersonic craft, may further improve aviation efficiency.

bit.ly/PWGreenAviation

With clean power generation key to a green transport system, Taj Bhutta writes about David MacKay's 'Sustainable Energy – without the hot air'



Book corner

This book addresses the issue of the sustainable energy crisis in an objective manner. 'Sustainable Energy – without the hot air' gives easy-to-follow calculations and plans for change on both a personal level and at an international scale.

David MacKay – who was a Cambridge academic and chief scientific advisor to the UK government on energy and climate change – uses energy ideas to carry out calculations to analyse and compare different energy sources. In so doing, he provides an excellent means to demonstrate the informative power of energy calculations.

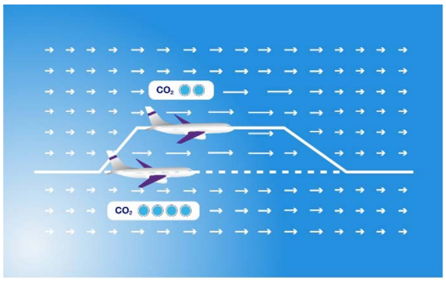
Although the book was published in 2008, and some chapters, such as the one on solar power, are a bit out of date (due to big advances in photovoltaics), it still has plenty of material for teachers to draw upon.

For example, in chapter 5 is a calculation of the energy per person for a flight from London to Cape Town – which is shown to be equivalent to leaving a 1 kW electric fire on for 24 hours.

There are a lot of topics covered, so this is probably not one for students, but I would highly recommend it as a source of case studies for any teacher who wants to incorporate more about sustainable energy into their physics teaching.

David MacKay, who sadly died prematurely in 2016, was very generous with his ideas and writing. Having paid for the initial publication of this book himself, he then made it available online for free. See **withouthotair.com** *for details.*

Sylvia Knight from RMetS explains how weather forecasting can help optimise the costs and environmental footprint of air travel.



For teaching resources exploring these two climate solutions, visit **bit.ly/RMetSClimateChange**

Getting the right flight height

Aviation accounts for around 2.5% of global CO_2 emissions and is one of the hardest sectors to decarbonise. Significant improvements in energy efficiency can be made by optimising flight times. The less time an aircraft is in the air, the less fuel it uses. Very high-resolution, 3D, real-time forecasts of wind speeds can guide pilots to fly where wind speeds will reduce flight times.

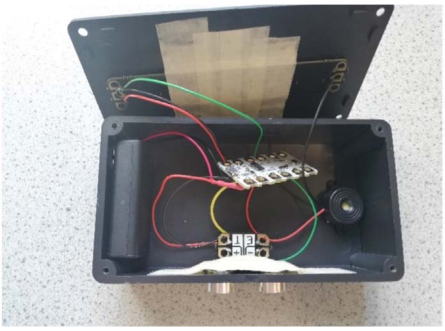
In 2021, the Met Office reported that Norwegian was an early adopter of the technology. Based on its Boeing 737 aircraft and pre-Covid 19 air traffic levels, it was found that CO_2 emissions could be reduced by 10–15,000 tonnes per year. This equates to the emissions from 31 million miles in an average car.

However, aviation's impact on climate change is mostly due not to carbon emissions, but the contrails aeroplanes sometimes leave behind. They are produced when the very humid air coming out of jet engines expands into the surrounding atmosphere and cools, forming ice crystals. Contrails act like greenhouse gases. They reflect less of the Sun's light than lower, warmer clouds which consist of water droplets. And, like higher, colder, icy clouds, they absorb more infrared radiation.

Whether a contrail forms, and how long it lasts, depends on the temperature and humidity of the air. Detailed 3D maps of the atmosphere are helping pilots to fly at altitudes where contrails won't form. Just a few hundred metres of height can make the difference between a contrail which lasts for hours or not leaving a contrail at all. Changing the altitude of fewer than 2% of flights could potentially reduce contrail-linked climate change by a staggering 59%.

These 3D vector addition problems are a very nice example of how GCSE physics skills can be applied to real-world climate solutions.

Andres Tretiakov and Rina Osmani, physics technicians at St Paul's School in London, write about how sensor technology can help prevent prangs in the car park – and the school corridor.



The whole assembly in a black plastic electronics project box of approx. 150 x 80 x 50 mm. The black box was attached to a trolley using Velcro strips.

more...
Andres Tretiakov was a winner of the IOP's Technician Award in 2023. Find out about IOP Awards at **iop.org/about/awards**

An ultrasonic distance sensor for lab trolleys

Between lessons, corridors can get hectic with the movement of dozens of students. As technicians moving heavy and expensive equipment around on trolleys, we find it quickly becomes tricky to dodge distracted students and avoid collisions. To improve safety, we created a system using an inexpensive device called an ultrasonic distance sensor (HC-SR04).

Ultrasonic distance sensors are ubiquitous in modern vehicles. They help countless people with their parking maneouvres and alert drivers to the presence of objects, animals or children in blind spot areas. Similar to echo location in bats, the device emits ultrasonic sound waves (in cycles of eight 40KHz bursts) through a transducer. The 'ping' bounces off an object or obstacle within its 'sight' range (about 400 cm) and the receiver detects if there is a pulse signal back. By measuring the time taken between emitted wave and detected wave, the distance can be calculated.

Using the equation v = s x t, we can say that distance to object = [velocity (v) x time (t)] / 2. We know that the speed of sound in air is approx. 343 m/s at 20˚C, and the device measures the time between emitter and receiver, so we can calculate the distance.

We also used Crumble (a simple circuit and free code source) which includes an easy software to code and allowed us to calibrate the sensor to certain distances, which we linked with a traffic light system and buzzer tone effects. As the distance between sensor and object/obstacle decreases, the LED lights change from green to yellow to red, and the frequency of beeps from the buzzer increases. And, hopefully, no more crashes in the corridors.

Holly Margerison-Smith, Education Manager at the Institution of Engineering and Technology, shares a resource that enables students to imagine the future for long-distance travel.

For a full suite of transport-related resources, visit **bit.ly/IETTransport**

Vacuum tube train

A costly, and sometimes very time-consuming, aeroplane journey is currently your only option if you intend to travel a long distance. However, what about in the future? One method that has been proposed is the vacuum tube train. This may be able to reach speeds of 4,000 mph, but is it a realistic option?

In this IET activity, students design a model vacuum tube train. They begin by working in small groups to design a way of getting a ball (the train) to travel from one end of a plastic tube to the other as fast as possible, without using gravity.

Students should be supplied with a variety of marbles and ball bearings in various sizes. They should be allowed to choose which sizes they want (this will depend on the method they employ). Options may include using a magnet to pull the ball, using force from a metal rod or air from a pump to push it. Learners can't rely on gravity – the tubing needs to be placed on a level desk or floor.

Groups are asked to record the speed and then modify their design to make it faster. They will need to use stop clocks to measure time and then calculate speed. If you have data-loggers to measure speed, these can be used instead. Students should understand the need for repeating their measurements and record them in a table.

Groups can modify the ball if they wish. They might want to make it more aerodynamic by using paper or by using a lubricant.

As an optional extension, students could modify their design so it has a safe stopping mechanism. Alternatively, students could write an explanation as to why air resistance isn't a problem in a vacuum tube train and why this is an advantage.

Crash testing is used to ensure safe design standards for modes of transportation including cars, aircraft and wheelchairs. Dr Anna Ploszajski, writing for the Royal Academy of Engineering's Ingenia magazine, explains why the system currently favours men's safety over women's.

This is extracted from 'How crashing cars can help us make them safer'. Read the full article at **bit.ly/IngeniaCrashTesting**

Gender equality and car safety

In 2019, the Center for Applied Biomechanics at the University of Virginia published a study that found that women were 73% more likely to be injured than men in a frontal crash, and three times more likely to suffer from whiplash injuries in rear impact crashes. These figures suggest that current vehicle design disproportionately benefits drivers who are men.

Today, there are three types of crash test dummies for adults used in the European New Car Assessment programme (EuroNCAP) and its American equivalent, the National Highway Traffic Safety Administration (NHTSA): the '95th percentile male' (188 cm tall, weighing 100 kg); the '50th percentile male' (175 cm, 77 kg); and the '5th percentile female' (152 cm, 50 kg). These standards were developed in the 1970s and have remained the same ever since. (Before the 1970s – and even afterwards – cadavers, live human volunteers and animals such as chimpanzees, bears and pigs were used as crash test dummies.)

While this sounds as if crash test dummies would represent most road users, the 'female' dummies are merely scaled-down versions of the larger ones, and are roughly the size of a 12-year-old girl, not an average woman. The lack of representation of women road users in crash testing could go some way to explaining the discrepancy of road injuries by gender.

In October 2022, a team of Swedish engineers developed the first crash test dummy designed to match the body shape, size and weight of an average woman (162 cm, 62 kg). Although such dummies are not yet a legal requirement, Humanetics, the largest producer of test dummies, has developed models that represent 'elderly', 'large and obese', children of different sizes, and a 5th percentile female dummy with an adult woman's shape.

It's vital that engineers working in crash testing and vehicle safety policy use dummies representative of the full spectrum of road users, to make everyone as safe as their '50th percentile male' counterparts.

Discover STEM careers in the railways

Looking to inspire students with STEM careers?

They can explore the breadth of careers in the rail industry online with Railway Futures. Jump into the digital version of the National Railway Museum to explore the different roles and routes into the innovations, technology and engineering of the railway industry.

Watch videos, hear stories and find out more about career opportunities online with a virtual visit to the Railway Futures Careers Fair at the National Railway Museum: **railwaymuseum.exhibition.app/**

Perfect for KS3 and KS4.

AECOM NetworkRail

Engage Grants

With the support of UKRI, the British Science Association provides Engage funding to help UK schools in challenging circumstances run CREST Awards.

Schools with high numbers of students who are often underrepresented in STEM are encouraged to apply. The grant is £350 cash to run CREST Awards, which you can spend on materials, equipment, field trips, teacher CPD and more! Awardees will also receive up to £350 CREST Awards for free.

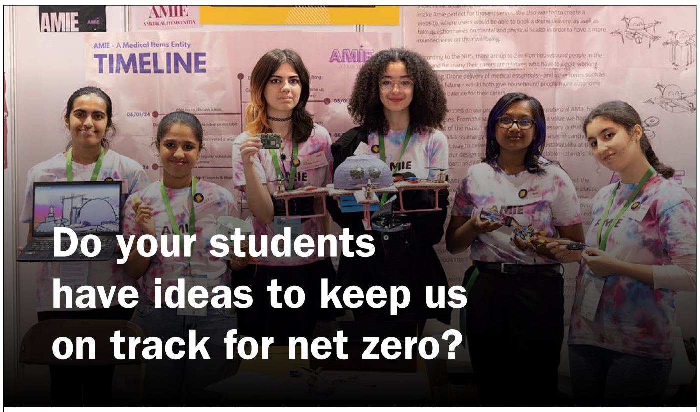
The **CREST Awards scheme** aims to inspire young people to think and behave like scientists and engineers. It is the BSA's flagship programme for young people, providing science enrichment activities to inspire and engage 5 to 19 year olds.

The current round of applications opens on 10 September and closes on 15 October 2024

See **bsa.sc/CREST_EG** for more details.

BRITISH SCIENCE ASSOCIATION

CREST AWARDS



The Big Bang Competition is almost here! Inspire students to problem-solve and come up with an amazing idea to tackle real issues in STEM by starting a project for **The Big Bang Competition.**

Not sure where to start? Build a STEM project step-by-step and get creative with **The Big Bang Challenge** – inspiring resources for educators and young people to help with project work, including how innovation in transport can help achieve net zero by 2050.

The competition will be open for entries in the coming weeks. We can't wait to see your ideas!

thebigbang.org.uk/Competition

Develop the tools to teach physics

Upskill biology, chemistry and non-specialist teachers of physics at KS3/4

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ELECTRICITY	ENERGY	FORCES
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www.stem.org.uk/SKPT

SKPT
SUBJECT KNOWLEDGE FOR PHYSICS TEACHING

Upcoming events...

For the latest information on IOP events, see spark.iop.org/events

21 September
Frontiers of Physics conference
Dublin
For teachers of physics in Ireland.
See more at **iop.eventsair.com/fop2024/**

30 September – 4 October
Welsh Physics Teachers conference
Online (to 2 October)
Brecon (4 October, in-person CPD day)
Details at **bit.ly/IOPBrecon2024**

5 October
BGE Science Conference
Edinburgh Napier University
Supporting the teaching of the sciences in the Broad General Education

31 October
Physics Education Research Conference
London

21 May 2025
50th Stirling Physics Meeting
The 50th annual conference for all involved in the teaching of physics in Scotland.

ASSOCIATION FOR SCIENCE EDUCATION

The ASE has joined forces with Physics Partners on 10 modules designed to provide subject-specific support for science teachers.

- **Forces Unveiled:** 25 September
- **Energy Explored:** 8 October
- **Electrifying Circuits:** 5 November
- **Wave Wonders:** 12 November
- **Maths in Motion:** 4 December
- **The Heat is On:** 17 December
- **Magnetic Mysteries:** 15 January
- **Cosmic Journeys:** 30 January
- **Radioactivity Revealed:** 6 March
- **Practical Mastery:** 19 March

Other CPD

Starting September
Technicians leadership programme

24 September
An introduction to professional registration: online sessions for technicians and teachers

Starting 1 October
ASE SEND programme

12 November
Building Science Identity, Teacher Developers Network

16 November
Northern Conference and West of England Convention

9–11 January 2025
Annual Conference, University of Nottingham

Full details **ase.org.uk/events**

BRITISH SCIENCE WEEK

British Science Week 2025 – get a helping hand for your school

Kick Start Grants, supported by UKRI and delivered by the British Science Association, **help schools in challenging circumstances** to organise their own activities and events during British Science Week.

Applications open 17 September – 5 November 2024

bsa.sc/Kick-Start-Grant-BSW

EngineeringUK
INSPIRING FUTURES TOGETHER

Tomorrow's Engineers Week 2024
11–15 November

This year's theme is **Power up your passion.** Ignite curiosity in your students by exploring how their passions can align with engineering careers.

Register your school or class to take part and be the first to hear about exciting opportunities in the lead up to #TEWeek24 and access free classroom resources and activities!

teweek.org.uk

Seen elsewhere...

Hydrogen racing boat

British sailor Phil Sharp aims to skipper a hydrogen-fuelled boat in a major international race.

bit.ly/OceanRaceHydrogen

Credit: sail World

Wireless charging on the go

A BBC article about how wireless charging built into the road can support electric cars and vans.

bit.ly/BBCElectricRoads

Credit: BBC

Technicians in transport

A range of job profiles from the Technicians: we make the difference campaign, including roles in transport

bit.ly/TechnicianRoles

Technicians
We make the difference

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