# Classroom physics

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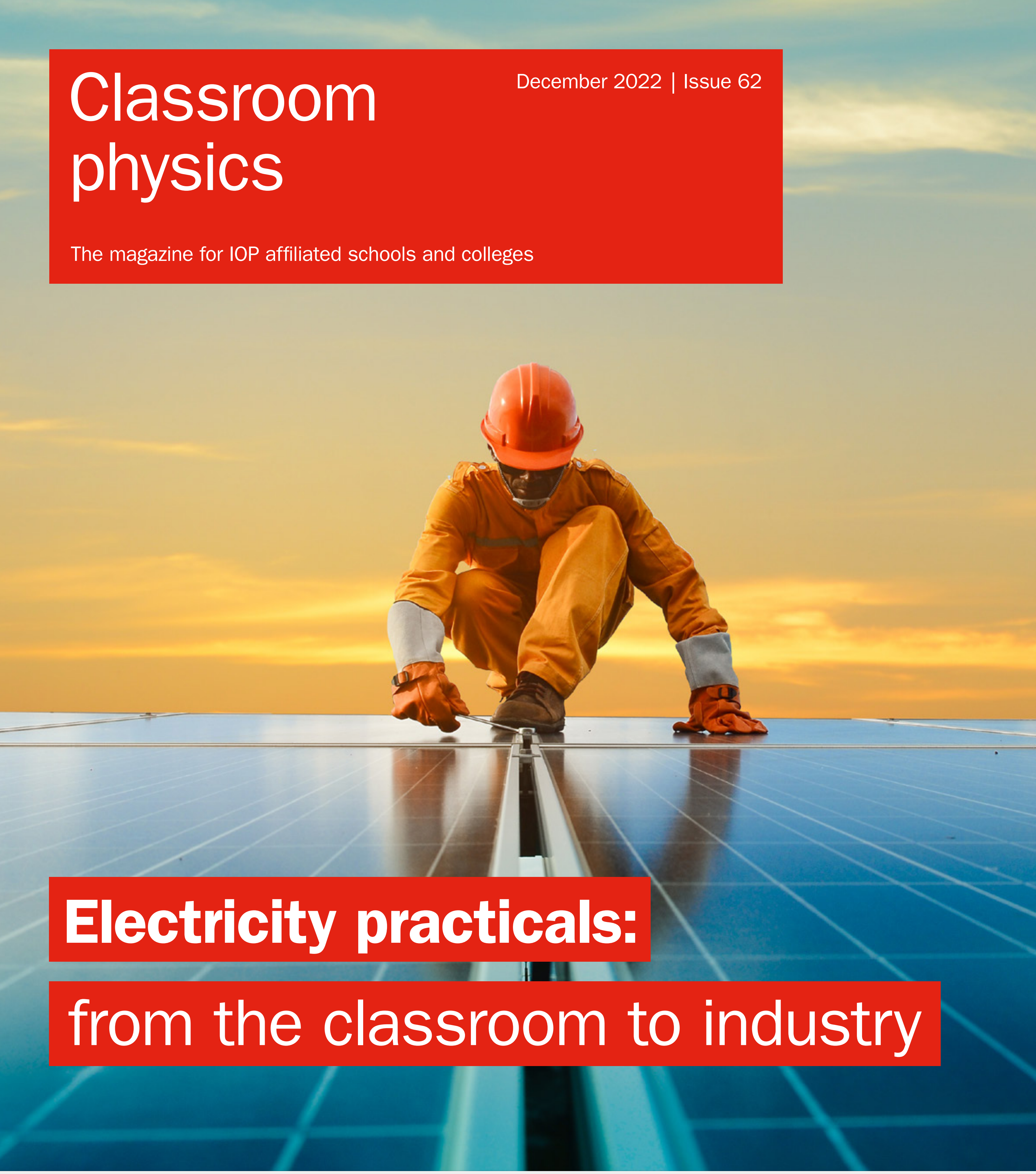
The magazine for IOP affiliated schools and colleges



## Electricity practicals: from the classroom to industry

**Spotlight on green electricity generation**

**Circuit training: what to do if your circuit isn't working**

**James Clerk Maxwell's poetic side**

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# This issue

## News



## Features



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## Listings



Credit: Photo by Peechie274 - pexels

# Electricity: a practical necessity

**Electrical power. So essential to our everyday lives – and yet so easy to take for granted.**

This issue of Classroom Physics comes as electricity bills are surging for many households and businesses, putting additional financial pressure on schools. Meanwhile in Ukraine, citizens are being deprived of electrical power with intermittent blackouts reported, just as winter starts to set in. And, only last month, world leaders met to discuss the future of electricity generation (and how we deal with the consequences of past electricity generation) at the COP27 summit in Egypt. You could say it's a highly charged topic.

In this issue we offer support for teaching electricity in the classroom. The pull-out section focuses on building circuits and tips for making introductory lessons for 11–14-year-olds go as smoothly as possible. We also have resources shared from across the science teaching community, with tools and tips for creating circuits in the lab, maintaining electrical components, getting to grips with diagrams, and the anecdotes and shared experiences from fellow teachers that can make all the difference.

Look out also for news and other information about networks and support for career development and sharing practice. Beyond the practicalities of teaching electricity, we also look to the future with our green electricity feature. Generating power from renewable sources is essential to a decarbonised future – as well as offering huge opportunities for your students if they want to pursue a career in physics or engineering.

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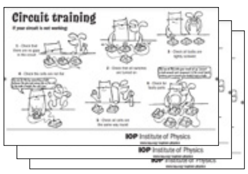
**IOP Affiliated Schools and Colleges will receive with this issue...**

A class set of Circuit training cards (see pages 9–12 for more details)




A Green Engineering Careers poster (see pages 6–7 for more on green electricity)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Read Classroom Physics online and access previous editions at **spark.iop.org/classroom-physics**

# GCSE and A-level grading 'to return to pre-pandemic levels'

**In September, Ofqual announced details of the 2023 exam process in England.**

All subjects will be graded at pre-pandemic levels as the government looks to return education to a normal footing after the disruption of the last few years. However, decisions about grade boundaries will be calibrated to 2017 levels, to reflect protections in place in that year for students who were the first to sit the reformed GCSEs and A levels. This means that while overall grades are expected to be worse than last year, some protection remains in place for students.

Ofqual chief inspector Jo Saxton wrote in a statement: "Students in the 2023 cohort have not experienced national school and college closures during their 2-year courses of study, but we know they have experienced some disruption."

There will be no advance notice of which topics will be tested, but GCSE maths, physics and combined science candidates will still be allowed to use formulae and equation sheets in exams.

An earlier announcement had already declared that non-exam assessment would return to pre-pandemic arrangements for the 2023 cohort, since public health measures are no longer in place.

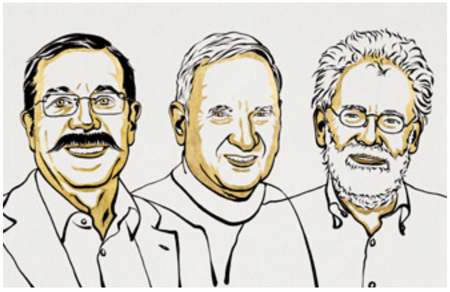
In Scotland, the 2023 SQA course assessments for National 5, Higher and Advanced Higher Physics are running on the same basis as those in 2022, with exams but no assignments. The physics exams will take place on Wednesday 17 May 2023.

# Entanglement pioneers share 2022 Nobel Prize

**This year's Nobel Prize for Physics, announced in October, was awarded to three physicists for their work on entangled quantum particles.**

Alain Aspect, John F. Clauser and Anton Zeilinger experimentally showed that quantum entanglement is real. Using an idea put forward by John Bell in 1964, they measured many particles to show that they influence each other at a speed faster than that of light. Described by Einstein as "spooky action at a distance", the idea of quantum entanglement subverts the well-established notion that objects are influenced only by their local surroundings.

Credit: © Nobel Prize Outreach. Illustration: Niklas Elmehed.



Alain Aspect, John F. Clauser and Anton Zeilinger

The prizewinners each conducted experiments in the 1970s and 80s using entangled photons. Taken together, their work shows with a high degree of precision that quantum entanglement is a real phenomenon and seems to rule out other interpretations of quantum mechanics such as the idea of *Hidden Variables.*

The findings are paving the way for technologies such as ultra-secure quantum communications.

Credit: Shutterstock

# Initial Teacher Training intake lower than hoped

**Preliminary figures for next year's Initial Teacher Training intake indicate that recruitment continues to fall well short of the overall target for new teachers, with new physics teachers in particularly short supply.**

Estimates for intake in England show 12,624 people enrolled for ITT in 2022/23, just 60% of the target of 20,945 for the year. The intake for physics teachers is estimated at 514, which equates to 20% of the target of 2610, and is showing a year-on-year decline of 10% from the 567 physics specialists who underwent ITT in 2021/22.

Following a review of ITT provision by the government, some providers were not re-accredited to provide ITT training, which could be contributing to the problem. The government has announced its intention to launch a task force to look at the issue.

No figures have been published yet for Scotland, but Stuart Farmer, IOP Learning and Skills manager for Scotland, reports that universities, which manage all teacher recruitment in Scotland, have also seen below-target recruitment.

# Limit Less round-up

**Limit Less is the IOP's campaign to remove the barriers that too many young people face to continuing with physics post-16. Since 2020, the IOP has been campaigning for systemic change to ensure physics can be accessible and appealing to all, regardless of gender, race, socioeconomic background, sexuality or disability.**

During 2022 we were delighted to meet hundreds of teachers from across the UK and Ireland at several in-person events, with the first 'Physics for All' event in Birmingham proving a huge success. We look forward to meeting many more of you in 2023 – keep an eye on **iop.org/events**

An important part of our campaign is to challenge misconceptions around physics – and physicists – in communities and schools. This includes promoting positive coverage in both social and traditional media which doesn't reinforce stereotypes.

During 2022 the need for this work was brought home by the government's social mobility commission chair – and arguably Britain's most famous teacher – Katharine Birbalsingh, who stated that fewer girls choose physics because of an aversion to "hard maths". While it was frustrating to see an influential person express such inaccurate and unhelpful comments, we were encouraged by the strength of the backlash in the media and online. A further response was made by IOP Deputy Chief Executive Rachel Youngman when she spoke before the Science and Technology Select Committee in Westminster, She highlighted the impact of sexism and emphasised the importance of a whole-school approach to equity and inclusion. We're working to influence legislation, with the goal that every school in the UK and Ireland should be supported to produce a comprehensive whole-school equity plan.

To help others to communicate more usefully about physics, the campaign team has also produced guidelines for talking about physics online, which can be accessed at **iop.org/LimitLess**

**Support Limit Less today**

Hundreds of teachers have already backed the Limit Less manifesto for meaningful change, including dozens of school and MAT leaders who have signed the manifesto on behalf of their institution. Join them here:

**iop.org/manifesto**

Together, we can support young people to fulfil their potential and change the world.

Limit Less

# Peer support network launches to support retention

**Heads of Physics from schools in Abingdon and Oxford have launched a network to support local physics teacher retention.**

The group aims to develop a local physics teacher network to provide support, ideas and a forum for teachers to share best practice with others passionate about physics.

The network has secured membership from over 50 local physics teachers, representing more than 25 local schools. The launch event in October, a Teach Meet held at St Helen and St Katharine School, Abingdon, saw over 35 local teachers coming together to talk about physics education. Alongside discussion of affordable apparatus, attendees heard CPD talks on the LIGO International Physics & Astronomy Educator Program, use of NASA's micro-observatory by school astronomy clubs, Isaac Physics as a homework platform, use of Vernier Smart Carts in the classroom and introducing electricity to Y8s with Energy Sticks.

A 2019 report from the Gatsby Foundation, 'Increasing the Quantity and Quality of Science Teachers in Schools', found that England has a severe shortage of teachers, particularly in the sciences, which is set to worsen. For the numbers of physics teachers to catch up with the required level, one in three physics graduates would need to enter the teaching profession each year.

For Katie Brudenell, Head of Physics at St Helen and St Katharine, this makes teacher retention more important than ever. "The Gatsby report identifies subject-specific development as an evidence-based strategy for supporting retention," she said. "Teachers can learn and improve through talking to, and selectively borrowing from, other teachers. Likewise, professional development that increases science teachers' subject knowledge, as well as their pedagogical skills, has been shown to improve retention, most likely due to the increased efficacy and job satisfaction among participating science teachers."

**more...**

Inspired to create your own network?

Contact **abingdonoxonphysnetwork@gmail.com** to find out more

# Engagement with research 'could improve the quality of science teaching'

Credit: Shutterstock

**Journal clubs and teacher-led research were among the topics discussed at a conference in Sheffield in September which looked at the impact of teachers' engagement with academic research.**

The event was part of a Wellcome-funded programme led by Sheffield Institute of Education and the National Foundation for Education Research (NFER), which assessed the impact of a range of research-based projects involving 468 science teachers. Teachers participating in the projects reported improved confidence in accessing, assessing the quality of and applying research, improved use of research in teaching practice, and better science pedagogical practices.

The report concludes that supporting teachers to engage with and carry out pedagogical research "has the potential to improve the quality of science teaching", and makes recommendations for how teachers' working environments can be optimised to enable engagement with research, including by senior and middle school leaders.

Conference delegates heard presentations from the projects, as well as a video from Dr Mark Rickinson at Monash University in Melbourne, Australia, who shared insights from a project he ran that looked at how to support and get best results from research use among teachers.

**more...**

More information about the event, including the video, research digests and lesson plans that can be downloaded and adapted, can be found at the project website:

**https://bit.ly/3Wrz4KS**

# Brecon Conference

**The 21st IOP Welsh Physics Teachers' Conference met at Brecon in October, combining in-person with online sessions for the first time after two years of being exclusively online. The event format enabled 375 registrants to participate, including some from as far afield as the US, New Zealand and Indonesia.**

In the online portion of the event, academics from Welsh universities delivered sessions for teachers at all stages of physics education. Among many innovative topics were how gas laws work in space suits and the diving suits astronauts train in, and developing scientific skills through the study of exoplanets. (See a related IOP Spark teaching resource here: **https://spark.iop.org/collections/teaching-exoplanets)**

On the final day, teachers and technicians led in-person sessions. Among them, Ed Male, recipient of the 2021 Teachers of Physics Award in Wales, delivered a presentation on 'Harry Potter – Magic or Science?', while Anthony Clowser's session 'The Physics of Archaeology' saw teachers making kit to demonstrate how electrical resistance is used to find buried objects.

Physics teacher and CP contributor, Dave Cotton, commented on the return to meeting face-to-face. "When I set Google Maps to give me directions to Christ College, Brecon, it told me I had last been there three years ago, before Covid came along and disrupted so many events like this one. It was great to be back in a real room with real people, networking and meeting fellow physicists."

**more...**

Access resources from the event:

**https://bit.ly/3zGAaZL**

# Green electricity: powering the future

**For the first time in your students' lifetimes, the country is seriously contemplating power outages this winter. The price of keeping the lights and heating on, for households, businesses and schools, has become part of the national conversation. How we generate electricity is also at the heart of concerns about climate change: as the global agenda targets carbon neutrality, societies around the world are working towards a future free from our current dependence on fossil fuels.**

**Against this backdrop, classroom discussions about electricity generation are more topical than ever.**

**So our features for this issue both look at the future of electricity production. Not only because it's a topic directly linked to the science curriculum, but also because it represents a host of STEM career opportunities for students – in which they can make a difference to the future of our planet.**

## Nuclear options

Nuclear power, which currently supplies about a fifth of the UK's energy needs, is a controversial industry. On one hand, it provides abundant, reliable, carbon-free electricity for millions of homes and businesses. On the other, it's very expensive to build new reactors, presents long-term problems of waste storage, and of course requires very careful management of risk.

Your students will likely have a range of opinions on the relative merits of nuclear power compared with other electricity sources, but the UK government continues to invest in the industry. A new reactor for the Sizewell plant in Suffolk was signed off in September by the outgoing Prime Minister Boris Johnson, and in October the government announced the site of the UK's prototype fusion energy plant ('STEP' or Spherical Tokamak for Energy Production) in West Burton, Nottinghamshire.

Both developments look set to offer significant employment opportunities. The new plant at Sizewell is expected to support 70,000 jobs across 3,000 UK suppliers, as well as several thousand roles in the running of the site. Meanwhile, the government has announced that STEP "will commit immediately to the development of apprenticeship schemes in the region" - so look out for some opportunities for school leavers in the East Midlands and beyond to be part of developing the exciting potential of fusion power generation.

### An apprentice's story

For Victoria Brown, a Maintenance Assistant Team Leader for EDF Energy at Dungeness nuclear power station in Kent, an apprenticeship opened the door to a career in the nuclear industry. After her GCSEs, she joined a four-year scheme, during which she achieved NVQ level 2 and 3 in


Credit: Neon Futures

Engineering Maintenance and a higher national certificate in Electrical and Electronic Engineering. She qualified as an instrument technician and has worked her way up.

At 24, she is now taking a leadership role in the maintenance of the plant. She says: "I take responsibility for the safety, effectiveness, productivity and quality of work of the maintenance team."

It's a significant responsibility, as recent history has shown. "We know from historic accidents at Chernobyl and Fukushima that if safety is not at the heart of absolutely everything we do, things can go catastrophically wrong", she says. "Those working in the nuclear industry are very aware that we have a personal obligation to the public and environment. Our plant is subject to continuous audits and inspections to ensure things are running safely and we operate in a very cautious way. There are many fail-safes and we always take conservative decisions - if there is the slightest chance something is unsafe then it won't go ahead."

For more on Victoria's story, and other careers in green engineering, see:

**https://neonfutures.org.uk/case-study/**

## Here comes the sun

When Egypt played host to the COP27 meeting in November, clean power generation was high on the agenda.

Egypt offers an interesting case study on renewable power. Historically, much of its supply has come from thermal and hydroelectric. The famous Aswan High Dam is one of several large-scale civil engineering projects designed to use the Nile. When it began electricity generation in the 1960s, the Aswan High Dam provided half of all Egypt's power and brought electricity to millions of rural Egyptians for the first time. However, today it rarely operates at full capacity owing to low water levels, and the growing economy has a greater demand for electrical power.

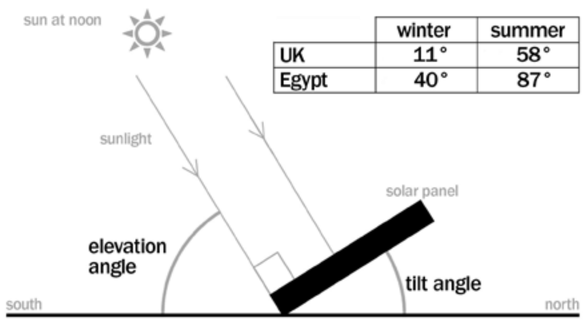
Responding to this need, during the last decade a massive solar farm has been installed at Benban, a desert region about 650km south of Cairo. Covering an area of 37 $km^2$, it's the fourth largest solar farm in the world and is visible from space. In fact, NASA was involved in finding the optimal location for the site.

### Teaching and learning opportunities

Benban is a great example of emerging green technology to integrate into your teaching.

**11–14: Seasons**

For 11–14s, you could include it in a lesson on seasons. Solar panels generate most power when sunlight strikes them perpendicularly. Provide the sun's elevation angles for summer and winter and challenge your students to work out what angle to mount their solar panel.




- *Why are elevation angles higher in summer?*
- *Why are they highest in Egypt?*
- *Which tilt angle is best?*

Variable tilt solar panels that follow the daily and annual motion of the sun are an option. However, the additional cost and complexity of the tracking equipment needed means that these are only suitable for ground-based installations such as the one at Benban.

For a fixed solar panel, a good rule of thumb is to use the average of the summer and winter elevations (ie $34.5^{0}$ for UK and $63.5^{0}$ for Egypt). For sunlight to strike a panel perpendicularly: **tilt = $90^{0}$ – elevation.** This suggests an ideal tilt angle of $55.5^{0}$ for the UK and $26.5^{0}$ for Egypt. In reality, when mounting on a building, the slope and orientation of the surface you are attaching to usually restricts options (roof pitches in the UK are usually between $30^{0}$ and $50^{0}$).

**14–16: Solar pros and cons**

For 14–16s, compare Egypt's location with the UK's to illustrate the advantages and disadvantages of solar power. Your students could research the terrain, day-length and weather at Benban to explain why Egypt has the advantage when it comes to large-scale solar power generation.

Compared with the UK, Egypt has: large areas of unused land (desert); less variation in day-length over a year; and less cloud cover/clearer skies.

Some textbooks list high cost as a disadvantage of solar power. This is no longer the case. The cost of solar technology has dramatically reduced in the last decade due to advances in photonics.

**Post-16: Photons**

For post-16 students you can draw on the fact that solar cells are quantum devices. They work through the photovoltaic effect which, like the photoelectric effect, involves photon absorption and electron transfer. The photovoltaic equivalent of the work function is called the excitation energy and for silicon is around 1 eV. Your students could use the relationship $E = hc/\lambda$ to explain why silicon generates electricity for all visible wavelengths, while metals such as zinc do not.

| Device | Material | Effect | Minimum photon energy required | Threshold wavelength |
|---|---|---|---|---|
| Solar cell | Silicon | Photovoltaic | 1.12 eV | 1110 nm |
| Photocell | Zinc | Photoelectric | 3.72 eV | 333 nm |

**Photonics: a growing industry**

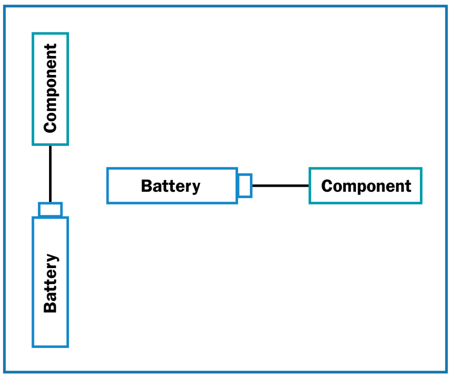
Photovoltaics is just one part of the growing photonics sector in which the UK has become a world leader. Photonics encompasses a wide variety of uses of light in technology, with applications ranging from optical sensors, computing, communications, medical and military, among many others. The sector was recently estimated to be worth £14.5bn a year to the UK.

Physics education research

In this column, **James de Winter** (University of Uppsala and University of Cambridge) and **Richard Brock** (King's College London) highlight accessible and usable resources based on research into physics education.

Get involved with physics education research discussions by joining the **Physics Education Research** group on Talk Physics at **talkphysics.org/groups/physics-education-research-per** or email **research@teachphysics.co.uk**

# This way up: Does it matter which way round I draw circuit diagrams?




**Circuit diagrams are an integral part of teaching DC electricity at school, providing a simplified representation of what can become a mess of cables and components on the table in front of students. In many textbooks and exam papers, the convention seems to be that the components are orientated the same way and drawn horizontally. But is this the most helpful way to ensure students understand the concepts behind the circuit diagram?**

As part of a study into the impact of the context of questions on understanding, John and Allie (2016a) considered whether the choice and orientation of components in a circuit diagram made a difference to student responses. Sixty first-year students at two South African universities were asked a set of questions based on a simple circuit diagram showing a battery and different components in two orientations, horizontal and vertical.

The authors developed a set of questions that, in each case, varied one of three things to see if it made a difference to student responses:

- The orientation of the battery and component (vertical, horizontal)
- The component (bulb, resistor, heater)
- The question asked ("will [component] light/heat up?", "will charge flow in [component]?" and "will there be current in [component]?").

In each case, the majority answered correctly, based on an understanding that as the circuits were incomplete, a current would not flow. However, there was variation in the incorrect responses and associated explanations. A greater number expected vertically orientated bulbs and horizontally orientated heaters to heat/light up or have charge/current flowing in them compared to horizontal bulbs and vertical heaters.

What does this mean for secondary school teachers? A quote from the paper should give us pause for thought:

"The results showed that the student responses are triggered by the context framed by the questions and the results obtained from investigations using light bulbs cannot be generalized and may be reinterpreted."

When selecting examples in our teaching and assessment, it's worth considering that, while we, as experts, may classify two circuit diagrams as identical, our students may not see them as identical. We might consider introducing greater variety in components and orientation to ensure we can be confident that students are fluent with the conceptual ideas we're teaching.

See the original research:
John, I., & Allie, S. (2016a). DC circuits: I. Evidence for fine grained contextual dependence. European Journal of Physics, 38(1), 015701.

**https://bit.ly/3U1brap**

## more...

The authors considered possible reasons for contextual variations in two subsequent papers:

John, I., & Allie, S. (2016b). DC circuits: II. Identification of foothold ideas in DC circuits. *European Journal of Physics,* 38(1), 015702.

**https://bit.ly/3DXJnPA**

John, I., & Allie, S. (2019). DC circuits: III. The complex terrain of sense-making. *European Journal of Physics,* 40(5), 055704.

**https://bit.ly/3fuEN25**

Pull out and keep!

Electricity 11-14

# Building circuits

**Inside this issue:**

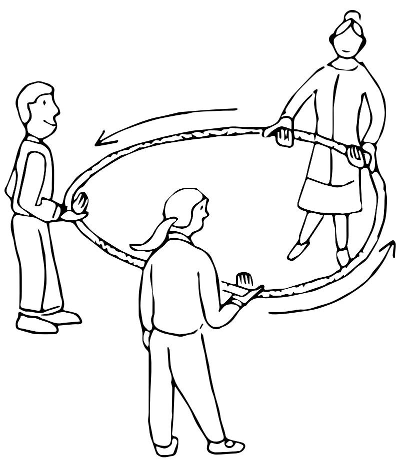


# Avoiding circuit chaos

*Eleanor Wylie* shares her tips for introductory electricity teaching.

There can be few lessons more fraught with pitfalls than those that involve building a circuit. Loose connections, mixed bulbs and flat cells often result in a sea of frustrated faces and lots of hands up. But it doesn't have to be this way. With some scaffolding and a little help from the IOP's intrepid cat and dog team you can get them started on the right track from their very first electricity practical and have them experiencing those light bulb moments you were hoping for. On the right we've got some equipment and teaching tips to help your lessons go more smoothly. Inside this pull-out are two activities we've developed for the start of secondary school. Both are intended to build confidence and resilience. The first is a demo to show students how to trouble-shoot circuits. The second is a class activity that helps students relate circuit symbols to real circuits.

Credit: IOP



The rope loop circuit model

## Equipment tips

1. **Use short leads to avoid spaghetti circuits**

   Your prep room may stock connecting leads of 50 cm or longer. Don't use these for their first lesson if at all possible. Select shorter (eg 20 cm) leads to make it easier for your students to keep things untangled.

2. **Use monochrome leads to save time**

   Many younger students think the colour of a connecting lead has a physical significance. They can waste time working out whether a red, black or yellow one will work better for a particular purpose – when of course it doesn't matter. For their first try at circuit building, arrange it so that each group only works with one colour.

3. **Check bulb ratings to reduce misconceptions**

   A dim bulb after a bright one can reinforce the idea that current is somehow used up in a circuit. Before sending out the kit, check the bulb ratings. These are usually etched into the screw-in part of the bulb. Make sure all power ratings are the same.

## Teaching tips

1. **Stick with series**

   Series circuits are the simplest to understand. Don't move on too quickly in your teaching. Only introduce parallel circuits once students are confident with circuit symbols and understand the concepts of electrical current and resistance

2. **Use both hands to trace current**

   When tracing current around a circuit diagram we often start with a single pointed finger at the battery. This can reinforce the idea that something has to flow from battery to bulb before it lights. Use both hands: one at the battery and one at the bulb to emphasise that the current starts flowing in all parts of the circuit at the same time.

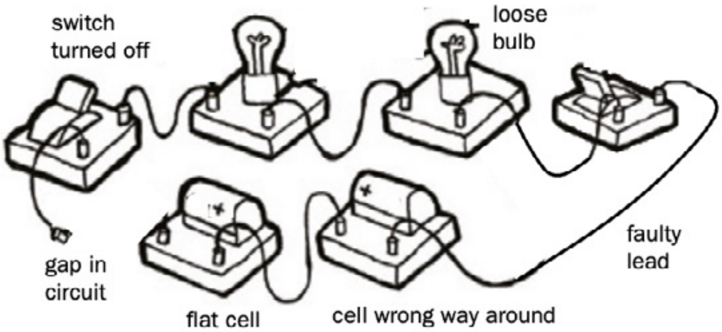
3. **Use only one circuit model**

   When introducing series circuits, some teachers are tempted to present different models (eg pizza delivery, water etc). But this can lead to confusion and distract from learning about real circuits. Stick with one model. We recommend the Rope Loop Circuit at **spark.iop.org/rope-loop-circuit**

**Eleanor Wylie** is a Professional Support Coach for the IOP Learning and Skills department.

# **Demonstration:** Trouble-shooting circuits

This demonstration introduces diagnostic procedures for series circuits.




### Equipment:

- 2 live cells
- 1 flat cell
- 3 bulbs
- 1 switch
- 7 good leads
- 1 faulty lead

A class set of Circuit training cards (page 12)

### Preparation

Set up a circuit shown above before the lesson.

Deliberately:

1. Incorporate a gap somewhere in the circuit
2. Turn off one of the switches
3. Use one flat cell
4. Put one cell the 'wrong way around'
5. Unscrew one of the bulbs
6. Use one faulty lead

After you've set it up, ensure all students will be able to see the circuit. You could use a web-cam or a visualizer to help.

### Procedure

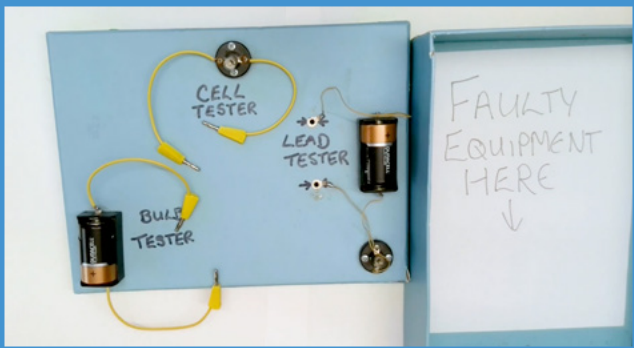
Explain how you know the circuit isn't working (the bulbs aren't alight). Ask students to use their Circuit training cards to suggest what to do.

As students suggest ideas, fix the circuit by going through the steps in the order they suggest them. Show them how to:

- Identify and close the gap in the circuit
- Ensure all switches are ON
- Check for and tighten loose bulbs
- Spot cells that are the 'wrong way around' and turn them around
- Check and replace a flat cell by connecting a spare bulb across positive and negative terminals (if the bulb doesn't light, the cell is flat)
- Identify and replace the faulty lead by checking each component and lead in turn by connecting the spare lead across each

**Component testing station**

If the circuit still doesn't work, more than one component is faulty. We recommend building a component testing station and providing a 'hospital' tray so that faulty equipment gets taken out of circulation.

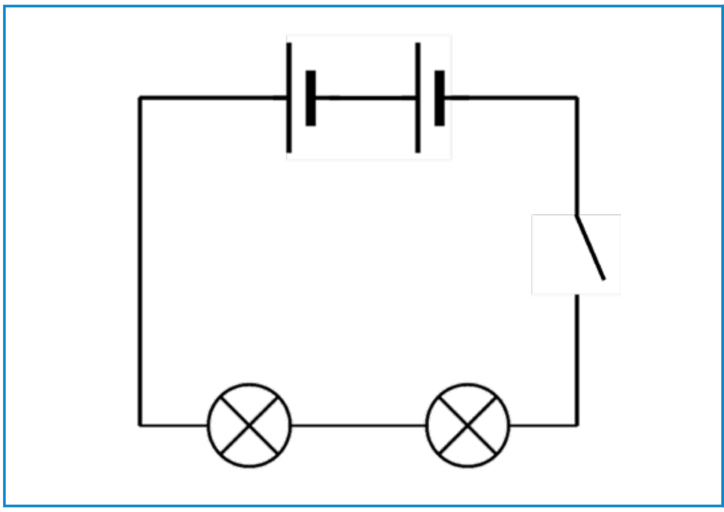


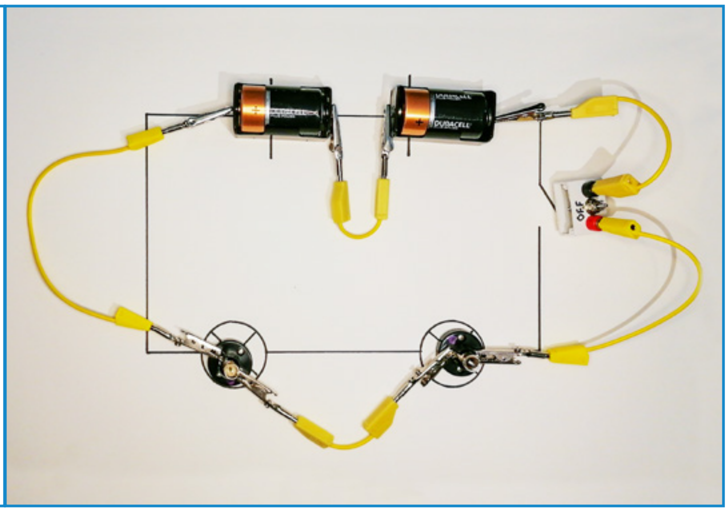

### more...

For more on the component testing station and lots of other great electricity teaching ideas, watch Exploring Circuits Practically (11-14) at: **spark.iop.org/electricity-cpd-videos**

# **Class Activity:** Circuits on diagrams

This activity helps students make the links between circuit diagrams and real circuits.





### Equipment

Each group of students will need:

- 2 cells
- 2 bulbs
- 1 switch
- 5 connecting leads
- Poster paper
- Marker pen
- Blu Tack (optional)
- Circuit training card (page 12)

### Procedure

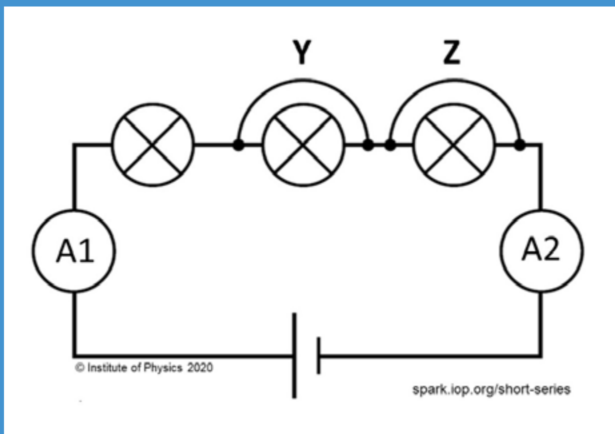
Ask students to:

1. Draw a large version of the circuit diagram (above) on a poster paper.
2. Place components on the corresponding symbols.
3. Make connections between components by placing leads along the lines on the diagram (providing Blu Tack to allow students to attach leads to paper if they want).
4. If their circuit doesn't work, use the Circuit training card to check for faulty components.

**Diagnostic activity: Short series**

The circuit below allows students to investigate up to three bulbs in series without having to take their circuit apart. Ask them to predict and explain how the readings on the ammeters A1 and A2 will change when leads Y and Z are removed.

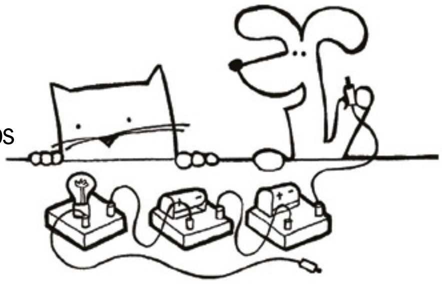
Find out more at:
**spark.iop.org/short-series**



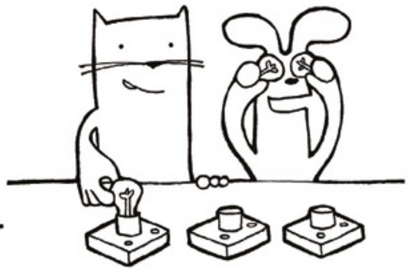
# Circuit training

**If your circuit is not working:**

**1** - Check that there are no gaps in the circuit

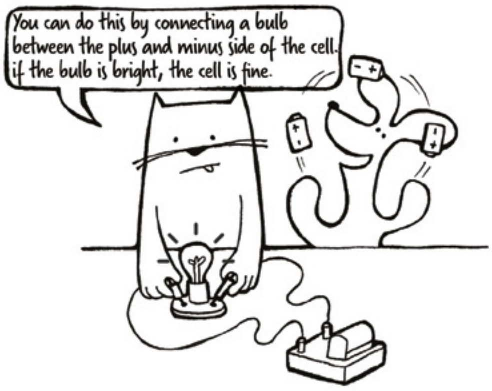



**2** - Check that all switches are turned on



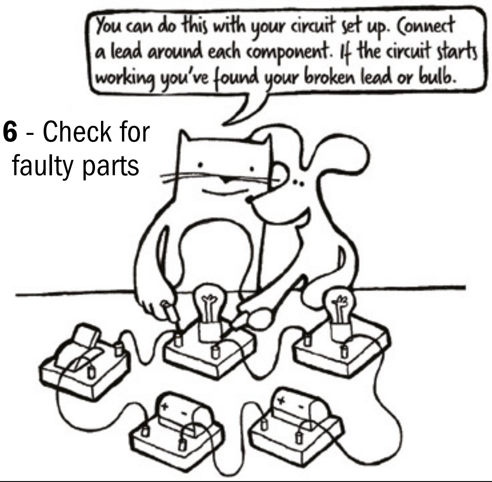
**3** - Check all bulbs are tightly screwed

**4** - Check the cells are not flat




**5** - Check all cells are the same way round

**6** - Check for faulty parts



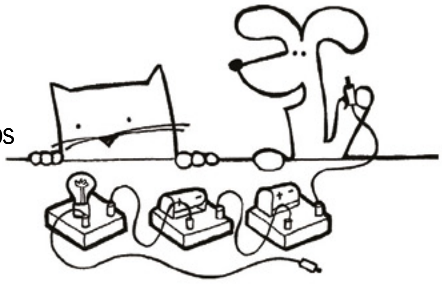

**IOP** Institute of Physics

www.iop.org/explore-physics

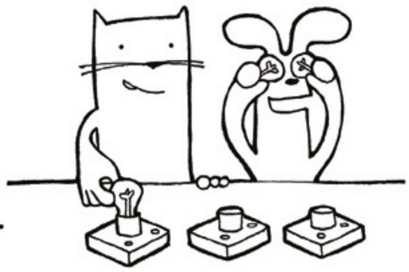
Circuit training

If your circuit is not working:

1 - Check that there are no gaps in the circuit

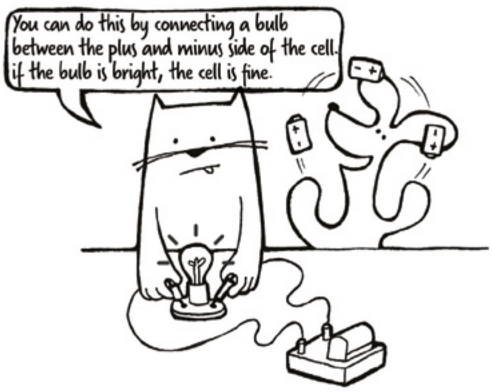


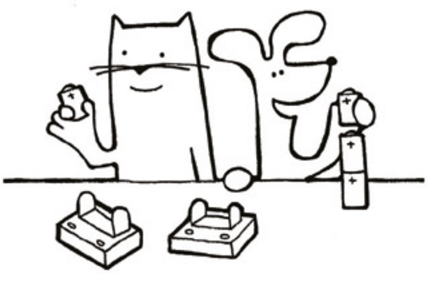

2 - Check that all switches are turned on



3 - Check all bulbs are tightly screwed

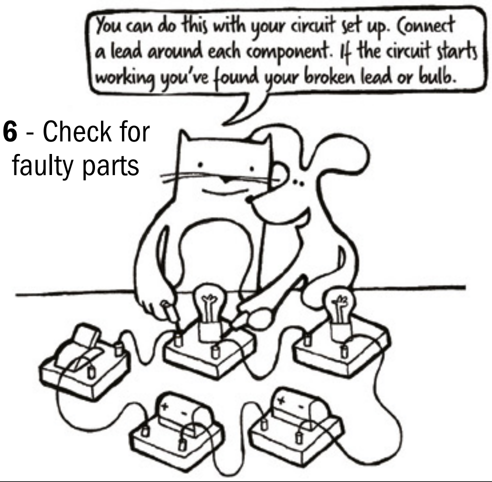
4 - Check the cells are not flat



5 - Check all cells are the same way round

6 - Check for faulty parts

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# Electrical stories

### Cooking Faraday's goose

Practical work in electricity brings to mind Michael Faraday. Faraday had overheard Wollaston and Davy discussing the force exerted on a current by a magnet, sparking his experimental interest. He hung a wire from a hook into a pool of mercury and connected them to a voltaic pile. Having made the wire rotate using a magnet, on Christmas Day 1821 he made the wire spin using only the Earth's magnetic field. This prompted Faraday to call his wife to observe. She, however, had other concerns, and replied that their Christmas goose would burn if she left the kitchen. Faraday is reported to have replied, "Oh, damn the goose, come down."

### Haslett: The power pioneer

After leaving school, Caroline Haslett took a secretarial course and began her career as a clerk at the Cochran Boiler Company, which made parts for ships. She became active in the suffragette movement, left Cochran's and became the first secretary of the Women's Engineering Society and the first editor of the *Woman Engineer* journal, founded in 1919.

Haslett's suffragette background led to the society adopting the colours of the movement (white, purple and green) to acknowledge the sacrifices made by women to win the vote, the year before. During the Second World War, Haslett was the only woman on the Institution of Electrical Engineers committee focusing on domestic installation, which recommended the introduction of shutters on plug sockets to ensure the safety of children.

After the war, she published a discussion of gender equality called 'Problems have no sex'. Reflecting her electrical interests she requested, on her death, that her body be electrically cremated.

### The poetic side of Maxwell

James Clerk Maxwell, who developed the classical theory of electrodynamics, was multi-talented. At the age of 13, he won his school mathematics medal and the first prize for English and poetry. Maxwell continued to write poetry and a collection of his work was published in 1882, including several poems with electrical themes:

*Take then a coil of copper pure,*
*And fix it, on your whirling table;*
*Place the electrodes firm and sure*
*As near the axis as you're able,*
*And soon you'll learn the way to work it,*
*With galvanometer in circuit.*

Valentine by a telegraph clerk ♂ to a telegraph clerk ♀

*The tendrils of my soul are twined*
*With thine, though many a mile span,*
*And thine in close—coiled circuits wind*
*Around the needle of my heart.*

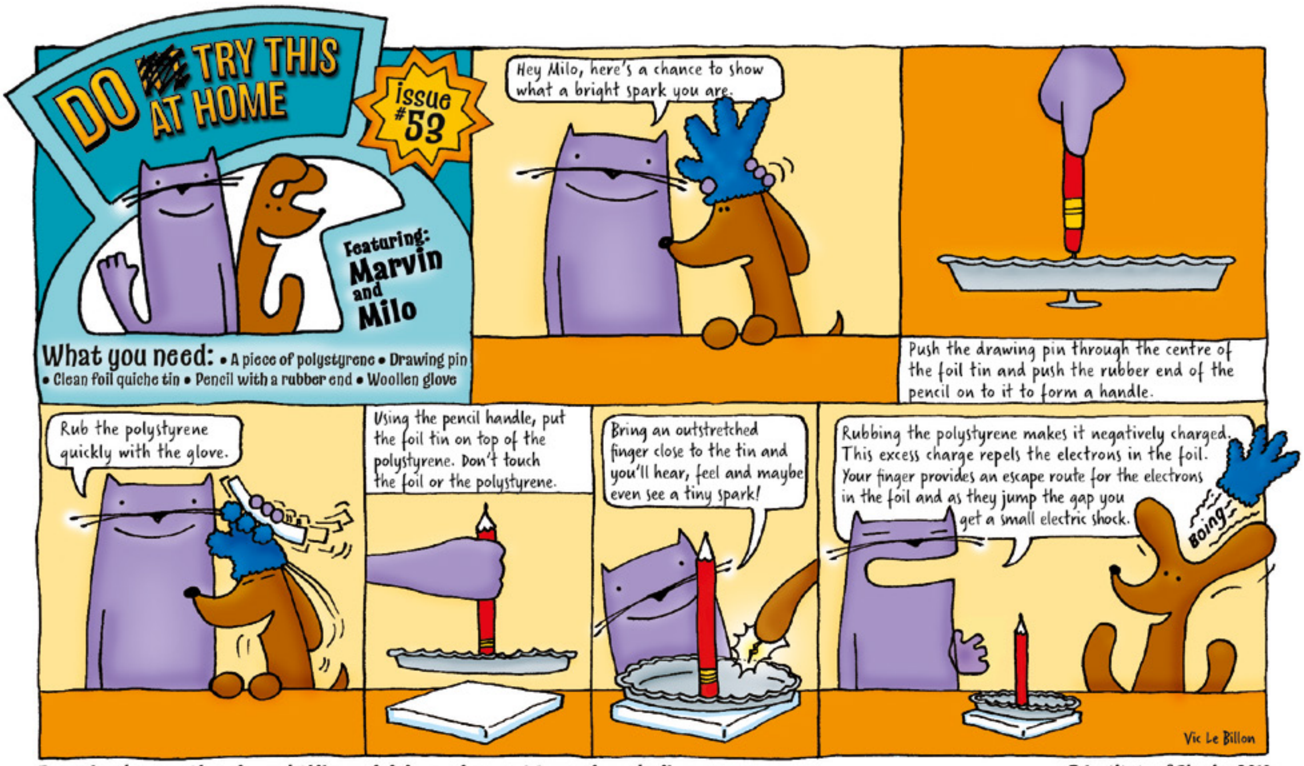
*Constant as Daniell, strong as Grove,*
*Ebullient through its depths like Smee,*
*My heart pours forth its tide of love,*
*And all its circuits close in thee.*

---

**spark.iop.org/stories-physics**

Compiled by Richard Brock, lecturer at King's College London and former physics teacher.

Follow him on Twitter **@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 **electricity practicals** from the archive and the current volume.

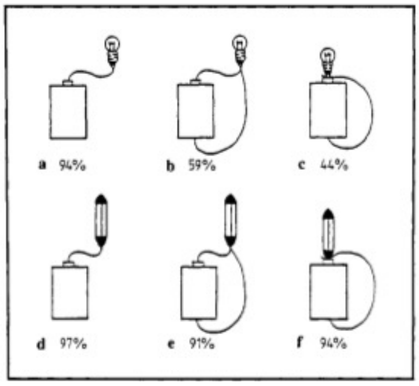
Access over 50 years of articles at **iopscience.org/physed**

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

## A light bulb moment

Although it's not ostensibly about electricity-related practical activities, the first paper I recommend reading from the Physics Education archive is ‘Pupils' understanding of simple electrical circuits. Some implications for instruction’, by David Shipstone. The article talks about the basic theory underpinning the teaching of simple electric circuits, but spills over into practical work, with clear links to practical activities related to electricity.

The paper was written back in 1988 but the points raised in the paper remain relevant. For example, if you still use MES lamps then “...it has become clear that an important source of difficulty is the construction of the MES lamp, which was not designed for teaching children about electricity…”.




Credit: David Shipstone

Proportions giving correct answers to the question 'Does the lamp light or doesn't it?'

So an explanation of how a filament bulb works might be useful before you start practical activities. There are a number of concrete points in the paper that would be worth considering before your classes begin electricity practicals.

**https://bit.ly/3T8qRs5**

## Short and sweet, and salty

‘Current in a salt solution’ is a short Frontline article by a colleague of mine, Tony Reeves. I recommend this practical because, having tried it myself with classes, I was impressed with the way students could operate at different levels, performing the same activities but applying different models and complexity of thinking.

We used plastic transparent boxes from a well-known chocolate brand, but any plastic container would do. One word of advice would be to keep metal apparatus separate, as the salt is very corrosive. Making foil electrodes, students can vary the concentration of the salt solution and change all sorts of things like the size of the electrodes, potential difference, concentration of salt solution and temperature. They can also put a barrier in the way and change the size of that. The model can be adapted to suit different ages.

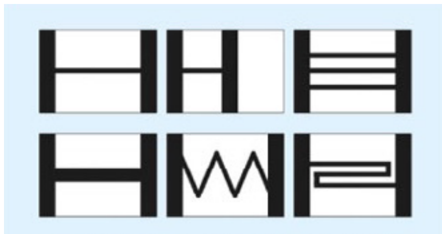
**https://bit.ly/3zGp8U1**

## Send the right signal

When teaching about fibre optics I once had a class of older students send messages down a fibre, flashing torches and using Morse code. It was a fantastic lesson as I learned a great deal! Firstly, it's much harder than it looks, and secondly, you need a clock. What I intended as a quick ten-minute activity took more like half an hour. We hadn’t discussed what constituted a dot and a dash beforehand and so I heard plenty of “was that a dash?” being shouted across the lab (which defeated the object of using the fibres).

So, experience suggests that activities where students actually do send messages will teach them a lot about the physics involved in communication. The activity described in ‘Hands-on activity using the amplitude and frequency of electromagnetic waves to demonstrate the principle of information transfer’ is for older students and far more complicated than what I attempted, but students will gain a lot from having a go at making this work in real life.

**https://bit.ly/3DWRyeZ**



Credit: IOP

Pencil-lead resistors

## Make your mark

Two papers that describe practicals that can be done with pencil leads are ‘Hand-drawn resistors and a simple tester using a light-emitting diode’, and ‘Pencil leads: 20 project ideas’. Some of these activities involve students drawing their own resistors using different types of pencil – HB, B1, B2, etc – and changing the dimensions. The shape of the resistor can also be investigated. The first of these papers offers inexpensive ideas for electricity-related practical activities. The latter paper describes more advanced ideas that might be more suited to 16–18-year-olds.

**https://bit.ly/3h9DzJP**

**https://bit.ly/3UoFfO0**

## Augmented reality

If you aren't yet familiar with augmented reality (AR) then imagine pointing your camera at something and having the computer draw extra bits on the viewing screen. It's just like the filters you get on phones that make you look like a cat. For education purposes, the main use is taking a concrete instance and adding an abstract model to it, but in a concrete way.

In this Open Access paper, 'Experiments for students with built-in theory: 'PUMA: Spannungslabor' – an augmented reality app for studying electricity', a piece of apparatus is presented that's coupled with an augmented reality description of what's happening in an electric circuit. Wires can be coloured according to potential difference and pretend electrons can be shown moving. Often QR codes are used, but these aren't always the traditional black and white squares – they just have to be something that the computer can recognise. It's well worth keeping up to date with these developments as AR has a lot of potential when it comes to helping students understand physics.

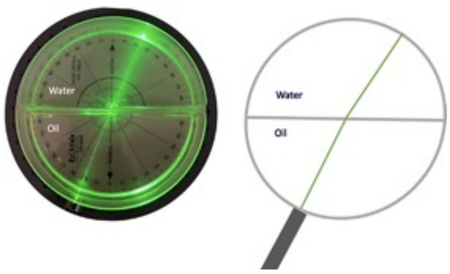
**https://bit.ly/3fwS761**

Credit: Physics Education

Screenshots from the app showing the effect of closing a switch to bypass a light bulb. Scanning the QR code in the left image prompts a short video about the experiment.

## Sequencing Snell's law

Another Open Access paper, 'Shedding light on boundaries: re-sequencing Snell's law instruction to first build conceptual understanding', is also worth reading if you are planning your scheme of work for a light topic.




Refraction of a laser beam through oil and water

If you look through the many papers in the Physics Education archive, you'll soon notice the importance placed on the sequencing of concepts. Physics Education Research is still in its infancy but we do know that some concepts are best taught before others. "Although many students can use Snell's law to perform basic calculations, the mathematical relationship is often divorced from students' conceptual knowledge…" and these researchers have devised and evaluated a sequence of fairly standard classroom activities that they feel tackles this issue. I suspect that having a well-thought-out approach to a teaching and learning sequence is key, with the thinking out being the important activity, rather than the actual final sequence. Looking at the sequences that others think work well can help with your own planning.

**https://bit.ly/3WvZdrW**

## Quick Links

Open Access

**Infinity, self-similarity and continued fractions in physics**

Creating resistor network puzzles

**https://bit.ly/3FYINUp**

Open Access

**Rewarding problem solving over final answers**

An unexpected boost for gender equity

**https://bit.ly/3NQHNT3**

**The impact of weightlessness on a charged needle electroscope**

Eyes on the needle

**https://bit.ly/3DOkqoM**

Open Access

**Maths and physics: a changing relationship**

Perspectives on maths shift as teachers develop

**https://bit.ly/3WVEPku**

**A new compass clock face question type**

Enabling freehand drawing in online tests

**https://bit.ly/3WJZNCJ**

**Shrinking violet**

Colourful diffraction demonstrations. Don't be shy – take a read

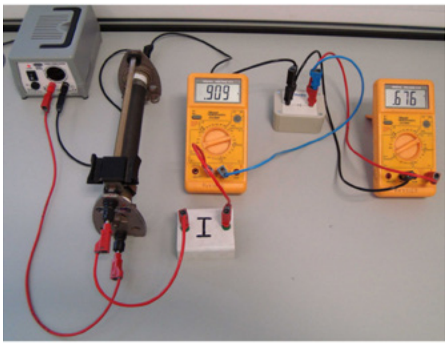
**https://bit.ly/3EgFKVa**

# talkphysics

David Cotton, editor of our online discussion forum, chooses his favourite TalkPhysics discussion threads on **electricity practicals.**

Log in or register to join the conversation at **talkphysics.org**

Credit: David Cotton



Measuring voltage and current

To help students succeed in setting up circuits correctly, it's important that they understand the use of meters and the resistance of components. This thread seeks advice on the setting up of circuits for measuring I/V characteristics of bulbs, resistors and diodes. The advice follows the method given on IOPSpark **(https://spark.iop.org/iv-characteristic-semiconductor-diode)**. There's also a discussion on the use of a potential divider circuit to enable variation of the supply voltage and reduction of the current to zero:

**https://bit.ly/3USE4qy**

An important part of setting up students to complete electricity practicals is initially modelling the expected behaviour of circuits. There's lots of good ideas here from Dorian Pascoe for which PhET simulations can be used:

**https://bit.ly/3zEZ2kg**

Another important tool to aid student understanding is the use of physical models. The resources for Kerry Colyer's CPD session contain advice on the different models:

**https://bit.ly/3Woge7H**

Part of the 'Energy in the new curriculum' series on TalkPhysics includes a hydroelectric power station as an energy chain example. It includes advice on keeping energy analysis straightforward by identifying appropriate start and end points. The post ends in a useful discussion of the stores and pathways approach to energy:

**https://bit.ly/3zG0Idv**

# physicsworld

Stories from our magazine for the global physics community.
Visit **physicsworld.com**

Credit: NASA/Johns Hopkins APL

Close-up: The last complete image of asteroid moonlet Dimorphos as taken by the DRACO imager on NASA's DART mission from about 12 kilometres from the asteroid and two seconds before impact.

## DART mission successfully hits asteroid in first-of-its-kind test

NASA has announced that its asteroid-deflection mission has managed to successfully hit its target with scientists now studying how much the body has been deflected by the impact.

DART, which was launched in November 2021, was sent on a roughly 11 million-kilometre journey towards a binary, near-Earth asteroid system. This system consists of a 780 m-diameter asteroid called Didymos and a smaller, 160 m body, Dimorphos, that orbits it.

**https://bit.ly/3DTev1N**

## From ATLAS to the control room: a high-school student's week at CERN

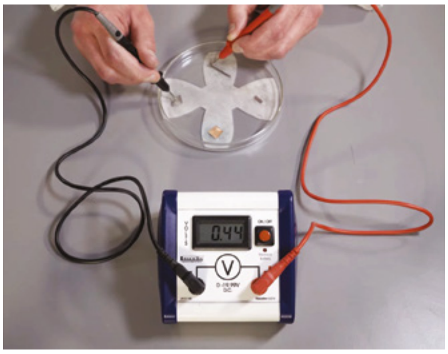
As an A-level science student, it's never too early to adventure out into the real world to see what it's like working in a laboratory. For Annabelle Gill, the institute in question just happened to be the world-renowned CERN particle-physics laboratory in Geneva. There, she had the opportunity to spend a week meeting a host of CERN employees, from experimental physicists and electronics engineers to computing specialists and technicians, as she learnt about the many different experiments and devices housed in the Swiss and French countryside. She describes the fascinating facilities she visited, the people she met and the variety of jobs she discovered are available to STEM students at research facilities like CERN.

**https://bit.ly/3h6jS5O**

EIC is the Royal Society of Chemistry's magazine for teachers. Visit **edu.rsc.org/eic**

All you need to teach your 14–16 students electricity are Petri dishes and galvanic cells, says chemistry teacher and CLEAPSS adviser David Paterson

Credit: © Royal Society of Chemistry



Help students learn the underlying chemistry of cells with this simple microscale practical

## A microscale approach to electrochemical cells

Galvanic cells and electrolytic cells are both fascinating and tricky to teach and learn about. I like to link metal reactivity and galvanic cells with a quick and simple practical to make galvanic cells in a Petri dish.
The set-up is simple – a Petri dish, a strip of filter paper, small pieces of metal (usually magnesium, zinc, iron and copper), a few drops of metal solutions (usually metal sulfate solutions), a few drops of saturated potassium nitrate solution and a multimeter.

Students make a cell by:

- Cutting and laying the filter paper in the Petri dish
- Adding a couple of drops of different metal solutions to either end of the paper
- Placing a piece of the corresponding metal on top of the filter paper, and
- Adding a couple of drops of potassium nitrate solution to the middle of the paper.

Once the cell is set up, students can measure the potential difference generated in the cell using the multimeter. It's also easy for students to swap around the probes to investigate what happens. They can work in groups to set up all the different combinations possible and to investigate the effect of different metals on the potential difference. Students learn about the underlying chemistry of galvanic cells, electricity and potential difference.

For example, they quickly discover that the largest potential difference comes from the magnesium/copper cell, with magnesium acting as the negative electrode. Linking this to the reactivity series and the underlying redox reactions is then an easy step. They also get to improve skills in setting up and troubleshooting equipment. Seeing that electrical current is generated from just a few simple materials and apparatus makes learning about electricity, electrochemical and fuel cells, electrolysis and redox less mystifying.

To find out more, visit **rsc.li/3RwQceK** and for more microscale ideas, check out **rsc.li/3RDTr4c**

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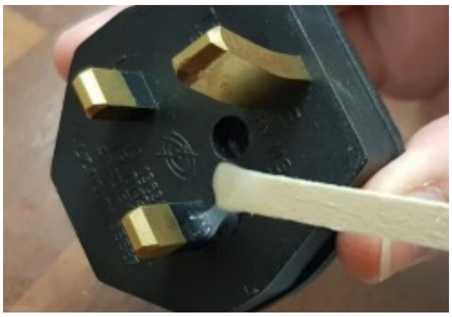
CLEAPSS is an advisory service supporting science and technology in schools. Its advice and guidance is recognised by Ofsted and the HSE for safe practice for practical work in schools. Visit **cleapss.org.uk**



Applying epoxy resin to hold pins in place

## New guidance on teaching students to wire plugs

We've recently uploaded a series of physics documents taken from our old handbook. The rationale for this is to make searching for specific guidance easier. These shorter documents may also be updated with new insights. One such example is GL268, 'Wiring a mains plug by pupils'. In the past, we said to buy plugs with non-removable pins, but these are almost impossible to find. As well as bending the Earth pin and shutting off power to the lab sockets, we'd recommend using epoxy resin to hold the pins in place – this will prevent students from inserting the pins into the mains sockets.

See GL268 on **science.cleapss.org.uk** for more details.

## DIY spark counter

The new CLEAPSS guide GL172, 'Make your own spark counter', will enable you to construct an inexpensive and reliable spark counter for school science. The spark counter detects alpha radiation and demonstrates its ionising characteristics. If an alpha source is brought near to the device, it causes an electrical spark, producing a small flash of light and an audible click. Unlike the Geiger-Muller detector, it shows the range of alpha particles in air because it doesn't have a window that takes energy from an alpha particle as it travels through it. The spark counter also gives a good demonstration of how paper will block alpha particle transmission. The spark counter isn't sensitive to beta and gamma radiation, meaning that radium and americium can be used as if they were alpha-only emitting sources.

See GL172 on **science.cleapss.org.uk** for more details.

## Take the fear out of teaching electricity

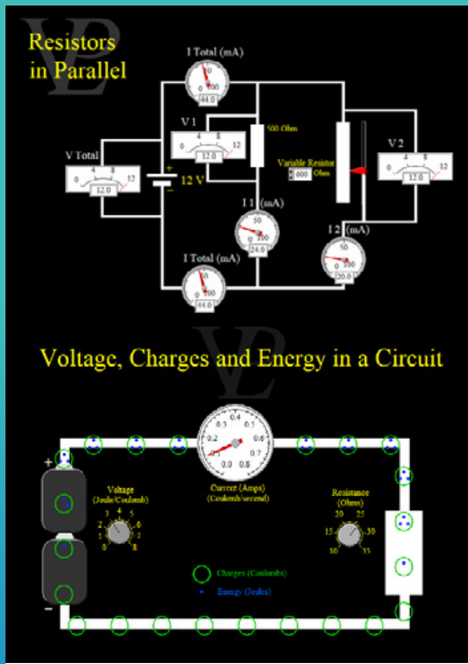
For years, the National Physical Laboratory (NPL) has run CPD workshops for PGCE students training to be physics teachers. The vast majority are not physics graduates and our pre-session surveys show electricity to be one of the curriculum areas that trainee teachers worry about the most. NPL's teacher CPD workshops instil confidence by clarifying basic concepts, building them up from first principles.

We use Virtual Physical Laboratory (VPLab) software, which was written by an NPL scientist, to create virtual simulations that introduce core concepts such as current, resistance, electromagnetic fields and potential difference.

The advantage of VPLab is that experiments and demos can be done quickly without setting up equipment. Your pupils can experiment without fear of breaking something, and investigate according to their own abilities. Beyond simple circuits, virtual models also really help in understanding how current and voltage behave in series and parallel circuits.

The VPLab is available free of charge to anyone who attends a demonstration – which can be online after school hours.

Visit **www.npl.co.uk/vplab** or contact **john.nunn@npl.co.uk** for information.




# Funded partnership opportunities to support teachers of physics

**Physics teacher recruitment and retention is a particular and persistent concern.**

Physics teachers often find they're the sole specialist in a school science department and can feel isolated, while other teachers can feel overwhelmed teaching physics out of specialism. Ogden partnerships help to build a network of support and expertise, satisfying a need for 'relatedness' (Behzadnia et al., 2018; Deci & Ryan, 2000; Ryan & Deci, 2000).

Partnerships can provide professional support for teachers, sharing best practice and subject enhancement opportunities, and improving pedagogy and enrichment. Ogden partnership teachers are part of a professional community of practice, with an expanded network of support and access to free CPD to help build practical skills and classroom confidence.

A programme of KS3 Physics CPD is now available to partnership schools, building on the Trust's long-established programme of Phizzi CPD for primary teachers. The KS3 Physics CPD programme covers subject knowledge and practical approaches to teaching forces, waves and electricity. It includes time (and support) for planning and reflection.

The Trust also provides specialist coaching and mentoring for early career teachers looking to build their core physics skills or develop a physics specialism. External support of this kind can provide beneficial networking opportunities for teachers by broadening their informal and professional support networks (Walker et al., 2018) and reducing feelings of isolation (Hillier et al., 2013).

The Ogden Partnership programme offers five years of funding, CPD and support to schools that work together to enhance the teaching and learning of physics. Partnerships can include local clusters of schools, or established collaborations such as multi-academy trusts. Applications are now open for new school partnerships.

Visit **www.ogdentrust.com/school-partnerships** to find out more, or email **office@ogdentrust.com**

The Ogden Trust aims to increase the uptake of physics post-16 by supporting physics education and engagement for all young people (4–18), particularly those in under-represented groups.

Visit **ogdentrust.com**


## Wonderlab+

Discover the fun world of science and maths online with Wonderlab+.

Wonderlab+ is a new website for children designed to bring the wonder of the Science Museum Group's interactive galleries into the home or classroom.

Inspire your students to get hands-on with science through a large selection of free making activities, videos, quizzes and games.

Explore Wonderlab+ online at
**https://wonderlabplus.sciencemuseumgroup.org.uk/**

## The Inclusion in Schools programme – a whole-school CPD opportunity for your school

You may know from personal experience that the physics classroom post-16 is often not the most diverse. But it's not only in physics where there are barriers to many students' progression.

In the *Inclusion in Schools* programme, we work with you to review your current provision with respect to inclusion across four aspects of school life. From this, we will identify ways to improve your inclusive practice, developing a strategy which aligns with your school's unique context and improvement plan.

**All the support is fully funded by the DfE, so there's no cost to your school.**

**All secondary state-funded schools in England are eligible and we are currently recruiting!**

Find out more at
**https://bit.ly/3WqUeZH**

Or email us at **inclusioninschools@ase.org.uk**

The Association for Science Education — Promoting Excellence in Science Teaching and Learning

INCLUSION IN SCHOOLS

## Develop physics subject knowledge, pedagogy & confidence in the classroom

### FREE CPD for teachers in the English state sector teaching physics at KS3/4 without a physics specialism

Matter & Space and Energy modules available in Jan/Feb 2023. Book your FREE place now. Led by a subject specialist, each module will require up to 20 hours of learning over 8 weeks, including face-to-face sessions, online tutorials and independent work.

### Find out more:
**www.ogdentrust.com/SKPT**

SKPT
SUBJECT KNOWLEDGE FOR PHYSICS TEACHING

The Ogden Trust — making physics matter

## School Partnerships programme

enhancing physics teaching and learning

- Support & funding to build a **culture** of science in schools
- Free **CPD** to develop physics subject knowledge & teaching confidence
- Investment in partnership physics **enrichment**

### Interested in forming an Ogden school partnership?

Visit
ogdentrust.com/school-partnerships
to find out more

# IOP Teachers of Physics Awards

We are pleased to announce the winners of the 2022 Teachers of Physics Awards:

**Martin Cunniffe,**
St Patrick's Classical School, Navan

**Dr Daniel Jones,**
Monmouth School for Boys, Monmouth

**Vanessa McClafferty,**
Immanuel College, Bushey

**Nicola Marie Percy,**
Haberdashers' Girls' School, Elstree

**Thomas W. William-Powlett,** Birchwood High School, Bishop's Stortford

**Thomas Williams,** Royal Grammar School, Newcastle Upon Tyne

**Kayleigh Williamson,**
Grange Academy, Kilmarnock

We would also like to extend our congratulations to **Dr Kenneth Hargreaves** from Lockerbie Academy and **Dr Delphine Hawthorne** from Bedford School for winning the **2022 IOP Technician Award** in the secondary schools category.

"On behalf of the IOP, I warmly congratulate this year's Award winners. Each and every one of them has made a significant and positive impact in their profession, whether as a researcher, teacher, industrialist, technician or apprentice."

**Sheila Rowan CBE, IOP President**

Nominations for the 2023 IOP Awards are now open.

Visit **iop.org/about/awards**

## IOP/King's College London Stories Research

**If you enjoy using the stories about physics in Classroom Physics, you may be interested in research that looks at whether stories can help students learn physics.**

If you would like your students to participate, they can complete a short survey, which involves watching, at random, either a story version or a normal version of an explanation and having their knowledge checked before and after teaching. The survey includes an option for students to sign up for a second survey (via email) and to opt into an online interview. To take part, the students must be over 16, but they can be studying any subject.

**https://bit.ly/3X1gARL**

## IOP Scotland – Stirling Physics Teachers' Meeting

**Thursday, 25 May 2023**

The date of the Stirling Meeting is Thursday 25 May 2023, the week after the SQA physics exams. Further information and registration is available at **https://bit.ly/3zCoNld**

As well as being a standalone event in its own right, the Stirling Meeting will form part of the four-day residential IOP Scotland/SSERC Physics Teachers' Summer School which will run from Wed 24 to Sat 27 May 2023. In addition to the Stirling Meeting, the Summer School will include two days at SSERC and a visit to the School of Physics and Astronomy at the University of St Andrews, as well as evening activities and all accommodation, meals and some physics equipment to allow participants to undertake activities once back in school.

Please see **https://bit.ly/3U55oBL** for further information and to register your interest in the Summer School.

## IOP ASE Conference sessions, January 2023

If you're attending the ASE conference in January, be sure to look out for the following IOP-led sessions:

**Thursday, January 5**
11:00 - 11:55

What's the point of physics?
*Mark Whalley*

**Thursday, January 5**
13:00 - 13:55

Introducing the IOP's Physics Teacher Educator programme
*Rachel Hartley*

**Thursday, January 5**
14:00 - 14:55

Physics Teacher Retention - Challenges and Opportunities
*Mark Whalley and Ian Horsewell*

**Thursday, January 5**
14:00 - 14:55

Perimeter Institute:
How do scientists think?
*Stuart Farmer with*
*James de Winter (Cambridge)*

**Friday, January 6**
15:30 - 16:25

Physics Education Research club - bringing teachers and research together
*Carole Kenrick*

**Saturday, January 7**
13:00 - 13:55

Digital skills in science and the aspirations of young people
*Jess Hamer*

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