

Classroom physics

December 2019 Issue 51

The magazine for IOP Affiliated Schools

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Electric circuits: using the rope loop model

Meet our new head of teacher CPD

IOP teacher and technician award winners 2019

Towards a physics glossary for 16+

IOP Institute of Physics

www.iop.org

Meet our new CPD champion



Jonathan Sanderson at NUSTEM

Ally Davies has recently joined the IOP Education team

The IOP's Education team includes several former teachers of physics – and sometimes future teachers too. Over the summer, Robin Griffiths, head of our teacher professional support programme decided to go back to the classroom and we welcomed Ally Davies who has taken over this role. Here, he introduces himself...

I taught physics for about 25 years, mostly in comprehensive schools around Cambridge. I loved teaching, especially the challenge of understanding why students find certain areas of physics difficult. I have also been a teacher supporter for over 13 years. I hope to use this experience to act as an advocate for teachers.

In 2006 I began working half a day a week as an IOP Physics Network Coordinator. This was tremendously rewarding, particularly supporting teachers who were 'lone physicists' looking for a local community, or those teaching physics outside their comfort zone.

Since 2011, I have run the IOP regional CPD day for the East of England – this year, among the delegates were a teacher whom I taught at A-level and others whose teaching placements I supervised! I left the classroom in 2014 for a full-time teacher support role at Isaac Physics where I really got to know the physics teaching community both online and face-to-face.

I want to raise the profile of the great work that the IOP is already doing to support the physics teaching community. Recruitment and retention is our biggest challenge. I have seen that the IOP's free-to-access high-quality subject-specific teacher CPD brings about results, improving teacher confidence and job satisfaction. I am looking forward to facilitating these projects and supporting every teacher whatever their background and whatever stage of their teaching career.

Ally Davies

Head of Programme: Teacher Professional Support

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Free debate kit to accompany Royal Institution Christmas lectures



Paul Wilkinson

Dr Hannah Fry, Associate Professor in the Mathematics of Cities at University College London

We live in an era of big data and a time in which more and more of our lives are computer controlled. This year's Royal Institution Christmas Lectures, entitled *Secrets and Lies*, will explore suspicious statistics, engineering meltdowns and deadly data. Lecturer Hannah Fry will ask questions such as do algorithms have too much control over our privacy? Could A.I. decide if someone lives or dies?

IOP Affiliated Schools can order a debate kit which provides all you need to run a science-based classroom discussion. It centres on the societal and ethical issues surrounding the question: **Should our town centre be for self-driving cars only?**

The kits are free and were commissioned by the RI, produced by *I'm a Scientist, Get me out of here!* and funded by the IOP.

The kit shows students how to build a

discussion and back up their opinions with facts. Based on character cards and lesson notes, the activity takes very little preparation and is designed to last around 50 minutes. Additional resources include an interactive quiz, a lesson PowerPoint, a student competition and further reading and references on character's facts.

Students who got involved in the IOP's Big Data Zone on this year's *I'm a Scientist* discovered how algorithms help us model the structures of galaxies, discover far-away planets, develop new weather models and predict earthquakes.

more...

Order your debate kit bit.ly/RIdebatekit
IAS big data zone
bigdatan19.imascientist.org.uk
RI Xmas lectures rgb.org/christmas-lectures

Astronomy through a different lens

Richard Hechter, associate professor of science education at the University of Manitoba, Canada, writes:

Winter is the perfect time to grab a heavy coat, make a thermos of hot chocolate and go outside to bask in the wonder of the night sky. There, you can become engulfed by the vastness and scintillation of the sky, connecting in an often personal way. People throughout time and place have done this, transcending borders and societal expectations. This realisation is a critical aspect of today's approaches to teaching and learning astronomy.

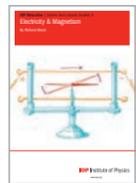
Sometimes, sadly, it is just too cold to go outside. Try using a different lens. Stellarium is free, open-access and easy to use astronomy software. It enables students to explore the sky, stars and constellations through cultural and religious lenses. They can use the "starlore" tab to toggle between different perspectives, engaging students of all backgrounds as they find themselves in the curriculum. Not only does this create an awareness of the richness of the night sky, it cultivates an empathy to others who have different, but equally valid, starlore.

more...

Stellarium.org or iop.org/space

Look out for this icon for ideas for electric circuits lessons

With this issue...



Stories from Physics: Electricity & Magnetism

The third booklet in our series collecting physics stories for secondary school students.

In this booklet you can read about how Donald Trump's uncle worked with Robert Van De Graaff (known for his static generator) to build an X-ray barbecue that saved many lives.



Careers postcards

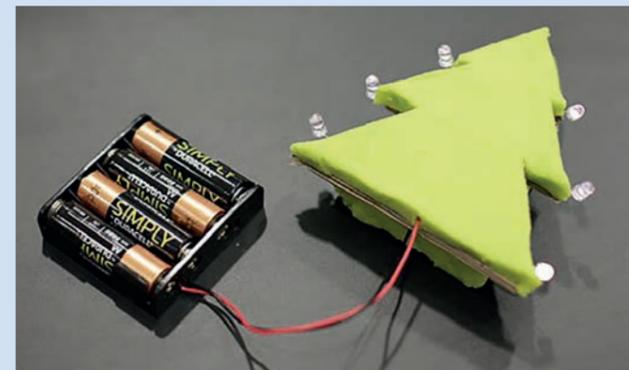
A set of 16 postcards containing information about careers in physics

from audiologist to water testing analyst and many more in between. Perfect for National Careers Week in March, this resource was developed by NUSTEM at Northumbria University. More information on page 18.

Classroom physics

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Merry Squishmas: play-dough circuits



To celebrate the end of term, why not get your class to build a festive circuit out of conductive play dough?

This activity is about building a Christmas-tree circuit, but challenge your students to think about making conducting circuits in other seasonal/non-seasonal shapes or using other circuit components.

For instructions, including a recipe for dough, visit spark.iop.org/squishy-circuits

IOP teacher support in Wales



Delegates at the Brecon meeting get hands-on making squishy circuits (see page 3 for a link to this activity)

IOP Education in Wales is changing. We've welcomed our new Education Manager, Samantha Borley, plus several new IOP Coaches, but said a sad farewell to David Cunnah, longstanding IOP Wales National Manager.

The 18th Annual Welsh Physics Teachers Conference took place in Brecon in October. Almost 100 teachers, technicians and trainees enjoyed a range of practical workshops and networking opportunities. There were also lectures from Professor Rachel Cross (Aberystwyth University) and Professors Averil Macdonald and Alun Vaughan (University of Southampton).

We work with schools in two main projects funded by the Welsh government:

- **Stimulating Physics Network Wales** is our team of physics coaches who provide free high quality, bespoke CPD to teachers of physics and their students in secondary schools. This could be CPD sessions, pupil support activities or online support. We are also able to help with adapting to the new curriculum. If you are a newly qualified teacher or if physics isn't your specialism, get in touch if you would like support.
- **Improving Gender Balance** has begun its pilot year and is working with two clusters of secondary schools and a selection of their feeder primary schools to identify and address issues around gender imbalance in subject choices. The bespoke interventions will include inclusive teaching workshops and IOP coach attendance at options/parents' evenings in order to engage the wider school community.

more...

Contact Samantha
samantha.borley@iop.org.uk
Find your local IOP teacher CPD in UK or Ireland iop.org/network.

Got an idea you have always wanted to develop?

If you are a practising teacher in a UK school or college and have an innovative idea about physics teaching, then the Anthony Waterhouse Fellowship can help you bring the idea to fruition. Each Fellowship is worth up to £3,500. This can be used to buy materials, software or services to help you develop your idea into something that other teachers can use.

The Fellowship was generously endowed to the Institute by Helen Parsons in memory of her physicist brother Anthony Waterhouse who died tragically while still at university.

more...

The closing date for applications is Monday 13 April 2020.
Contact ellen.phillips@iop.org with queries or for advice on eligibility.
iop.org/waterhousefellowship.

This year, we awarded four Fellowships. The resulting resources will be open access and freely available from our website upon completion in June 2020.

- **A micro wind tunnel** – a cheap and lightweight design for building a wind tunnel for lessons or student research projects.
- **Teaching astrophysics through the achievements of female astrophysicists** – a scheme of work grounded in the stories of women.
- **Improving the teaching of mathematics in physics, using cognitive science research** – introducing physics teachers to cognitive load theory. Read the blog at spark.iop.org/maths-in-physics
- **Building physics vocabulary at Key Stage 3** – a 'super glossary' focusing on subject-specific terms to develop academic literacy.

£28K to train to teach: IOP Scholarships 2020



Scholars at an IOP masterclass

The IOP are offering 150 DfE-funded scholarships to outstanding individuals entering physics teacher training in England in September 2020. Successful applicants will join our IOP scholarship community with awards of £28,000 tax-free, free IOP membership, plus career-development events and networking.

Those entering physics teacher training next year can also apply for an additional £6,000 in Early Career Payments (visit the DfE website for more information). If your school is recruiting for School Direct, make sure your applicants know about IOP scholarships.

more...

iop.org/scholarships

New home for Guzled Scottish teaching materials

Over 1,000 teaching resources created by the Scottish teaching community for teaching physics in Scotland have been added to a new forum on TalkPhysics. IOP coach Sally Weatherly, set up Guzled Scotland four years ago to enable teachers to share resources. She said the move was necessary to enable the resources could remain free and easily accessible. The TalkPhysics platform also enables users to upload their own resources, receive notifications of new additions and have discussions on the same platform. Guzled Scotland will be deactivated after 1 January 2020.

more...

talkphysics.org/groups/teaching-physics-in-scotland

Teacher Awards 2019 Winners

The IOP Teaching of Physics Awards celebrate outstanding classroom practice in the teaching of physics and recognise the success of secondary school teachers in the UK and Ireland who, by their dedication and excellence in the classroom, have raised the status of physics and science in their school.

Chris Shepherd, IOP Teacher Support Manager, said, "I am delighted to be able to recognise and applaud these colleagues

who, through personal commitment, skill and dedication, have made significant positive differences to the teaching of physics, student experience and level of student achievement in their school. On behalf of the Institute of Physics, I warmly congratulate them."

Each winner received a prize of £1,000, a paperweight award and a certificate, which were presented at the Institute of Physics annual awards dinner in November.



Andrew Seal,
Beechen Cliff School,
Bath

"Andrew is an enthusiastic head of science. The high demand from external applicants for A-level physics is a testament to his impact."



Karen Young,
Loreto College, Dublin

"Karen has led her subject from strength to strength. She inspires confidence through independent learning and has established a mentoring programme within the school."



Nick Sewell,
Ysgol Friars, Bangor

"Nick creates a fun and enriching classroom. His busy lab, filled with contraptions which he has built, inspires his pupils to take a hands-on approach to practical work."



Rachael Donoghue,
Caistor Grammar
School, Lincolnshire

"Rachael's enthusiastic leadership of her department has led to physics being one of the most popular A-level courses within the school."



Nancy Hunter,
Anderson High School,
Shetland

"Nancy is an experienced and outstanding teacher. Within the classroom, she creates a rich educational environment and strives to remove any barriers to learning."



Georgios Aronis,
University Technical
College, Reading

"Georgios goes the extra mile in supporting his pupils to strive for success. Determined to inspire future physics teachers, he is an encouraging and motivating mentor."



Simon Hewitt,
The Judd School,
Kent

"Simon is an experienced leader of a fantastic team. He encourages bold, exciting demonstrations and experiments within his department, often building new equipment for enriching the subject."

Norfolk school technician wins new IOP Technician Award



Grainne McAdam,
Caister Academy, winner of the first
IOP Technician Award

This year the IOP has honoured technicians, recognising and celebrating their skills and experience and their contribution to the ways physics impacts on all of us. There were four categories: secondary school, further education and higher education, business and/or facilities and team. Each winner received a prize of £1,000, a trophy and a certificate, which were presented at the Institute of Physics annual awards dinner in November.

"Grainne is senior science technician at Caister Academy. She has secured funding for pupil activities and set up a local science technician network, now with nearly 60 members, since she took over the role. The department has not had a physics specialist teacher for many years and Grainne has looked at ways she can best support teachers within the team who are teaching physics."

**Who do you think deserves recognition?
Nominate them for a 2020 IOP Award at
iop.org/awards**

#chatphysics gets physics teachers tweeting



Fabio Di Salvo

Every Thursday at 7pm, a growing number of teachers settle down to an hour's chat about teaching physics. Topics have included "Literacy and literature in physics" with @MissNeutrino to "How to use rockets in your physics lessons" with @DrDavidBoyce and "Strategies for disengaged students" with @FabPhysics.

The weekly forum was created by Fabio Di Salvo, head of physics at a secondary school in Surrey. He set it up because he is the only physicist at his school and he thought many other teachers are in a similar situation.

He explains, "Physics teachers lack that subject specific community within their school. Twitter is a great place to meet other

teachers and people are really willing to help out with any questions. I thought having a specific time and place on Twitter for physics teachers to get together would be useful to many. It's great weekly CPD and, even if some people don't contribute to the chat, I believe everyone can get lots of great ideas by following. We've had so many great hosts over the past few months with lots more lined up, and we're always looking for more."

more...

Tune in every Thursday at 7pm by following @ChatPhysics and the #chatphysics hashtag. If you are interested in guest hosting a Chatphysics, contact Fabio on Twitter via @FabPhysics.

@IOPTeaching reaches 13.6k followers

Are you following the IOP Education Team on Twitter? We regularly tweet from @IOPTeaching (formerly @TakeOnPhysics). We share the latest resources, let you know about upcoming CPD and retweet great ideas that we come across on the Twittersphere and beyond.

Tag us in your tweets and you'll reach a huge network of people. With over 13,600 followers, we connect teachers, technicians, thinkers in education, STEM organisations, policy groups, and many many more.

Most of our teaching coaches are active on Twitter too. So you'll find there is almost always someone there who can jump in to help with urgent physics questions and offer suggestions for teaching. @IOPTeaching will help you stay in touch with the latest news – and possibly the gossip – from the physics teaching community. Our following is growing daily. It's not quite as big as Barack Obama's or Katy Perry's. But they don't tweet about teaching physics.

more...

Follow @IOPTeaching. Our favourite hashtags are #IOPSpark and #teachphysics.

Weighty and stressful issues: towards a physics glossary



The glossary has been a challenging and ambitious project – but always enjoyable

Have a browse through the IOPSpark physics glossary. Working with the National Physical Laboratory, we have developed descriptions for over 30 physical quantities encountered in post-16 school physics. The aim is to provide an authoritative reference that can be used by students, their teachers and awarding bodies. It is a challenging and ambitious project and is still a work in progress.

Glossary project co-ordinator Daniel Heanes explained, "The project came from a discussion on our online teacher forum about how EMF should be defined and how this was inconsistent between different exam boards. Further discussion led to the discovery of a number of other anomalies and to address this we put together a working group of educational experts.

"I thought we would knock out some definitions in a few months. That was more than four years ago. Many of the definitions took considerable finessing, not least EMF. Other challenges included how to describe the tensor nature of stress in a way that wouldn't stress out a 16-year-old.

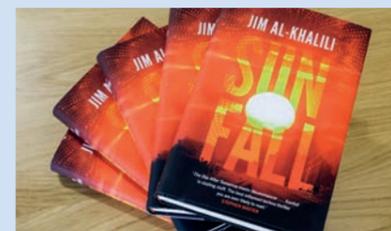
"Weight also weighed heavily on our minds – it doesn't have an agreed definition amongst engineers and scientists so what should we list? In the end we've opted to refer to gravitational forces and contact forces instead."

The next steps will be to complete the 16-19 collection and look at versions for younger age groups.

more...

spark.iop.org/collections/glossary

Winners of signed copies of *Sunfall*



Thank you to everyone who registered for a chance to get a signed copy of Jim Al-Khalili's new book, his first novel, *Sunfall*. We pulled names out of a hat. We hope the following lucky recipients are enjoying reading it!

Gregory Farrelly, Cambridge Tutors College, Croydon. **Heather Fenton**, Stockport Grammar School, Cheshire. **John Fishwick**, Colfe's School, London. **Jackie Flaherty**, Chipping Campden School, Gloucestershire. **Emma Geraghty**, Surbiton High School, Surrey. **Patrick McCarthy**, Skibbereen Community School, County Cork. **John Mitchell**, Richard Hale School, Hertford. **Ben Moore**, Great Barr School, Birmingham. **Brian Wardle**, Queen Elizabeth Sixth Form College, Darlington. **John Watson**, Campbeltown Grammar School, Argyll-Bute.

MyPhysicsCourse - updated website

We are delighted to announce that we have transformed and relaunched our website designed to help students find a university physics course.

MyPhysicsCourse lists all IOP accredited and recognised undergraduate physics degrees and will be an invaluable tool for students as they explore their university options.

Students can search by course, entry requirements, university or a combination. From physics with mathematics to physics with music, they can use the enhanced search functionality on MyPhysicsCourse to explore the breadth of physics courses available across the UK and Ireland. Students can access contact details for university physics departments, information about bursaries and scholarships and follow links direct to university physics department websites.

With UCAS applications closing in a few weeks, your leavers can use MyPhysicsCourse as a final check for their choice of course. In addition, it is the perfect place for younger physicists to begin researching their future options with physics and begin their journey towards becoming the physicists of the future.

• IOP accredited degrees

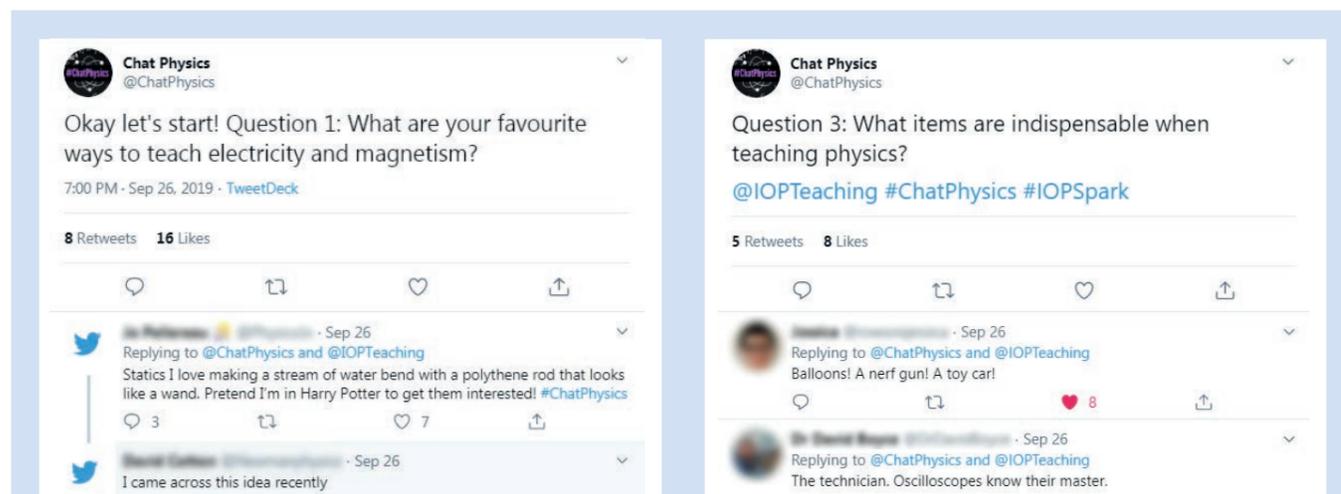
We have rigorously checked these courses and concluded they offer the best possible start to a career in physics. Students studying towards an accredited degree are eligible for schemes such as the IOP undergraduate research bursary and aid in the process of obtaining professional awards such as chartered physicist.

• IOP recognised degrees

These courses do not meet all the requirements of accreditation but have been deemed to contain enough physics for graduates to obtain membership of the Institute of Physics.

more...

myphysicscourse.iop.org

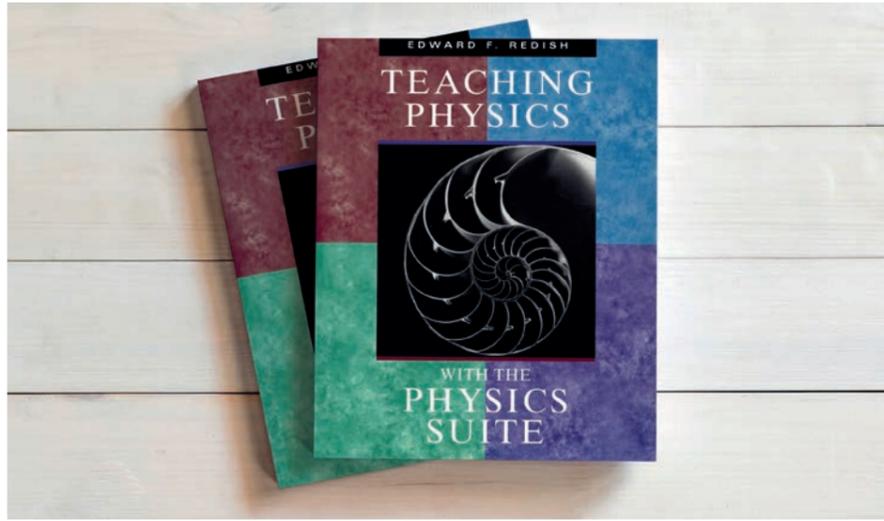


We hosted a #ChatPhysics in September, to showcase teaching resources from IOPSpark. We lined up a team of IOP coaches to answer questions and offer support. Catch up with the conversation at bit.ly/IOPchatphysics

@IOPTeaching #IOPSpark #teachphysics

Teaching Physics with the Physics Suite

By Edward F. Redish (Wiley 2003)



Whilst its title might suggest this book is a manual for a set of resources, in reality most of the book draws together work from one of the most respected voices in physics education research, Edward Redish, professor of physics at the University of Maryland.

Unlike our previous recommendation, *Five Easy Lessons*, by Randall Knight (see CP December 2018 issue), this book does not deal with topic specific material but looks at teaching and learning physics across the discipline. To quote from the opening chapter:

“In this book, my goal is to provide a guide for teachers of physics who are interested in implementing some of the best modern methods that have been developed as a result of the community’s taking a scientific approach to figuring out how to teach physics.”

Redish – widely known as Joe – has spent 50 years researching how physics is, could and should be taught and this book summarises research in physics education and beyond that can help us all think about how to develop our practice.

Why this is worth reading

This book is one of the best resources to help answer the question, “How can I become a better physics teacher?” It is research-informed and provides meaningful and realistic messages that you can adopt in your practice. It is perhaps the single best book available for a teacher to read who wants to get a deeper insight into teaching and learning in physics.

We feel these two chapters are the best place to start and should be more than enough to get you seeking a copy. Of course, only you can join the dots between Redish’s book and your lesson plans. But hopefully this will not be too arduous and you will learn a lot in the process!

Chapter 2: Cognitive Principles and Guidelines for Instruction

This is a distillation of research on cognition and learning. Ideas around working memory and cognitive load are gaining attention on educational social media, but the discussion can be rather general. By contrast, here Redish describes, in detail, how cognitive science can be applied to physics education and suggests instructional methods that teachers can use.

Chapter 5: Evaluating our Instruction

Here Redish highlights a key aspect of ‘research-informed practice’ that is often left out of the conversation, namely the tools and approaches to evaluate the effectiveness of any change in classroom practice. This chapter describes some much used and tested tools for capturing students’ understanding and attitudes (see our previous columns). Many of these tools are available on the CD that comes with the book or are online at physport.org.

more...

Second hand copies of the book are easily available or it can be downloaded from www2.physics.umd.edu/~redish/Book

...the book draws together work from one of the most respected voices in 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. This column is usually focussed on one area of PER but from time to time we’ll suggest a book or paper that we feel is of particular value.

Join other physics teachers interested in the latest research, discussing classroom applications, attending seminars and getting involved with research. Email us at research@teachphysics.co.uk or join the Physics Education Research (PER) group on Talk Physics at talkphysics.org/groups/physics-education-research-per



Classroom activities

Pull out and keep

Take care handling circuit models

Many analogies are used to introduce the concepts of circuits, from water pipes to pizza delivery. But how helpful are they?

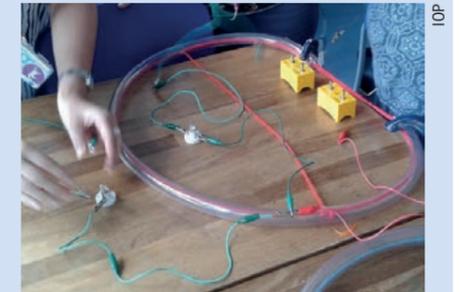
There are some fundamental circuit ideas you’d want students to understand by the age of 14. From primary school, they should know something flows and that a circuit needs to be complete for this to happen. Next they need the ideas of charge (what’s flowing), current (rate of flow), potential difference (cause of flow) and resistance (opposition to flow).

Teachers are often tempted to introduce a range of models and ask their students to analyse the strengths

and limits of each. But without a secure understanding of the underlying principles of circuits above, you risk breaking the fragile schema which they’ve tentatively been building.

Instead, focus your teaching on how electricity works and stick to one model. **The Rope Loop (Activity 1)** is a good one – it isn’t a silver bullet, but it is simple and hands on.

When your students are building circuits, rather than spending time assembling one then disassembling it to build a new one, try using the **Continual Conversion approach (Activity 2)**. It is a neat approach and takes away a layer of trauma – for both students and teacher.



The tabletop rope loop model is great for younger students bit.ly/tabletoploop

more...

Thanks to IOP coach Tom Norris for this version of the Rope Loop model.

bit.ly/TNropeloop

Thanks to Gethyn Jones, director of physics at Harris City Academy Crystal for continual conversion approach.

bit.ly/CPcircuits

professional practice group

Don’t let your students get their wires crossed

- Research shows students often use the terms *current*, *voltage*, *electricity*, *power* and *energy* interchangeably when explaining what happens in an electric circuit.
- A simple circuit questionnaire can uncover where students are starting from – and how much they can retrieve later. This is a revealing exercise at all Key Stages – even for post-16 students.
- Younger students may think that the battery (the ‘source’) gives something to the bulb (the ‘consumer’) so a single wire from a battery terminal to a bulb terminal will be enough to light the bulb. Show them there is more than one wire and it’s actually a loop. Also, show them what the stripped bare copper looks like inside the insulation.
- Be careful with everyday language. Referring to a ‘power’ pack to supply a voltage could cause confusion. Moving your hand around a circuit diagram to mimic the current could be reinforcing the idea of something being dropped off in sequence, with the first bulb being brighter than the next.
- Teach series and parallel circuits separately. Focus first on a secure understanding of current in a series circuit using the Rope Loop model (see Activity 1) and practice connecting an ammeter correctly. This will address the ‘consumer’ model, outlined above, by showing that the current is the same all the way around the circuit and through each component.
- When talking about energy, introduce the idea of the circuit transferring energy from the battery to the surroundings. The current raises the temperature of the bulb’s filament (by electrical working); and the hot filament transfers energy to the surroundings by heating. Now you can begin to make qualitative observations based on bulb brightness.
- Driver et al (1994) suggest describing voltage as the strength of the ‘push of the battery’ and ensuring the distinction between current and voltage is embedded at this stage. Keep the definition of voltage as per unit charge until later, when you introduce equations and calculations.

Tip: invest in LED bulbs as these have a more reliable brightness than traditional filament bulb so brightness comparisons within a circuit are much more straightforward.

more...

spark.iop.org/circuits-questions.



Activity 1: Rope loop model

This activity introduces students to simple electrical circuits using a mechanical analogue. Although some teachers do it with 10-20 students holding onto a rope at different points, it works better with just one or two volunteers. Too many hands leads to gripping the rope too tightly or pulling too hard and you'll end up battling to get the rope – and your students – to do what you want!



The rope should lie lightly in the upturned palm of the 'light bulb', rather than being gripped palm down. This will also enable you to see what your volunteer is up to!

Equipment

- A length of rope approx 3m – ideally made of nylon and speckled
- Duct tape (optional)

Preparation and health and safety

Tie the rope into a loop. If you are using a nylon rope, melt or glue the ends together then cover the join with duct tape. Avoid rope burns by making sure students don't grip the rope too tightly.

Procedure

Ask for one student volunteer. They represent the **light bulb** in a circuit. Get them to grip the rope lightly with one hand so rope can slip through easily. You, the teacher, are the **battery** and, as such, you provide the **voltage**. Do this by making the rope circulate, pulling it at a steady rate, hand over hand. The rate of flow of the rope is the **current**. Ask your students to think about:

- Where did the current start flowing first?
- How does the current in and out of the bulb/battery compare?
- What is happening to the 'light bulb's' hand?

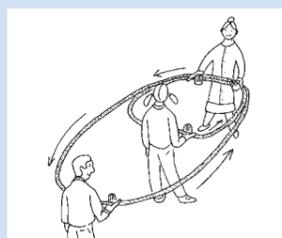
Extension ideas

1. Model a **series circuit** by adding a second bulb-volunteer next to the first. The flow decreases because there is more resistance in the circuit.



2. Model a **parallel circuit** by adding a second, shorter rope loop to the system. You, the battery, hold both ropes in your hand, providing the same voltage to both loops. Where the ropes overlap in your hand, the speed of the flow is exactly the same as before so the current in the original

loop is unchanged. But there are now more electrons flowing – and you, the battery, will tire more quickly.



3. Model **alternating current**, by constantly changing the direction of motion of the rope. The temperature of the bulb quickly rises and, over time, the circuit

transfers energy to the surroundings by heating. However, and importantly, no 'electrons' have travelled from the AC source to the bulb.

more... spark.iop.org/rope-loop-teaching-model

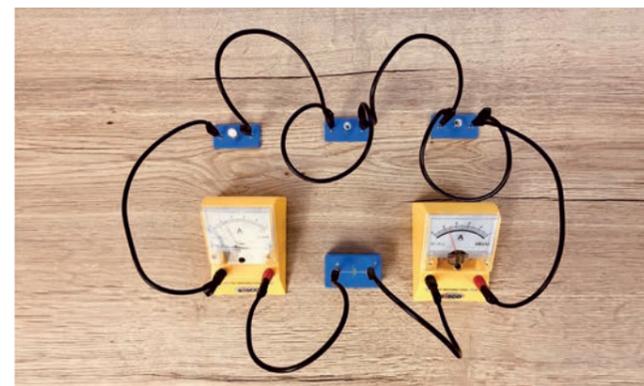
Model	Circuit
The rate of flow of rope into and out of your hand and those of the volunteer's is the same.	The rate of flow of current into and out of the battery and bulb are the same.
The speckles are already there in the loop, they start moving at once and at the same speed everywhere around the loop.	The electrons are already there in the circuit, they start moving at once and at the same speed everywhere around the circuit.
As the rope moves, the temperature of the volunteer's hand will rise and raise the temperature of the surroundings. The energy stored chemically by the 'battery' has decreased and the energy stored thermally by the surroundings has increased.	As the current flows, the temperature of the bulb's filament will rise and will raise the temperature of the surroundings. The energy stored chemically by the battery has decreased and the energy stored thermally by the surroundings has increased.
Energy is being transferred by the whole system working mechanically. It should be clear that there is no way that one side of the rope is 'carrying energy' from the source to the volunteer's hands.	Energy is being transferred by the whole system working electrically. As with the rope loop, it is not the case that the electrons in the wires have 'carried energy' from the battery to the bulb.



Activity 2: Circuits using continual conversion

This approach to investigating circuits avoids students assembling and disassembling circuits, helping them see the similarities and differences between different set-ups. It also makes brightness comparisons simple. Run the series activity first then, in a later lesson, do the parallel circuits activity. Student instruction sheets and circuit diagrams are printed on page 12.

Circuit A: series



Equipment

Each group of students will need:

- Electrical cell (or other power supply)
- 3 identical bulbs
- 2 ammeters
- 8 leads
- Copies of either Circuit A or Circuit B student instructions sheet (overleaf)

Procedure

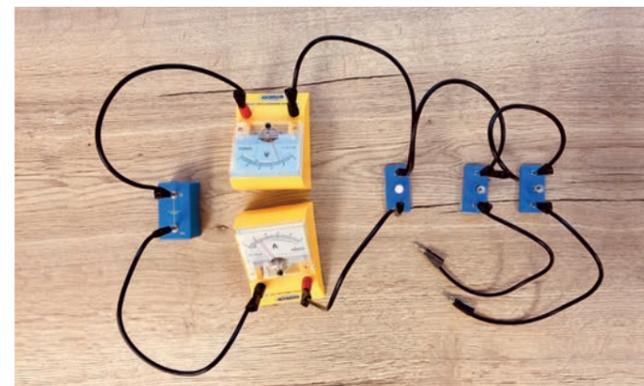
Before the lesson, set up the circuit and leave it at the side of the lab. Ask students to follow the instructions on their activity sheet – they can look at your set up if they get stuck. In both scenarios, students should note the identical readings on both ammeters to demonstrate the idea that current is conserved.

Short-circuiting the bulbs in series

In circuit A, at the start of the activity, the students use leads Y & Z to bypass two of the bulbs. Ensure they do not short circuit all the bulbs: there must be at least one bulb in the circuit to avoid the current becoming too high and damaging the ammeter.

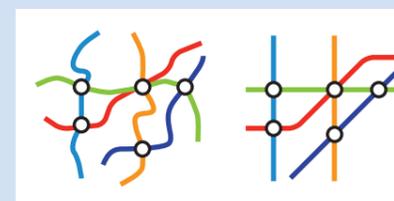
more... spark.iop.org/investigating-series-and-parallel-circuits

Circuit B: parallel



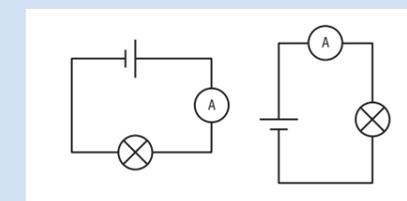
Circuits tips

Get on track with a Tube map



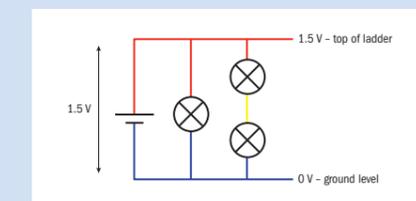
Most circuit diagrams don't look like the jumble of wires they represent. This can be confusing for younger students. To help them make the connection, compare a geographically accurate London underground map (bit.ly/CPgeotube) to the famous schematic version. There is a lovely transformation between the two at bit.ly/CPtubemap

Turn thinking around by moving the battery



Most circuit diagrams are drawn with the battery at the top and the components underneath. If your students only see this arrangement, they may struggle when faced with a circuit drawn 'on its side'. Introduce different circuit diagrams early – it will also help them get used to phrases like "voltage drop" at all angles.

Realise potential by colouring it in



Voltage is difficult to visualise. Colouring in the connecting wires helps students see potential drops across light bulbs and power supplies. See *Potential difference in colour* at bit.ly/PEdReeves03 for more detailed instructions (bear in mind colour blindness issues when choosing colours for this activity. Advice at bit.ly/IOPcolourblind)

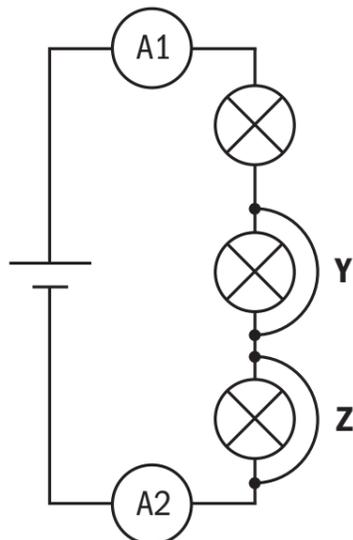


Activity 2: Student instructions

Circuit A: bulbs in series

In this activity you will **predict**, **observe** and **explain** what happens in circuits with a single loop.

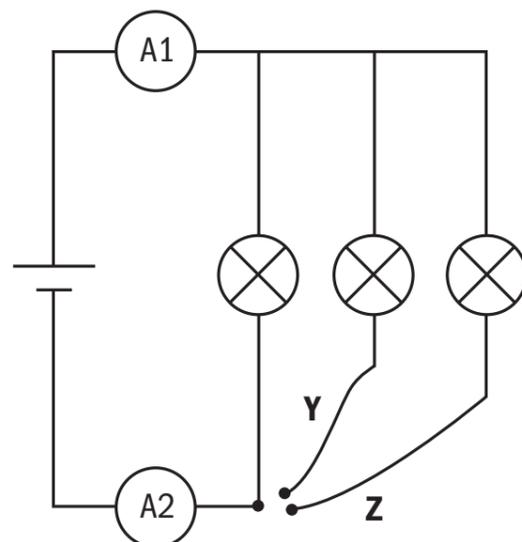
1. Set up the circuit shown on the right. Connect leads around two of the bulbs to 'short circuit' them. To start, only one bulb should be lit. Record the readings on both ammeters.
2. Predict what will happen if you disconnect lead **Y**: will the ammeter readings stay the same, increase or decrease? Disconnect lead **Y**. What happens to the readings?
Write your own explanation about why the readings changed.
3. Predict for what will happen if you also disconnect lead **Z**. Disconnect lead **Z**. Record your observations and write an explanation.
4. Predict what will happen when you reconnect lead **Y**. Connect lead **Y**. Record your observations and write an explanation.



Circuit B: bulbs in parallel

In this activity you will **predict**, **observe** and **explain** what happens in circuits with more than one loop.

1. Build the circuit shown on the right. To start, only one bulb should light up. Record the readings on both ammeters.
2. Predict what will happen if you connect lead **Y**: will the ammeter readings stay the same, increase or decrease? Connect lead **Y**. What happens to the readings?
Write your own explanation about why the readings changed.
3. Predict what will happen if you also connect lead **Z**. Now connect lead **Z**. Record your observations and write an explanation.
4. Disconnect the two leads. Repeat step 2 but this time for lead **Z**.



The capacitor plague

Between the late 1990s and the first years of the new millennium, electrolytic capacitors began to fail surprisingly often, causing up to 70% of computer system failures in the period. The phenomenon became known as the 'capacitor plague'. A story circulated that the plague was the result of industrial espionage, but since capacitors from multiple manufacturers were affected, this theory is unlikely to be true. More likely, the failures resulted from badly manufactured dielectric material, which deteriorated over time, releasing hydrogen and leading to the deformation or explosive destruction of the aluminium cases of the capacitors. Capacitors that were susceptible have since been redesigned to include inhibitors which prevent such failure.

Termen's Theremin and 'The Thing'

Lev Termen, a Russian engineer and physicist, invented an instrument to measure the density and dielectric constant of gases. He noted that moving his hands near the device resulted in changes in its capacitance, altering the frequency of the auditory output. Termen used this effect to design a burglar alarm, called 'the radio watchman', which sensed an intruder by detecting changes to the capacitance of an aerial. He went on to develop the Theremin, an early electronic musical instrument controlled without physical contact from the performer. Termen also invented 'The Thing', a listening device (or 'bug') that was composed of a capacitive membrane connected to an antenna, and

which didn't need a power supply. Sound waves caused the membrane to vibrate, changing the capacitance of the device. When radio waves struck the antenna, the changing capacitance of the membrane modulated the received signal which was then transmitted.

The Thing was hidden in a wooden plaque displaying the Great Seal of the United States and presented to the US ambassador to Moscow in 1945 as a 'gesture of friendship'. It was accidentally discovered by a British radio operator in 1952 and removed.

Kleist's and Musschenbroek's jars

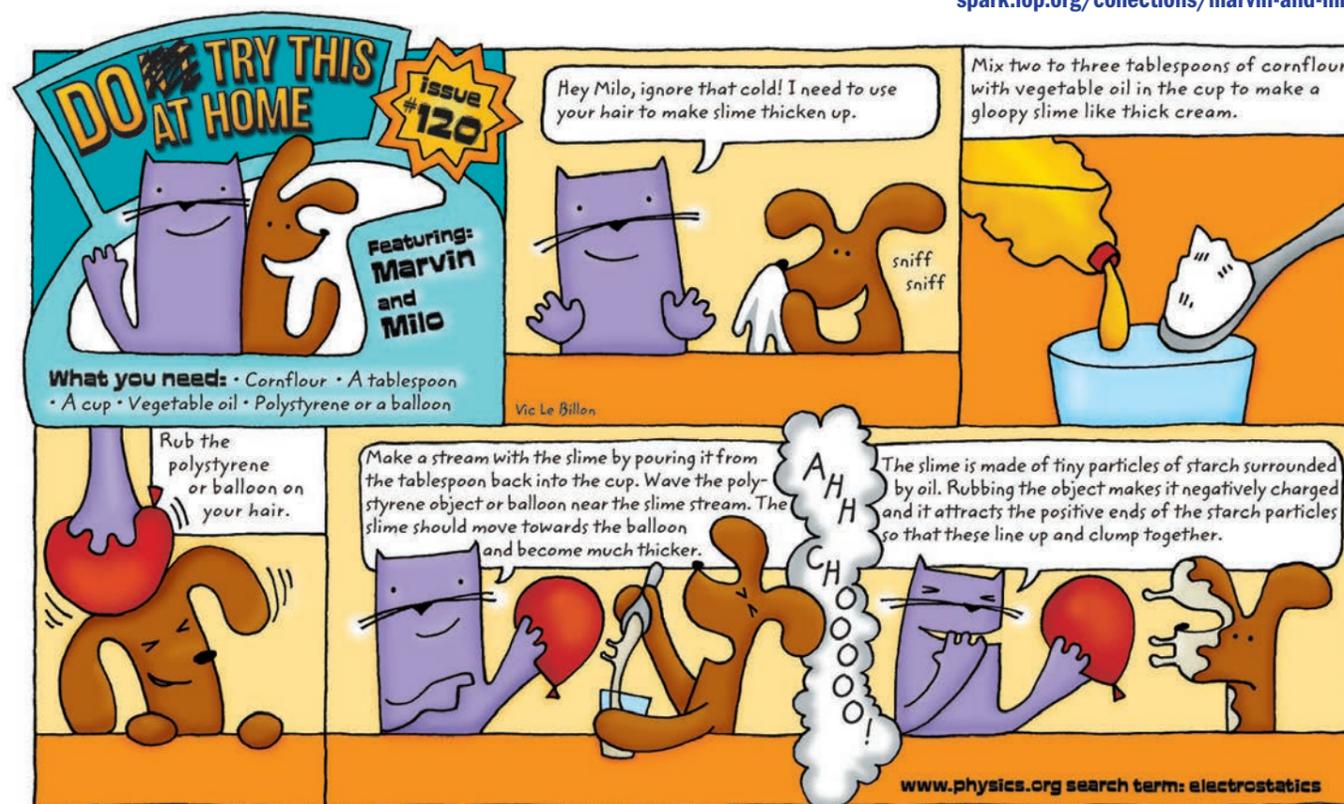
The Leyden jar is an early charge storage device which was discovered independently by Ewald Georg von Kleist and Pieter van Musschenbroek. In October 1745, Von Kleist poured alcohol, water or mercury (sources differ) into a medicine bottle, placed a stopper in its neck and hammered a nail through the cork. He connected the nail to a static generator and noticed 'a pencil of fire' surrounding the nail inside the bottle. Even after walking 60 paces around his room, the fire remained in the bottle. When he touched the nail, he received a shock that: 'stuns my arms and my shoulders'. A year later, van Musschenbroek also received a shock from a jar and commented: 'For the whole kingdom of France, I would not take a second shock.'

more...

Follow Richard Brock's *Stories from Physics* on Twitter @RBrockPhysics

Electric Slime

Marvin & Milo cartoons can be downloaded at spark.iop.org/collections/marvin-and-milo



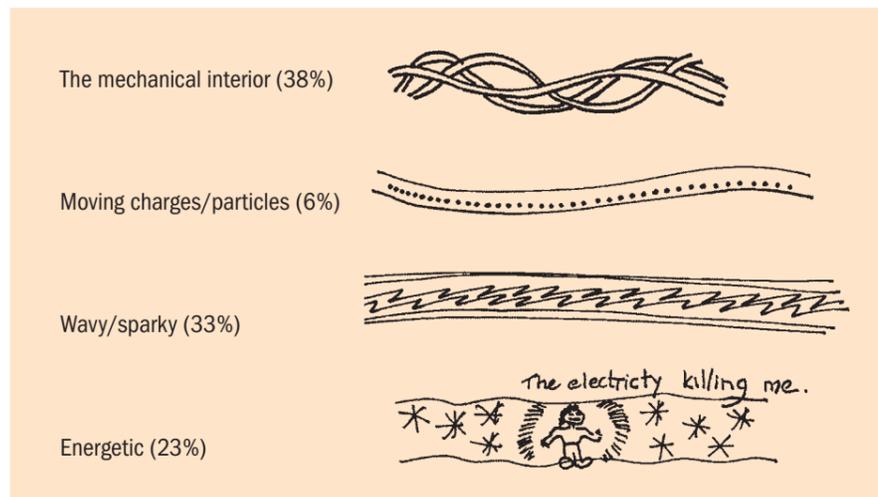


From the archive: over 50 years of articles online at iopscience.org/phised

How do you picture electricity?

It may be useful to consider where students' thinking might be or have progressed from when you come to teach them about electricity. To that end, Bob Kibble wrote this paper in 1999 looking at primary school pupils' ideas about electricity. It begins: "What models do student teachers and pupils hold to help them explain electrical phenomena? Student teachers in Edinburgh have engaged in a small action research project to explore ways in which children picture what happens inside an electric circuit."

more...
Read the whole paper at bit.ly/PEdKibble99



Pupils aged 9-11 drew what they imagined they'd see in a wire if they were small enough to go inside

Introducing electric fields

Having considered what your students might be thinking about electricity, the next step might be to consider what you are thinking. John Roche's 2016 paper looks at the history of electric fields and ends up discussing the role of electric fields in circuits.

As teachers we often simplify the models we use. But it's important not to forget the simplifications ourselves.

This paper will remind you of where you want to end up when teaching electricity – with a good working model for your 16+ year old students. You might wonder why having a good conceptual model is important for students. In some recent work with a university department we found that PhD students and beyond often resorted to conceptual models that they picked up in school when asked to explain electric circuits.

Despite having much more advanced mathematical models, their conceptual models had barely made any progress.

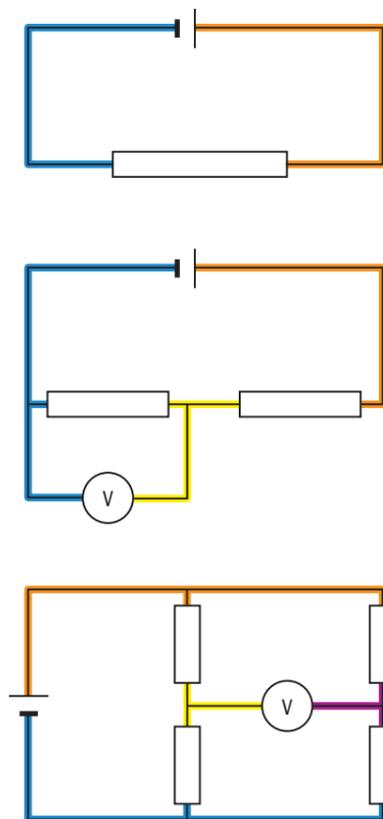
more...
Read the whole paper at bit.ly/PEdRoche16

Potential difference in colour

The rope loop is a good analogy for current (see page 10), but younger students still struggle to get to grips with potential. This paper by teacher Tony Reeves offers a nice analogy:

"Perhaps the nearest thing we can invoke is the use of contours on maps. Contour lines are all the same colour, and whilst it is easy to tell at a glance where an area of steep terrain is, it takes a closer look to determine the direction of the slope as we have to look at the values on the contour lines. If we were mapping an arid planet (with no public houses, green areas or other such features to contend with) we could then direct the available colours into coding the contours for different height levels, thus emphasising clearly the difference between a hill and a valley. This is very much what we are doing when we colour in voltages to help in our understanding of a circuit.

more...
Read the whole paper at bit.ly/PEdReeves03



Using colour in the teaching of potential difference in circuits is similar to using contours on maps to code for different height levels

Latest articles and papers online at iopscience.org/phised

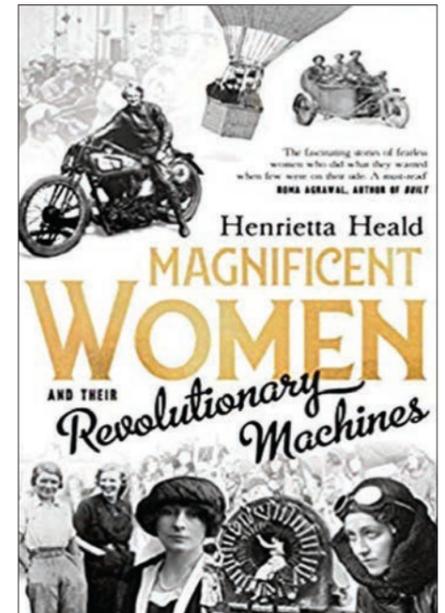
Remember the past, celebrate the present, transform the future

Marking the centenary of the Women's Engineering Society, Henrietta Heald's *Magnificent Women and their Revolutionary Machines* details the story of the society's beginning and the lives of its pioneering members. In a review of the book, IOP coach Ruth Wiltsher writes: "There is an interesting timeline of milestones in the UK for women in technology, engineering, politics and society, starting in 1805 and ending in 2018.

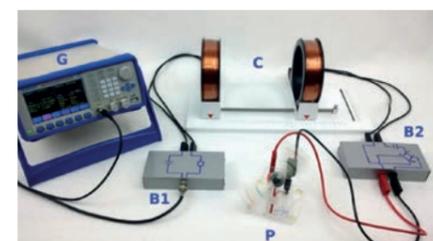
"The book covers a wide range of topics in its thirteen chapters including 'The All-Electric Home' and aeronautical engineering. In many

of the fields covered there are stories of the pioneering work of little known women, such as Beatrice Shilling, whose restrictor was used in aircraft carburettors until 1943. "The book should appeal to those involved in secondary science and careers education, both male and female. And it should certainly find a place in a science department library."

more...
Read the whole review at bit.ly/PEdWES



Wireless power transfer experiments



This paper is all about making a wireless charger demonstration to show how phones can be charged just by placing them on a charging point.

The transfer of energy without any electric leads or cables is not only a modern subject of research, but the technology has already found its way into our daily lives. Especially in consumer electronics, a lot of applications are commercially available, mostly non-contact charging applications for toothbrushes, mobile phones, etc. The setup design is user-friendly, straightforward, and easy to assemble for the students.

more...
Read the whole paper at bit.ly/PEdcharger

More recent articles in Physics Education

Inexpensive endoscope activities bit.ly/PEdendo

Getting charged up – the corona way bit.ly/PEdcorona

Examination of prisms via spectacle lenses bit.ly/PEdprisms

The science of ice cream bit.ly/PEdicecream

Developing critical analysis of explanations bit.ly/PEdcritic

What happens next?



Two identical glass bottles (250 ml) each contain a few millimetres of water. They are blown across their mouths to produce a note of fixed frequency. An indigestion tablet is dropped into one of the bottle and the water effervesces. The mouth of the bottle is blown again. How will the frequency change if at all? Find the answer to this question – and view the What happens next? archive – at bit.ly/PEdwhatnext



talkphysics

An electromagnetic curio



Physics teacher Joe got an electric shock from a metal gate under a high tension overhead power line. He posted a picture of the huge pylon and the metal gate and a close up of a spark when he held his knuckle close. Early next morning, he took a compact fluorescent light bulb which lit up when held to the gate! This sparked a

discussion about the myth of being able to steal electricity by living near an overhead power line. And, of course, users shared a few of their homemade activities in this area.

more...

Read in full at bit.ly/TPelectromag

Van de Graaff generator



There is so much you can do with the Van de Graaff once you have it up and running. This post contains a playlist of videos of demos beloved by Dave Cotton, editor of TalkPhysics. He keeps adding to it – his latest shows him bending a stream of water with his finger.

more...

Read in full at bit.ly/TPvandg

Edited highlights from our online discussion forum. Log in or register to join these discussions at talkphysics.org.



Teaching students how to apply their knowledge regardless of context

When we are teaching and assessing science, we need to be aware of both the concepts being studied and the contexts that help students engage with the sometimes abstract concepts. Indeed, some exam boards provide specifications that allow for a 'concept-led' approach and a 'context-led' approach. Students will have to answer questions in exams that are based on 'unfamiliar contexts'.

Correction: in our previous issue, we reproduced an article from EIC by Niki Kaiser about the periodic table. We incorrectly stated that this was part of a series based on EEF guidance.

When some students first read these unfamiliar-context questions in exams, they can feel they are being asked about something they haven't been taught. Completing past papers helps students to get used to the style of assessment and how to manage their time. Don't just stick to the questions

for the specification you are using. Many exam boards make past papers available online. From these you can select questions based on a particular concept, widening the pool of exam writers' work your students are seeing.

Interpreting exam questions is an important skill that needs to be taught. Don't leave it to the revision period before the exams. Model how to break down questions – circle command words and underline key information. Next discuss your thinking about which concepts are relevant. Bullet point an outline of the answer. Finally, bring it together by writing the answer, and check back that all command words and key information have been dealt with.

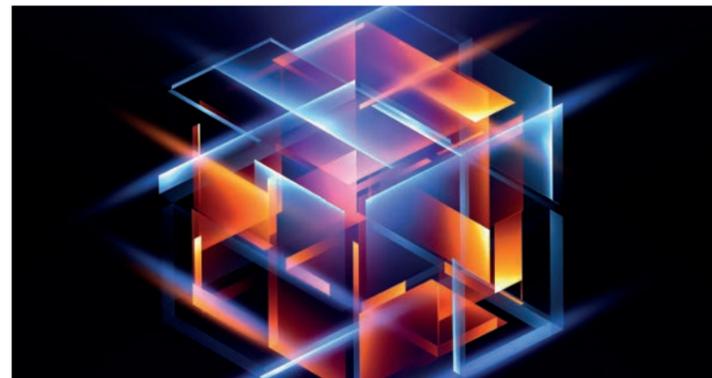


No parroting back here, just applying knowledge to different contexts

more...

By David Paterson, teacher of chemistry at Aldenham School. Full article at rsc.li/2llqG5v

physicsworld Is Google's quantum supremacy not so supreme?



Google's Sycamore quantum processor hit the headlines when a paper suggested that the device is the first to have achieved quantum supremacy by solving a problem more than a billion times faster than a conventional (classical) supercomputer. But now, researchers at IBM claim that the Google team has vastly overestimated how long the problem would take to solve on a supercomputer – saying that the

actual speed-up offered by Sycamore is more like a factor of 1,000.

The Google paper describes how 53 programmable superconducting quantum bits were used to determine the output of a randomly-chosen quantum circuit. While the calculation has no practical application, it does provide a way of comparing the performance of Sycamore to that of classical computer.

The quantum calculation took 200 s to complete and the Google researchers estimated that the same calculation would take 10,000 years to execute on a state-of-the-art supercomputer.

But IBM's Edwin Pednault, John Gunnels and Jay Gambetta argue that the same task could be performed in just 2.5 days using the Summit supercomputer at Oak Ridge National Laboratory in the US. Writing in the IBM Research Blog, they say that the Summit calculation would be more accurate than the Sycamore calculation and with further optimization, the execution time could be reduced.

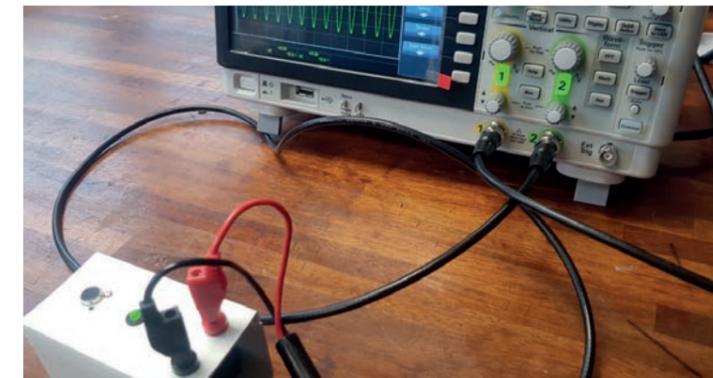
more...

Read the full blog post by Hamish Johnston at bit.ly/PWsyncamore

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



Sound experiments (sound as a pound?)



A common problem with using a commercially bought microphone for sound experiments (with an oscilloscope) is that the voltage output is very low, typically 50 to 100mV. This makes seeing waveforms on the oscilloscope challenging as the voltage division needs to be very sensitive. We've been investigating the use of pre-built amplified microphone modules and have had great success with the

MAX4466 Electret Amplified Microphone Module (mouser.com 485-1063). This amplified module gives a far higher voltage output compared with unamplified crystal microphones. The difference can be seen in the picture right (the yellow trace is a typical crystal microphone and the green trace is the amplified module). CLEAPSS are massive fans of digital storage and USB oscilloscopes.

The ability to pause the trace and take detailed measurements makes them invaluable in the science classroom. The picture below shows clearly the time-lag between the two microphones and results for the speed of sound were very close to the accepted value.



more...

For the Making an amplified microphone module, log in to the website and search for **GL329**.

For Determining the speed of sound with a digital storage oscilloscope, log in to the CLEAPSS website and search for **PP065**.



Careers in STEM

For more information about Careers in STEM visit: nustem.uk/careers

With the implementation of the Gatsby careers benchmarks, subject teachers are expected to embed careers information in the classroom. This is a challenge because the physics curriculum is already very full!

We've included a set of NUSTEM's Careers in STEM postcards for IOP Affiliated Schools.

They showcase a broad range of jobs: some require physics and some the skills from physics, whilst entry points range from apprenticeship to postgraduate. We also include three personal attributes to help students identify with the job and the characteristics needed for it. You can help them see they already possess many of these qualities.

Digital versions of the cards are available at nustem.uk/careers.



Teachers in Residence

Connecting secondary teachers with industry professionals

Would you like the opportunity to work with a UK-based design, manufacturing, engineering or construction business?

We are inviting science teachers to take part in a 5-day internship to:

- develop a deeper understanding of modern industry, and the technical skills and attributes required by employers
- have a clearer view of the career pathways and opportunities available for your students, which in turn will support your school's delivery of the government careers strategy.

If you can commit five days of holiday/release from your school, we'll match you to a company, immerse you in their day-to-day activity where you'll gain first-hand experience and develop meaningful industry engagement links.

For further info contact lata.patel@data.org.uk



SCHOOL PARTNERSHIPS PROGRAMME

An Ogden school partnership is a group of schools within a local area who want to work together to enhance the teaching and learning of physics. The programme offers grant funding to a partnership over five years and is available for primary and secondary partnerships.

For more information visit our website: www.ogdentrust.com

Aims of the School Partnerships programme include:

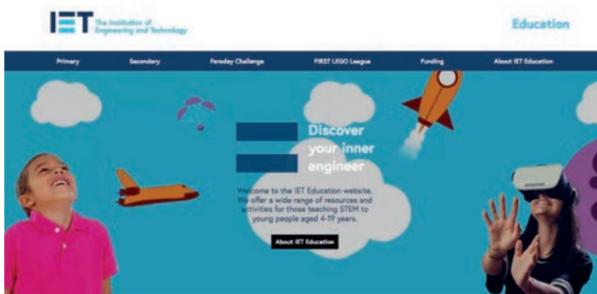
- Supporting physics teaching through subject specific CPD and supporting schools to improve teacher retention
- Supporting students to develop physics identity through collaborative partnerships, student enrichment and enhancement activities, working with families and careers awareness



“Working with The Ogden Trust over the past five years has been really rewarding and transformational for our students and our teachers.”

Phil Atherton, Head of Physics
Kingsbridge Community College

Applications open: 1 September 2019
Submission deadline: 1 February 2020



The new-look IET Education website has now launched

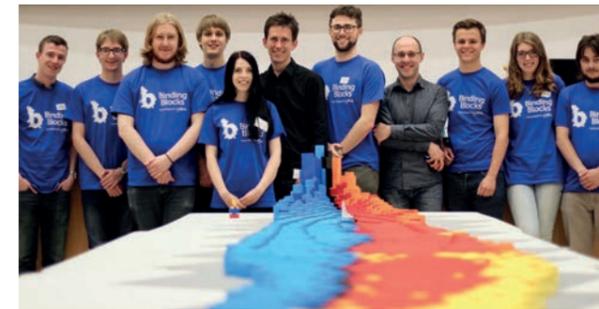
To coincide with the Institution of Engineering and Technology's new brand we have given the old Faraday website a brand-new look and have now relaunched it as 'IET Education'. The site brings together all of our education brands and sites in one place - with useful information and downloadable materials, plus updates on our competitions and challenges for primary and secondary school teachers, parents and students.

There are also details on the funding we provide, together with the partners and supporters we work with to champion STEM learning and inspire the next generation of engineers and technicians.

education.theiet.org



Exploring the mysteries of the nucleus... with Lego



University of York

Opening in February 2020, the next exhibition at our King's Cross building will be based around the University of York's hugely successful Binding Blocks nuclear physics schools outreach project.

The exhibition will feature a 7 m Lego model illustrating the nuclear chart and isotopes of the elements plus displays exploring nuclear fusion, astrophysics and medical physics.

york.ac.uk/physics/bindingblocks



IOP Institute of Physics
iop.org

ASE Annual Conference

8 – 11 January 2020, University of Reading

The largest science education conference in Europe, with over 450 workshops, talks, teacher takeaways and CPD sessions including:

- Keynote from Paul Hardaker, IOP chief executive
- International Day
- Twilight session from 3pm for technicians
- Dedicated PGCE day (trainee teachers get one free day when they purchase ASE membership)

ase.org.uk/annual-conference



ASE



Look out for the ASE Good Practical Science poster, arriving in schools in mid-December

Who do you know who deserves to be recognised for influencing science, mathematics or computing education?

Nominations for the 2020 Royal Society Kavli Education Medal are now open. The Medal recognises someone who has had a significant impact on science, mathematics or computing education at any level from primary through to further education. The nominated individual could be a practicing teacher, school leader, education researcher, academic, policy maker or someone else who influences the direction of science, mathematics or computing education in the UK.

Anyone making a nomination will need to have identified two other people who can act as referees and self-nominations are not valid. To find out more about the Medal or to nominate someone, visit royalsociety.org/grants-schemes-awards/awards/kavli-education-medal.

What will you investigate?

You could receive up to £3,000 to run an investigative STEM project in your classroom through the Royal Society's Partnership Grants scheme. The next round of funding will open in February 2020 and projects have to be run in partnership with a STEM professional from academia or industry. Now is the perfect time to begin thinking of project ideas and finding your STEM partner.

To find out more about the scheme and the application process, contact the Royal Society's Schools Engagement team via education@royalsociety.org. They can also provide advice in the lead up to and during the application process, including guidance on project themes, ideas on where to find a STEM partner and checking draft application forms.



Kholosov



Find a CPD event near you at talkphysics.org/events



Making salad bowl accelerators at an IOP CPD day in Northumbria in October

IOP Yorkshire CPD Day

8 January 2020 9.30am – 3pm
University of Leeds, LS2 9JT
bit.ly/IOPyorks20

A-level physics support for beginning teachers

15 January 5 – 7 pm
Burlington Danes Academy, W12 0HR
bit.ly/IOPbegin

Teaching electromagnetism

27 January 5 – 7 pm
Truro College, TR1 3XX
bit.ly/IOPem20

IOP South Regional Day

4 February 9 am – 4 pm
IOP, London, N1 9BU
bit.ly/IOPsouthfeb20

IOP North Regional Day

13 February 9 am – 4 pm
Museum of Science and Industry, M3 4FP
bit.ly/IOPNorth

Low temperature physics

17 February 9:30 am – 4 pm
University of Lancaster Physics Department,
LA1 4YB
bit.ly/IOPlowtemp

Oxfordshire Regional Day

29 February 10 am – 4 pm
Abingdon School, OX14 1DE
bit.ly/IOPsouthab20

Canterbury Regional Day

7 March 10:15 am – 4:15 pm
St Anselms RC School, CT1 3EN
bit.ly/IOPcant20

South Regional CPD Day

27 March
Clifton College, Bristol BS8 3JH
bit.ly/IOPclifton20

Making physics GCSE required practical work easy

20 April 2020 5 – 7 pm
Truro College, TR1 3XX
bit.ly/IOPgcsetruro

Teacher CPD: Gravity and Relativity

19 June All Day
University of Lancaster Physics Department,
LA1 4YB 2020
bit.ly/IOPgravitycpd

46th Stirling Physics Teachers' Meeting

6 May
Stirling Court Hotel, FK9 4LA
stirlingmeeting.org/home

Contact your IOP regional education manager to find out about opportunities near you:

Scotland

Stuart Farmer
stuart.farmer@iop.org

Ireland

Lucy Kinghan
lucy.kinghan@iop.org

Wales

Samantha Borley
samantha.borley@iop.org

England

Yorkshire and northeast
Jenny Search
education-yane@iop.org

Northwest

Graham Perrin
education-northwest@iop.org

Midlands

Ian Horwell
education-midlands@iop.org

London, East-Anglia and Kent

Jessica Rowson
education-leak@iop.org

South

Trevor Plant
education-south@iop.org

All events listed are funded by the IOP and free to attend unless otherwise stated. All teachers of physics are welcome, whether or not you consider yourself a physicist!