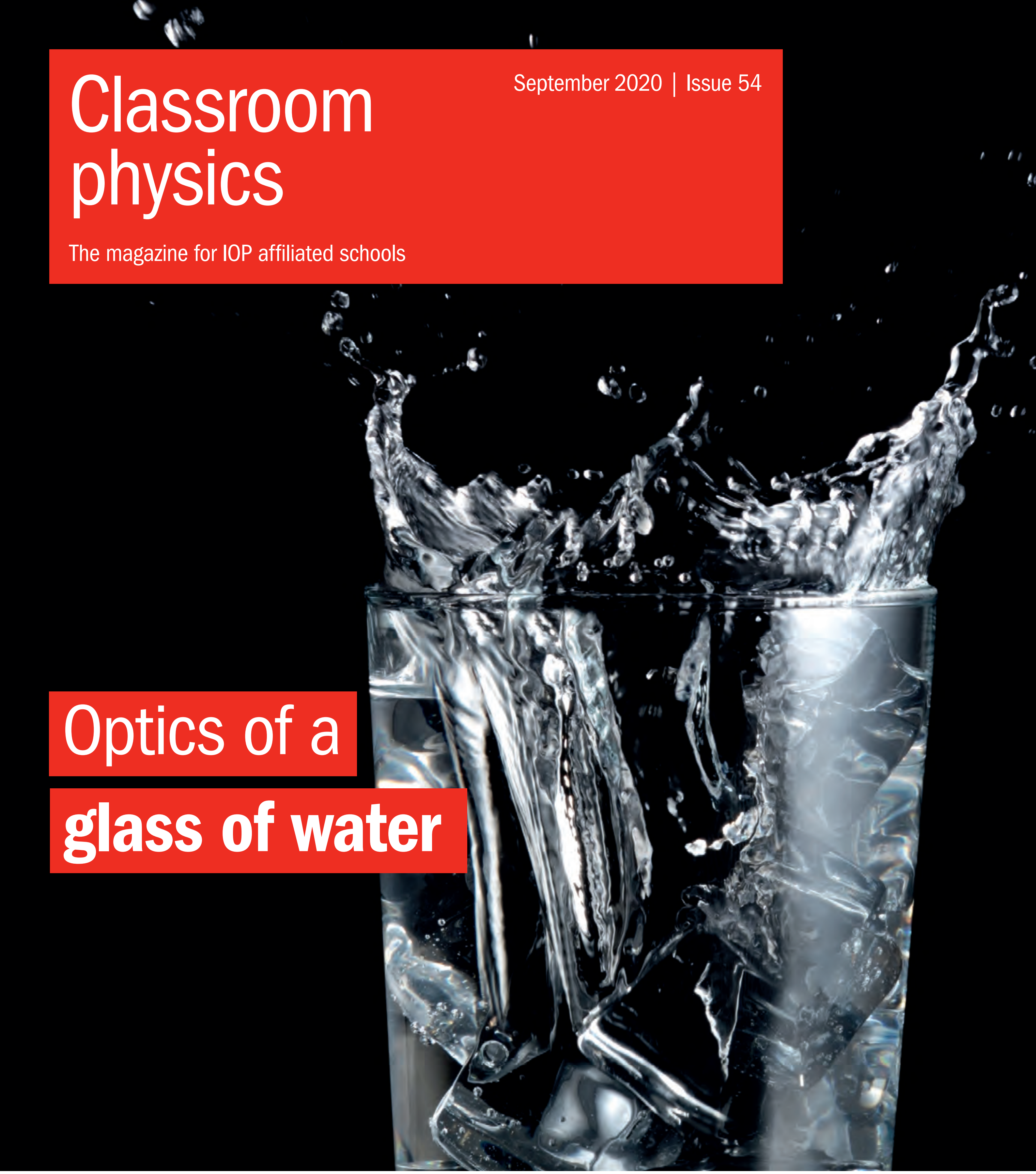
September 2020 | Issue 54

Classroom physics

The magazine for IOP affiliated schools



Optics of a glass of water

Online teacher CPD – the way forward

Celebrating 60 years of the laser

Your Future with Physics: our new careers hub

iop.org

IOP Institute of Physics

This issue

Physics CPD – looking forward from lockdown

Credit: IOP/Shutterstock

For well over a decade, IOP has provided physics CPD at no cost to teachers and technicians across the IOP nations (England, Ireland, Northern Ireland, Scotland and Wales). Almost all of this has been face to face. Whilst we had been developing plans to introduce more online support, COVID-19 forced us to accelerate this move significantly.

After an intense four months delivering online CPD, the end of the school year gave an opportunity to reflect.

We have been delighted to see hundreds of schools engaging, many for the first time. Between April and July, we ran over 300 online sessions - more than 3 sessions per weekday on average - providing over 5,000 teacher-hours of training. Most attendees were teachers or technicians from the home nations, but we also welcomed colleagues from around the world along with supply teachers, education consultants and those providing initial and in-service training for teachers. Repeat business might be considered a sign of success: most schools attended three or more sessions and many attended dozens.

Now, perhaps more than ever, it's important to ensure our support is directed towards those students in the greatest need.

We were pleased to see that the most deprived schools seemed to be accessing more CPD than others; those schools in the highest quartile by percentage of students with free school meals accounted for 33% of our CPD provided to state schools. Overall, over 90% of uptake was from teachers in state-maintained schools and 44% came from schools with above average uptake of free school meals.

We hope that the move online has been positive. It eliminates barriers such as travel time and cost, but we know that other barriers remain: internet access can be a limit for some, as well as caring/family commitments or employer permission for sessions during school hours.

We do hope you (and your colleagues) will be able to join us over the coming year.

Find out more about our CPD programme for this autumn term on the back page.

Please complete our online survey to help us understand and tackle the barriers to CPD participation.

bit.ly/IOPcpdsurvey

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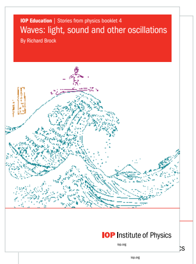
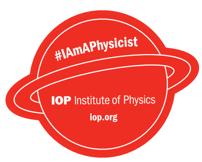
With this issue...

Stories from Physics
Two booklets because we missed one in June

Laser pointer
Celebrate 60 years of lasers

Laptop badge
Be proud of who you are





What is online teacher CPD like?

We had been facilitating teacher CPD face-to-face for many years when we rapidly had to switch to online sessions. So how different was the experience - and was it still worthwhile? Three attendees give their verdict...

"A great opportunity to participate in CPD"

Online sessions enabled me to participate in CPD I would not normally due to funding or getting time off. I ended up attending several sessions and pulled in other members of my department. Everyone came back with ideas that we have put into our schemes of work. Despite not being able to physically try the experiments, the presenters did an excellent job of producing props, presentations and videos so we could see how they worked.

Laura (physics teacher)

"The chat box in the corner was most valuable"

In the strangest of all summer terms, I nervously found myself signed up for a three-day virtual physics fest. Every session gave me something to think about. Was it the same as being there in person? Sadly, no. But the chat box in the corner was most valuable. It silently, but rapidly, filled with ideas, explanations and links from members of the audience, giving this whole process the edge over any live session.

Sharon (science teacher)

"Fabulous! But no biscuits"

The main difference was not being sat at a table with a nice cup of tea and a plate of biscuits. When you do that, you learn much more than the 'official' CPD because you can talk to everyone else. The IOP did a fabulous job of mitigating this by having IOP coaches monitoring the chat, so we could have conversations. I met people I'm now in contact with via Twitter and it was great to see some familiar faces.

Helen (physics teacher)

Physics teaching and learning resources for remote study

As Classroom Physics went to print, all students were expected to be going back to school. However, with local lockdowns becoming common-place, it is not impossible that students will have periods of home-learning. So here is a reminder of the physics teaching and learning resources we have developed for this purpose. They can all be accessed from:
spark.iop.org/covid-19

Resources by physics topic

You can also browse by resource type within these collections

1. Earth and Space
2. Electricity and Magnetism
3. Energy and Thermal Physics
4. Forces and Motion
5. Light, Sound and Waves
6. Properties of Matter
7. Quantum and Nuclear Physics

Resources by age range

- 11 – 14 year olds
- 14 – 16 year olds
- 16 – 19 year olds

Resources by type

1. Videos to watch at home
2. Home experiments
3. Questions to check understanding and identify misconceptions

Follow the IOP Education Department on Twitter @IOPTeaching

Early career teacher support in the wake of lockdown

Credit: IOP

Whilst ultimately it is students whose education has been most disrupted by schools closing their doors, it is important to remember that student and early career teachers may also have had setbacks to their professional development.

In the past months, we have consulted teacher trainers to find out their concerns. These centred around the need to support the current cohort in September with a reduced timetable and subject-based support, to avoid even higher dropout rates than normal. Placements for the next cohort were another significant concern, both in terms of schools being unwilling to provide them, and possible limited duration.

We are continuing to work with ITE providers and the teaching community to deliver the extra support new teachers may require. Additionally, we have partnered with other organisations to communicate these issues to government to find ways to provide the resources.

This academic year, we are putting in place a comprehensive programme of teacher CPD which will include sessions specifically designed to address these needs. Mark Whalley, IOP Education Manager said, “We will have regular online CPD sessions which are dedicated to new and early career teachers. Our coaches will provide subject knowledge workshops and teaching support as well as making themselves available to offer advice direct to participants.”

Despite the current uncertainties, this year we have seen a significant increase in the number of people applying to the IOP teacher training scholarship scheme. We are also pleased to have been able to award considerably more scholarships to prospective teachers embarking on initial teacher education this September compared to last.

Last year, the number of new physics teachers was particularly low. At the start of September, UCAS reported that just 520 people entered postgraduate initial teacher education in physics. According to the latest UCAS data, this year, 550 people have accepted places on ITE courses (final figures are likely to be slightly higher).

Calling trainee science teachers!
Being part of the IOP community can be of great benefit to trainee science teachers, whatever their specialism. This year, we want to keep in touch with as many people starting this journey possible. We'll share events, CPD, support opportunities and our resources. Please forward this registration url to any trainee teachers you know:

iop.org/student-teacher

Reciprocal agreement for IOP and ASE members

Did you know that current ASE members can join the IOP at a 30% discount on the full annual rate for new memberships? And IOP members can claim a 30% discount on their first year of membership with ASE.

more...
Visit **membership.iop.org/reciprocal_agreements** to find out more

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

IOP Institute of Physics

Great Science Share: wherever they are!

The 5th Great Science Share for Schools saw registrations for over 90,000 young people aged 3-14 years with over half of these signing up during lockdown. This annual campaign has now reached over 200,000 youngsters in 12 countries, nurturing them to share scientific questions with new audiences.

Many families got involved for the first time this year and teachers and parents have found the value in engaging with the campaign to raise the profile of science and increase engagement with a growing audience in secondary schools.

more...
Explore the science shared by visiting **greatscienceshare.org/showcase** and follow **@GreatSciShare** on Twitter to find out about the 2021 Great Science Share.

Credit: Great Science Share

“We made a teddy zip line, finding out what gradient and materials worked best. Lots of fun!” Owen shares his Great Science Share investigation

Your Future with Physics: our new careers hub

Credit: IOP

"Physics gets a bad rep because people think it's really hard and so they shy away from it – especially girls. Being a successful musician is hard, but people aspire to do that. It's just a matter of realising that it's not out of your reach." Advice from Yolanda, post-doctoral researcher into MRI techniques to look at the brain.

The IOP has launched a new online hub dedicated to exploring the wide range of occupations and careers that a physics education can lead to. Your Future with Physics has user-friendly menus to guide visitors through a world of information for secondary school students and their parents, carers and teachers.

On the hub, young people tell the stories of their career journeys to date, explaining why they made the choices they did and how taking physics made a difference to them.

Advice on A-levels, Scottish Highers and Irish Leaving Certificate choices is illustrated by the accounts of students who describe how they made those choices themselves, and those in higher education explain how they decided which universities to apply to.

New and alternative routes into careers, such as through apprenticeships and technical qualifications are also described, explained and demystified through interviews and chat with young men and women who have taken these routes, both in physics and beyond.

The hub launched as the IOP revealed the results of a recently commissioned survey, which showed that 78% of employers had a positive impression of an applicant with physics at A-level or above on their CV.

Censuswide surveyed 500 hiring managers from across the UK's professional sectors, including charities, legal, sales, media and marketing. One recruiter said: "When I see physics on a CV, it indicates strong general knowledge, a deep-thinker and the ability to make decisions objectively - all valuable assets in my workplace."

Rachel Youngman, deputy chief executive at IOP said: "This research shows that having physics on CVs helps young people to get their foot in the door when applying for roles and makes it more likely that they will stand out from other candidates."

She continued, "Physicists work in every sector, from solutions to climate change, creating the latest technologies in cancer diagnosis, AI and video gaming, to the public sector and traditionally non-scientific sectors including charities, sales and banking.

"We hope our new digital resource will inspire parents, carers and young people about the opportunities that the study of physics will bring."

more...
iop.org/your-physics-future

Help us get more young people choosing physics

The IOP is launching its first public-facing influencing campaign with the aim of increasing the number of young people who study physics, or start an apprenticeship, from age 16.

Our campaign is especially focused on young people who are underrepresented in the physics community and who may be deterred from choosing to do physics because of the barriers and stereotypes that they experience.

Members of the physics community have been sharing their experiences with us and their compelling stories will powerfully illustrate why change is needed. If you also had to overcome challenges to pursue physics when you were younger, we would be very grateful if you would share your experiences with us.

more...
Share your story at

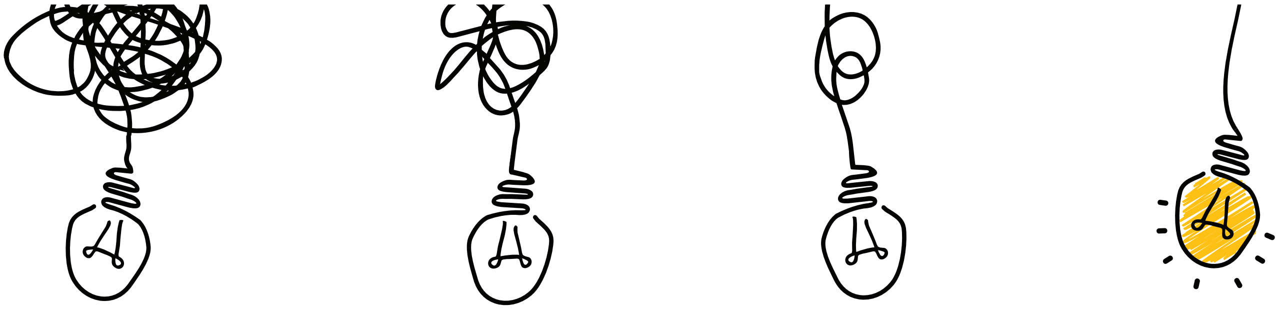
iop.org/your-stories

MyPhysicsCourse – updated for 2021 entry

Credit: IOP

Our hub for undergraduate physics degrees in the UK and Ireland is ready for your students. As well as listing all courses, it gives advice about entry requirements, subject combinations and costs so is suitable for those still choosing their post-16 options as well as students who are at the next stage and choosing where to study.

myphysicscourse.iop.org



Credit: Martyn Win for Spacex/ University of Exeter

Challenging common misconceptions when teaching physics

By the time a student arrives in a physics classroom, they've had over a decade's worth of experience of interacting with physics in the real world and forming their own ideas about how physics works. Research has shown that taking these student ideas into account greatly improves teaching efficacy.

And after a break from formal schooling that your students had only ever dreamed of before Covid, your task of identifying and addressing misconceptions is likely to be a challenge.

We have a developed a collection of the common misconceptions and explored children's thinking discussed in the academic literature with leading researchers. You can access them on IOPSpark, our teacher resources website. Each misconception includes diagnostic tools, resources to address the problem and a list of references to follow if you would like to know more.

However, only you can make the decisions about what is most appropriate for your classes and students. We hope that by showing a range of ideas that children can hold in each physics domain, and presenting these alongside research-informed resources, will support the use of evidence in physics teaching.

This is an ongoing project and we are constantly adding more content.

more...

Browse our collection of misconceptions
Misconceptions research and toolkit

spark.iop.org/misconceptions
spark.iop.org/misconceptions-blogs

Using IOPSpark misconceptions

We currently have over 120 misconceptions covering four domains of physics:

- Light, sound and waves
- Forces and motion
- Electricity and magnetism
- Energy and thermal physics

Alongside them, we also have a toolkit of articles to help you think about how to use the content.

Assessing pupil thinking

Substantial evidence suggests that the holding of misconceptions can prevent pupils' further understanding of physics. Suppose we were teaching Newton's Second Law, and came across the following misconception: "Many pupils are unable to apply Newton's Second Law to examples of motion in 2D." Now we are aware of this potential stumbling block, we could assess pupils' thinking by asking them to explain, discuss or draw the motion of a bowling ball being thrown out of a horizontally-moving aeroplane.

Developing pupil thinking

Once you have a clearer picture of the sorts of ideas your pupils might have about physics, the next question to consider is: how can you help develop these ideas to challenge misconceptions and deepen their understanding of physics? The process by which concepts develop continues to be a topic of active research for the education community. We examine four approaches: coherence, knowledge in pieces, competing concepts and sociocultural.

Developing curricula

Whether you're a technician, a teacher, the head of your department, or someone involved with the running of a school or a multi-academy trust, you are an important part of the curriculum-making process. After all, curriculum development doesn't start and end with a national curriculum: interpreting and structuring its content, planning and teaching lessons, and managing the context in which students learn (through, for example, the use of practical activities) all have a profound impact on learners' understanding of physics.

Developing your own understanding of physics

One of the benefits of familiarising yourself with common student misconceptions is that it may help to develop your own knowledge too! The IOPSpark misconceptions resources may improve your physics content knowledge by simply filling in any gaps you might have. With the growing need for physics teaching to be carried out by teachers whose specialism is in another subject, it is entirely understandable that some teachers of physics may find themselves grappling with their own misconceptions from time to time.

Cognitive load theory – some strategies to teach light

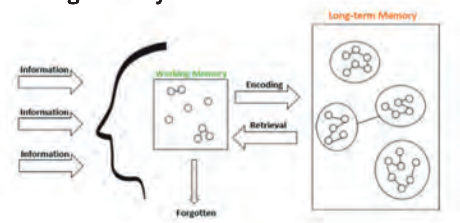
In the last few years, cognitive load theory (CLT) has been receiving a lot of attention by educators and has started to shape the classroom practice of many teachers. So, what is CLT? Alessio Bernardelli, a member of the IOP's Professional Practice Group, explains

The simplest way to think about it is that cognitive load is the heavy lifting the brain has to do when completing tasks. If you can reduce the cognitive load of the task, the learner can focus on the relevant information.

The value of cognitive load theory is that it helps us sequence and design activities which are well suited to learning more and learning to solve problems. Reducing the cognitive load of a task means students can focus on the important concepts and learn more efficiently.

It is inefficient to continue with new learning unless this knowledge is secure. This can take several lessons. So before moving on to the next stage of the learning, this knowledge needs to be well embedded. Quizzing is a very effective way to do this, as is comparing similarities and differences.

Working memory



Your working memory is your thinking workspace. It can only really cope with two or three new things, but it can draw on previously learnt things really easily. So the key to efficient learning is to build a well-stocked long term memory. You need to do this one small piece at a time.

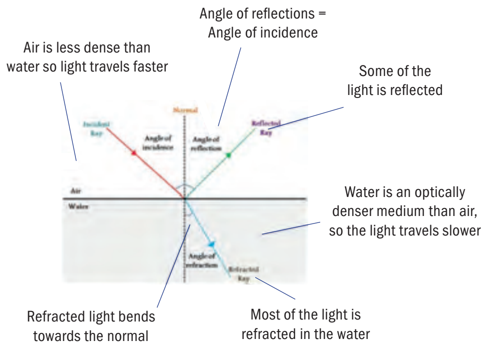
more...

This paper gives a good introduction to the theory

Cognitive Load Theory: New Conceptualizations, Specifications, and Integrated Research Perspectives
Fred Paas, Tamara van Gog and John Sweller
bit.ly/CPclt2

Ben Rogers, author of *The Big Ideas in Physics and How to Teach Them* contributed to this article.

An example to reduce the cognitive load when reading about refraction



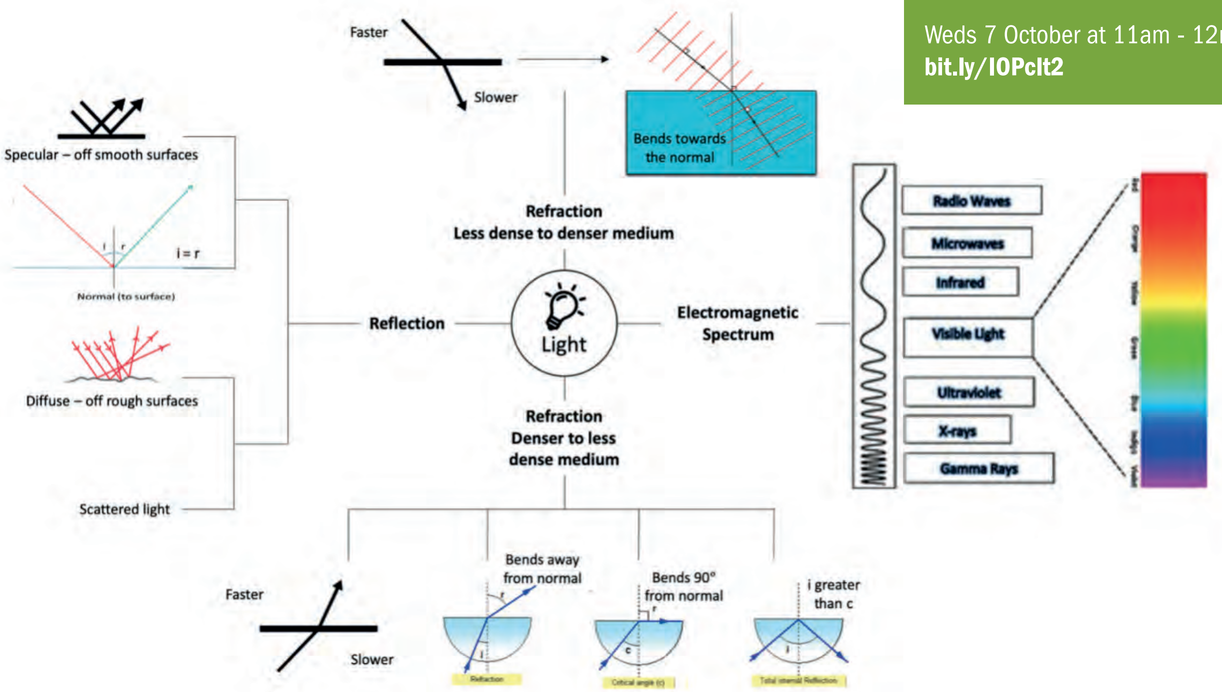
The diagram above is adapted from a paragraph in a text book and should reduce the cognitive load. The labels make it simple for the reader to match the text to the relevant part of the diagram. Previously, the reader had to hold that information in the working memory. The diagram is also easy to search for information, compared to the text. If you want to go back and check one part of the argument, it is much easier to find than in a paragraph.

Join Alessio for an online CLT workshop

Monday 5 October 4 - 5pm
bit.ly/IOPclt1
or

Weds 7 October at 11am - 12noon
bit.ly/IOPclt2

Graphic Organisers



Graphic organisers are particularly useful, both as a teaching method and as a retrieval task for students to develop their own. This is an example of a graphic organiser incorporating different elements of light.

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.**

If you would like to join other physics teachers interested in engaging with 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**

Online self-study, motivation and student engagement

This column is all about engaging with academic research to help us reflect on our own teaching practice. There are many levels on which you can do this, but sometimes gaining an insight into the ways in which researchers consider and analyse their data can be as valuable as the actual findings.

A recent study explored how to address the challenge of engaging all students via self-paced interactive electronic learning tutorials for introductory physics. It tracked American undergraduates involved in using online self-study learning modules covering topics such as Newton's laws, conservation of energy and momentum. The paper is available freely (see link below) but it is the analytical framework that we will consider here as it may be of use for developing online, self-study courses to supplement face-to-face teaching.

The authors, DeVore, Marshman and Singh, propose four key considerations when developing and implementing effective and engaging online self-study courses. They outline a Self-study for Engaged Learning Framework (SELF) to help with this process. Fuller detail can be found in the paper, but we have summarised the four key considerations below in the form of example questions that one might ask when reflecting on course design and implementation.

The value of this framework is that it can help us be consistent, rigorous and thorough. It can help us ask the right kind of questions to develop and improve the quality of what we do. It does not lead to a single clear and unambiguous 'correct' approach to design, but asking these questions can improve the effectiveness of practice.

more...

Read *Challenge of engaging all students via self-paced interactive electronic learning tutorials for introductory physics* in *Physical Review Physics Education Research* at

bit.ly/PERselfpaced

Self-study for Engaged Learning Framework (SELF)

Internal tool considerations:

- When designing the tool, did I think about how the materials are presented, how they build upon each other and how students can engage with them?
- How does it develop knowledge, understanding and mastery?
- How can it provide formative feedback?
- How can it facilitate 'productive struggle' that is encouraging but not demotivating?

External tool considerations:

- How does the tool help students monitor their own progress and success?
- Does it support students to collaborate and communicate with each other?
- Are there ways in which it can support students to manage their time well?

Internal user considerations:

- Have I integrated what the students bring to the task, such as subject knowledge, prior experiences, motivations, attitudes and goals?

External user considerations:

- What help and support is in place to help students to self-manage?
- How have I balanced the expectations between what might be done in class or face-to-face and what is expected from self-study?
- What is the impact of context in which students will be working, such as support from family and teachers?

Pull out and keep!

Optics of a glass of water

What's inside:

Reflections

It took lockdown for me to realise what had been sitting in front of me.

Before I became a teacher, I was a researcher, developing new miniature solid state lasers. Designing optical systems was part of my day job. But it took being stuck at home for me to really appreciate the wonders of the humble glass of water: it's an optical fibre in your hand!

Admittedly, it's a crude one where total internal reflection happens at an air-interface and so is easily ruined if you hold it with wet hands. But, if you leave the glass sitting on the table, peer into the top and look down at the side of the glass through the water, what you see isn't the surface on the other side, but a mirror image of what's below.

For light entering from top or bottom, a glass of water is a waveguide. For light travelling in the horizontal plane, it's a lens. The glass-water combo is remarkably versatile for demonstrating many optical phenomena.

Some of the best physics demos are the least complex, using the most basic of kit. You can use a glass of water to introduce total internal reflection, optical fibre communications, images formed by a converging lens and focal length. The experiments on the following pages can all be carried out in the school lab or at home in the kitchen.

And, maybe best of all, once your students have got the hang of these activities, they can use their new-found knowledge to wow their friends and family with some optical illusions.

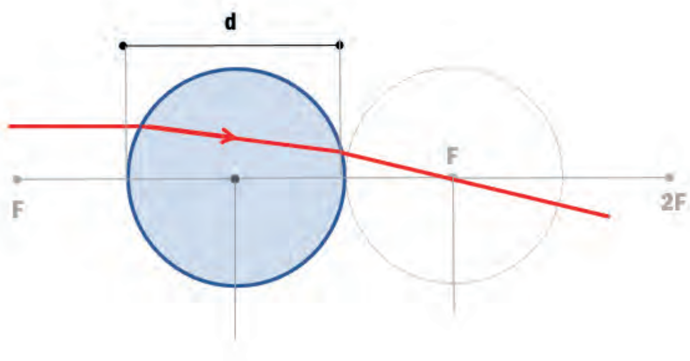
Dr Taj Bhutta
IOP school engagement manager

more...
The experiments in this pull-out were adapted from our *Do try this at home series* for parents and carers. Watch them, and many more, at

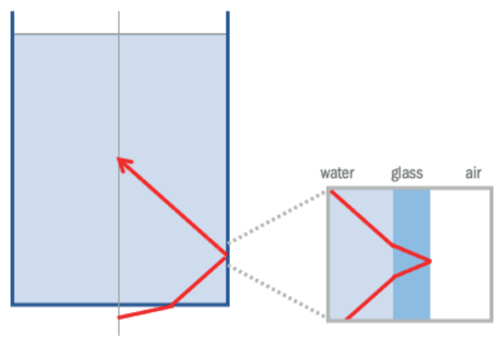
iop.org/athome

Optical properties of a glass of water

Credit: IOP



Looking down into a glass or water, the focal point F is diameter d away from the centre of the glass.



The glass of water acts like a crude optical fibre: total internal reflection happens at the outside vertical edge of the glass.

Activity 1: Vanishing coin

In this activity students see how a coin under a glass of water can't be seen through its side. You can use it to introduce total internal reflection.

Equipment

Each student will need:

- A small empty beaker or glass with straight sides
- A larger jug/beaker of water
- A coin
- Paper or card
- Scissors
- Tissue or cloth to mop up spillages

Procedure

Ask students to:

1. Put the beaker/glass upside down on the paper. Draw around it and cut out to make a lid.
2. Place coin on bench/table, making sure that both are completely dry.
3. Place the glass on top of the coin.
4. Pour water into the glass so that it is completely full.
5. Add the lid. The coin should not be visible when viewed through the side of the glass.
6. Lift the lid. They should be able to see an image of the coin (or multiple images if they are using a tall glass).

Teaching notes

Discuss what needs to happen for us to be able to see the coin, namely that light has to bounce off the coin and enter our eye. Provide (simplified) ray diagrams for the empty glass, showing light through the side of the glass, and the full glass, where light cannot escape through the sides because it reflects. Introduce the term 'total internal reflection'.

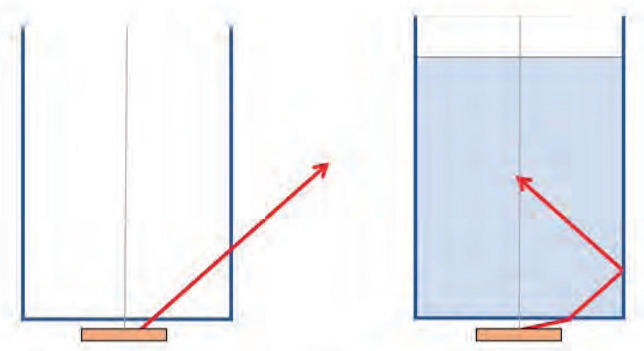
Technical notes

The coin and bottom of the glass have to be completely dry for this activity to work. Ridges on the coin and imperfections in the glass create a small air gap between the top of the coin and the bottom of the glass. If you add a drop of water between coin and glass, the coin becomes visible. Substituting air for water reduces the angle of refraction as light enters the glass and this in turn reduces the angle of incidence at the glass-air interface at the side of the glass so that it is no longer larger than the critical angle.

more...

For step-by-step instructions and a video for how to use this activity at home, visit

iop.org/episode-10-vanishing-coin



Simplified ray diagrams for a coin underneath an empty glass and a glass with water

Activity 2: Inverting image

In this activity students see how an arrow can look different through a glass of water. You can use it to introduce the types of images created by converging lenses.

Equipment

Each student will need:

- A clear, straight-sided glass or beaker
- A4 sheet of paper
- A felt tip pen
- A jug or bottle of water for pouring
- A copy of the student instructions on page 12 (optional)

Procedure

Ask students to:

1. Draw two short identical arrows on the A4 paper. They should be of a length equal to about a third of the diameter of the glass and pointing the same way, one above the other.
2. Stand the paper upright – lean it against a book or wall if necessary.
3. Place the empty glass/beaker so that it is touching the paper.
4. Partly fill the glass so that one of the arrows is visible through water in the glass and the other can be seen through the air above the water.
5. Gradually move the glass away from the paper.

Teaching notes

Discuss why the lower arrow appears to reverse direction. This is because the light changes direction before it enters our eye. Introduce the terms ‘object’, ‘image’, ‘magnified’, ‘diminished’ and ‘inverted’.

Technical notes

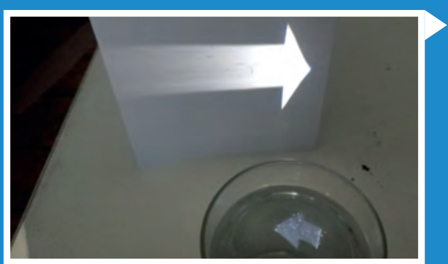
A glass of water is a (very) thick lens, so the closest an object can be placed is half a focal length. For a typical glass of diameter 7 cm, students will observe the magnified image reverse direction after a distance of 3.5 cm as they move the glass away.

Only light travelling through the central portion of a lens converges to the focal point. Limit image distortion by keeping the size of the object (the arrows) to about a third of the diameter of the glass.

more...

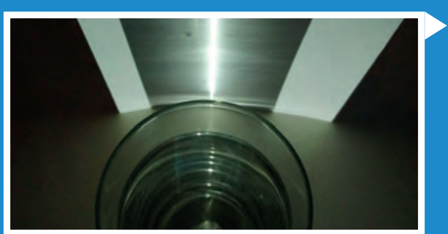
For step-by-step instructions and a video for how to use this activity at home, visit

iop.org/episode-4-reversing-arrow



Projecting a real image

Cut out an arrow from a piece of card. Shine a torch through it and use the glass of water (lens) to project a reversed image of the arrow onto a piece of paper.



Investigating focal length

A glass of water brings light to a line rather than a spot focus because a cylinder lens only focuses in one direction. Students can use containers of different diameters (jars, drinks glasses etc), a torch and ruler to determine focal length for different diameters. If they plot a graph of focal length against diameter they should find that the gradient is equal to one.

Inverting Image

What you need:

- A clear, straight-sided glass or jar
- A4 paper
- A felt tip pen
- A jug or bottle of water for pouring

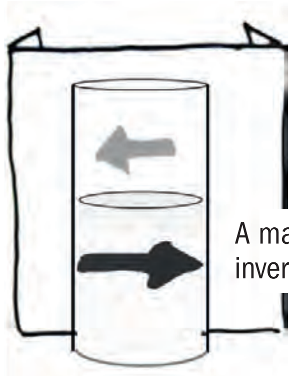
What you need to do:

1. On your paper, draw two short arrows, one above the other. Make your arrows about a third as long as your glass is wide, both pointing to the left.
2. Stand your paper upright – you could fold the sides, lean it against a wall or use a box or book.
3. Place the empty glass next to the paper, so you can see the arrows through the glass.
4. Pour your water into the glass so that one of the arrows is below the water and the other above it.
5. Gradually move the glass away from the paper. What happens to the bottom arrow?

Now do this:

An arrow drawn on the paper is called the **object**. The thing you see is called the **image**.

We are used to seeing things through air which has little effect on what we see. However, when there is water in the way, the image can change. It can be **magnified** (bigger) or **diminished** (smaller), the **same way round** or **inverted** (reversed).



A magnified inverted image

The following sentences describe how the image of the bottom arrow changes as you move the half-filled glass away from the arrows on the paper. Copy and complete the sentences using words from the list. You can use any word more than once or not at all.

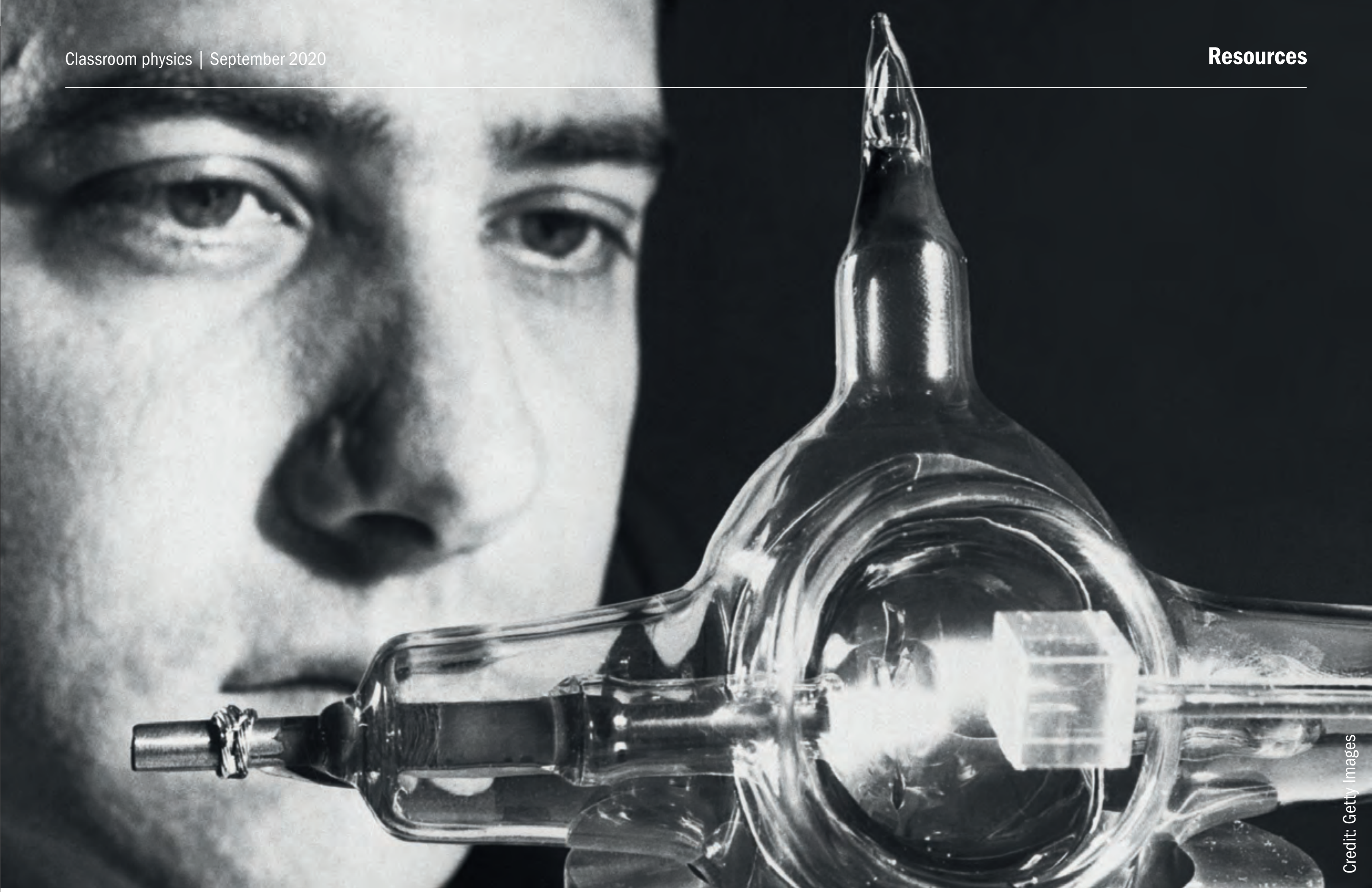
object	**image**	**magnified**
diminished	**the same way round**	**inverted**

Compared to the object, when the glass is next to the paper, the image of the bottom arrow is .... and ....

As you move the glass away from the paper, the .... changes. It becomes inverted.

The inverted .... starts off .... becomes the same size as the object and then becomes ....

Something else to try:
Set up a mobile phone on the table, with the camera facing towards the arrows and make a video clip of the image changing. Or, learn how to do the reversing arrow optical illusion for fun with friends online by watching **iop.org/episode-4-reversing-arrow**



Dr. Theodore H. Maiman, of Hughes Research Laboratories studies a ruby crystal in the shape of a cube in a laser (Light Amplification by Simulated Emission of Radiation) which is the essential element in a new electronic device. Date taken: 07 July, 1960

Why should we celebrate 60 years of the laser?

In 1917, physicists knew that atoms could absorb and emit light spontaneously. Einstein's insight was that light from one atom could stimulate the next one to emit light that was in-step with the original and of the same wavelength.

Almost 40 years passed before scientists figured out how to harness this idea. But it wasn't in the world's first laser, it was in Microwave Amplification by Stimulated Emission of Radiation, or MASER for short. The race to build a similar device using visible light – the laser – was now on.

It's been 60 years since Theodore Maiman produced the first laser light. Maiman's device was a solid state laser in which ruby atoms incorporated in a transparent sapphire crystal were pumped using a photographer's flash lamp. His breakthrough was rapidly followed by another milestone: the demonstration of the first semiconductor laser in 1962.

Making lasers out of semiconducting material has the advantage that the atoms inside the material can be excited directly using an electric current, and so don't need an optical pump source. This means they can easily be integrated into an electrical circuit to make very compact systems. But early semiconductor lasers could only operate at low temperatures and it took many more decades of research into precision crystal fabrication techniques and the invention of a new type of semiconductor structure - the heterostructure diode - before devices that operated at room temperature became commercially available. But when they did, they revolutionised the world.

These new lasers drove the CD and DVD revolution and then the development of the global optical fibre communication networks that we all rely on today. They also ushered in a new age for solid state lasers. Pumping solid state lasers using multiple laser diodes rather than lamps allowed them to be scaled up to the powers needed to drive nuclear fusion.
Lasers have grown into a huge and varied family of technologies that are just as useful in the home as they are in space telescopes, transforming our communications and computing, introducing pain-free surgery and giving the beauty industry a significant make-over. Today's semiconductor lasers can be mass produced for a low-cost device with a footprint that is smaller than a pen. Everyone can now have a laser in their pocket.
To celebrate, we have included a laser pointer with each copy of this issue of Classroom Physics.

Dr Taj Bhutta, IOP school engagement manager and former laser physicist

more...

For a student-friendly history of the laser see:
iop.org/laser

Classroom activities using lasers:
Seeing with light - an activity (11-14)
spark.iop.org/seeing-light-activity

Hearing a laser beam (14-16)
spark.iop.org/hearing-laser-beam

How lasers work (16+)
spark.iop.org/episode-504-how-lasers-work

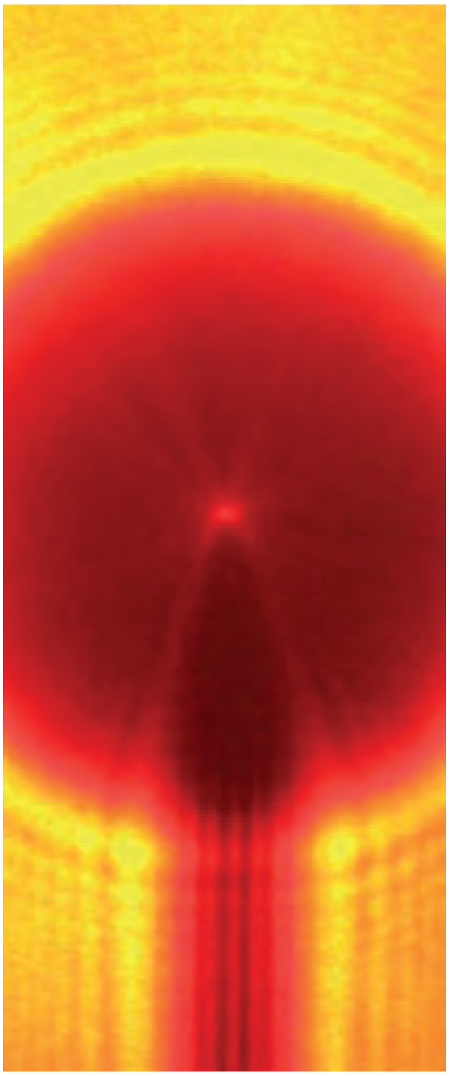
Physics*education*

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

Physics Education editor Gary Williams highlights his favourite papers on **sound and waves** from the archive (this page) and picks his top articles from the current volume (opposite page).

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.



Diffraction from a pin head (featuring Poisson's spot). The picture is seriously overexposed (hence the yellow colour) for artistic purposes as well as to bring out some hard-to-see details.

Demonstrations of wave optics

Interference and diffraction of light for large audiences using a laser and a multimedia projector

One of the first things I think about when I work on a demonstration is how I can make it bigger. I could show a standing wave on a rubber band, but that's a bit tame. Better, I could get a length of rubber or a rope and attach it to an electric drill with a bent nail as a bit. Bigger isn't just because I like the challenge - it quite often means that more students will get a better view of what's going on.

The authors of this 2011 paper describe how to set up projectors and lasers to show demonstrations on a bigger scale, include Poisson's spot. If you are not familiar with this, it provides evidence for the wave nature of light. Behind the shadow of a spherical object like a ball bearing or the end of a pin, right in the middle of the shadow where it should be darkest, there is a small spot of light! You can only really explain this as constructive interference of waves as they pass around the sphere.

more...
bit.ly/PEDivanov

Cool things to do with lasers

This paper from 2007 covers the physics of laser cooling. It states: "Laser cooling hinges on three well known processes, which we will now review. They are: radiation pressure, the Doppler effect and resonance."

But there is plenty of interesting physics for 16+ students to get their teeth into and all set in an up-to-date context, as the paper also covers absolute zero, the de Broglie relation, energy levels, circular motion, Bose–Einstein condensation, magnetic fields and ends with a worksheet!

more...
bit.ly/PEDlasercool

Light travels in straight lines?

A physical simulation of light propagation in a graded index optical fibre

This method for showing curved laser beams is fantastic for open days as well as in class. Seeing the red beam in the liquid is always impressive. It was written in 1992, when lasers were in their 30s, but it still has the wow factor, as the authors wrote: "We have found that even for experienced physicists this bending is quite startling at first sight, so familiar are we with the 'fact' that, on a macroscopic scale, light rays always travel in straight lines."

In this paper, not only do they describe how to make the beam curve one way, they also tell you how to make it curve the other way, which ultimately leads to an analogy of how optical fibres work.

Place a ball of black plasticine in the bottom of the tank and tell people it's the latest kit for the physics department, a small black hole. As evidenced by the curved space-time shown by the beam!

more...
bit.ly/PEDlines

Physicseducation

Studying the Oobleck with video-analysis

Credit: Shutterstock

This paper is the excuse you needed to play with Oobleck

In 1949, Theodor Seuss Geisel, known as Dr Seuss, published the book Bartholomew and the Oobleck. It follows the adventures of a little boy named Bartholomew Cubbins, who must rescue his kingdom from a kind of sticky green goo called 'Oobleck' . Because of this, scientists use the name Oobleck to refer to a solution of cornstarch in water which appears thicker or thinner depending on how it is physically manipulated.

Oobleck is an interesting example of a non-Newtonian fluid. With a high impact, it behaves like a solid and feels like a lump of rubber. But move slowly and you can pass your fingers through it like it is a liquid. In this article, the authors use video analysis and a large bowl of Oobleck to study the behaviour of sports balls as they fall from a height and bounce on the surface of the Oobleck.

more...
bit.ly/PEDoobleck

Using Möbius strip to describe non-integral spin of electrons

If you have ever looked at a Möbius strip and wondered how you might use this fascinating idea in your teaching, then take a look at this article. It presents a simple demonstration that can be used in secondary school to explain the meaning of the half-spin of fermions like electrons. You can use a simple-to-construct Möbius strip to distinguish 2π and 4π rotations of a point moving on the strip. This idea can then be extended to a pointer/arrow (in classroom settings, say a pen representing a classical analogue to the intrinsic spin vector), to show how a 4π rotation is needed to return the pointer, to its initial configuration with respect to the strip.

more...
bit.ly/PEDmobstrip

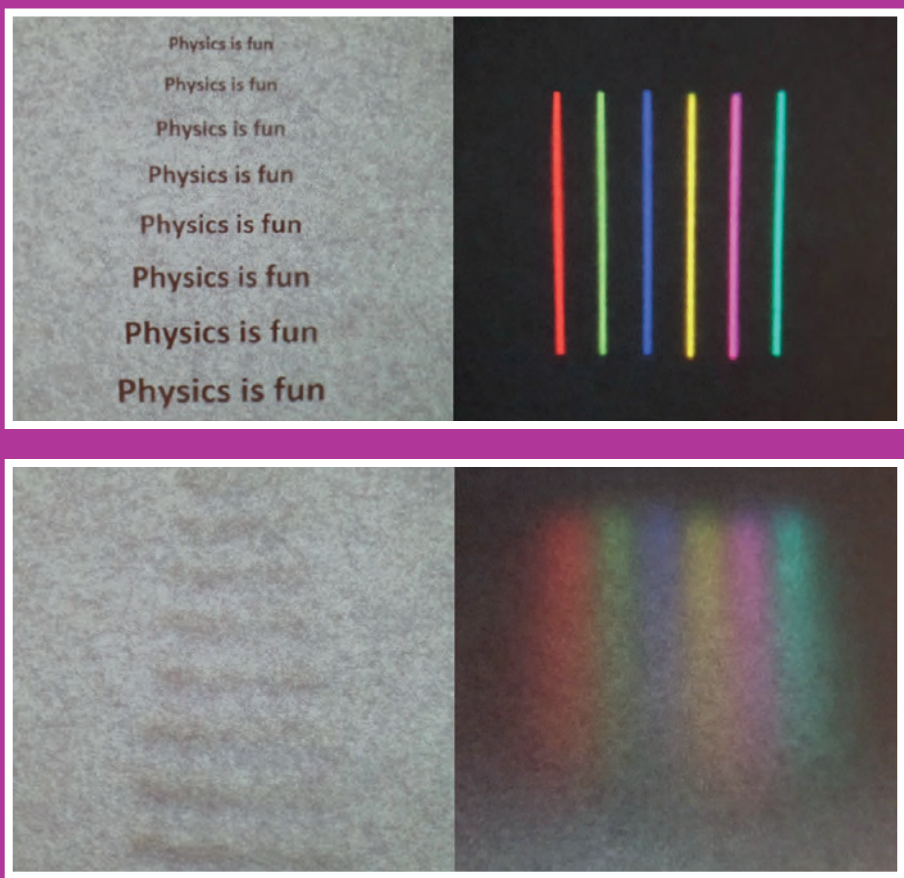
What happens next?

Why do the images behind the paper become blurry?

If a piece of paper is placed on a computer, television or mobile phone screen, the images on the screen behind the paper can be easily seen. If the paper is moved away from the screen, these images start to become blurry. What is the reason for this phenomenon?

Find the answer at

bit.ly/PEDblur



Credit: IOP

Why can we see images clearly through a piece of paper on a screen, but they blur as the paper moves away?

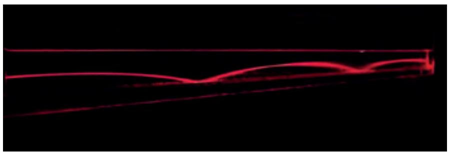
talkphysics

Dave Cotton, editor of our online discussion forum, writes about a recent webinar. Log in or register to join these discussions at **talkphysics.org**

Tales from TalkPhysics

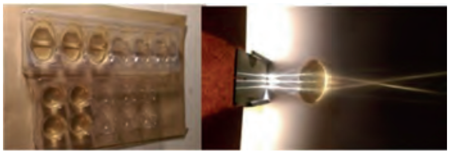
A session at one of our summer CPD events saw IOP Coaches talk about their favourite discussions from **bit.ly/TPsouth2020**

Jelly lenses
Kerry Colyer told us how she used the idea of showing refraction with different solutions in petri dishes and showing students lenses made from jelly. The original thread was for an idea for primary school liaison.



bit.ly/TPrefractdemos

Refraction tank
Nic Mitchener, a regular contributor, joined the session to show some of the great demonstrations he shares on TalkPhysics. This one, the bending of light in a refraction tank, is great for teaching graded optical fibres.



bit.ly/TPreftank

Homopolar motor
Another regular demonstration from TalkPhysics is the homopolar motor – it was number 7 in our Top 10 Demonstrations poll. The motors are easy to set up and have a real wow effect when seen by students.

bit.ly/TPhomopolar

Infrared cameras in the classroom
Mark Ormerod showed us a great set of experiments you can do with a thermal camera. He followed his dog's trail from the heat from the paw prints. He also showed how far the heat from his hand had passed through the pages of a book.

bit.ly/TPinfra-red

Beta balloons
The session ended with another regular, the physics of balloons. So many ideas with balloons inside other balloons including modelling beta decay.

bit.ly/TPballoons

The Fun Fly Stick
This seems to be a regular at IOP CPD. There are lots of Marvin & Milo electrostatics ideas using Fun Fly Sticks.

bit.ly/TPflystick

physicsworld

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

Credit: Shutterstock

Making images with sound

The next step in 3D animation could actually be, well, 3D. Researchers at the University of Bristol are manipulating objects by balancing the pull of gravity with regions of high air pressure built up from sound waves. Changing the sound waves produced by an array of speakers allows them to precisely move a small polystyrene ball to trace out images in the air. This can build up a persistent image in our vision if the frequency is high enough for the ball to draw out the image in 0.1 seconds or less. The image can then be coloured by using external lights to illuminate the ball throughout its flight.

Find out more in the full article:

physicsworld.com/a/making-images-with-sound/

Fighting flat-Earth theory

As a physicist, it can be hard hearing about followers of the flat-Earth theory. Everything we have trained for has taught us the logical arguments to dispel this conspiracy: watch the motion of stars across the sky, observe a Foucault's pendulum moving around a dais throughout the day or simply flick though a hoard of photographic evidence. Author Rachel Brazil argues, however, that this might not be enough. Convincing flat-Earthers that the theories aren't true is more challenging than just presenting the physics as believers "seem to have a very low standard of evidence for what they want to believe but an impossibly high standard of evidence for what they don't want to believe".

Read the full story:

more...
physicsworld.com/a/fighting-flat-earth-theory/

Science and Technology Facilities Council

Credit: Shutterstock

Find out how to measure the speed of light using chocolate buttons and a microwave by visiting the **#STFCscienceathome** social media campaign's tweet at **bit.ly/STFCchoc**

Unusual applications for laser science

The Central Laser Facility (CLF) at the STFC Rutherford Appleton Laboratory is one of the world's leading laser facilities.

In March, it invited rapid access proposals to its Octopus imaging facility for research relevant to the SARS-CoV-2 virus and COVID-19.

Here are some other unexpected ways lasers are used which yourstudents might enjoy:

Shock and awe: unlocking the power of the Sun

The CLF is exploring the possibility of tapping the power of the Sun by creating a 'star in a lab'. With a recently proposed method of laser-driven fusion called 'shock ignition', scientists are hoping to recreate the Sun's nuclear engine here on Earth. The process, which uses a form of hydrogen found in seawater called deuterium, has the potential to unlock a limitless source of cheap, carbon-free energy.

bit.ly/STFCsun

Viewing art through the scientist's lens

A team of scientists from Polytechnic University of Milan have used a technique called Raman Spectroscopy at the CLF to study the chemical make-up of pigments used in a series of Russian paintings from the early 20th century. The results, which were able to identify the types of pigments used and when the paintings were created, could also be used in future art restoration and conservation projects.

bit.ly/STFCart

How to beat a mind-controlling parasite

CLF scientists have made a breakthrough in understanding how a parasite called Toxoplasma gondii reproduces with its host. The parasite causes toxoplasmosis and can infect almost any warm-blooded animal but reproduces in cats. It can control the behaviour of its host and is thought to infect as much as half the world's human population.

bit.ly/STFCparasite

CLEAPSS

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**

Problems with laser pointers

Laser pointers can be obtained from online sellers for a small cost, initially making them seem attractive for use in class practical work.

However, we are finding that the cheap pointers are often unsuitable because they are not Class 2 lasers, even though they are advertised as such. Their power output is often much higher. Public Health England examined laser pointers sold as Class 2 and found some were Class 3B.

We have also measured the power output of cheap laser pointers here at CLEAPSS and worryingly, found many had power outputs over 10 mW, even though they were advertised as 1 mW. At these power levels, your natural aversion response (blinking and looking away) is generally not quick enough to protect you from injury following accidental direct exposure to the beam.

In addition, some cheap green laser pointers have been found to emit unacceptable levels of infrared light, which would cause eye damage if viewed directly. Since the infrared emission is outside of the visible range the affected individual would be unaware of the emission.

We are not suggesting a ban on laser pointers for use in science practicals, but please be careful with your choice of supplier. Choose a supplier who has a reputation to protect and with whom you can communicate easily if you have concerns or want additional information (we recommend RS Components, Rapid Electronics, or Farnell). Check the advertising information and datasheets carefully, make sure it says the device is CE marked and Class 2 (not just 'less than 1 mW').

We want to stress that this is not a fuss over nothing. A recent publication in the journal of the Royal College of Ophthalmologists reported serious eye injuries to children who had misused laser pointers.

more...

CLEAPSS guide PS052 Lasers, Laser Devices and LEDs

bit.ly/CLEAPSSlasers

Stories from physics

Laser tales

A close shave

In the early days of laser technology, the power of lasers was measured by their ability to burn through razor blades. A laser with a power of one Gillette could burn through one razor blade in one pulse.

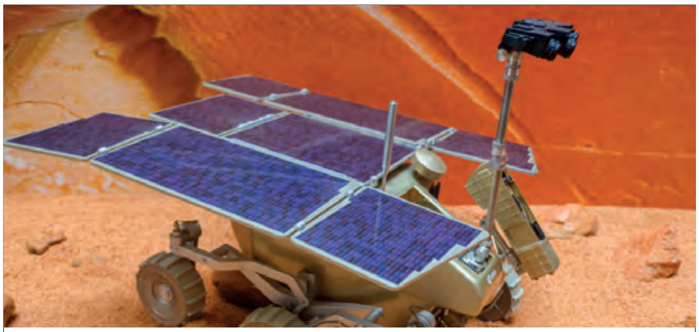
A natural space laser

From 1974-1995, NASA scientists used a jet transport aircraft named the Kuiper Airborne Observatory (KAO) to carry out research in infrared astronomy. They fitted a 36-inch infrared telescope to a Lockheed C-141A Starlifter, allowing observations to be made above much of the infrared-blocking water vapour in the atmosphere. The KAO made significant discoveries including the first imaging of Uranus' rings and the detection of an atmosphere around Pluto. During a flight from Hawaii to California, the KAO detected a characteristic feature of laser radiation in the spectrum of a gas and dust cloud surrounding the star MWC 349. Just as in an artificial laser, intense ultraviolet radiation from the star excites hydrogen atoms in its cloud in a process known as pumping. When infrared radiation from the star is absorbed by the hydrogen atoms, they emit an infrared laser beam.

Jelly lasers

Theodore Hänsch, a German postdoctoral student, travelled to Stanford University to continue his research on lasers. With his supervisor, Arthur L. Schawlow, Hänsch worked on developing dye lasers, devices which use organic dyes as the material which amplifies radiation. Whilst "playing around in the lab", Hänsch found that if he fired the beam at a drop of sodium fluorescein solution (a fluorescent tracer used by forensic scientists to detect blood stains) that was hanging from the point of a pipette, the drop acted like a tiny laser and emitted its own beam of green radiation. His supervisor saw a photo of this and decided "anything will lase if you hit it hard enough!" The pair experimented by firing a laser at 12 different flavours of jelly and found that, whilst the desserts fluoresced, they didn't display any laser action. Schawlow consumed the disappointing jellies for his breakfast. Undeterred, they made a jelly using clear gelatine with a little sodium fluorescein added and successfully constructed the first jelly laser. Whilst sodium flourecein is not toxic, Schawlow did not consume this functioning, but presumably not terribly tasty, laser. The jelly laser led to the development of a distributed feedback laser (a type of laser diode used in sensor technology) by Bell Laboratories.

These stories were collected by Richard Brock, lecturer at King's College London and former physics teacher. Follow him on Twitter



Telescopes on Mars during National Astronomy Week 14-22 November 2020

During this week, Mars will be easily visible through telescopes in the evening sky - it won't be as close again until 2035. Astronomers up and down the UK will be holding observing sessions with their telescopes, to make sure that as many people as possible get a chance to see Mars through a telescope, as well as Jupiter, Saturn and the Moon.

National Astronomy Weeks take place when there is a big astronomical event that will get everyone talking. Previous NAWs have marked the return of Halley's Comet, the close approach of Mars in 2003 and the 400th anniversary of the invention of the telescope.

Find out more at **astronomyweek.org.uk**

Measurement at Home

This series of online measurement challenges enables experiments at home using readily available equipment and comprises simple instructions, a short video and a worksheet. Results submitted to NPL inform a report summarising findings, which often contains surprises and ideas for further research.

Some challenges are reminiscent of awarding bodies' required practicals – eg 'Measuring the speed of sound using toilet rolls' has a striking resemblance to EdExcel's 'Speed of sound'.

npl.co.uk/mah

NPL

Virtual Physical Laboratory: lifeline for lockdown lab lessons

We've been providing interactive experiments (including highlighted required practicals) from the Virtual Physical Laboratory (VPLab) for use by students at home. Teachers email with requests for specific simulations for students to run at home to support their learning. Online demonstrations to new users and complimentary licenses for the full VPLab are also available to UK teachers who attend a demonstration (online or in person).

npl.co.uk/resources/virtual-physical-laboratory

VPLAB

How can you help your students look to the future?

Nuffield Research Placements are engaging, hands-on experiences, where students work with a host organisation to make a meaningful contribution to an active research project.

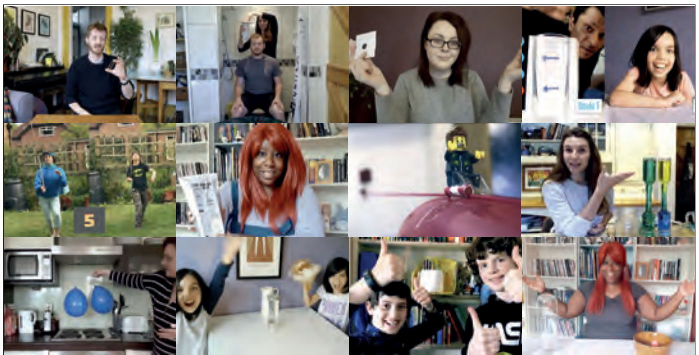
They are a fantastic opportunity for students to apply skills and knowledge learned at school and work alongside science, technology, engineering or maths (STEM) researchers and industry professionals.

The placements enhance UCAS personal statements and applications to higher education. Students also learn more about different career paths and can use their project to apply for a Gold CREST Award or the Big Bang Competition.

For eligibility criteria and to apply, visit

nuffieldfoundation.org/students-teachers/nuffield-research-placements

Nuffield Research Placements



Credit: Shutterstock

Do Try This at Home

Over the past months, the IOP outreach team created a new series of physics videos to help parents and carers get their children excited about science at home. The collection is now complete and they are well worth a watch, with plenty of simple ideas for practical activities and accompanying explanations. Highlights include:

- Ping Pong Pick Up
- Toilet Roll Solar System
- Rocket Balloon
- Waterproof Hanky
- Milk Carton Sprinkler

Check out all 13 videos at **iop.org/athome**

IOP Institute of Physics

Find an online IOP CPD event at talkphysics.org/events

Welsh Physics Teachers Conference Brecon 2020

5 - 10 October | Various times

A fabulous week of presentations and workshop for teachers, technicians and PGCE students with opportunities to network with colleagues online.

bit.ly/IOPbrecon20

A Day for Everyone Teaching Physics

10 October | 10am - 2:30pm

Organised by the IOP and Northumbria University, sessions will be led by experienced coaches and presenters.

bit.ly/IOPyorksne20

East Midlands Annual Teacher Network Day

7 November

Contact nealgupta@talktalk.net

Observing and exploring space – a NASA in Aberdeen workshop

3 November | 5 - 5:45pm

Using NASA materials to cover the bench-marks from the Scottish Curriculum for Excellence Experiences and Outcomes.

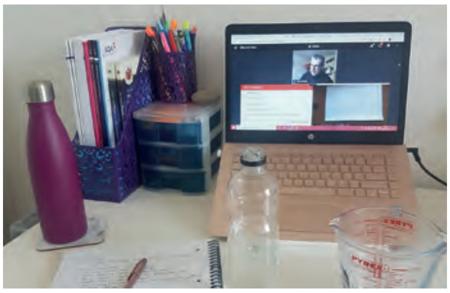
bit.ly/IOPbrecon20

Regional CPD Day at Bath University

5 December | 9:30am – 3:30pm

In partnership with the University of Bath.

bit.ly/IOPbath20



Credit: IOP

Grab a cuppa, a measuring jug and a thermometer and join an online IOP CPD session

IOP Domains: our new online CPD programme

Structured CPD

The IOP Domains CPD programme begins in September and runs through the academic year. Delivered entirely online, you are welcome to join as many sessions as you like. Each half-term, we will focus on a particular physics topic to match the domains on IOPSpark (Forces, Energy & Thermal Physics, Electricity & Magnetism, Light, Sound & Waves, Matter & Nuclear Physics and Earth in Space). Each week, we will cycle through a series of audiences including early career teachers and more general audiences. There will also be reflective sessions and ones which respond to audience demand.

Other IOP CPD

Alongside this structured programme, our fabulous coaches will continue to run sessions and workshops around their interests and other topics beyond the basic curriculum. There will continue to be regional CPD days and one-off sessions run by the coaches alone and in conjunction with partners. As schools begin to allow in outside visitors, we expect these sessions to move gradually from being exclusively online to again being face-to-face and regionally focused.

You will find information about all our CPD events by visiting **talkphysics.org/events**

All the events listed above are open to all teachers of physics wherever you are in the UK or Ireland. We have included the locations to give an indication of the regional teams involved.

Contact your IOP regional education manager to find out about teacher support in your area:

Scotland
Stuart Farmer
education-scotland@iop.org

Ireland
Lucy Kinghan
education-ireland@iop.org

Wales
Cerian Angharad
education-wales@iop.org

England

Yorkshire and north east
Jenny Search
education-yane@iop.org

North west
Graham Perrin
education-northwest@iop.org

Midlands
Ian Horsewell
education-midlands@iop.org

London, East Anglia and Kent
Jessica Rowson
education-leak@iop.org

South
Trevor Plant
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For support running CPD, contact our Professional Practice Group

education-ppg@iop.org

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