March 2021 | Issue 56

Classroom physics

The magazine for IOP affiliated schools

Credit: Phyphox

Smartphone **Physics**

The lab in your pocket

Subjects Matter CPD report

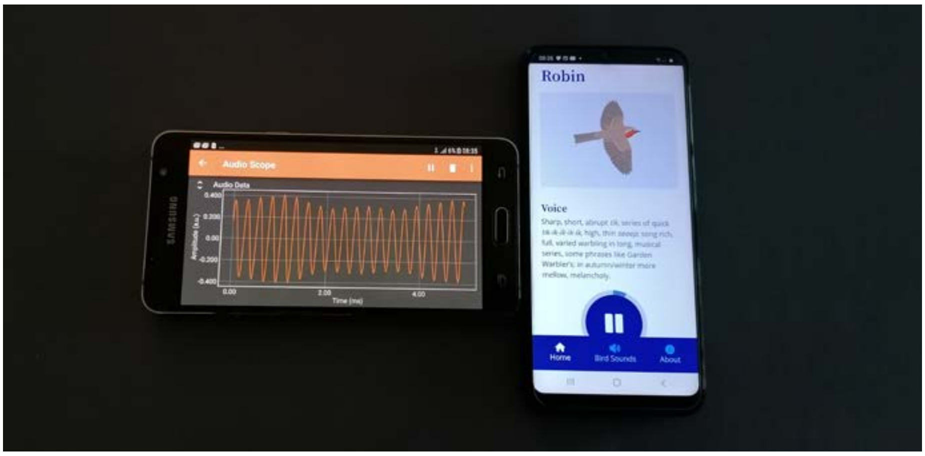
The Ten Most Beautiful Experiments - book review

iop.org

IOP Institute of Physics

This issue

Physics teaching and learning continues whether at home or at school



IOP coach Mark Whalley recommends using phyphox to display the trace of birdsong. Use the RSPB's birdsong playlist at **rspb.org.uk/birds-and-wildlife/bird-songs/what-bird-is-that**.

We want to start by saying a big thank you. To everyone who has contributed to enabling young people to continue studying physics during the past year, thank you! We recognise the hard work of teachers across the UK and Ireland, teaching physics in challenging circumstances and in ongoing uncertainty.

As ever, our team of teacher coaches is here to support you – turn to the back cover to find out how to get in touch with your local coach.

Thinking about how to make practical physics possible if students are not in school or if lab work is highly restricted, we have dedicated this issue of *Classroom Physics* to the physics lab in your pocket – your smartphone. We look into the physics behind it (page 6 **How sensors make smartphones smart**) and share some great ideas of how to use it in our centre pull-out (pages 9 – 12 **Smartphone Lab**).

You can also find other teachers' ideas for using smartphones in lessons on the digests pages – from journal articles (page 14 – 15 **Physics Education digest**) to **TalkPhysics discussion threads** (page 16) and **advice from CLEAPSS** (page 17). And of course, **Marvin & Milo** (page 13) have a clever idea that you or your students may be able to try at home or in the lab.

Our DOMAINS online teacher CPD programme has been a great success. As we write, the team are focussing their sessions on Waves. Next term, they will move on to Matter & Nuclear before finishing the year with Earth in Space. Each topic is accompanied by videos - you can catch up on topics you missed or prepare for your upcoming sessions at **iop.org/domains**. Book your sessions at **talkphysics.org/events**.

Finally, don't forget that we have a full suite of remote teaching and learning resources covering all curriculum topics across all age groups. Turn to page 19 or visit **spark.iop.org/covid-19**.

Keep well

Caroline Davis
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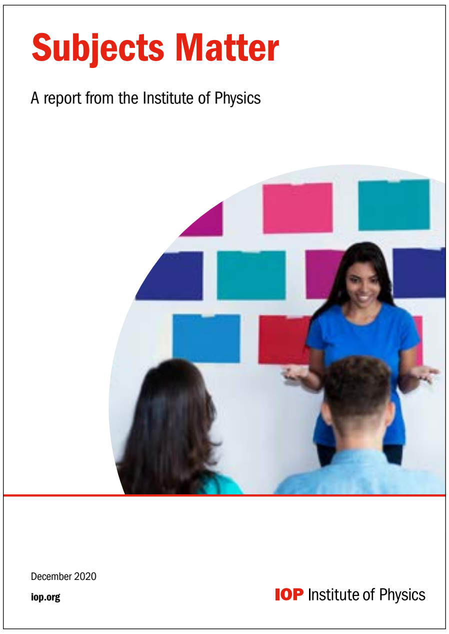
With this issue...

Pocket Physics x 5
For more copies email **affiliation@iop.org.** Students can have a copy sent to their home by emailling **qubit@iop.org**

Smartphone Lab activities x 2
Extra copies of the pull-out for your colleagues

Follow the IOP Education Department on Twitter @IOPTeaching

Invest in teachers to improve student outcomes, says IOP


Subjects Matter

A report from the Institute of Physics

December 2020

iop.org

IOP Institute of Physics

The Institute of Physics has published a set of recommendations for a systematic and joined-up approach to subject-specific CPD (continuing professional development). These have been published in our latest report Subjects Matter.

The report was developed in coalition with teachers, subject organisations and CPD providers from the UK and Ireland across all subjects.

A common feature of the world's best education systems is substantial investment in teachers' CPD, but levels of investment and participation in CPD are relatively low in the UK.

The report makes the case that a system of subject-specific CPD will improve teachers' ownership of their professional learning, help them to identify the right CPD at the right time and give them assurance that the provision is high quality.

High quality subject-specific CPD is particularly important in a teachers' early career or for a teacher teaching physics as an out-of-field subject. However, it is also important for developing new ideas and new approaches for more experienced, in-field teachers. As well as high quality professional learning being interesting, satisfying and motivating (everyone likes to learn new things and get better), Dylan William's tenet applies: "Every teacher needs to improve, not because they are not good enough, but because they can be even better."

We are recommending that a structured and systematic approach – with increases in funding, choice, access and quality assurance - will reduce the somewhat haphazard, piecemeal and lucky-dip approach to subject-specific CPD that currently exists.

We argue that, in so doing, we can improve participation in subject-specific CPD, increase the quality of teaching and therefore improve students' learning and outcomes. We are also hopeful that an increased participation in CPD events will help to build and strengthen local and regional communities of physics teaching - all of which can improve teachers' wellbeing and job satisfaction.

In addition, by increasing individuals' control over CPD, teachers will be more likely to invest their time in professional learning and have a greater sense of agency over their own teaching and their career, again features that have been linked with improved job satisfaction.

Emily Perry, Professor of Education at Sheffield Institute of Education, Sheffield Hallam University welcomed the publication of the Subjects Matter report, saying: "There is a strong body of evidence which shows that many teachers lack access to high quality CPD. Therefore, I welcome this report from the Institute of Physics, which draws together the evidence to propose constructive, achievable ways in which the UK governments can improve the quality and provision of teacher CPD.

"It's very helpful to see how teachers can be better supported to engage in subject-specific CPD, through changes in the culture, provision and its quality. The IOP has provided recommendations that will result in all teachers gaining access to high quality support to improve their subject and pedagogical expertise, thereby increasing their retention in the profession and improving the educational outcomes of children and young people."

more...

The full report and its recommendations are available at **iop.org/subjects-matter**

Recommendations:

1. **Improve professional standards through a systematic approach to developing teachers' subject knowledge for teaching.**

2. **Fund, develop and implement a national system of subject-specific CPD in each subject.**

3. **Establish an entitlement for teachers which ensures that at least half of their professional learning is subject-specific in a way.**

Institute of Physics launches challenging new podcast

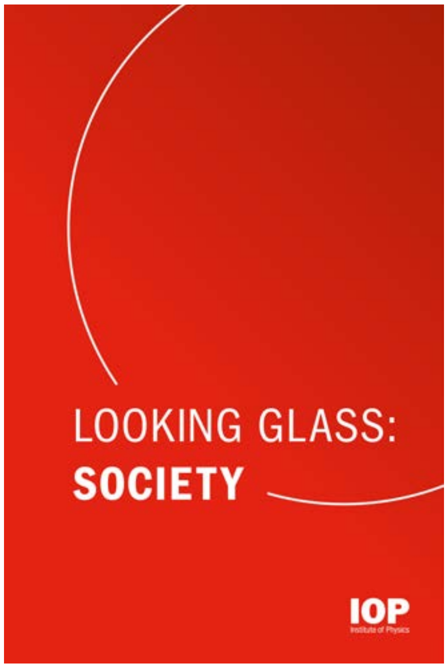
Our new *Looking Glass* series explores some of the most pressing challenges we face as a society – and asks what role physics has to play in solving them.

Host Angela Saini, an award-winning science journalist, talks to thought leaders and innovators on topics from healthcare inequality to climate change and cancel culture to the ethics of artificial intelligence to understand the issues and potential solutions.

Rachel Youngman, IOP deputy chief executive said: "We are living through a period where so many aspects of our society are being laid bare. We are seeing research that is normally hidden away in labs being played out on our TV screens every day. I hope *Looking Glass* will help us all to reflect on our role as active citizens. To explore the incredible ways that physics sits squarely in our society and helps our lives."

The podcasts are aimed at adults interested in how science influences and shapes society and are suitable for older physics students. They ask questions such as: "Can scientists offer sustainable solutions for climate change?", "How do we look beyond the traditional western scientific canon and be more reflective of other knowledge systems?" and "How can we ensure Big Data & AI are used for our benefit?" They may also be of interest to students beyond the science department so do spread the word.

Launched in IOP's 100th anniversary year, *Looking Glass* is also an inquiry into the purpose of a scientific institution in the 21st century, to help us understand how we must evolve to be part of a modern society, and help shape it.



more...

Looking Glass: Society is available through all major podcast apps and at:

iop.org/lookingglass or

play.acast.com/s/looking-glass

News from the nations

Credit: Shutterstock/Morozov Alexey

Scotland

This year, both the Stirling Physics Teachers Meeting and Physics Teachers Summer School will be taking place virtually rather than face-to-face with events planned over a number of weeks at the end of May and in June. Details of all the events, including how to register for them, will be available at **talkphysics.org/events**. You will also find details there of events presented by the IOP Scotland Physics Coaches.

Ireland

IOP Ireland Physics Hub takes place online every Thursday at 7pm during school term. It offers teachers the opportunity to share ideas relevant to the teaching of physics today. Each hub has a different focus and has previously covered topics such as remote teaching resources, assessment in physics, inclusion and more. Teachers are welcome to request topics for future hubs and share their ideas with their peers. Book your place via **talkphysics.org/events.** If you want to present your ideas, or request a topic for our next Physics Hub, please email **education-ireland@iop.org**.

Wales

In September 2020 the IOP team launched a series of GCSE Physics Welsh syllabus online CPD modules for NQTs and teachers of physics as well as delivering DOMAINS CPD sessions in Wales. Topics have included Stars and Planets, Further Motion concepts, Work, Energy Forces and Electricity. Online workshops are a fantastic platform to make new connections with schools, teachers and our coaches. If you would like to know more, contact us at **education-wales@iop.org**. The annual 19th Annual Welsh Physics Teachers took place in October. Over 800 delegates registered for the 44 sessions. We have also added more Welsh language activities designed to be easy to do with household items **spark.iop.org/collections/marfin-milo**

more...

See back page for how to contact your local IOP coach

2021
IOP Awards

Celebrating excellence in physics teaching

Excellence is everywhere in physics. It's in research, education and business; in people at all stages of their careers; in all parts of the UK and Ireland. The IOP Awards proudly reflect the full breadth of excellence that makes physics such an exciting discipline. We've made the nomination process and the judging more accessible and transparent and added the option to nominate yourself.

So whether it's your own or someone else's, let's share the brilliance of the work of the physics teaching community. Submit your nomination for the 2021 IOP Awards today.

For this year's IOP Teachers of Physics Awards, we're looking to celebrate individuals who demonstrate:

- Teaching excellence
- Staff development within the school or within a group of schools
- Work beyond the classroom
- Work with the wider educational community
- Inclusion

more...
iop.org/about/awards/teachers-physics-award

"She creates a **rich educational environment** and strives to remove any barriers to learning."

"Determined to **inspire future physics teachers,** he is an **encouraging and motivating mentor."**

"Her **enthusiastic leadership** has led to **physics** being one of the **most popular A-level** courses within the school."

"He is always **encouraging and reassuring,** inspiring his pupils **to believe that they can succeed."**

Limit Less careers in physics

National Careers Week took place during the first week of March. We ran a series of webinars for students aged 12 – 14 showcasing careers in physics and exploring the opportunities that studying physics can unlock.

The speakers came from all over the world of physics, including research and industry, well-known organisations and innovative start-ups. They talked about the diverse routes into these careers, including technical and vocational pathways, and the exciting possibilities that an apprenticeship could bring.

Themed around the role of physics and physicists in addressing global challenge, the sessions were:

- Climate Change
- Robotics and Artificial Intelligence
- Physics in Medicine

This events were part of Limit Less, the new campaign from the Institute of Physics to support young people to change the world and fulfil their potential by doing physics.

more...

If your students weren't able to join the webinars live, we've uploaded them to watch anytime at **iop.org/careersweek.**

Support young people to change the world

Limit Less is our campaign to support young people to change the world and fulfil their potential by doing physics

Join the campaign by registering at **iop.org/LimitLess**

Credit: Shutterstock

Credit: Shutterstock

Even the most basic smartphones have at least 10 sensors - enough to allow anyone to transform their device into a powerful mobile physics lab.

How sensors make smartphones smart

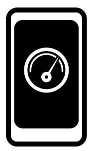
They are your guide when you are lost, your camera for snapping selfies, your digital wallet, DJ and games console, and they can even be your personal assistant. Oh, and you can also call people with them. Smartphones today are now so smart that many of us cannot imagine working, resting or playing without them. And a lot of these smart functions stem from some seriously smart sensors.

There is a dizzying array of microscopic sensors inside the latest smartphones. Even a bog-standard mobile will have at least 10 sensors packing enough punch to allow anyone to transform their device into a powerful mobile physics lab. Here is how five of the most useful smartphone sensors work.

Visit **physicsworld.com** and search for **smartphone** to find articles about how smartphones are being used in medicine, astronomy, particle physics and many more areas

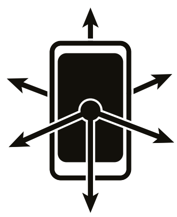
Common sensors in most smartphones

1. Accelerometer
2. Gyroscope
3. Magnetometer (compass)
4. Microphone
5. Proximity sensor
6. GPS
7. Ambient light sensor
8. Touchscreen
9. Barometer
10. Thermometer (internal)



Accelerometer

This measures acceleration (the rate of change of velocity) and, if you know the mass, they can be used to calculate the resultant force on an object. Though there are many different types of smartphone accelerometer, they all consist of a tiny electronic device etched onto a silicon chip known as a micro-electromechanical system (MEMS). Components of a MEMS accelerometer respond to acceleration mechanically – a movement or a stress. This induces a voltage that is used to gauge motion and orientation. Measuring acceleration in three dimensions, your phone can interpret accelerometer readings to switch off when dropped or tell if you are walking, running, driving or flying.



Gyroscope

Stabilising the International Space Station are four huge gyroscopes, almost as large as the station's astronauts. In contrast, your smartphone's electronic gyroscope is the width of a human hair. Unrecognisable to the scientists who first developed and used gyroscopes in the 18th and 19th centuries, smartphone gyroscopes are MEMS devices like accelerometers, but instead of responding to acceleration, the mechanical parts of the device respond to the phone's rotation. When combined, smartphone accelerometers and gyroscopes provide the motion and orientation information required for everything from auto-rotating your phone to enabling mobile augmented reality experiences.

IOP book recommendation:

The Ten Most Beautiful Experiments

Reviewed by Mark Whalley

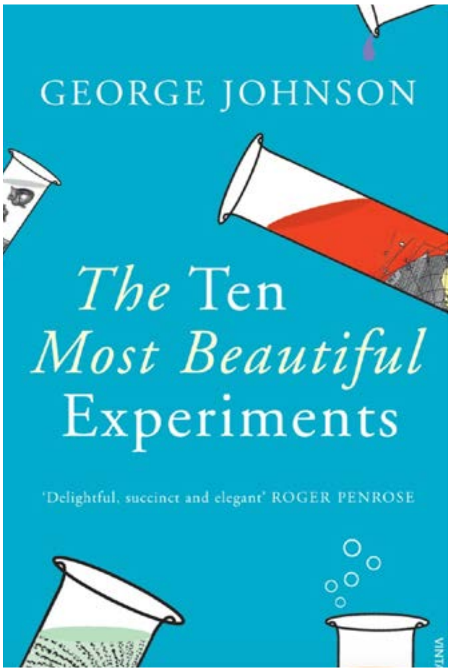
Stories really do matter; they add colour and texture to the content of lessons and bring out the human drama behind the equations and experiments.

This book by George Johnson is now 10 years old but it's a cracker and I think every teacher should have read it. Johnson gives us a glimpse into ten lines of experimental investigation across the sciences, six of which are definitely physics. They include an excellent account of Joule's mechanical equivalent of heat and also the rather alarming account of Newton experimenting on his own eye by inserting a bodkin between socket and ball and seeing how his perception of light changed! The beauty of this well-written book is that it provides valuable insight into 10 lives and experiments without the need to read 10 weighty biographies. The chapters are short and quick to read and you're sure to find something you can use in the classroom. A must for the bookshelf of all science teachers.

Mark Whalley has been an IOP coach for three years, has taught physics at every level over more than 25 years and has a special interest in astronomy

more...

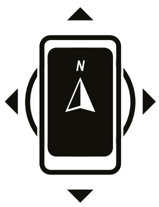
The Ten Most Beautiful Experiments by George Johnson is widely available from booksellers



Credit: The ten most beautiful experiments

Microphone

Arguably your smartphone's most important sensor, given its role in performing the phone's original singular task of calling people, the microphone is embedded in a pinhole just below the screen. Most smartphone microphones today are MEMS devices, essentially consisting of a charged diaphragm, a pre-amplifier and an analogue-to-digital converter. When you make a sound, air pressure moves the diaphragm, which alters the voltage across the membrane. This voltage is boosted by the pre-amplifier and finally converted to a digital signal that the smartphone can use.



Magnetometer

Your smartphone contains three MEMS-based magnetic field sensors, fixed perpendicular to each other, to find the direction of Magnetic North. These sensors are mainly used in navigation applications, starting up when you open Google Maps, for example. But some apps wield these magnetic measurements more creatively, allowing you to use your phone as a metal detector. Physicists use sophisticated magnetometers to measure space weather and events like coronal mass ejections, which send strong magnetic fields from the Sun out into the cosmos, scrambling technology here on Earth. Though challenging, you can analyse your smartphone's raw magnetometer data to spot these solar events too.

Proximity sensor

Consisting of an infrared (IR) diode and an IR radiation detector, your proximity sensor will be located at the top of the screen, near the receiver. It emits a beam of IR light, some of which bounces back if an object is about 10 cm or less from the device. When the IR radiation signal registers that the beam has been reflected back, this information can be used by the phone to automatically turn off the device's screen, as it typically means that the phone is close to your ear or in your pocket. This helps prevent unintended screen taps and needlessly draining your battery.

Physics education research

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

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

Experimental set-up for the study of acceleration of a smartphone moving on a ramp.

Credit: *Physics Education* IOP Science

Using mobile device dataloggers to support physics learning

Whilst there is much potential for the use of dataloggers on tablets and phones to support learning, the research evidence base on the use of such technology is currently rather sparse.

A 2016 paper considers how smartphone acceleration datalogging applications (the researchers used the Vernier Graphical Analysis and SPARKvue applications), impact secondary school students' conceptual knowledge of acceleration. In the study, 143 students aged 15-16 were randomly allocated to two groups. They were investigating a trolley rolling down a ramp and a simple pendulum - one group used smartphones, the other used normal school laboratory equipment.

The researchers report that the participants' understanding of acceleration was roughly the same across the two groups before the intervention, with all students struggling to define acceleration and interpret acceleration graphs. The data from the post-test suggests a very weak statistical difference in test scores between the control and condition group. The authors interpret this difference as providing preliminary evidence that smartphone datalogging may have some advantages. Whilst frustrating to not have a clear recommendation or 'best' way, the authors raise some interesting considerations for those developing teaching with smartphone datalogging tools.

Firstly, smartphone datalogging may have some advantages over traditional school laboratory work because it is the movement of the phone/datalogger itself that is being recorded – traditionally, technology would be used to measure a separate object. Typical school experiments are less direct, for example, measuring velocity and using those values to calculate acceleration. Smartphone dataloggers may allow students to better link the measurement of motion with the moving object. This distinction seems important and is something that could be emphasised in any experimental set up, clarifying if "what are we are measuring?" and "how are we measuring it?" are the same or separate.

The authors also note that there are ways in which the smartphone app may cause misunderstandings, observing that students' understanding of acceleration as a vector quantity did not improve from pre- to post-test. They speculate that this may have occurred because the application presents data from phone sensors in three axes (x, y, and z) perhaps causing students' difficulties in understanding the three-dimensional nature of acceleration. The output from many smartphone apps defaults to these three separate acceleration values, but can be set to show a single absolute (e.g. phyphox) or norm (e.g. FizziQ) value.

more...

Read Mazzella, A., & Testa, I. (2016) *An investigation into the effectiveness of smartphone experiments on students' conceptual knowledge about acceleration at* **bit.ly/PEDsmartphone**

Download the Vernier Graphical Analysis application: **vernier.com/product/graphical-analysis-4/**

Pull out and keep!

Smartphone Lab

What's inside:

Activity 1: Sound waveforms (11-14)

Activity 2: Speed of sound (14-16)

Activity 3: Period of a pendulum (16-19)

Student worksheet: Where on Earth am I?

The lab in your pocket

From microphones to magnetometers, modern phones are jam packed full of sensors. Coupled with the right app, they can transform into a mobile lab which can enable your students to investigate the speed of sound by just clapping their hands, or find the time period of a pendulum by attaching a piece of string. Our favourite app is *phyphox* (pronounced "fiffox"), which is short for "physical phone experiments".

Phyphox was developed by Sebastian Staacks and the team at Aachen University in Germany. "We originally developed the app for our introductory undergraduates physics lectures because we wanted an easy way for a large number of students to do experiments quickly to re-enforce what they were learning in the lectures," Sebastian explains.

After their success with university students, the team set up a website and made the app available to download for free from Android and Apple app stores. He continues, "Schools have become a major user, perhaps because they face similar challenges that we faced in our lecture series. If you don't have easy access to a lab, how can everyone participate in practical work? A smartphone with phyphox solves that!"

As more and more teaching moves online and the equipment that students can access becomes even more limited, phyphox has become ever more popular. The team have seen an increase of over 30% in downloads since the pandemic began inspired them to produce new activities called the "home lab challenge" – a collection of experiments specifically designed to be done at home.

Mark Whalley, our IOP education manager is a fan: "Phyphox not only gives easy-to-use measurements, but it also does lots of on-board analysis. There are plenty of opportunities to use it across the secondary curriculum in the UK. If you are using it in school for a demo you can cast the phone data to your laptop so the whole class can see. Although the thought of getting your head around a physics app can seem a bit daunting to some, once you've had a play you'll be inventing your own experiments before you know it. And how can you not love the applause-meter!"

In this pull-out, all the activities use smartphones and all of them can be done at home or in school.

- **Activity 1:** Sound waveforms using phyphox for 11 - 14 year olds
- **Activity 2:** Speed of sound using phyphox for 14 - 16 year olds
- **Activity 3:** Period of a pendulum using phyphox for 16 - 19 year olds
- **Student worksheet:**
  Where on Earth am I?
  Leads students through an activity from the National Physical Laboratory on accuracy in measurement in GPS data using another popular app,
  Physics Toolbox.

Credit: phyphox

Phyphox creator Sebastian Staacks and his favourite experiment: centripetal acceleration with a salad bowl spinner - instructions at **phyphox.org/2016/11**

more...

Download phyphox and explore their suggested experiments at **phyphox.org.**

Download Physics Toolbox and explore their website at **vieyrasoftware.net.**

Activity 1: Sound waveforms (11 - 14)

In this activity students use the phyphox app to investigate pitch and loudness of sounds

Equipment

Each student will need:

- A smartphone with the phyphox app installed
- Two different sized bottles with long necks (optional)

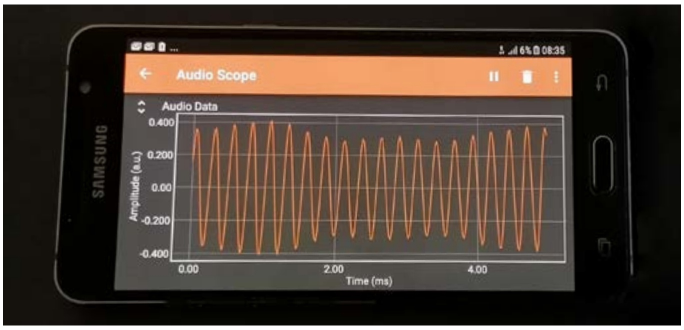
Procedure

Ask students to:

1. Open the phyphox app, click **Audio Scope** and press the play icon.

2. Whistle and observe the trace on the screen. If your students can't whistle, they can ask someone else to help or blow over a bottle to make a sound.

3. Whistle a loud, steady note but this time, pause the trace to see the waveform mid-whistle.



4. Repeat, but this time whistle more quietly. How does the waveform change with loudness?

5. Whistle with a high pitch and then a low pitch. How does the waveform changes with pitch?

Students should see that when the sound is louder the peaks of the waveform are higher. When the pitch is higher the peaks are closer together.

more...

Video instructions, a worksheet and extension material available at **spark.iop.org/whistling-waveforms**

Activity 2: Speed of sound (14 - 16)

In this activity students work with a partner at home (or in school) and use phyphox app to estimate the speed of sound

Equipment

Each pair of students will need:

- Two phones with phyphox installed

Procedure

Ask students to:

1. Place the phones 3 m apart.

2. Stand next to their phone and open the phyphox app. Click on the Acoustic stopwatch and press play. Their partner should do the same.

3. Clap once. When their partner hears the clap they should also clap.

4. Subtract the times displayed on the phones to find the difference. This gives the time delay for the sounds to travel 6 m (twice the distance between the phones).

5. Divide 6 m by the time delay to work out the speed of a sound wave.

6. Repeat for two more distances and find an average value for the speed of sound.

Teachers' notes

The acoustic watch starts counting when it hears a noise above a certain threshold and stops when a second noise is detected. The phone closest to the source of the noise will detect it before the other phone.

If the phones are a distance d apart and the speed of sound is v, the further away phone will detect a sound wave a time d/v after the nearby phone. In this experiment there are two claps, and so the total distance travelled is $2d$. Finding the difference between the times t_1 and t_2 displayed on the phones eliminates your partner's reaction time and gives the following relationship for the speed of sound:

$$v = \frac{2d}{t_1 - t_2}$$

Students should be able to obtain an estimate for the speed of sound of between 300 and 400 ms^{-1}. Echoes can cause erroneous readings. Students could try to identify sources of possible echoes and eliminate them, change location or increase the threshold on the acoustic stopwatch if this proves to be an issue.

more...

Video instructions available at **phyphox.org/experiment/speed-of-sound**

Activity 3:
Period of a pendulum (16 - 19)

In this activity students use the phyphox app to determine the gravitational field strength using a pendulum

Equipment

Each student will need:

- A phone with phyphox installed
- A length of string
- A small clear plastic bag which can be sealed (optional)

Procedure

Ask students to:

1. Open the phyphox app and click on **Pendulum**.

2. Click on the top right part of the screen and switch on **do a timed run** (use the default settings of 3 seconds for **start delay** and 10 seconds for **experimental duration**).

3. Securely attach the phone to one end of the string. For example, you could put it in a clear plastic bag and then attach the string.

4. Hold the other end of the string and pull the phone-pendulum to one side. Press play and let the pendulum go.

5. Keeping your hand steady, let the phone swing for more than 13 seconds to enable the app to record for at least 10 seconds. Make a note of the period from the reading.

6. Measure the length of the pendulum l (length of string + distance to centre of phone).

7. Repeat steps 4 to 6 for more pendulum lengths.

8. Plot a straight-line graph to determine the acceleration of free-fall g.

Teaching notes

If students are unfamiliar with the relationship for the period T of a pendulum introduce it:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

They can determine g by plotting T^2 against l (the gradient of the straight-line graph will be equal to $4\pi^2/g$).

more...

Video instructions available at **phyphox.org/experiment/pendulum**

Where on Earth am I?

Help the National Physical Laboratory to explore how good Global Positioning System (GPS) is and to see if being in a building affects location accuracy.

How long this activity takes

Estimated time: 30 minutes

What you need

- A smartphone (or tablet)
- Download of the free **Physics Toolbox Sensor Suite** app (from Apple or Android stores)
- Pen and paper

What to do

1. Watch the video at **bit.ly/NPLwhere**
2. Open the Physics Toolbox app and click on **GPS**
3. Choose a location indoors. Wait 2 minutes for values to settle and make a note of the latitude reading (if the readings don't settle, take a photo and jot down the value from that)
4. Move your device about 100 paces from your measurement position. This forces the GPS on the phone to reset
5. Return to your measurement position to record latitude again (again wait 2 minutes for it to settle)
6. Repeat step 4 and 5 to collect a total of five latitude readings
7. Calculate the difference between the smallest and largest values. e.g. 51.000051 - 51.000001 = 0.000050
8. Convert to metres by multiplying by 110000 m, e.g. 0.00005 x 110000 m = 5.5 m. This is your range for the indoor location
9. Repeat steps 3-8 but this time choose an outdoor location, away from trees and buildings. Record your observations in a table like below

	Weather conditions (sunny, cloudy, etc):	
Indoor location	Range in measured position (metres):	
	Number of walls between you and sky	
Outdoor location	Range in measured position (metres):	
	Surroundings (e.g.: how far from trees/buildings):	

10. You can share your results using the NPL webpage: **npl.co.uk/measurement-at-home/where-on-earth-am-i**

NPL

Mary Tsingou's explosive computer simulation

Video games graphics mean many readers will be familiar with simulated explosions. However, such animations owe a debt to a neglected Greek-American physicist, Mary Tsingou. After graduating, Tsingou started working at the Los Alamos National Laboratory doing calculations on mechanical calculators. With her colleague Mary Hunt, Tsingou progressed onto programming an early electronic computer, MANIAC I. Whilst MANIAC I was intended to be used for military applications, at the weekend, the Marys used the computer to solve physics problems and play chess. With John Pasta, she developed one of the first forms of computer graphics, using an oscilloscope to display a simulated explosion. Tsingou contributed to a paper, in collaboration with Pasta, Fermi and Ulam, related to a simulation of energy distribution in solids. The resulting publication is a seminal work in chaos theory. Tsingou was not added as a co-author on the paper, but mentioned as a co-worker, despite writing code for a simulation and producing graphs that were used in the publication. Since 2008, the neglect of Tsingou's contributions has been noted and the paper is usually now referred to as the Fermi-Pasta-Ulam-Tsingou paper.

The Harvard computers

Whilst the term computer typically brings to mind digital devices, it has also been used to refer to humans who perform calculations. At the end of the 1800s, Edward Charles Pickering, the director of the Harvard Observatory, became so frustrated with the ability of a researcher hired to analyse spectra that he is reported to have said: "My Scottish maid could do better!" He brought his maid, Williamina Fleming, into his team of analysts, which became known as the 'Harvard computers'. Fleming discovered many novae and variable stars and took the first recorded spectrum of a meteor. Another member of the 'Harvard computers', Annie Jump Cannon, developed extraordinary proficiency, becoming able to categorise the spectra of three stars per minute. Jump Cannon created the Harvard stellar classification system and like her colleague, Henrietta Swan Leavitt, who made significant contributions to the study of variable stars, had a hearing impairment. Whilst Pickering was progressive in encouraging women to contribute to research, the female members of his team were largely restricted to clerical work and typically paid half the salary of their male colleagues.

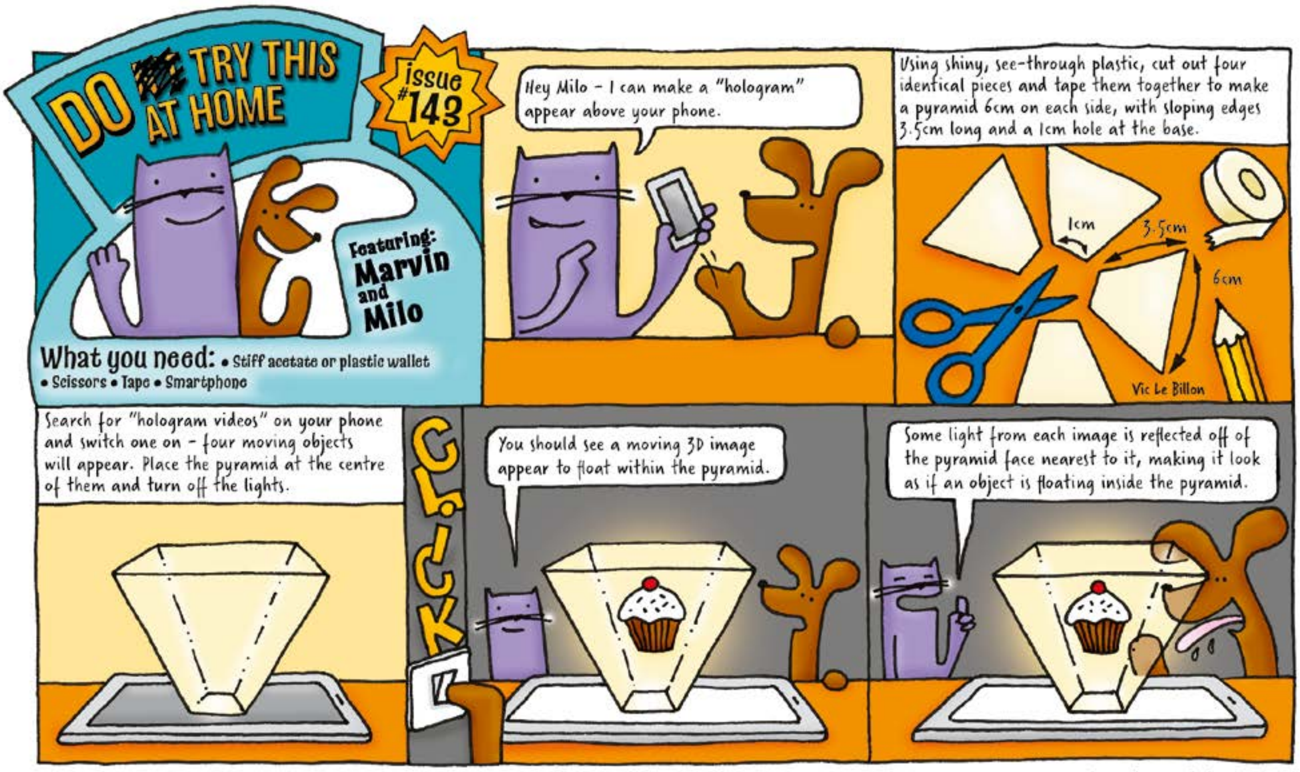
Calculating trajectories with mechanical computers

In the second decade of the twentieth century, the Royal Navy introduced table-sized mechanical computers to calculate the trajectories of projectiles, for example, the Dreyer Fire Control Table. The devices consisted of iron tables fitted with gears, rotating shafts and bicycle chains into which teams of seven sailors could enter data to target weapons. At the beginning of the Second World War, the American military attempted to develop mechanical computers that could calculate the trajectories of artillery shells. Before joining the Manhattan Project, Richard Feynman spent a summer at Frankford Arsenal working on this kind of analogue ballistic computer. One of the most sophisticated of these devices, the Ford Rangekeeper, could take inputs of the current position, direction and speed of travel of a ship and calculate where to target weapons to ensure a direct hit on a moving target. The Rangekeeper used a mechanical ball-and-cylinder system to solve integration problems.

more...

spark.iop.org/stories-physics

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



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

Physics*education*

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

Editor Gary Williams highlights his favourite papers on **smartphones** from the archive (this page) and the current volume (opposite page).

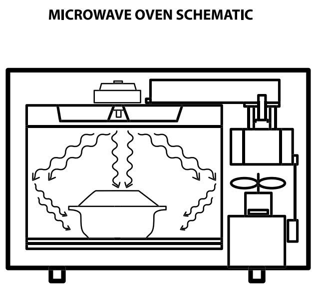
Access over 50 years of articles at **iopscience.org/physed**

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

Microwave ovens and mobile phones

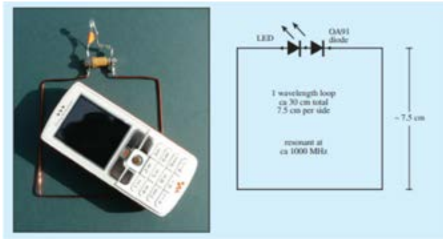
The first reference that I could find to modern day mobile phones in a *Physics Education* paper was that given in a paper about uses of microwave ovens in 2004. The authors describe a number of exciting demonstrations, including putting a mobile phone inside the Faraday cage of the microwave oven and the phone not receiving the signal when it is rung. They also point out that the microwave oven should not be switched on with the phone inside it - apparently it will cease to be a phone in a fraction of a second. After unplugging our microwave oven, I tried this with my partner's new phone and the result was the same - the signal did not get past the Faraday cage. The paper also contains details of how to do weird things with soap, how to explode eggs and what happens to chocolate figures wrapped in foil.

more...
Read the paper at **bit.ly/PEDmicrowave04**



Credit: Shutterstock/TrishaMcmillan

Microwave ovens act as Faraday cages but mobile phones can detect radiation leaking out



Credit: Physics Education

Detecting a mobile phone signal

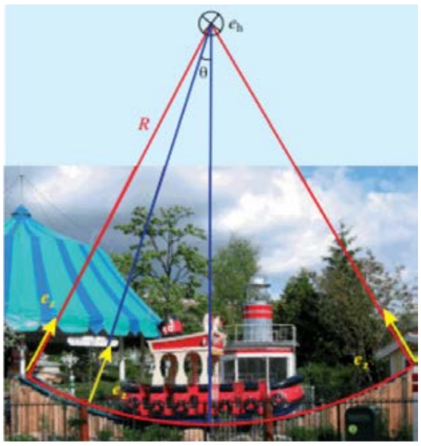
Jonathan Hare, from BBC TV's *Rough Science* and *Hollywood Science* series has written a number of papers for *Physics Education.* In this 2010 paper, he describes a way to detect a mobile phone signal with a very simple aerial, a diode and an LED. This was worth the effort although it took a little more work than suggested in the paper, requiring a couple of attempts and investigation of a different diode. Seeing the LED light up when the aerial, just a length of copper wire bent into a square, is placed near the phone, is magical. There is no cell, battery or capacitor in the circuit so the electricity is being generated in the wire by the electromagnetic waves emitted by the phone. I found it worked best when sending a text message rather than ringing someone. Jonathan then attaches the aerial to a datalogger to investigate the signals further.

more...
Read the paper at **bit.ly/PEDmobile**

Accelerometer and rotation in a pendulum ride

One of the first mentions I could find of a smartphone was from 2011. Ann-Marie Pendrill and Johan Rohlen used the accelerometers in the iPhone 4 to investigate the forces acting on a number of fairground rides. It is interesting to look at previous papers on this topic and see how the accelerometers were housed in increasingly smaller units until they could be incorporated into a phone. Looking through the *Physics Education* archive you can see this as a recurring theme with the smartphone ending up housing a wide array of sensors.

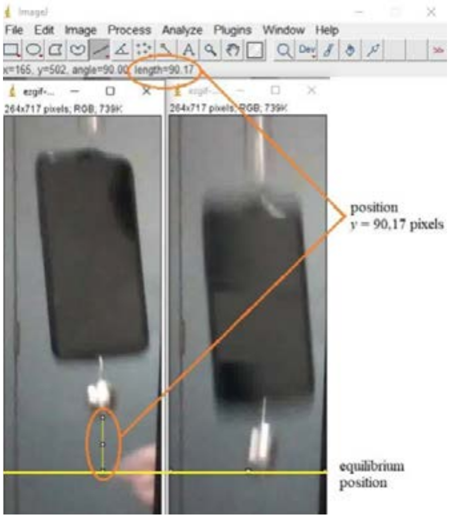
more...
Read the paper at **bit.ly/PEDaccelerometer**



Credit: Physics Education

The ride and the radius of the circular arc of the rail, which takes the place of the string in a pendulum

Physics*education*



Credit: Physics Education

Position calculation form video tracker frame using Image-J.

Comparing sensors

Activities designed for smartphones can sometimes be standard experiments or investigations where the smartphone has simply replaced the sensor or housing that was used previously without any improvement in pedagogy, accuracy or precision. In the paper *Comparison between the use of acceleration sensor and video tracker on smartphone for spring oscillation experiment* the authors compare measuring acceleration using the accelerometers in a smartphone to using video analysis. Given that students may have access to doing experiments by eye, with smartphone sensors, with Arduinos and sensors, and using video analysis, it really makes sense to have them investigate which is best across a number of applications. For this everyday experiment of a mass-spring system oscillating the authors found the accelerometer sensors in the smartphone have the most accurate results.

more...

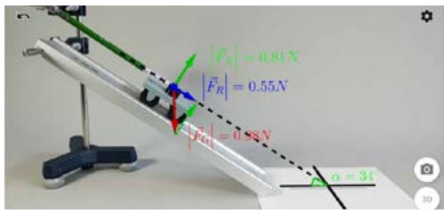
Read the paper at **bit.ly/PEDsensors**

Augmented reality

To really start to uncover the potential of smartphones and similar devices to improve teaching and learning we need to get to grips with AR (Augmented Reality). In AR, the camera of the device is used to show what is happening on a screen and then add some extra detail or information to it. So in the image shown here, the device is programmed to recognise the trolley and the ramp and to show the relevant arrows attached to them as the scene is being viewed live. Other AR simulations have shown particles in a container that speed up when taken towards a hotplate and slow down when taken towards a fridge.

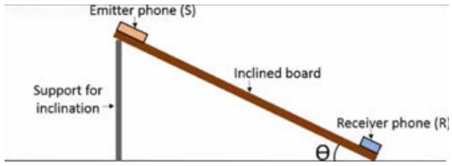
more...

Read the paper at **bit.ly/PEDar**



Credit: Physics Education

Experimental setup viewed through a smartphone during an AR experiment concerning forces on inclined planes.



Credit: Physics Education

Phone sliding down a ramp and velocity by sound

This next paper is included because I would never have believed it would work. If you can make it work too, the teaching opportunities it presents stretch well beyond this simple investigation. The authors have taken two phones and have one emitting sound and the other detecting it. One is placed at the top of a slope and the other at the bottom. The higher phone is allowed to slide down the slope. Using the Doppler effect, the acceleration of the phone is calculated. The authors have also used the software Tracker **(tracker.physlets.org)** to find the acceleration and provide convincing results. Having an opportunity to get your hands on an experiment that could link to astronomy should be very welcome.

more...

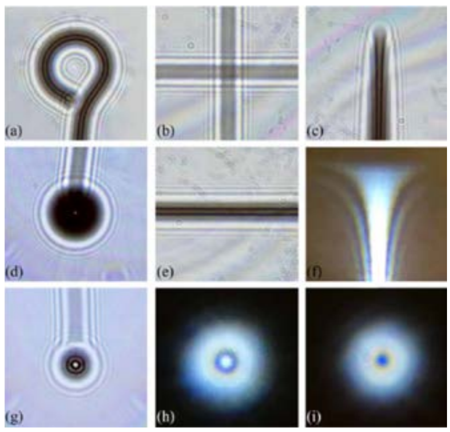
Read the paper at **bit.ly/PEDphoneslide**

Fresnel diffraction

The images showing Fresnel diffraction are very impressive and shown in the paper *Setup for studying Fresnel diffraction by photographing diffraction patterns using a smartphone.* The authors Mayer and Varaksina explain how to build the apparatus to take such images using a smartphone camera, although any camera ought to work. Of special note are the images showing the Poisson spot which demonstrates the wave nature of light. The spot is the bright centre point created by constructive interference of light waves in the centre of the shadow of an opaque object which according to corpuscular theory should not be there.

more...

Read the paper at **bit.ly/PEDfresnel**



Credit: Physics Education

Photographs of Fresnel diffraction patterns captured using a smartphone

Other recent articles

Teaching optics under lockdown: **bit.ly/PEDlockdownoptics**

Developing polarisation equipment **bit.ly/PEDpolarise**

Simulating polarised waves **bit.ly/PEDsimulatewaves**

How to fairly share a watermelon **bit.ly/PEDmelon**

Observing chaos **bit.ly/PEDchaos**

Scanning electron microscopes and seashells **bit.ly/PEDshells**

talkphysics

Dave Cotton, editor of our online discussion forum, chooses his favourite recent TalkPhysics discussion threads.

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

Mobile phone threads on TalkPhysics

Mobile phones and ways to use them have been featured in TalkPhysics threads for many years. Mobile phones have some good uses in the teaching of physics.

Phone drop

Would you drop yours from the top of the stairs? This was done at the Charterhouse regional day – you can watch the video including what is going on inside the box at **bit.ly/TPphonedrop**

Musical instruments

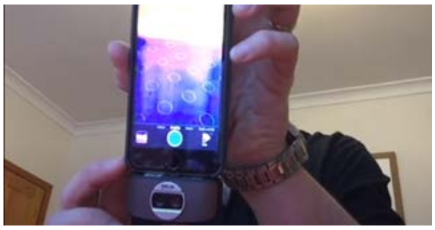
Last summer, IOP coach Cara Hutton ran a session titled Musical instruments with phyphox. You can find her slideshow below - it included discussions on how you could use some stringed instruments or tuned percussion (depending on the exam board) to add context/interest to the wave in a solid required practical.
bit.ly/TPmusicalphone

POP physics

See how IOP coach Joe Rowing uses phyphox to calculate the height to which a popper would jump in the air.

bit.ly/TPpopphysics

Infrared phone imaging



The CCD image sensor inside many mobile phones can be used to show the infrared when pointed at a TV remote.
bit.ly/TPremotecontrol

You can also get thermal cameras to add on to mobile phones (Flir is one manufacturer). You can watch IOP coach Alessio's webinar on their use here (it has one of my favourite density demonstrations at 8:14)
bit.ly/TPircam

physicsworld

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

Credit: Shutterstock/SergeyBitos

"Smart speaker, tell me about your acoustic sensor"

Many of us have wondered how much our devices are listening in to us, but have you ever asked not how *much,* but simply *how?* Pip Knight takes a deep dive to explore how acoustic sensors have evolved from their very first beginnings in the late 19th century. Remarkably, one of the most popular commercial designs, the condenser microphone, relies on concepts very familiar to any student of GCSE or A-level electricity. Pairing these devices with modern machine learning algorithms enables simple sound waves to be interpreted as fully coherent sentences. State-of-the-art inventions are exploring avenues for even more powerful devices with designs ranging from internal ear mimicry to holey-patches placed on a speakers throat; some of these could even be capable of offering early-warning signs of Covid-19.

Full article at **bit.ly/PWsensor**

Do quantum effects play a role in consciousness?

The light of the mind is blue, wrote the poet Sylvia Plath in The Moon and the Yew Tree, but it may actually be red. The role of biophotons in the brain is a growing area of research in neurobiology – and where there are photons there might be quantum mechanics. Betony Adams and Francesco Petruccione explore this developing, and contentious, field of quantum biophysics. Recent research suggests a link between intelligence and the frequency of biophotons in animals' brains. In 2016 Zhuo Wang and colleagues at the South-Central University for Nationalities in China studied brain slices from bullfrogs, mice, chickens, pigs, monkeys and humans that had been stimulated by an excitatory neurotransmitter. They found that increasing intelligence was associated with a shift in the biophoton's frequency towards the red end of the spectrum.

Full article at **bit.ly/PWquantumbrain** eic

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

Credit: Shutterstock

How wearable tech uses chemistry to help monitor your health

Personal fitness monitoring is a multi-billion pound industry. Devices such as smartwatches work by taking advantage of several core biological and chemical concepts common to everyone.

Smartwatches use a flashing green light to measure your heart rate from your wrist. Spectroscopy tells us that blood absorbs green light because red and green are opposite each other on the colour wheel. The rear of the smartwatch contains an optical sensor to detect the reflected light. The main difference from spectrometers is that the light source and detector are positioned on the same side in smartwatches, while they are opposite each other in spectrometers.

The device measures the change in concentration of red blood cells as the blood vessels expand and contract. The detector measures the reflected light and a software algorithm converts the changes in light intensity into your pulse rate.

The newest devices and software use advanced algorithms to monitor pulse rate data and detect issues such as atrial fibrillation (irregular heartbeat). Recent advances in battery technology have allowed for more sensors and a higher degree of accuracy in wearables.

The use of spectroscopy in personal fitness monitoring has progressed rapidly over the past decade. Technological advancements and miniaturisation have even put optical heart rate monitors into a ring that you can wear on your finger. Based on recent advances in materials science, Valeria Nicolosi, expert in nanomaterials and energy storage and a professor at Trinity College, Dublin predicts: 'There will be no reason to wear a smartwatch as we will be able to have clothes with seamlessly embedded sensors.'

John O'Donoghue,
RSC education coordinator

more...

Full article including a practical activity using kitchen cupboard ingredients with a smartphone to investigate how transmission of light changes with colour and concentrations at **rsc.li/3pJTaze**

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**

Using your smartphone with Arduino

If, like CLEAPSS, you are a fan of using Arduino in the classroom then the number of laptops available to get the data from the sensors may be a limiting factor. There are a number of alternatives to the serial monitor within the Arduino laptop software. One we approach that we have used successfully is to use a smartphone to view the data.

The Arduino is connected to the mobile device via a USB on-the-go cable (USB OTG). This will not only power the Arduino through the 5V USB connection, but will also show the data on the mobile device. Search your device's app store for 'serial monitor' to download a suitable app – we use UsbTerminal. No computer needed!

more...

GL255 - Arduino starter guide is at **bit.ly/CLEAPSSarduino**

Credit: CLEAPPS

A mobile phone displaying data from the CLEAPSS pressure sensor.

Credit: CLEAPPS

A mobile phone displaying data from the CLEAPSS light gate.

Got a physics NQT starting this September?

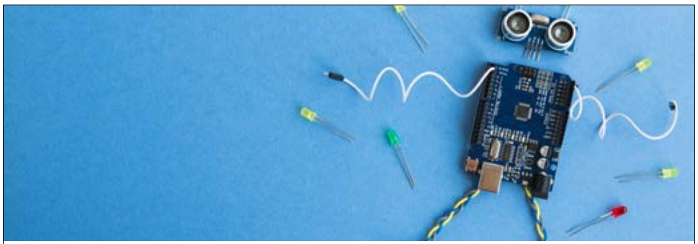
If so, you could be eligible to be part of a major national trial being run by the IOP. And you would receive £250 for your science department.

Once again, there are fewer than 600 trainee physics teachers in ITT this year, so we need to understand how to encourage as many as possible to enter and stay in the profession.

The KEEP Teaching trial is part of the IOP's work in this area. We're looking for 120 schools with physics teachers starting their NQT year this September. Could your school be one of them?

Schools and trainees can register interest **iop.org/keeptrial** and we'll send you more details.

IOP Institute of Physics



School Grants Scheme – what could you do with £600?

Over a quarter of a million students have already benefited from our School Grants scheme – thank you for these innovative and engaging projects!

And we are looking forward to the next set of proposals. The closing date for applications for autumn term ideas is 1 June:

- grants of £600 are available for projects, events and activities promoting physics and engineering
- we're particularly keen on promoting: particle physics, astronomy, space and nuclear physics, energy, transport, information and communications, design and promotion, and the built environment
- open to schools, colleges or home school groups based in the UK and Ireland

The scheme is run jointly by the Institute of Physics, Institution of Engineering & Technology and the Science & Technology Facilities Council.

iop.org/schoolgrants
#IOPSchoolGrants

Science & Technolog Facilities Council | IET The Institution of Engineering and Technology | **IOP** Institute of Physics

Lewis Matheson, who also works as an IOP School Based Physics Coach in Bath, runs the YouTube channel Physics Online. It is used by many students every month and features his popular weekly Monday livestreams with more videos are added every week.

His materials support A Level and all aspects of the GCSE course - including theory, worked examples and all the required practical activities. Everything is organised by topic and exam board. There are also materials to support teachers and technicians.

youtube.com/physicsonline

physicsonline.com

Note: this is not an IOP channel. Whist many of Lewis's resources are free, some are behind a paywall

Qubit

The IOP e-newsletter for students of physics aged 16 - 19

Qubit is written especially for school and college students studying physics. Subscribers can read about:

- what's new in physics
- exam and university guidance
- information about physics careers
- upcoming events and competitions.

Students can sign up at **iop.org/qubit**

Teaching & learning resources for remote/blended study spark.iop.org/covid-19

Resources by physics topic

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

Credit: Shutterstock/A3pfamily

Practical activities for pupils at home during lockdown

If you are suggesting practical activities that pupils could safely carry out at home, CLEAPSS has produced a guidance leaflet which discusses the implications of practical work at home (see GL339 – Practical activities for pupils at home during extended periods of school closure).

It is important to remember that some children may have limited adult supervision and some may have younger siblings. You also do not know enough about the environment that the pupils will be working in to be able to ensure that they are going to be safe. Remember, if you are going to suggest an activity the pupil's safety is still your responsibility.

Home environments typically have:

- No access to specialist equipment and chemicals. (Note: under no circumstances should chemicals or specialist equipment be sent home for use by pupils)
- No expert supervision (and possibly no supervision at all)
- No access to PPE
- No access to immediate remedial measures or First Aid
- No suitable disposal route.

This does not however mean that there are no worthwhile practical activities that could be safely carried out at home and activities originally intended for use in primary schools can be a useful starting point.

With this in mind CLEAPSS, has reviewed its range of practical procedures intended for use in primary schools. These activities are intrinsically safe and make use of resources available around the home or readily available cheaply from high street stores or online.

They can be used creatively by teachers to explore quite complex underlying scientific ideas, for example, through the addition of more challenging questions or a research task.

Finally, make sure your school has flagged up the practicals to parents through the channels it normally uses to get important messages home. You cannot rely solely on the pupils telling their parents/guardian.

more...

GL339 – Practical activities for pupils at home is at **bit.ly/CLEAPSS339**

DOMAINS CPD programme - through the curriculum through the year

Term 2020/21	Topic
Autumn 1 (late Sept)	Forces
Autumn 2 (early Nov)	Energy and Thermal Physics
Spring 1 (early Jan)	Electricity and Magnetism
Spring 2 (late Feb)	Light, Sound and Waves
Summer 1 (mid Apr)	Matter and Nuclear Physics
Summer 2 (early June)	Earth in Space

Browse and book at talkphysics.org/events

Each term, we concentrate on a different topic, supplying you with videos followed up with online workshops. Sessions are tailored to your level of teaching experience from early career through to experienced teachers and providers of teacher CPD. We list the sessions regionally to help you get to know your local IOP team and meet other teachers in your area. But you are welcome to register for any online sessions that take your fancy.

Coming up in the summer term...

Matter and Nuclear Physics

You'll see lots of ideas for using models to teach these two important areas, from states of matter and internal energy in the matter section, through to models for radioactive decay and to help understand the strong force in the nuclear section.

Earth in Space

Our final set of videos and support sessions will focus on the elements of astronomy taught in secondary science and physics.
For 11 - 14s, we look at the scale of space; for 14 - 16s, we discover the speed of space before exploring the stuff of space for 16 - 19s.

Missed a topic? You can catch up on the CPD videos at **iop.org/domains**

Other IOP teacher CPD events

19 March 2021
Woah! – The Physics of Viral videos
4:00-5:00pm
bit.ly/IOPviral

24 March 2021
Citizen Science CPD event with Lancaster University Physics Department
All Day
bit.ly/IOPcitizenscience

31 March 2021
Improving literacy and exam technique at KS5
4:00-6:00pm
bit.ly/IOPliteracyKS5

30 April 2021
Geogebra – A Step-by Step Introduction for Physics Teachers
4:00-5:00pm
bit.ly/IOPgeoge

14 May 2021
Projectiles & Suvat
4:00-5:00pm
bit.ly/IOPsuvat21

15 June 2021
Sustainability Physics: Teacher CPD event with Lancaster University Physics Department
All day
bit.ly/IOPsustain

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
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England

Yorkshire and north east
Jenny Search
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London, East Anglia and Kent
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Trevor Plant
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For support running CPD, contact our Professional Practice Group

education-ppg@iop.org

Classroom Physics is published by Institute of Physics, 37 Caledonian Road, King's Cross, London N1 9BU, UK. Tel 020 7470 4800.