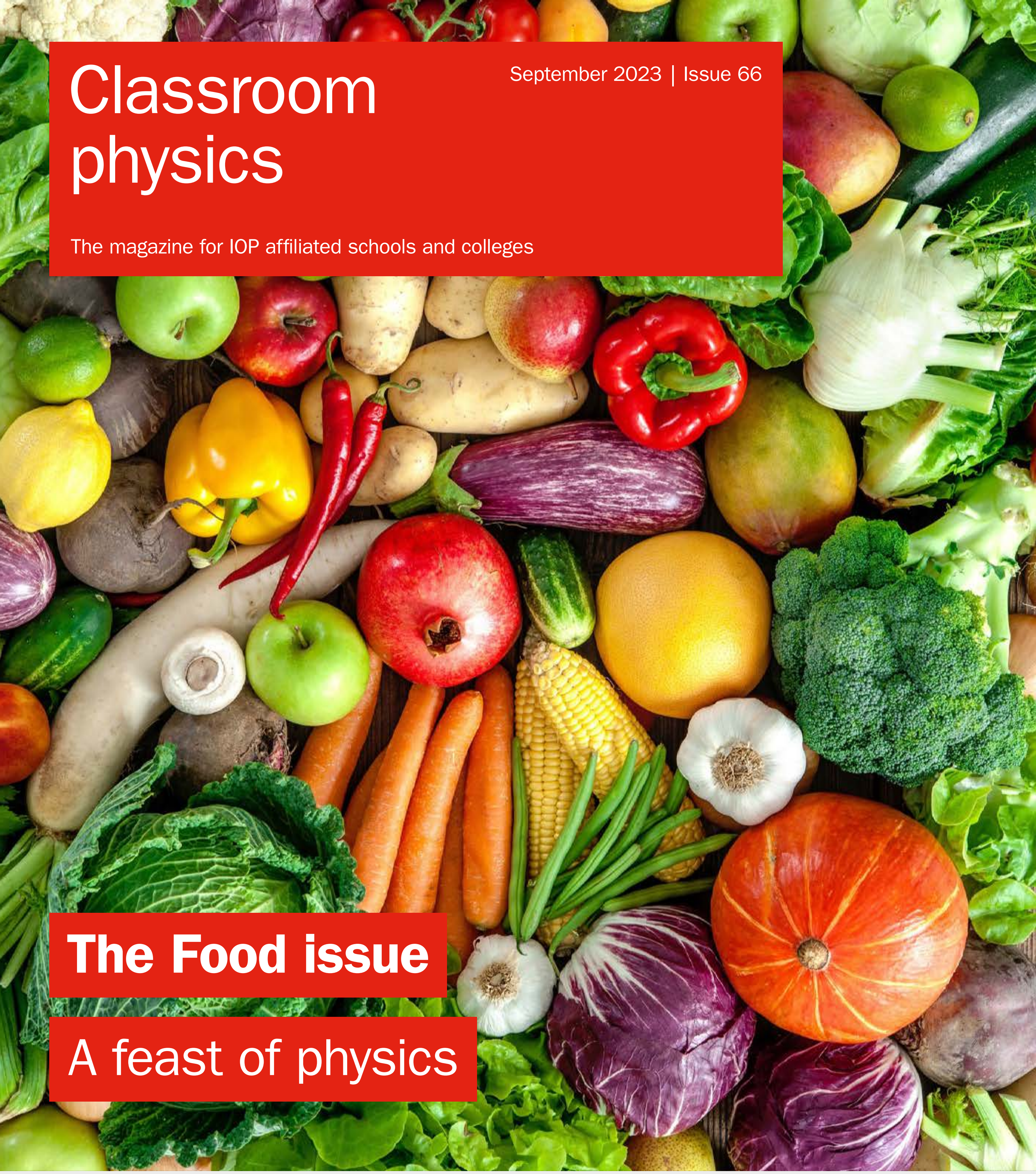
September 2023 | Issue 66

Classroom physics

The magazine for IOP affiliated schools and colleges



The Food issue

A feast of physics

Cool running: explaining refrigeration

Making waves: teaching oscillations with everyday cooking ingredients

Was Einstein a veggie?

iop.org

IOP Institute of Physics

This issue

Credit: Shutterstock

Editor's note

Welcome to the first issue of the new school year. We hope you had a great summer break.

Food is a fruitful topic for physics teachers. This issue is full to bursting with tasty teaching tips, succulent subject knowledge… and the odd half-baked food metaphor.

Our pull-out section (pages 9–12) shows some novel ways that food can play a part in lessons about waves and oscillation – both as a means to root physics learning in objects and materials that are part of students' everyday lives, but also to demonstrate the impact of physics on technologies and processes that we all rely on.

Another example of a physics-driven staple of our daily lives is the fridge, the focus of our feature article on page 6. It's such a standard piece of kit and yet can be challenging to explain.

Digging deeper into the hidden physics that makes so much of the modern world work, we also look at how physics innovations are changing the way we grow food – from space-based land analysis to AI-driven pest control (see page 7). Linked with this article are information sources about career opportunities in food technology and related areas – including for school leavers with science and maths skills.

We're again grateful to the many organisations and individuals who have sent us content and resources to include, which cover topics as diverse as what astronauts eat in space and the controversy of coloured sprinkles.

Finally, be sure to look out on page 20 for opportunities this term to engage with our teams around the UK and Ireland, whether in person or online.

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

One of six green engineering careers posters with suggested discussion points and homework tasks on the back.

Download or order all six at: **neonfutures.org.uk/resource/green-engineering-careers-posters/**

Follow us on Twitter **@IOPTeaching**

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

IOP activities round-up

The IOP team hosted a wide range of events during the summer term.

At the end of June, our Celebration of Physics event at Aerospace Bristol combined teacher CPD with activities for children. We welcomed 150 pupils from six local primary schools to take part in workshops and talks.

We also began a series of Community Days by welcoming over 40 colleagues to our event at the University of Birmingham. See page 20 for information on forthcoming events.

Credit: IOP

The Celebration of Physics event at Aerospace Bristol.

Events and key developments in Scotland and Wales

In collaboration with the RSC (Royal Society of Chemistry), the IOP Wales coaching team recently organised two teacher CPD days at Swansea University and Bangor University. Over 60 teachers joined us for our workshop, ‘Sustainably teaching about Sustainability’, as well as workshops from the RSC and the RICE (Reduced Industrial Carbon Emissions) project. A full report can be read on Talk Physics.

The Welsh Physics Teachers Conference will be returning to Brecon in October, with talks, workshops and opportunities for teachers and technicians to network. Our online evening programme runs through the week starting Monday 2 October and will culminate in a hybrid networking event with teachers joining us from all over the UK and Ireland, and from as far away as the USA and New Zealand.

The in-person conference will take place in Brecon on Friday 6 October, with keynote speakers Dr Gwenllian Williams of Leeds University and Martin McHugh, CEO of the Compound Semiconductor Applications Catapult. There will be a variety of hands-on workshops available as well as an opportunity for technicians to participate in parallel workshops with multi-award winning senior school science technician Paul Cook. On Saturday, we invite teachers to bring their families for child-friendly teacher CPD and WJEC-specified practical workshops. More information can be found on Talk Physics.

Our annal meeting for teachers in Scotland took place earlier in the summer in Stirling. We were pleased to see a big increase in attendees over last year’s event with 150 people. Sessions were a mixture of seminars and workshops. The annual summer school welcomed 16 teachers, most of them early in their career. Feedback from delegates at both events has been very positive.

It's been a busy few months for both Scottish and Welsh education policy. Read more on developments in Wales and Scotland on the next page.

The IOP Ireland team have been busy putting together the programme for our annual Frontiers of Physics conference, which will take place in Dublin in late September. Frontiers of Physics is open to all teachers of physics, including those newly qualified and teachers of Junior Cert Science.

Limit Less

On 5 July the Limit Less team held its inaugural parliamentary event. 30 MPs and members of the House of Lords attended, all taking time out to learn about Limit Less and have detailed conversations with IOP staff and students from Mortimer Community College.

The campaign is publishing new resources in the next few weeks. An animation on whole school equity is scheduled to be launched on 22 September, along with two accompanying documents – one aimed at a broad audience, and a second for school governors/trustees, delivered by the National Governance Association (NGA). As mentioned in the last issue, we've teamed up with the NGA on their upcoming Governors for Schools digital conference, to promote inclusion and dismantle the barriers preventing many young students following their chosen paths. (See page 20 for more details.)

The Eurekas, our competition for young people, received 219 entries this year – doubling the tally from 2022 whilst maintaining a high level of quality and creativity. We asked 11–16 year-olds to answer the question, ‘How does physics power your passion?’. Congratulations to Anika from the Avanti Fields School in Leicester, who won first prize for her racing track board game exploring Newton’s third law of motion.

See this year’s full shortlist, and information on how to stay in touch about next year’s competition, on the Eurekas website:

theeurekas.co.uk/submissions-2023/

Reports on education reform in Scotland

Scotland moved closer to making reforms to its system of education and skills with the publication of three reports during the summer term.

In the results of the National Discussion on Education, the Scottish Government highlighted the key message that "all learners matter" and stressed the guiding principles that the system should be ambitious, inclusive and supportive. In particular, the system should equip young people with the knowledge, skills and confidence to succeed in an increasingly complex and fast-changing world, moving from standardised expectations about stages of progress based on age towards more flexible pathways and supported transitions. The report emphasised the global context (especially tackling climate change and adapting to a digitally-dependent world), as well as tackling bullying and discrimination, and being aware of learners' mental health and wellbeing.

The report also contained a robust critique of the variability of the curriculum and the experiences and outcomes framework of the Broad General Education phase. IOP Scotland's submission to the Discussion was specifically cited on the issue of subject-specific professional learning.

The independent review of the skills delivery landscape issued its report, entitled 'Fit for the Future: developing a post-school learning system to fuel economic transformation'. The review makes various recommendations about the structure of the bodies responsible for skills development in Scotland. It also urged the Government to look at the skills needed to deliver its Climate Change Plan, echoing IOP Scotland's call for focused planning. It recommended that apprenticeships should continue to be employer-centric, but that they should also "incorporate providers and learners to ensure the resulting standards and awards meet the needs of all system users" – again reflecting the call made by IOP Scotland.

The independent review of qualifications and assessments delivered its final report. Key recommendations were the adoption of a Scottish Diploma of Achievement as a graduation certificate for all school leavers; stopping exams in S4 and introducing a wider range of assessment methods for Highers and Advanced Highers; and introducing a digital profile for all learners to record personal achievements and plan future learning.

The Scottish Government is now considering next steps.

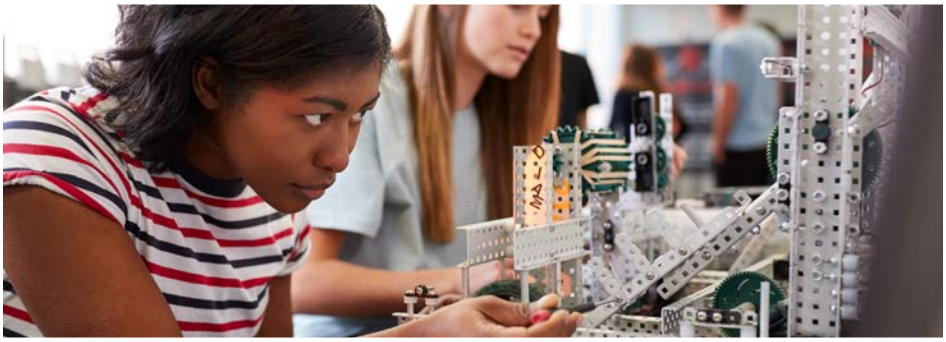
more...

View all the reports on the Scottish Government website: **bit.ly/ScotEdReform**

IOP issues statement on new combined science GCSE for Wales

Qualifications Wales has announced a new single award GCSE for science in Wales, prompting the IOP and other science bodies to voice concerns about entrenching inequality.

There is already an unequal system of science education in the UK, with schools offering either a double science award worth two GCSEs or three individual science GCSEs (triple science). The IOP has expressed support for all secondary school pupils to follow the same route through the sciences at GCSE, with a common, double award qualification that gives a solid grounding in physics, chemistry and biology.



One of the routes now proposed for Wales, worth only a single GCSE, would not provide enough grounding in the individual disciplines, cutting off opportunities for young people in Wales.

In a statement, the IOP said of the single award: "It has been made clear to us that such a qualification would not equip a pupil to progress to further study in the sciences, and as such, could potentially close down a young person's opportunities to pursue a wide range of careers at a time when our society and economy require greater scientific literacy than ever before."

The statement concludes: "We urge the Welsh government and Qualifications Wales to return to their original proposal of a single route through the sciences at Key Stage 4, and retract the single award proposal, at least until it can be consulted upon appropriately."

more...

Read the full IOP statement here: **bit.ly/WelshScienceGCSE**

Superheroes to the rescue

During the last academic year, the IOP in Ireland supported Midlands Science, a non-profit organisation that works to promote STEM in the counties of Laois, Offaly, Longford and Westmeath, on a project exploring the physics of superheroes. Working with Transition Year students in two schools in Mullingar, the project assembled a range of superheroes from the Marvel universe and beyond, explaining the real-world physics behind their superpowers.

Credit: Midlands Science

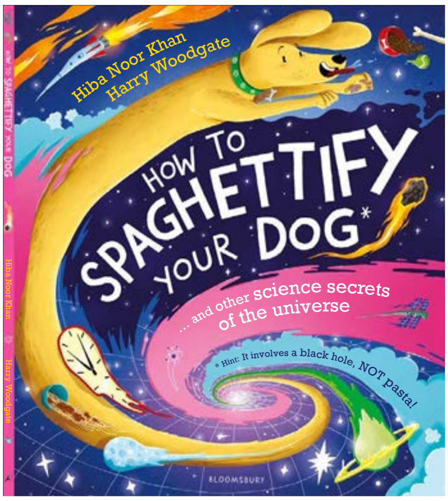
Above: Dr Barry Fitzgerald, a science communicator and author, developed and delivered the Superhero Science programme in partnership with Midlands Science.

Students were encouraged to become superheroes themselves, exploring how the physics they'd learned could be used to solve some of the world's biggest problems. Ideas were shared on everything from sustainability to medical physics, with students presenting their work at the National Science Park in Mullingar.

Evaluation of the Superhero Science project shows it had an impact on students as they prepared to make their Leaving Certificate subject choices. Participants' positive attitude towards physics increased by 24% over the course of the project, and this was particularly pronounced among the girls who took part. The participating boys' school saw a 20% rise in students choosing physics as a Leaving Cert option, while the numbers almost tripled at the girls' school. The IOP will continue to support Midlands Science as they explore the future of the project.

How to Spaghettify your Dog, by Hiba Noor Khan (Bloomsbury)

Review by David Cotton



Credit: Bloomsbury

"Physics is the science of absolutely everything – the gigantic and the miniscule, visible and invisible. It is both beautifully simple and unimaginably complex, and through it we can make sense of the wonderful world around us."

So begins Hiba Noor Khan's new book – a book designed to fascinate and inspire children in their search to know more about the universe.

Hiba, a former physics teacher, takes a broad set of concepts, from atoms to black holes, and depicts them in an engaging way, with vivid cartoon illustrations from Harry Woodgate. The spaghettification of the title – that weird phenomenon of intense gravitational fields around black holes – is just one example among many of a concept made accessible for young readers. I would say it is most suitable for children aged 10–14.

The author also presents experiments to perform alongside explanations of the physics, making this an activity book as well as a reference. This book would be a good addition to a school library or a suitable prize for a science student – or indeed a great gift for any intellectually curious children you know.

Children need to be encouraged to develop their curiosity for physics and the universe around them. With such a shortage of physicists and engineers, let's hope an entertaining illustrated book like this can attract more children to follow their curiosity!

Appliance science

Refrigeration makes the modern food industry possible, enabling the transportation and storage of fresh produce. Explaining how fridges work can be challenging, but Charles Tracy and Taj Bhutta offer some ideas.

Before we had modern refrigeration, options for keeping food fresh in the home were very limited. The main method was the ice box, which simply used thermal conduction between ice and food to keep the food cold. In the UK, ice was initially sourced from frozen lakes in winter and stored in ice houses for summer. As demand grew in the early 19th century, a trade in ice imported from Norway became established and its price rose. The demand for cheap effective refrigeration drove the development of modern fridge systems that used a fluid pumped around a closed loop to cool an internal compartment.

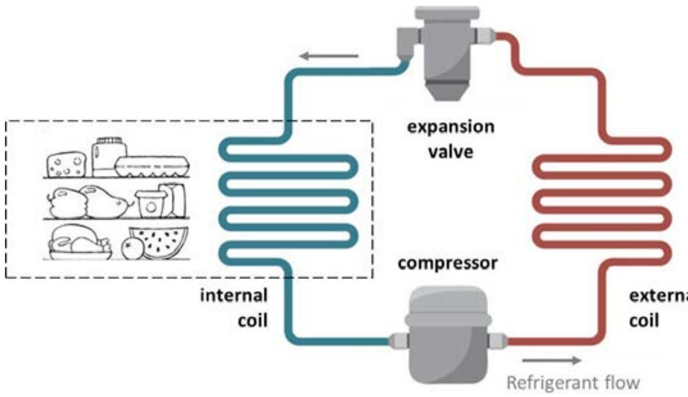
Many online explanations of how fridges work refer to heat being pumped around the system and may reinforce the common misconception that heat is a substance. The fact that domestic fridges use refrigerants that undergo phase changes is an additional complication that may confuse students. We'd suggest starting with a simplified model, where the refrigerant remains a gas throughout the process, which can be explained in terms of simple particle models and demonstrations.

The core components of a modern fridge are shown below. The refrigerant is pumped around the pipes. Its temperature drops when it is forced to expand into the internal coil. You can demonstrate this effect dramatically with a cylinder of carbon dioxide and an expander nozzle; the carbon dioxide is cooled so much that it solidifies to form dry ice. After passing through the internal coil, the refrigerant is recompressed so it's ready for another pass through the expansion valve. This increases the refrigerant's temperature and is an effect you can demonstrate by putting your thumb over the hole of a bike pump and pushing the plunger in quickly.

Although refrigeration systems that use a gas as a working fluid are used for aircraft air-conditioning systems, they're too inefficient (and bulky) for use in the kitchen. Domestic fridges use refrigerants that have a boiling point of around -15°C. During the expansion part of the cycle, the increase in volume and corresponding drop in pressure causes the refrigerant to change from liquid to gas, lowering the temperature more than expansion alone would have done. A similar everyday example that your students may be familiar with is a cannister of compressed air of the type used for cleaning keyboards. The air emerging feels cold because it has expanded and the cannister feels cold because of evaporation. In the external coil, the refrigerant condenses in preparation for the next cycle.

Did you know?

The phenomenon of cooling by evaporation was known by Arab engineers over 2000 years ago in what is now Iran. They built huge cooling structures, called Yakhchāls, to store food and even make ice. Yakhchāls worked by blowing a breeze over water passing through the building, forcing it to evaporate and so reducing its temperature.



Component	What happens	Simplified particle model
Expansion Valve	Expansion of the refrigerant reduces its temperature.	Gas particles bouncing off a surface that is moving away from them bounce off with a lower speed, thereby reducing the temperature of the gas.
Internal Coil	The refrigerant cools its surroundings and its temperature rises.	In collisions between slow-moving gas particles and vigorously vibrating particles in the solid structure of the coil, the gas particles bounce off at a higher speed and the amplitude of the vibrating particles reduces. This increases the temperature of the gas and reduces the temperature of the coil and its surroundings.
Compressor	Compression of the refrigerant raises its temperature.	Gas particles bouncing off a surface that is moving towards them bounce off with a higher speed, thereby increasing the temperature of the gas.
External Coil	The refrigerant warms its surroundings and its temperature drops.	In collisions between fast gas particles and slowly vibrating ones in the external coil, the gas particles bounce off at a lower speed and the amplitude of the vibrating particles increases. This reduces the temperature of the gas and increases the temperature of the coil and its surroundings.

The physics of farming

As the world's population grows, and food demand soars, farmers are having to get smarter about how they grow more food from a finite amount of land. Fortunately, physicists are there to help work out how to keep food on the table.

Satellite data

Satellite technology is transforming the way we understand what's happening to the natural environment, and is increasingly seen as key to planning how we use land for agriculture. Images taken from satellites are helping scientists to observe land in remote areas that are hard to access, and create detailed digital models of the terrain that help planners work out which areas are most suited to different types of food production.

Satellite data also mean we can better monitor the effects of climate change on agriculture and predict droughts, harvests and potential crop damage. In 2017, ESA reported that its satellite data had increased the warning time ahead of a swarm of locusts in north Africa. Because of the detail in new satellite images, they could tell when the ideal breeding conditions were for locusts, giving local authorities in countries like Mauritania time to prepare. Locust swarms can eat through entire crops over large areas in just a few hours.

bit.ly/SatelliteLocusts

AI weedkillers

Combatting weeds is key to maximising yields and reducing waste. Technology is enabling new systems to come onto the market that are helping farmers to deal with this problem in environmentally friendly ways. One such system uses high definition cameras and artificial intelligence to scan the ground looking for weeds – using AI to learn how to tell weeds apart from crops – then fires a 150 W laser with millimetre accuracy at the offending plant. This removes the need for chemicals, and is much easier than digging the plants up by hand. The system is mounted on the underside of a plough that can be dragged across the field by a tractor. It even has lights so can work at night.

Credit: Shutterstock

Vertical farms: the future of food production?

bit.ly/AIWeedkiller

Vertical farms

A popular idea for farming in the future is the vertical farm, where food is grown 'upwards' in specially designed buildings, rather than outward across the land. This maximises the growing space available while using only a small footprint. Light, temperature and water use are all carefully controlled using high-tech sensors. Plants get the water and nutrients they need through hydroponic systems, which feed plants' roots directly, instead of through soil. Hydroponic systems are also part of NASA's plans for growing food in space, where the lack of gravity makes watering plants more complicated.

Growing food 'upwards' (not literally upwards but in layers, with growing spaces stacked on top of each other) also means that food can be made much closer to population centres. This reduces the cost and energy needed for transportation and storage.

go.nasa.gov/3DOYOJm

Opportunities

The science and engineering of food production is an important part of the economy, as well as being essential for the future health of the planet. For information about careers and apprenticeship opportunities, try the following resources.

Net zero farming through engineering

Charlotte is an apprentice at Bicton College and works on her family farm as well as studying. Find out more about how she is dedicated to making sure that the future of the farm is net zero with this Neon case study from EngineeringUK:

bit.ly/NeonAgriculture

The Land-based Engineering Training and Education Committee (LE-TEC Ltd) promotes training and education for people working with farm and horticultural machinery and in associated areas. They run an apprenticeship programme and provide information for 12–16 year-olds on land-based engineering careers:

bit.ly/AEAopportunities

The science of learning physics

In this column, **James de Winter** (University of Cambridge and University of Uppsala) 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**

Some readers may know the names Docktor and Mestre from their paper 'Synthesis of discipline-based education research in physics', which is an impressive overview of research on undergraduate physics education and well worth a read for those who want an overview of Physics Education Research (PER) (follow the link in the left-hand column).

Their latest contribution to physics education, *The Science of Learning Physics,* is clear in its aim: to share research evidence to help you teach physics better. As with many PER books, the evidence base leans towards undergraduate teaching (often in the US) and so some caution is needed in assuming a direct match to the UK school context. Nonetheless, there is much in the book that will be of interest and relevant to school physics teachers.

The book's chapters focus on, among other topics, how students form concepts (and how to 'fix broken ones'), the transition from novice to expert, and how to take a conceptual approach to problem-solving (as we discuss below). To give a flavour of the material in the book, we will focus on an example approach introduced, the Hierarchical Analysis Tool (HAT).

Thinking HATs on

The HAT is a software tool that supports students' quantitative problem solving. Of practical interest to school physics teachers is the way the tool encourages students to consider the principles underlying a problem. First, students are asked to identify the major principle that will be applied in the solution (such as conservation of energy, or a Newtonian law). Then they are asked to describe the system in terms of that principle (such as, what energy changes occur in the problem? What forces act? etc), before starting to engage with equations. As such, the approach forces students to adopt a conceptual approach (by considering framing principles) rather than simply manipulating formulae. Mestre and Docktor's research suggests that encouraging students to reflect on the principles underlying a problem leads to better performance in problem-solving tasks.

In the introduction to the book, Mestre and Docktor observe that:

"Whether you are new to teaching physics or a seasoned veteran, we present a variety of ideas and strategies for you to consider. Some ideas might be a small "tweak" to your existing practices whereas others require more substantial revisions to instruction."

A research-informed, subject-specific guide that draws from up-to-date evidence, Mestre and Docktor's book is well worth your time, whether you want to make small tweaks or more substantial revisions to your classroom practice.

References

Docktor, J.L. and Mestre, J.P. (2014), Synthesis of discipline-based education research in physics. *Physical Review Special Topics - Physics Education Research, 10(2), 020119.* **bit.ly/PERDocktorMestre**

Mestre, J.P. & Docktor, J.L. (2020), *The Science Of Learning Physics: Cognitive Strategies For Improving Instruction.* WSPC.

A smörgåsbord of food and cooking science

James saw our theme for this issue and offered an extra, non-PER book recommendation:

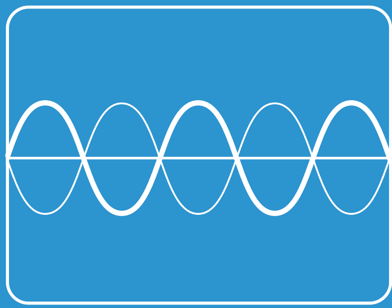
"If you want to know the science behind the perfect soufflée (optimum bubble size to expand just enough during cooking), whether searing meat really does seal in the juices (it doesn't), or why you should only grind your coffee when you need it (stored carbon dioxide in the beans excludes the oxygen, keeping them fresher), then get a copy of *On Food and Cooking – The Science and Lore of the Kitchen* by Harold McGee.

It's probably the best book on food science ever written."
- JdW

Pull out and keep!

Food (14–18)

Oscillations and waves



Inside this issue:

- **Demonstration: Poppadom standing wave (ages 14+)**
- **Activity: Wobbling pasta (ages 16+)**
- **Worksheet: Microwave card sort**

Developing a taste for physics

Linking physics to students' everyday experiences is one of our top tips for inclusive science teaching. For this purpose, there can be few contexts better than food. From breakfast to dinner – and snacks in between – it's a part of everyone's daily life.

Food provides a rich source of contexts to introduce many of the concepts in thermal physics. Traditional heating methods involve energy transfer by conduction, convection and radiation. More modern techniques involve microwaves and electromagnetic induction and illustrate how the temperature of a substance can be raised by other means – as well as how developments in physics have a direct impact on our everyday lives.

For teaching specific latent heat, you can take advantage of the fact that chocolate changes from a solid to a liquid at just below body temperature. Ask your class to put a milk chocolate button in their mouth and let it melt so they can feel the cooling effect as it changes state.

For teaching specific heat capacity, ask you class to collect and bring in food labels with microwaving instructions. By assuming that the hot food will be at a temperature of around 70°C (that is, about 50°C above room temperature) they can use the mass, power and time data on the label to estimate the specific heat capacity of the contents.

Alternatively, carry out an experiment in class and measure the food temperature before and after cooking.

Another area that lends itself well to teaching with food is materials. Sweets display a surprising range of physical properties. Stretching strawberry shoelaces or squashing marshmallows allows contextualised investigations into Hooke's law and Young's modulus. Asking your students to compare biting into a toffee and biting into a biscuit gives direct experience of tough and brittle behaviour respectively. (See page 18 for more on this.)

But it's not just lessons on materials and thermal physics that can benefit from a culinary twist. Inside this pull-out are two activities on the theme of oscillations and waves. The first, on page 10, is our take on the classic standing wave demonstration using a microwave oven. We suggest using poppadoms instead of the traditional chocolate bar for less messy results. On page 11 is an investigation into simple harmonic motion using uncooked pasta. Both are suitable for carrying out in a school lab because neither involve eating or drinking. For experiments that do require consumption, such as melting chocolate buttons, our tip is to book a classroom or food tech room to ensure your students get a real taste of physics.

Niloufar Wijetunge and Ruth Wiltsher are IOP Professional Support Coaches

more…

For other food-based activity ideas developed by the IOP in partnership with NUSTEM see: **bit.ly/NUSTEMFood**

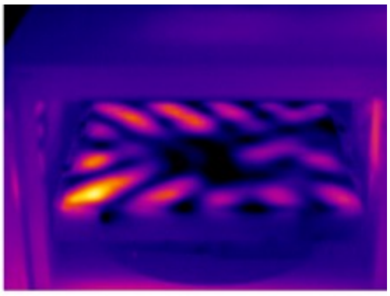
For investigations into Hooke's law and Young's modulus using sweets see: **spark.iop.org/squashing-sweets** and **spark.iop.org/stretchy-sweets**

Did you know?

The sugar coating on M&Ms was designed to stop chocolate from melting in soldiers' pockets during World War II.

Demonstration: Poppadom standing wave (ages 14+)

In this demonstration, students see how to estimate the frequency of electromagnetic radiation using the standing wave pattern in a microwave oven.



Credit: IOP Physics Education, January 2004

Dark spots on poppadoms and thermal image of hotspots in a microwave oven

Equipment:

- A microwave oven
- 3–5 poppadums
- A drinks glass (or coffee cup)
- 30 cm ruler

Procedure

1. Remove the turntable and place the drinks glass upside down in the centre of the microwave oven. Explain that you are doing this to stop the food rotating.
2. Spread the poppadoms across turntable and place it back in the oven on top of the drinks glass.
3. Start the microwave oven and look for dark spots appearing. Press stop when they do.
4. Remove from the microwave oven and show the dark spots to the class. Explain that these show the anti-nodes of the standing wave.
5. Determine the wavelength of the microwaves (λ) by measuring the distance between adjacent spots (equal to λ/2)
6. Provide the speed of light ($c = 3.00 \times 10^8$ m/s) and ask students to work out the frequency of the microwaves in the oven using $c = f\lambda$

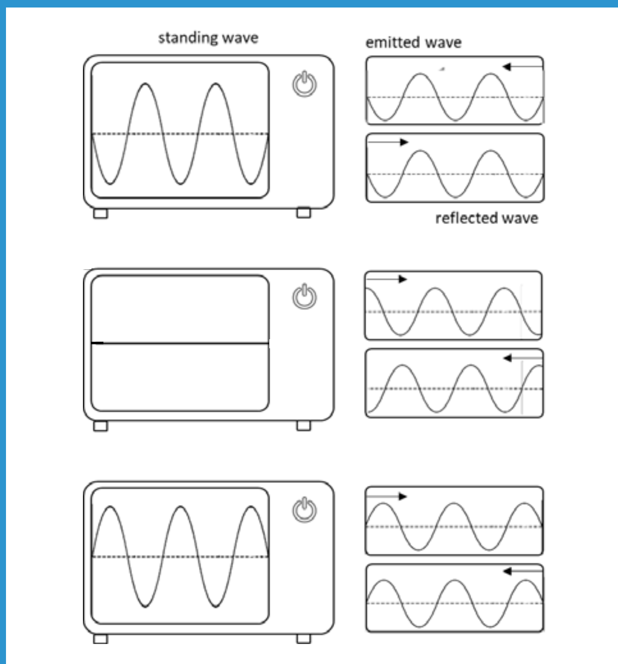
Teaching notes

Most microwave ovens operate at a frequency of 2.45 GHz and so produce microwaves of wavelength λ = 12.2 cm. This means that the spot spacing (λ/2) should be around 6 cm. But identifying the centre of a dark spot requires an element of judgement and so your value may be anything from 5 to 7 cm.

In a typical microwave oven, the cooking cavity length is set to 2½ λ. This gives an electric field variation along that direction that resembles the fifth harmonic of a guitar string.

Microwave card sort

The card sort on page 12 tests students' ability to match the transmitted and reflected waves to the resulting standing wave pattern. The correct answers are shown below.



Jelly baby wave machine (ages 14+)

This simple wave machine is a great way to introduce the concepts of reflection, refraction and superposition.

Watch how to make one on the IOP YouTube channel: **bit.ly/JellyBabyWave**

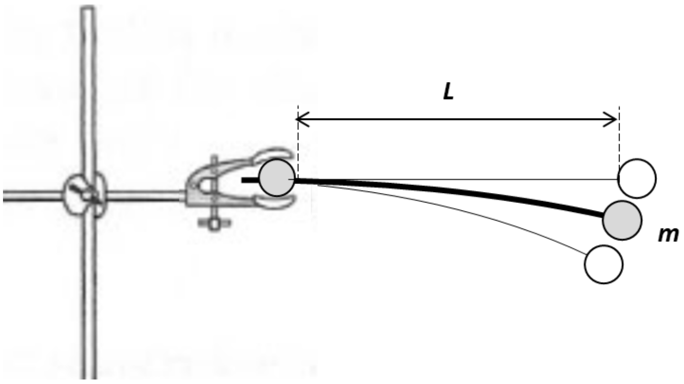
Did you know?

The idea of cooking with microwaves came to Percy Spencer in 1945 when a World War II radar magnetron he was standing next to melted a bar of confectionery in his pocket.

Read more about it at:
spark.iop.org/melting-bar-exploding-egg

Activity: Wobbling pasta (ages 16+)

In this activity, students investigate the oscillations of long-strand pasta. It extends (or replaces) the traditional mass-on-a-spring experiment for analysing simple harmonic motion.



Equipment

Each student will need:

- A few strands of long pasta (such as spaghetti or linguine)
- Blu Tack
- Clamp, stand and boss
- Stopwatch
- Access to a mass balance capable of measuring to 0.1 g or better.
- Slow-motion video capture on mobile phone (optional)
- Micrometre screw gauge and 30 cm rule (for extension activity)

Procedure

Ask students to:

1. Put a strand of pasta into a small ball of Blu Tack and hold it in a clamp and stand.
2. Attach a mass (m) of 2 g of Blu Tack to the end of the pasta.
3. Twang and time a number of oscillations to determine the time period (T).
4. Add another 2 g and repeat.
5. Repeat steps 3 and 4 until they reach m = 10 g.
6. Plot a straight-line graph to show that their results are consistent with the equation for simple harmonic motion:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Where k is a constant.

Teaching notes

To show that their results are consistent with the equation for T, students should plot T against $\sqrt{m}$ or T^2 against m. Their gradient will then be equal to $2\pi/\sqrt{k}$ or $4\pi^2/k$ respectively.

The vibrations are quite fast, especially for small values of m. Encourage students to think about how to determine the time period as precisely as possible. For example, they could measure $10T$ to reduce the uncertainty in their value of T, use a slow-motion camera if available and a fiducial marker to aid timing.

For pasta with a rectangular cross-section, the constant k is related to the vibrating length L and the Young's modulus E of the pasta by:

$$k = \frac{Ewt^3}{4L^3}$$

Where w is the width and t the thickness of the pasta

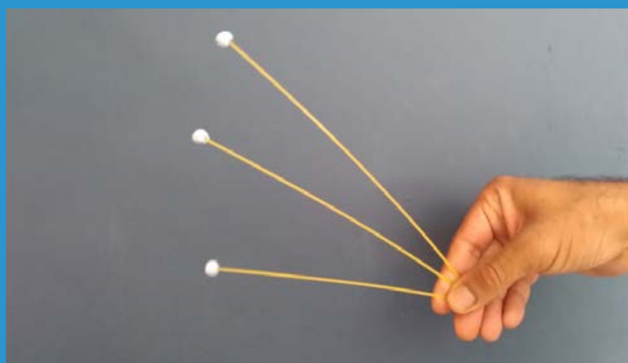
For pasta with a circular cross-section it is related by:

$$k = \frac{3\pi E d^4}{64L^3}$$

Where d is the diameter of the pasta.

As an extension activity, provide the appropriate equation and challenge your class to measure dimensions of their pasta and hence estimate E (they should get a value of the order of a few GPa, dependent on their brand of pasta).

Spaghetti resonance (16+)



Ask your students to attach Blu Tack to the end of spaghetti strands of different lengths and wobble them with their hands. Oscillating them back and forth at low, medium and high frequencies illustrates that different strands vibrate with maximum amplitude for different driving frequencies.

Microwave card sort

Standing waves are formed when waves travelling in opposite directions overlap. In a microwave oven the overlapping waves are those emitted by a microwave source and those reflected off the inside walls of the oven. You will be matching emitted and reflected waves to standing wave patterns.

Equipment:

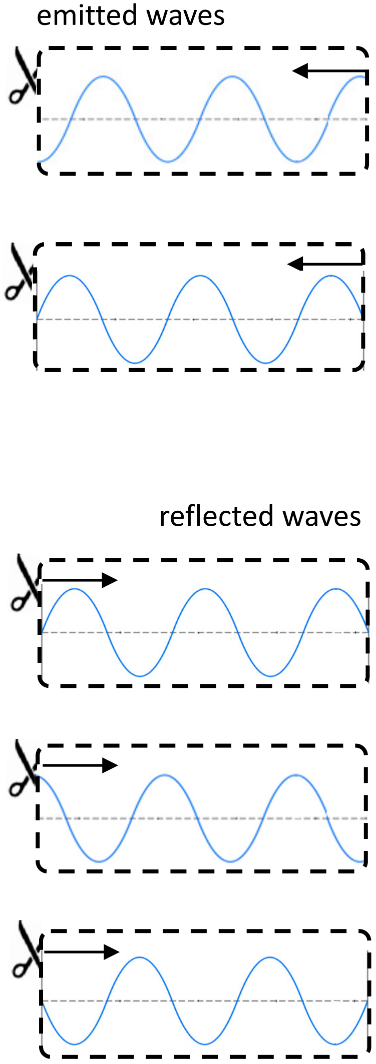
- Scissors
- Glue

Instructions

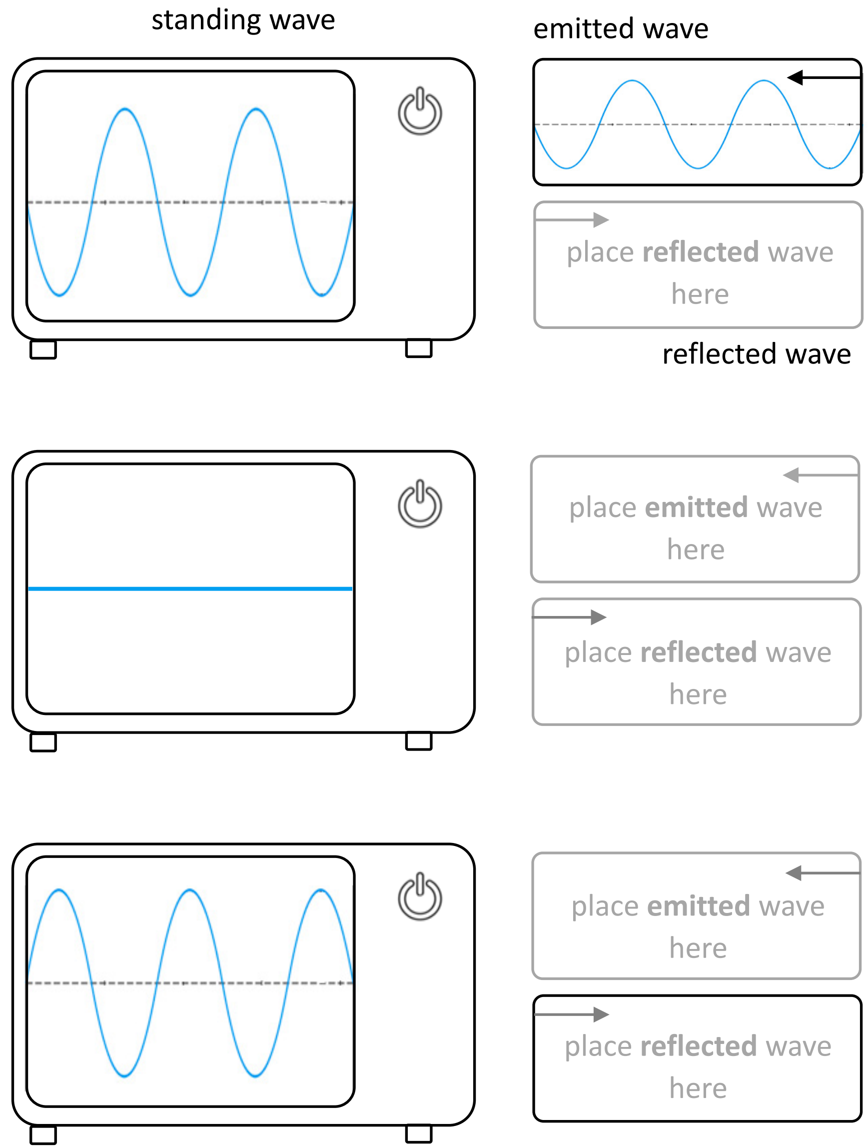
1. Cut out the emitted and reflected waves.

2. Place one emitted wave and one reflected wave next to each standing wave pattern.

3. Once you are happy with your choices, stick them in place.



Microwave oven standing waves



Stories from physics

Newton, Einstein and vegetarianism

Some sources claim that Newton followed a vegetarian diet. One of his half nieces is quoted as saying he would not eat the meat of strangled animals, because of the painful death the creatures suffered. He also believed the consumption of blood inclined people to be cruel. Einstein, too, is sometimes cited as a vegetarian, but biographers note several instances of meat consumption. Einstein acknowledged his conflicted position: "I have always eaten animal flesh with a somewhat guilty conscience.". In his seventies, after being diagnosed with digestive disorders, he was advised by doctors to reduce his meat intake, and reported feeling healthy on the restricted diet. One story runs that when his wife, Maja, complained that her vegetarianism prevented her from eating hotdogs, Einstein declared the hotdog a vegetable.

Buttery tea lenses

Interesting physical phenomena can be found in the most mundane places. Researchers from the Université Grenoble Alpes dipped buttered toast into hot tea (they note this may offend sensibilities in some countries) and reported on the formation of a buttery lens on the liquid's surface, pitted with holes that move, 'creating a beautiful ballet'. The researchers hypothesised that impurities in the butter act as surfactants, compounds that reduce surface tension. In a butter lens, the impurities fall slowly through the height of the butter layer, hitting the lower surface. At that point, they induce a Marangoni flow – a movement of fluid driven by a difference in surface tension, like the flow of wine up the side of a wine glass. The flow stresses the surface of the butter lens, which can cause a hole to open. The authors conclude that: 'a curiosity-driven approach to an everyday phenomenon can lead to observations that are interesting and unexpectedly varied'.

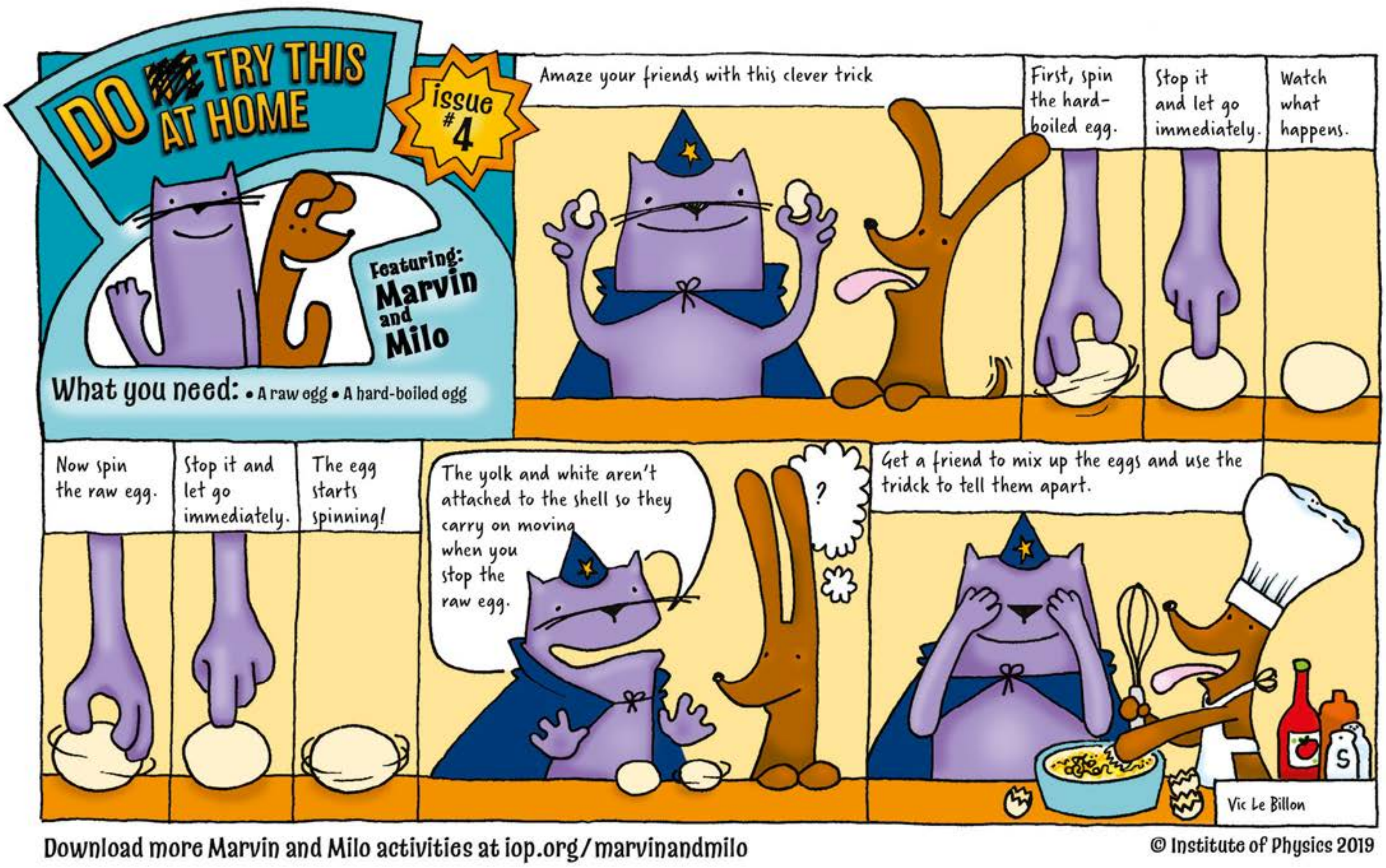
The Brazil nut effect – in space?

Consumers of cereals composed of different items (like muesli) may have noticed that larger objects in a mixture rise to the top on shaking. This is known as granular convection, or the Brazil nut effect. Several explanations have been proposed, including a reduction in the potential energy of the mixture. In its initial state, the energy of the mixture is not optimally low. On agitation, smaller particles move into spaces below larger particles, decreasing the total energy and forcing larger particles upwards. Researchers have argued that the Brazil nut effect can explain the distribution of surface features on comets. They argue seismic shaking could drive granular convection that brings larger particles to the comet's surface.

spark.iop.org/stories-physics

Compiled by Richard Brock.

Follow him on Twitter at **@RBrockPhysics**



Credit: IOP

Physics*education*

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

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

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

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

A very popular Open Access paper in Physics Education recently has been **"Let's have a coffee with the Standard Model of particle physics!"** The paper aims to explain the terms of the Langrangian equation used to describe the fundamental interactions between elementary particles. The paper uses Feynman diagrams to do this and is suitable for teachers of A-level physics and above. An interesting background physics paper, it might look daunting at first, but everything is broken down into easier steps.

I'm not sure if coffee or chocolate is more popular, but you can also find an Open Access paper on **"Bending bad—testing caramel wafer bars (#TestATunnocks)"** which could be a great way to start looking at materials testing. A number of tests are described, some of which use your senses rather than any expensive equipment. There's a lot connecting physics and chocolate so this can lead on to temperature and changing properties as well as sustainability: see **"A sweeter way of teaching health and safety"** and **"Testing the fracture behaviour of chocolate".**

Many of us will be familiar with the phrase "I could murder a cuppa", but the link from the next paper to food is slightly less tenuous. **"The cooling of a swede—part of an EUSO CSI challenge"** describes how a swede replaces the body of a murder victim and by modelling how it cools, students can estimate the time of a murder. This happens to be another Open Access paper and other vegetables may also work.

"The physics of baking good pizza" is another very popular paper which looks at stone ovens as well as steel ones, such as those found in our homes, and carries out a thermodynamic analysis which is aimed at undergraduates. Pizza is very popular and there's plenty to take from this paper for teachers of younger students. If they have noticed how quickly pizza cooks in a stone oven then you can lead straight into a discussion of why that's the case. You can also go from a simple question of how to fairly share a pizza to **"How to fairly share a watermelon"** – the 3D shape making it rather more challenging.

"Coffee with the standard model…"
bit.ly/PECoffee

"Bending bad…"
bit.ly/PEBendingBad

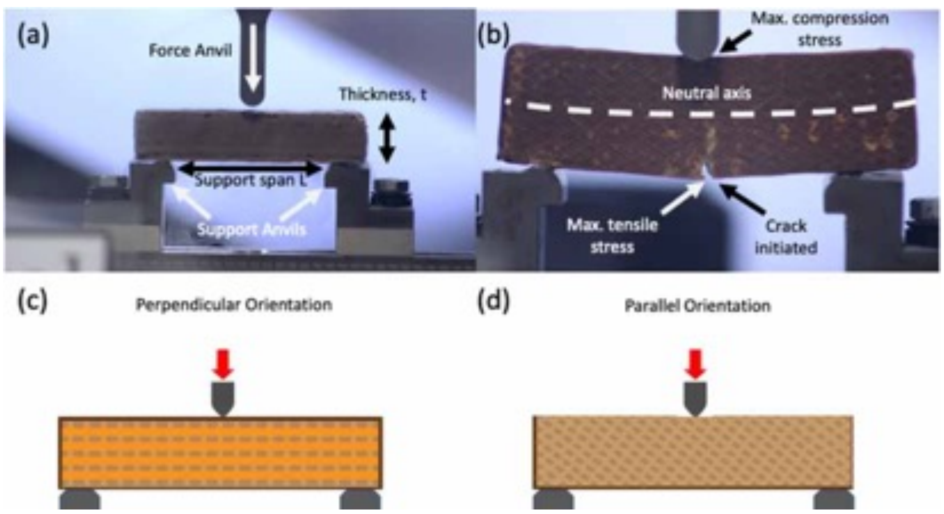
"A sweeter way of teaching health and safety"
bit.ly/PEHealthAndSafety

"Testing the fracture behaviour of chocolate"
bit.ly/PEFractureChocolate

"The cooling of a swede…"
bit.ly/PECoolingSwede

"The physics of baking good pizza"
bit.ly/PEBakingPizza

"How to fairly share a watermelon"
bit.ly/PEWatermelon



Credit: IOP

Materials testing techniques on a Tunnock's caramel wafer bar.

Physicseducation

Recent highlights

The plasma globe is an endless source of fascination and the Frontline article **"Transmission of electromagnetic waves from a plasma globe to a light emitting diode"** is a simple demonstration that allows for plenty of discussion. As well as the globe you just need an LED and some foil.

"Work-based measurement of k with a spring-mass system: a demo of the work done by a variable force" was a paper I enjoyed very much because of the obvious link to integration. Students can feel a spring changing the resisting force as they pull it, so can easily understand how the magnitude of the force is changing as the extension changes, and see that work done is not a simple force multiplied by distance. This could be a nice introduction to the need for integration.

"Using video analysis to study the behaviour of rubber balloons" is a relatively simple experimental setup and appears to produce useful results. I liked the simplicity of the setup but also the possible links to stretching of balloons and hysteresis and atmospheric pressure.

"Transmission of electromagnetic waves…"
bit.ly/PETransmitWaves

"Work-based measurement of k…"
bit.ly/PEWorkBased

"Using video analysis to study the behaviour of rubber balloons"
bit.ly/PEVideoAnalysis

From the archive

Having tried this myself, I can thoroughly recommend having a go. **"Learning about insulation and the flow of heat never tasted so good"** is all about baked Alaska. You can make one without doing too much cooking, buying some sponge cake and ice cream and putting it together with a bit of meringue. I speak with very little authority here, but I'm told meringue isn't cooked but just dehydrates. Having the freezing cold ice cream baked in a hot oven gives plenty of opportunity to talk about the insulating properties of cake and meringue and the air contained within.

"Paperclip Physics poses sticky problem" is one of my own, very short, articles, and is about making a bridge out of toffee. When I did this activity in the classroom, I must admit that I didn't make the bridge myself. One of my students had made the pieces at home over the weekend and the resulting bridge was so strong you could stand on it. There's plenty of physics to cover but if I did it again I might try buying the toffee and cutting it to shape, although it can be very hard.

Jon Ogborn has an excellent paper about properties of molecules associated with food in **"Soft matter: food for thought"**. There are recipes for jelly, French dressing, mayonnaise and meringue and the physics and chemistry associated with them is explained.

Credit: IOP

Golden brown meringue baked to perfection; hard to resist – the inside revealed; and the final vanishing trick.

"Learning about insulation…"
bit.ly/PEBakedAlaska

"Paperclip Physics…"
bit.ly/PEToffeeBridge

"Soft matter: food for thought"
bit.ly/PESoftMatter

Quick Links

"Measuring the pressure inside a party balloon with a ruler"
An introduction to metrology methods using simple tools

bit.ly/PEBalloonPressure

Open access

"Kissing the cheeks of Huygens"
A simple pendulum setup to confirm the usefulness of the cheeks of Huygens

bit.ly/PEKissingHuygens

Open access

"Development of hypothetico-deductive skills in an ISLE-based lab taught by novice instructors"
Does a lab instructor's experience of ISLE impact on students' learning?

bit.ly/PEHypothetico

Open access

"An easy-to-build optical spectrometer for the Rayleigh scattering investigation of coffee solution" Investigations with a low-cost optical spectrometer

bit.ly/PEEasySpectrometer

"Kitchen capers—the question"
A 'What happens next' series testing centre of mass, pressure and sound

bit.ly/PEKitchenCapers

Open access

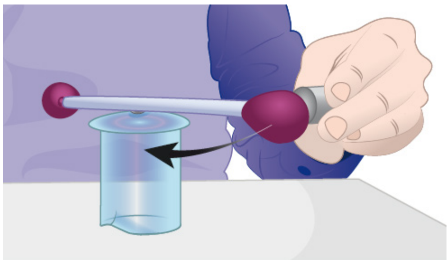
"Floating eggs?—the question"
Investigating why bad eggs float in water

bit.ly/PEFloatingEggs

talkphysics

David Cotton, editor of our online discussion forum, shares TalkPhysics discussion threads looking at the topic of food.

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



Demonstrating diamagnetism by repelling a grape with a magnet.

Physics and food have many applications in the physics classroom. My favourite demonstration is diamagnetism in grapes. This thread for a magnetism masterclass has a good method and a reference to Classroom Physics. The teaching tip in the June 2015 edition has a good explanation of the effect.

bit.ly/TPDiamagnetismGrapes

In the thread above there's a link to Dan Cottle's Real Physics with Fruit and Sweets. This was run as a workshop on TalkPhysics. This next thread is full of resources from the session including Dan's Google document, the Crunchie bar bone simulator, jelly baby wave machine, fruit batteries and many more ideas.

bit.ly/TPFruitandSweets

Another way of teaching radioactive decay and half-life with M&M sweets is explored in the next thread. Some M&Ms have no logo, and these can represent stable isotopes. A nice addition to this method is to put the decayed M&Ms after each trough into measuring cylinders to visually show the decay curve.

bit.ly/TPRadioactiveDecay

This thread, an open group on TalkPhysics, has some other good ideas, like Hooke's law with strawberry laces, diffraction pattern chocolate, lemon batteries and much more:

bit.ly/TPMoreFoodIdeas

physicsworld

Stories from our magazine for the global physics community.

Visit **physicsworld.com**

You are what you eat

This is a fascinating profile of food physicist Megan Povey, who has built a career at Leeds University looking at food "from the macro- to the nanoscale".

She spoke to Physics World in 2020 about her research, which uses ultrasound techniques and computer modelling of foods. Applications range from developing foods for older people who find digestion more difficult, to developing sweets with lower calorific value to help combat obesity. Her work is closely linked with industry and involves a multidisciplinary approach, working with engineers, chemists, biochemists, nutritionists, and commercial and business development teams.

The article also touches on Megan's personal journey as a trans woman.

bit.ly/PWWhatYouEat

Taking a bite out of food waste

This feature from 2019 explores the use of hyperspectral imaging and machine learning to reduce food waste.

A third of all food produced is currently wasted – costing almost a trillion dollars a year, and causing 8% of global carbon emissions. Using advanced imaging that reveals wavelengths right across the spectrum means it's possible to monitor food freshness much more precisely. Fish give off different light signatures depending on how fresh they are, for example, because their chemical composition changes over time.

The technique also enables manufacturers to spot any contaminants without needing to run costly testing.

bit.ly/PWFoodWaste

The Institution of Engineering and Technology

Holly Margerison-Smith, Education Manager at the Institution of Engineering and Technology, describes a range of resources illustrating the role science and engineering play in growing, packaging and delivering food for a growing population.

theiet.org

A three course meal of food engineering

The Institution of Engineering and Technology has a wide range of teaching resources, careers information and activities to get your students thinking about food in new ways, with topics close to home and around the world.

As a starter, students could listen to our Undercover Engineers podcast on Future Foods where hydrologist Nadav Tal explains how engineers are playing their part to help feed the planet.

Students could then move on to considering food packaging and protection. In an activity looking at the vacuum-forming process and its applications, students could produce a mould for casting a handmade chocolate egg, or take part in the egg drop challenge, where they assemble a protective structure to save an egg from breaking after it is dropped from height. ‘Plastic from milk’ is another interesting activity where teachers can work with students to make a mouldable plastic from milk, showing how plastic is made from natural resources.

Finally, we move to the topic of food aid, where engineers are working to help supply food to prevent hunger and malnutrition. People in countries affected by natural disasters or war often need food and other aid delivered to them. In the ‘Drop it’ resource, students can design a method of getting this safely from an aircraft to those who need it on the ground.

more...

To find all of these resources please visit:

education.theiet.org/

bit.ly/IETUndercover

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eic

Education in Chemistry is the Royal Society of Chemistry’s magazine for teachers.

edu.rsc.org/eic

How chemistry makes sweet treats colourful

What makes some food colourings brighter and more bakeable than others? It’s all to do with the stability of the chemicals, which determines how easily they break down at high temperatures.

Synthetic or artificial colours made in the lab tend to be more stable than those from natural sources. And since many companies are now switching to natural colours to satisfy food regulations, the colours can be noticeably weaker than in the past.

It’s a problem that Rich Myers, a baker from Leeds, experienced last year. In an episode that came to be known as ‘Sprinklegate’, West Yorkshire Trading Standards tested the sprinkles he was using in his popular, colourful cakes. They found the sprinkles contained higher levels of certain artificial food colourings than were allowed under UK law, as well as the banned red colourant, erythrosine (E127).

Not wanting to give up on his vibrantly coloured sprinkles, Rich worked with a manufacturer to create bright, bakeable sprinkles that are compliant with UK laws.

Creating new artificial colours was at odds with the trend for sweet manufacturers moving to natural colours. In another famous case, the blue Smartie made a welcome return when Nestlé realised it could use a natural compound called phycocyanin, from spirulina, to colour them.

But what makes chemistry lessons colourful and informative? Dissolving dyes from sweets for a chromatography practical with your 11–14 year-old learners. Find out more with the EIC article and free resource.

more...

Link chromatography and food colourings with this article by science writer, Hayley Bennett, and download the free resource at:

rsc.li/3JFXNGJ

Royal Astronomical Society

There are no fridges in space but the International Space Station does have an oven – and plenty of garlic and chilli sauce. Sheila Kanani, Education Outreach and Diversity officer for the Royal Astronomical Society, explains some of the challenges of eating on the International Space Station.

ras.ac.uk

more...

See these resources from STEM Learning for some more space-themed lessons on food and healthy eating: **bit.ly/STEMSpaceFood**

International spice station

Astronauts' food is rather different from food on Earth for various reasons, including the effect of gravity on food and the fact astronauts can't take everything with them that they'll need for their mission.

Astronauts are likely to eat a lot more packet foods or dried foods than on Earth, as dehydrated foods are lighter to transport. Boiling water is added on the ISS, creating meals including scrambled eggs and casseroles. There are some fresh fruit and veg – delivered every few months by uncrewed cargo ships.

The microgravity environment has a big impact on what can and can't be eaten. Sauces are allowed, but salt and pepper grains are not, as they would float away. You also can't have bread in space because the crumbs would go everywhere. So, if you want a bacon sandwich (which astronaut Tim Peake ate for his first meal in space) you'd need to use a tortilla wrap or chapati instead. Tim Peake used canned bread with no crusts!

Astronauts are allowed to take certain personalised pieces of equipment with them. Samantha Cristoforreti chose to take a coffee machine into space in 2015. Drinks can't be in open containers, however, so everything, even hot drinks, is drunk from a pouch with a straw. Astronauts can also make pizzas and cookies using a special oven (and special pizza bases!)

Whatever's on the menu, however, taste and smell are affected in space. On Earth, gravity pulls fluid down into our legs, but in microgravity the fluids can block nasal passages, which stops astronauts from smelling – a bit like when you have a cold. Smell can affect taste, so food in space tends to be made with as much flavour as possible to make them tasty and enjoyable. This means that astronauts eat a lot of garlic, and chilli sauce is always to hand!

The Ogden Trust

making physics matter

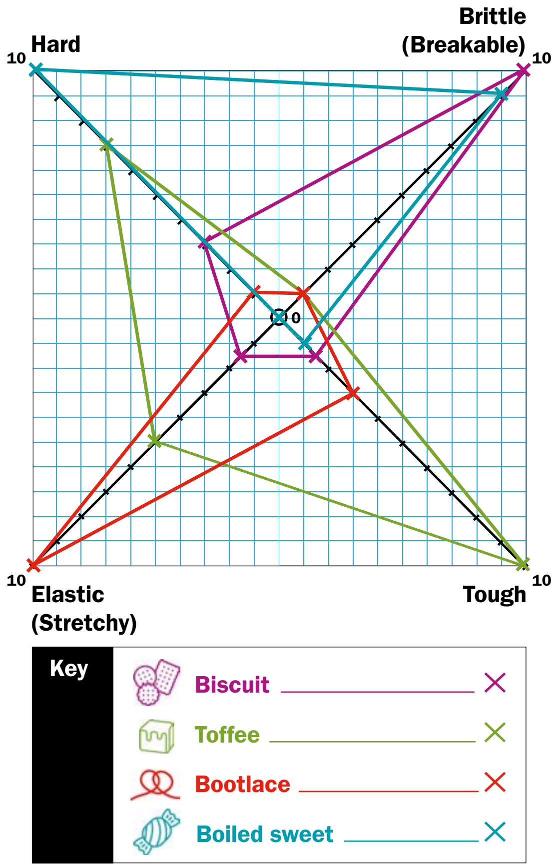
In this visual resource, Niloufar Wijetunge, a professional support coach for the IOP and Ogden Trust, shows how sweets can be used to aid understanding of the scientific definitions of material properties.

Check out other resources at TalkPhysics or the Ogden Trust website:

ogdentrust.com

Tasty materials

Students can struggle to recall newly learned scientific terminology and their definitions. One approach, supported by cognitive load theory, is to tailor lessons according to students' existing knowledge. For example, the scientific meanings of the terms tough, brittle, elastic and hard, can be associated with knowledge of everyday experiences such as a biscuit snapping (and not noticeably extending) when force is applied on it. Even better, the newly learned term could link alliteratively and/ or onomatopoeically to the experience: brittle like a biscuit, tough like a toffee, etc. Each sweet can be plotted on a spider diagram to show its unique profile of these material properties.



Upcoming events...

Physics Community Days

12 October

Bridgewater High School, Warrington

bit.ly/WarringtonPhysics2

25 October

NU-STEM, Northumbria University, Newcastle

bit.ly/NewcastlePhysics

Welsh Physics Teachers Conference

Online evening programme: week of 2 October

In person event: Friday 6 October
Family day: Saturday 7 October

Online and in-person in Brecon

bit.ly/Brecon2023

Governors for Schools Conference

26 and 27 September

Online

Supported by the IOP's Limit Less campaign

bit.ly/GovernorsForSchools

talkphysics

These workshops are designed for those who are supporting colleagues, either within their school or further afield, and cover the following topics:

28 September – Forces
16 November – Electricity
14 December – Maths in Physics
18 January – Energy
14 March – Waves
25 April – Atomic Physics
11 July – Matter

Dates are confirmed to the end of autumn term. For more information and to suggest other topics, visit:

bit.ly/PhysicsCentral2324

Limit Less

Limit Less careers resources

Visit the IOP website for Limit Less careers resources, with materials for teachers including lesson plans and guidance materials, and a series of booklets for 12–15 year-olds and their families around the UK and Ireland.

bit.ly/LLCareersInfo

Planet possibility autumn term events

Full listings and more details at: **physicspartners.com/events/planet-possibility/**

11 September, 4pm
Gender representation and unconscious bias in physics

13 September, 4pm
Numeracy in physics 1

14 September, 4.15pm
Teaching electricity 1

18 September, 5pm
Teaching forces 1

20 September, 4pm
Teaching electromagnetism 1

27 September, 4pm
Teaching waves 1

2 October, 4pm
Teaching Earth and space

4 October, 4pm
Teaching radioactivity 1

15 November, 4pm
Numeracy in physics 2

16 November, 4.15pm
Teaching electricity 2

22 November, 4pm
Teaching electromagnetism 2

26 November, 4pm
Teaching Earth and space 2

29 November, 4pm
Teaching radioactivity 2

30 November, 4pm,
Teaching waves 2

4 December, 5pm
Teaching forces 2

Seen elsewhere...

EngineerGuy

The magnetron is what makes microwave cooking possible. Watch its evolution from World War II radar system to household appliance:

bit.ly/MagnetronVideo

Future fridges

If our brief history of the fridge (page 6) was interesting, try this look at the possible future for refrigeration from the Royal Society of Chemistry:

rsc.li/46vc1nF

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