December 2023 | Issue 67

Classroom physics

The magazine for IOP affiliated schools and colleges

In-depth science

The physics of floating and sinking

Inspiring physicists win Nobel Prize(s)

Powering the future: Floating offshore wind farms

Practical activities: How cargo ships float and why cold water sinks

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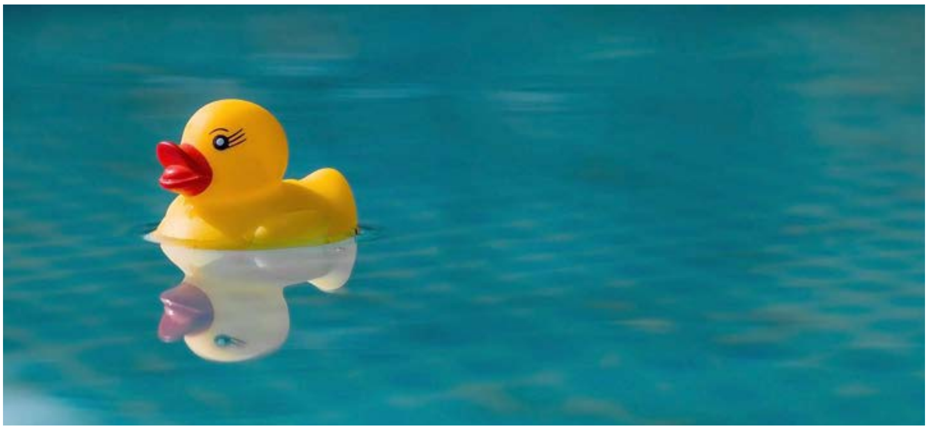
IOP Institute of Physics

This issue



Credit: Shutterstock

Editor's note

This issue is a chance to roll up your sleeves and get wet as we look at floating and sinking.

We've got a selection of exciting demos and activities from IOP's education coaches and a range of partner organisations, who have sent us some brilliant content from their resources. In the pull-out section (pages 9–12), we've got two water-based activities, exploring convection and density.

Your students may refer to astronauts in orbit as floating, when of course a better description would be that they are falling. As well as correcting them by explaining why they are in continuous free-fall, why not also tell them the story about the 'floating' tool bag (see page 13). Understanding why density is a good predictor of whether something floats or not isn't straightforward, especially for under 16s who do not yet have the maths skills to link density to the upthrust and gravitational forces. We've got an idea or two to help, using toy bricks, on page 11.

This issue sees a new feature (see page 16), which highlights book recommendations for the physics teaching community. We'd like to hear thoughts from readers about any books you think your colleagues should know about – whether aimed at fellow teachers and technicians, children or non-physicists. Get in touch at **education@iop.org** with your ideas!

Finally, as the Christmas holidays are almost here we thought we'd share some festive fun. To mark an expansion of the IOPSpark website we've tied in some jokes around the seven IOPSpark domains. See page 5 for more. (As for the quality of the jokes, I can only apologise.)

All of us on the Classroom Physics team wish you a Happy Christmas and a restful winter break.

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

A set of six postcards showing how engineers are working across different sectors to help us achieve net zero. Find out more on page 5.

To download or order more copies visit **neonfutures.org.uk/postcard**

Follow us on Twitter/X
@IOPTeaching

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

Teachers' and Technicians' Awards announced

In October the winners of the IOP Teachers of Physics Awards were announced. These awards recognise the success of secondary school physics teachers who have raised the profile of physics and science in schools. Seven teachers were recognised this year:

- Dr Panos Athanasopoulos, Prestatyn High School
- Jed Marshall, Alexandra Park School
- Khushali Mills, Our Lady's Grammar School
- Amelia Ross, St Bernadette Catholic Secondary School
- Christopher Rossi, St Joseph's College
- Tom Squires, Hillcrest School and Sixth Form Centre
- Wayne Tabernor, Alder Community High School

The IOP Technician Award recognises the skills and experience of technicians and their contribution to physics. Two Technician Awards went to technicians in secondary schools:

- Razika Berboucha, Lampton School Academy
- Andrés Tretiakov, St Paul's School

A profile of each winner is published on the IOP website, along with information about other IOP Awards.

These include the Apprentice Award, which this year goes to Saskia Burke, who completed a three-year apprenticeship in metrology at the National Physical Laboratory. She has written an article for this issue about the measurement of density (see page 17).

Congratulations to the winners across all categories.

The 2024 Teachers' and Technicians' Awards will open for nominations in February, with a simplified application process in place.

See **bit.ly/IOPAwards24**

Activities round-up

The autumn term has been busy for IOP teams around the UK and Ireland.

November saw two 'BGE and Beyond' conferences for teachers in Scotland. The events, held in Edinburgh and Inverness, provided opportunities for skills development, looking at hands-on practical work, teaching tricky topics, and cross-cutting themes including STEM leadership and increasing participation in physics.

The annual Brecon conference in Wales brought together more than 200 teachers and technicians from around Wales, other parts of the UK and the rest of the world, with contributions from New Zealand, the USA and Spain. Four evenings of online webinars covered topics as diverse as 'God and the Big Bang' and 'Why can't elephants fly?'. The in-person part of the conference, held at Christ College School in Brecon, brought together over 80 teachers, including trainees from almost all the Welsh ITE institutions, and 20 technicians.

In Ireland, the IOP appeared in front of the Oireachtas Joint Committee on Trade, Enterprise and Employment, to discuss the contribution physics can make to closing the skills gap. The wide-ranging conversation touched on early education, inclusion, teacher shortages and the importance of technical routes into employment.

IOP Ireland's autumn term teacher CPD supported teachers online and in person. Teachers have had the opportunity to attend sessions on misconceptions highlighted by common mistakes in last year's exams and the use of ChatGPT in classrooms. IOP Ireland also attended all three days of the Higher Options conference, meeting students undertaking their Transition Year or Leaving Cert to discuss further study and careers.

In Northern Ireland, the team attended the School Summit, where they met young people about to make their subject choices for A Level. The annual Science in Stormont event took place on 9 October, at which the IOP had the opportunity to share research into skills, education and research and development.

'Floating and sinking' session under new Curriculum for Wales

The IOP Wales team delivered a workshop on floating and sinking as one of five 'Teach physics with confidence' sessions for newly qualified and early career teachers in September.

The sessions looked at relevant physics but also used examples from biology and chemistry to reinforce areas of crossover between the subjects.

Schools in Wales are entering their second year under the new 'Curriculum for Wales', which is arranged around core principles of helping students become: ambitious, capable learners; enterprising, creative contributors; ethical, informed citizens; and healthy, confident individuals.

Rather than strict subject-based learning, the curriculum is organised into six Areas of Learning and Experience (AoLEs) as well as cross-curricular themes such as sustainability, citizenship and digital competence.

Physics sits within the Science & Technology AoLE, and the IOP Wales team have been delivering teacher support focusing on the interdependencies between physics and other sciences.

New whole-school equity resources launched

IOP's Limit Less campaign has launched new resources to support teachers, headteachers and governors to develop whole-school equity plans.

A still from the whole-school equity animation. The full version is available via iop.org/WholeSchool; look out for a shorter version on social media (#IOPLimitLess)

Too many young people are held back by the biases and prejudices of others when it comes to their education, training and careers. Their choices are influenced by stereotypes about gender, ethnicity and other aspects of identity.

The Limit Less campaign is calling for every school in the UK and Ireland to become truly inclusive – by taking a whole-school approach to equity. This involves the entire school community working together to create a plan to dismantle the barriers students face.

A plan for whole-school equity ensures that what's taught and communicated is inclusive and accessible, that young people have a voice in how the school is run – and that no-one is discouraged from exploring the future that best fits their talents.

The new resources, published in October, are an animation (pictured), a document to support educators with projects and programmes for their whole-school inclusion work, and guidance for those involved with school governance in England, from the National Governance Association.

These, and other resources including posters and flyers, and Welsh language versions, are all available via **iop.org/WholeSchool**

The Limit Less campaign is encouraging all teachers and headteachers to use the guidance as they consider how they can further progress a whole-school equity approach at their school. Governors are asked to read the NGA guidance and take it to their board of governors or trustees.

If you are implementing or in the process of developing a whole-school equity plan, please share your experiences with the Limit Less team – or with us at Classroom Physics – as your stories may help others to achieve impact in their schools.

more…

iop.org/WholeSchool

Contact: **campaigns@iop.org**

Early data shows effectiveness of Inclusion in Science webinars

The Association for Science Education (ASE) has been working with schools to improve inclusion and increase uptake of physics by under-represented groups, building on an earlier IOP project, Improving Gender Balance.

The Inclusion in Science CPD programme, a set of six online modules for teachers to build confidence and awareness of inclusion issues and implement improvements in lessons, began in October. (We carried an advert for the scheme in the last issue of Classroom Physics.)

The ASE has shared early data gathered from participants, which point to the resources being well received. 98% of participants reported the overall quality as 'good' or 'very good' and feedback has included: *'content was great'; 'fab session!'; and 'Loved the interaction'.* Most significantly, 96% of participants said the training would influence their classroom practice.

The scheme will re-run in January and is fully funded by the Department for Education.

more…

ase.org.uk/inclusion-in-schools-recruitment

Credit: Suhtterstock

New environment project and learning resources

Students and teachers are invited to take part in a citizen science project to monitor indoor air quality in UK schools.

The project, titled Schools' Air quality Monitoring for Health and Education (SAHME - pronounced 'Sammy') is looking to recruit a wide range of schools across the UK. It hopes to build a representative dataset and develop a clear understanding of air quality in schools, to inform better policy and practice and improve air quality.

Schools can apply for an indoor air quality monitor, which staff and pupils use to collect data that can be accessed via the SAHME app. Also available through the app are various learning activities for pupils of different ages and abilities. It is hoped the project will help generate enthusiasm for STEM.

Meanwhile, EngineeringUK has announced a pilot programme for schools exploring solutions to tackling climate change and environmental sustainability.

Launching in January 2024, the Climate Schools Programme is aimed at 11 to 14 year-olds in all parts of the UK, providing free resources, lesson plans and activities aligned with the curriculum for science, geography and English. EngineeringUK hopes the resources will inspire young people to explore green engineering careers.

Teachers and schools can register for free now.

more...

bit.ly/SAMHEWalkThrough

climateschoolsprogramme.org.uk

Green engineering postcards

You may have seen the green engineering careers posters we have sent out with previous issues of Classroom Physics that the IOP has produced in collaboration with EngineeringUK and other professional engineering organisations. Included with this issue is our latest offering – a set of green engineering careers postcards.

Designed for use in the classroom, each postcard includes discussion prompts such as: "Should we generate our own power at home?" and profiles of real engineers who are helping us to move to a more sustainable future. (For more on this, have a look at our article on page 6.)

As highlighted in the Department for Education's Sustainability and Climate Change strategy, "the challenges of climate change are formidable … but children and young people must be given the hope that they can be agents of change". Choosing a career in climate science or green engineering gives them agency. We hope these postcards will, for some of those in your class, be the first step in a career that helps engineer a more sustainable future for us all.

Students can read profiles of green engineers at **neonfutures.org.uk/green**
You can download more postcards at **neonfutures.org.uk/postcard**

New events list on IOPSpark

IOPSpark, the IOP's teaching resources website, now has listings for free events run by the IOP and partners. Whether you are an experienced teacher wanting to know about the latest research in areas like medical physics, or an early career teacher who wants advice on how to teach the more challenging aspects of momentum, there's a workshop for everyone.

spark.iop.org/events

Physics festive funnies (kind of)

As a Christmas 'treat' we present our seven best cracker jokes (one for each domain of IOPSpark)...

Earth and space:
Did you hear about the restaurant NASA is starting on the Moon?
Great food, no atmosphere!

Electricity and magnetism:
What is the name of the first electricity detective?
Sherlock Ohms

Energy and thermal physics:
What did the thermometer say to the graduated cylinder?
You may have graduated but I've got many degrees

Forces and motion
Two kittens are on a roof. Which one falls off first?
The one with the lowest mu

Light, sound and waves
Where does bad light end up?
In a prism

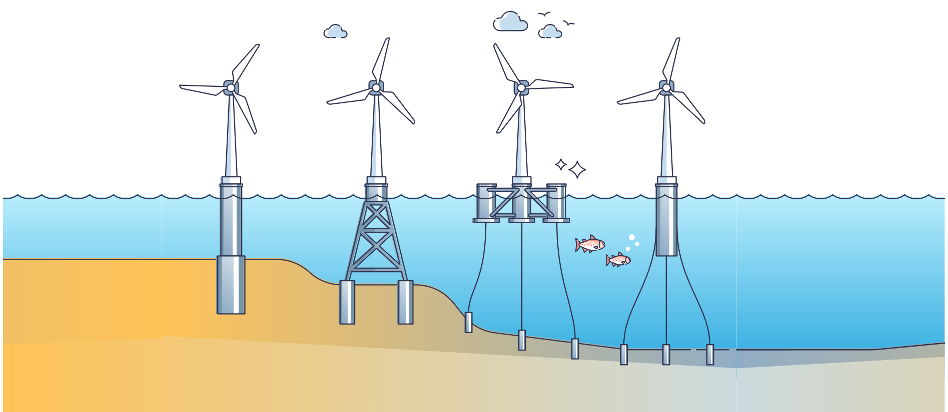
Properties of matter:
Why can't you trust an atom?
They make up everything

Quantum and nuclear
What did one electron say to the other electron?
Don't get excited. You'll only get into a state!

The physics of floating and sinking is important in nature, and vital for a green future. Here we feature some examples you might want to discuss with your students.

Rise to power

As we search for more renewable ways to generate electricity, floating offshore wind farms are a promising option.


Credit: Shutterstock

Types of offshore wind turbines: monopile, jacket tripod, semi-submersible and floating spar.

For decades, oil platforms have been used to access oil and gas reserves under the oceans.

Initially they were built directly onto the seabed, but as the search for new reserves led to deeper waters, this became increasingly impractical. Floating platforms were invented. that brought oil up from wells in the seabed through pipes known as risers. Floating oil platforms – like container ships – are some of the largest movable structures in the world and brilliant examples of objects that, despite their very large mass, are able to float. Today's deepwater platforms are built on large underwater chambers that can be filled with air or water to control buoyancy, and anchored in place to provide stability even in a hurricane.

Green options

Today, as the world seeks to move away from fossil fuels, engineers are taking the advances made in offshore oil and gas production and applying those lessons to generate clean electricity using offshore wind.

Like oil and gas, offshore wind was initially most easy to access close to shore. Indeed, many of the UK's wind farms are visible from the coast – though even the visible turbines are often still quite a long way out. They are visible because of their sheer size, with the largest reaching up to 270 m (almost as high as the Eiffel Tower). The blades on a modern offshore wind turbine can be over 100 m long, and a single rotation can generate enough energy to power a UK home for two days. But most of the strongest winds are away from land, over the open sea. The greater water depths involved, and the geology of the seabed, can make it uneconomical to build on the ocean floor, so the industry is looking at floating platforms.

Floating turbines offer several advantages. As well as allowing development in areas of deeper water, basing turbines on floating substructures, rather than building them directly on the seabed, makes the development of an offshore wind farm quicker and easier. Almost all of the technology can be manufactured off-sire and towed into position, whereas for 'fixed bottom' turbines, builders need calm seas to carry out construction. It also means the machinery can be easily removed and decomissioned at the end of its life.

Floating turbines are still in their infancy compared to the better established fixed bottom variety. But around the UK, projects are taking place to develop the technology. Off the north coast of Scotland is the Pentland Firth floating wind project. Here, Copenhagen Offshore Partners, a Danish firm specialising in offshore wind, plans to build seven floating turbines which will generate 100 MW of energy – enough for 70,000 homes.

One of the aims of this project is to show that floating offshore wind is a viable industry for the UK. The Pentland project will create hundreds of jobs to build and maintain the wind farm, with jobs at sea and throughout the supply chain on land. As a sector, offshore wind directly employs about 32,000 people, according to research published this year by the Offshore Wind Industry Council. This is expected to rise to more than 100,000 by the end of the decade.

Physics challenges

The proposed turbines for the Pentland Firth project are up to 300 metres in height. Floating such huge structures and keeping them stable are just two of the physics challenges inherent in offshore electricity production.

Encourage your students to list some of the other physics applications involved. These include conversion of kinetic energy into electricity, undersea transmission and connection with the grid, and energy storage solutions for overcoming intermittency of renewables.

Offshore wind offers great career opportunities for young people, including through apprenticeship routes. Find out more about three young people who began work at the Dogger Bank project – set to be the world's largest wind farm:

bit.ly/OffshoreApprentices

Credit: Shutterstock

Naturally buoyant

Controlling buoyancy is critical for life in the water. How has nature addressed this problem?

As humans, we're not evolved to go underwater. Apart from the fact that we can't breathe below the surface of water, swimming there requires us to propel ourselves down through the liquid. Our natural buoyancy, due to air in our lungs, pulls us back to the surface.

Divers overcome this challenge with weights to increase mass, and compressed air, which is used for both breathing and controlling buoyancy.

Unsurprisingly, fish and other sea creatures are somewhat better adapted. Evolution has served up a range of different ways in which sea creatures can move easily to different depths.

Bladders, livers and farts

Most fish have evolved a sac within their abdomen called the swim bladder, which they can fill with air, either directly by breathing through their mouth at the surface, or by diffusing oxygen from their blood. The bladder, as a volume of gas within their body, enables them to increase or reduce their density and control their position in the water. Sometimes, particularly in aquarium fish, the swim bladder can become infected, which leads to fish struggling to reach the surface, or swimming upside down.

Some types of fish, most notably sharks, don't have swim bladders, so rely on other aspects of their physiology. For some sharks, an oversized liver is a key way to stay afloat. The liver can be up to 25% of the whole body weight, and produces large amounts of low density oils to aid buoyancy. Some biologists have argued that a shark's body shape, with flattened nose and angled fins, creates lift when the shark is moving through the water. Others point to sharks' skeletons being largely made of cartilage, which is less dense than bone. The sand tiger shark simply gulps air at the surface and then 'farts' out the air until it achieves the ideal depth, where it can remain with minimal effort.

Humans have of course developed the capacity to control buoyancy under the water, through the submarine. Like boats, submarines float because, while massive, they're also large and full of air (see pull-out, page 11). They can control their buoyancy, and therefore their operating depth, by filling internal chambers with water or air.

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.

research@teachphysics.co.uk

Credit: Shutterstock

The persistence of misconceptions

Physics teachers will be well aware of research that reports the misconceptions their students hold, for example, the widely held belief that all objects in motion require a resultant force to keep moving. Teachers might confidently assume that years of studying and teaching had completely eradicated their own misconceptions. However, an intriguing study by Potvin and Gyr suggests that, whilst experts are less likely to apply misconceived ideas, misconceptions can continue to coexist alongside their correct scientific concepts.

The researchers interviewed 62 children aged 5–6, 127 school students aged 14–15, and 22 secondary school science teachers. They asked their participants to complete a computer-based sink/float task. The task involved being shown pairs of balls described as made of either polystyrene, wood or lead. The balls were of various sizes. The participants were asked which of the two balls has "a tendency to 'sink more'". The researchers considered two misconceptions in their data. The VOLUME misconception, that is, floating or sinking is determined by the volume of an object alone; and the MASS misconception, that floating or sinking is determined by the mass of an object alone.

As might be expected, the MASS and VOLUME misconceptions were much more prevalent in the pre-school children than the other two groups. Only 24% of pre-schoolers had a conception of sinking and floating based on density. The proportion of students with the correct scientific model rose to 72% for the high school students.

Of particular interest is that, when presented with some pairs of balls, some science teachers also answered incorrectly, with responses based on one of the misconceptions described above. The MASS misconception continued to exert some influence over some teachers' responses. Some experts with many years of experience retained the intuition that heavier objects are more likely to sink than lighter ones, in some contexts.

Potvin and Gyr propose a prevalence model of conceptual change. They suggest that misconceptions continue to coexist with correct scientific concepts, even after many years of formal teaching. Whilst the prevalence of misconceptions gradually reduces, there may be contexts, for example, when under time pressure, when even experts revert to using misconceptions. The coexistence of misconceptions with mature scientific knowledge has been reported in other studies – see, for example, Shtulman and Valcarcel's 2012 paper (in the sidebar).

The findings suggest teachers adopt a humble stance. Whilst teachers may rarely activate misconceptions, studies like Potvin and Gyr's propose that our intuitive initial ideas are never fully eradicated and continue to exist as possible explanatory resources. In teaching, rather than expecting a sudden transition to the consistent use of expert concepts, a more reasonable expectation is a gradual transition with periods of progression, but also regression to misconceptions that remain an enduring part of our conceptual repertories.

References

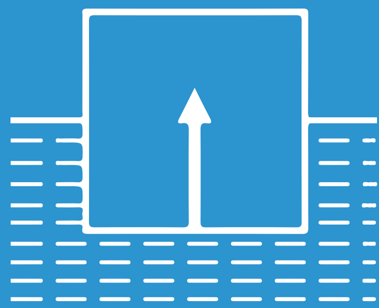
Potvin, P., & Cyr, G. (2017). Toward a durable prevalence of scientific conceptions: Tracking the effects of two interfering misconceptions about buoyancy from preschoolers to science teachers. *Journal of Research in Science Teaching,* 54(9), 1121-1142

Shtulman, A., & Valcarcel, J. (2012). Scientific knowledge suppresses but does not supplant earlier intuitions. *Cognition*, 124(2), 209-215.

Pull out and keep!

Properties of matter

Floating and sinking



Inside this issue:

- **Activity: Loaded ship**
- **Demonstration: Colourful convection**
- **Student worksheet: Making a model ship**

Will it float? Making predictions at 11–14

When faced with a heavy and light object, many young learners will predict that the light one will float and the heavy one will sink. Some realise that volume plays a part but will have difficulties in describing the concept of density.

In your first lesson on the topic of floating and sinking, you can elicit preconceived ideas by providing a bowl of water and objects of different densities. Some easy to source objects may be: a large wooden block, metal paperclip, polystyrene block and a drawing pin. Ask your class to arrange the objects in order from heaviest to lightest, and then to predict which will float and which will sink. Many are likely to think a paperclip will float because it's light, and the wood will sink because it's heavy, but of course when they test them the wood floats and the paperclip sinks.

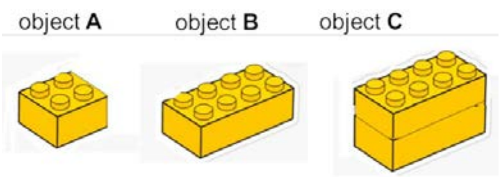
Make the statement: “If it’s not true that heavy objects sink and light objects float, how can we predict what will sink or float?" This works best with students working in small groups so they can discuss, predict and test ideas together. You may also want to provide a working definition that ‘density is how heavy or light an object is for its size’ to provide them with the descriptive tools they need to make predictions without having to (yet) fully understand the more formal definition of mass per unit volume.

The observation that less dense objects float on more dense fluids is useful for making predictions, but it's important to emphasise that it isn’t an explanation. The force responsible for keeping objects afloat is upthrust – also known as the buoyant force – and is an idea you can revisit when teaching pressure (see ‘Balanced forces’ on page 11). Although experiments with solid objects are the easiest to set up, it’s also important to give students the opportunity to explore hollow (air-filled) structures to understand how cargo ships made of metal stay afloat. Showing liquids floating on liquids will prepare them for the thermal convection topic.

Inside this pull-out are two suggested activities. In our Loaded ship activity on page 10, students add cargo to a model ship and measure the depth it sits at in the water. This introduces the idea of average density and provides a tangible example of how denser objects sit lower in the water. There is an accompanying student worksheet on page 12. On page 11 is our Colourful convection demo in which adding food dye to water allows students to see that hot water floats on cold.

Diagnostic question

Toy bricks come in different sizes that can be stuck together to make bigger objects.



Object A floats in water, will the objects B and C float or sink?

Teaching tip:

Put the question on the board and ask students to vote using an electronic voting system (e.g. mentimeter.com) or with mini-white boards.

Voting options:

I am sure this will float • I think this will float
I think this will sink • I am sure this will sink

After considering objects B and C you could ask them about an object made of 100 bricks.

Demo tip

Most toy bricks are made of a material that is denser than water. They float because of trapped air. For more reliable results, float your blocks upside down.

This diagnostic question was adapted from Best Evidence Science Teaching resources. For more on the theme of matter, see **bit.ly/BESTmatter**

Activity: Loaded ship

In this activity, students make a model of a cargo ship and investigate how deep it sits in the water for different loads.

Credit: IOP

Equipment

- A printed copy of the student worksheet (see ‘Making a model ship’, page 12)
- A large cardboard drinks carton. (e.g. 1 litre juice carton)
- Scissors
- Sticky tape
- A jug and access to tap water
- A ruler
- 10 g and/or 20 g slotted masses (200 g in total)
- Paper towels (for spillages)
- A few drops of blue food colouring (optional)
- A mass balance capable of measuring to 1 g or better (optional)

Procedure

Ask students to:

1. Follow the instructions on their worksheet to build a model cargo ship.
2. Fill the large container with water to a depth of at least 5 cm (adding the blue food dye if available).
3. Place the empty ship in the container and record the depth in cm.
4. Remove the ship and add cargo of mass 20 g.
5. Lower the ship into the container and adjust the positions of the mass(es) so that the ship sits level in the water. Record the new depth in cm.
6. Repeat steps 4 and 5 to obtain data for cargo mass (g) and depth (cm) up to a total mass of 200 g and/or depth of 4 cm.
7. Plot a graph of cargo mass (g) against depth (cm).
8. Draw a best-fit line through the data and extrapolate the graph to the height of the boat (6 cm) to find the maximum load the ship can carry before sinking.

Extension

Students can estimate the density of water using:

density of water =
gradient of graph ÷ surface area of bottom of boat

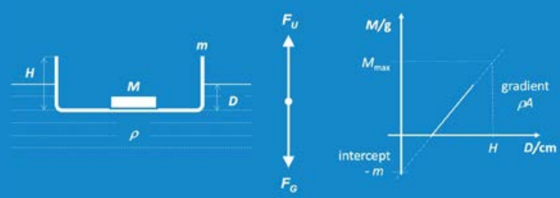
If a mass balance is available, they can also estimate the density of their ship for different loads by measuring the mass, width, length and height of their empty ship and using:

density of ship =
total mass of loaded ship ÷ volume of ship

They should find that the average density of their ship, even when fully loaded, is lower than that of water.

Alternatively, for older students, challenge them to work out water density and mass of empty ship from their graph.

Loaded ship: Straight-line graphs analysis at 16–18



The gravitational force that acts on the model ship of mass m carrying a cargo of mass M is:

$$F_G = (M + m)\,g$$

Where g is the gravitational field strength.

The upthrust force on the boat is equal to the difference in pressure ΔP between the top and bottom surfaces of its base:

$$F_U = \Delta PA$$

Where A is the surface area of the base of the ship.

The pressure difference is related to the water density ρ and depth D by:

$$\Delta P = \rho g D$$

Substituting the above expression into the one for F_U and making F_U equal to F_G leads to the following relationship:

$$M = \rho AD - m$$

Hence a graph M against D will be a straight line with gradient = ρA and a y-axis intercept = -m.

With special thanks to Milena Cabarkapa for help testing this activity.

Demonstration: Colourful convection

In this demonstration, students see that hot water floats on cold, and cold water sinks through hot.

Credit: IOP

See a video of this demonstration at spark.iop.org/colourful-convection

Equipment

- 2 trays
- Red and blue food colouring
- A stirrer
- Water from the hot tap (e.g. in an insulated flask)
- Water from the cold tap at room temperature (e.g. in a jug)
- 4 large, transparent, identical jars or bottles
- 2 pieces of card (the lids used for foil containers work well)

Preparation and safety

Practise in a large sink or basin before the lesson. If you use glass jars/bottles, ensure that they can be set up and taken down safely without danger of breakages.

Procedure

1. Place two jars on one tray and two jars on another.
2. On the first tray, put a few drops of red dye in one jar and fill it with hot water. Make sure the water reaches the open mouth of the jar.
3. Put a few drops of blue dye in another jar and fill it with cold water. Make sure the water reaches the open mouth of the jar.
4. Place the piece of card over the mouth of the red (hot) water jar and press firmly in place. Turn this jar upside down and place it directly on top of the jar of blue (cold) water.
5. Carefully slide the card out from between the two bottles so that their mouths are in contact. The red and blue water do not mix.
6. Repeat steps 1–5 for the other tray, but this time place the blue jar on top of the red. This time the red and blue water do mix.

Explanation

The density of the cold water (0.998 g/cm^3 at 20°C) is a little higher than that of the hot water (0.988 g/cm^3 at 50°C). On the first tray, where the hot water is on top, there is very little mixing because the hot water is already floating. On the second tray, the hot water is below; it rises and cold water flows downwards to replace it, so the two mix.

Teaching notes

Some students think the atoms or molecules that make up water get bigger when water expands. Provide a simple diagram of the arrangement of particles in the two jars to emphasise that the decrease in density is due to an increase in the (average) spacing between particles.

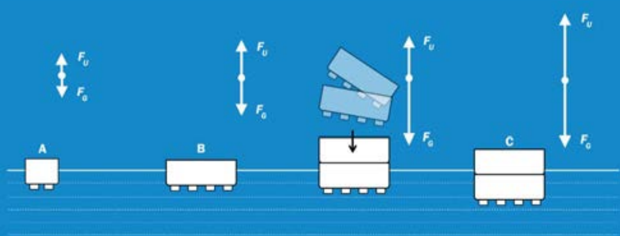
Download the diagram and watch the video at **spark.iop.org/colourful-convection**

Balanced forces: building understanding at 14–16

Pre-requisite knowledge:

- Gravitational force is proportional to mass
- Pressure acts in all directions in a liquid
- Pressure increases with depth in a liquid
- For an object submerged in a liquid, the force on each face is equal to pressure multiplied by surface area

Building structures out of toy bricks provides a familiar context in which to explain why upthrust and gravitational forces remain balanced even when more mass is added.



- Replacing A with B doubles the gravitational force F_G because B has twice the mass of A. The surface area of the base of B is twice that of A and so the upthrust force F_U is also doubled. The forces remain balanced.
- Adding another identical brick to B unbalances forces and so block C sinks. But, as it sinks, water pressure and hence upthrust increases. At double the original depth, upthrust becomes large enough to balance gravity once more.

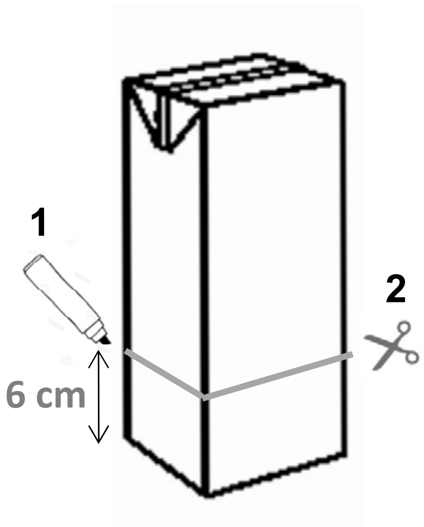
object	volume	mass	gravitational force	surface area of bottom	Depth	upthrust force
A	1	1	1	1	1	1
B	2	2	2	2	1	2
C	4	4	4	2	2	4

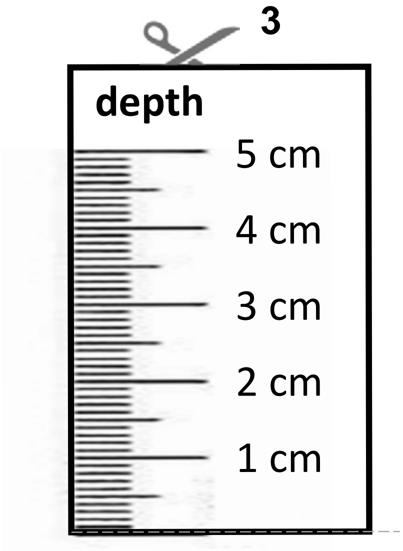
Making a model ship

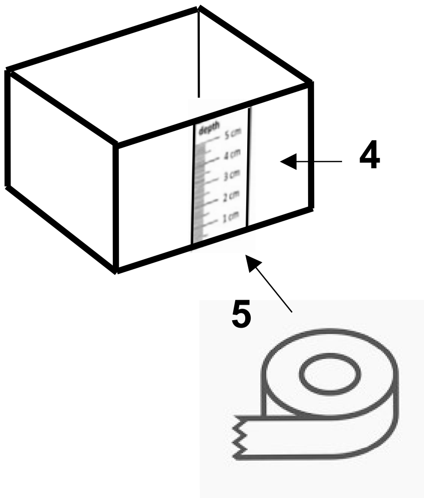
In this activity you will be making a model of a cargo ship and measuring how deep it sits in the water for different loads. To make your ship:

1. Draw a line around your carton at a height of 6 cm from the base
2. Cut along the line.
3. Cut out the depth meter.

4. Stick the depth to the side of your carton.
5. Make the depth meter waterproof by adding sticky tape.







IOP Institute of Physics

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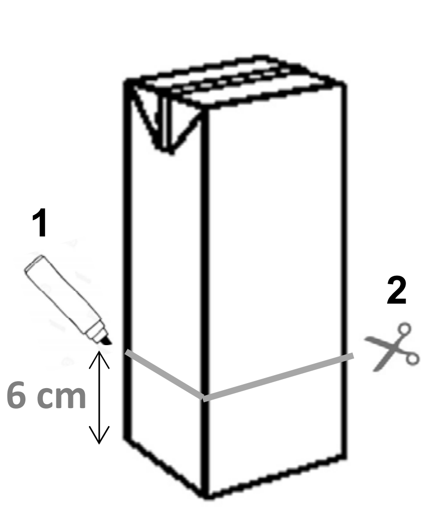
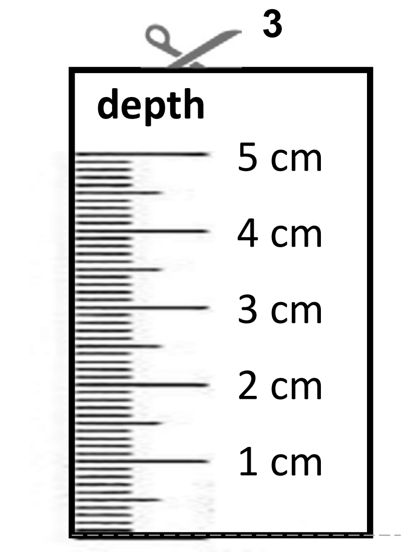
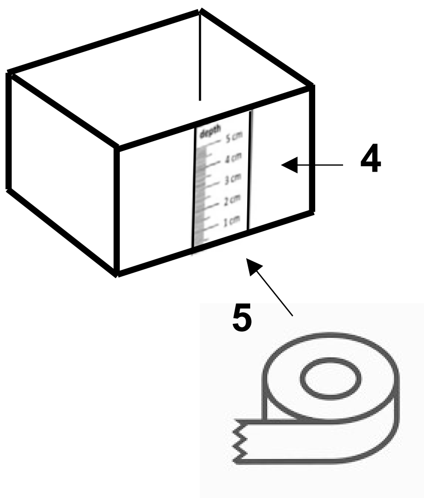






IOP Institute of Physics

Stories from physics

Floating nuclear power stations

Nuclear fission has been used as a method of propulsion for ships and submarines. An alternative water-based application, exploited by both the United States and Russia, is the floating nuclear power plant. In the 1960s, the US Army refitted a cargo ship to act as a platform for a nuclear reactor. The first floating nuclear power station, the *Sturgis*, contained a 10 MW pressurised water reactor fuelled by enriched uranium, but had no means of propulsion and had to be towed into location. In 1968, when a drought in Panama was hampering hydroelectric generation, it was towed to Gatun Lake to provide power to locks on the Panama Canal. By the late 1970s, the vessel was deemed impractical and decommissioned. Levels of radioactive contamination took until 2015 to be sufficiently low for the *Sturgis* to be scrapped. In 2019, in the Russian port of Pevek, the *Akademik Lomonosov* became the second floating nuclear plant to enter service, providing heat and power in an isolated region of northeast Russia.

The 'floating' bag

When is 'floating' not floating? When it's falling. In 2008, the Space Shuttle Endeavour carried out a mission to repair part of the International Space Station's structure and to deliver equipment and supplies. During a spacewalk, Ukrainian-American astronaut Heidemarie Stefanyshyn-Piper noticed an unusually large amount of grease in her tool bag. "I think we had a grease gun explode in the large bag, because there's grease in the bag," she reported to her colleague in the shuttle. Mission control decided that Stefanyshyn-Piper should clean up the grease with a dry wipe. Unfortunately, she accidently knocked the bag, which entered low Earth orbit where, eight months later, it eventually burned up. During its orbit, the tool bag could be seen by observers on Earth through telescopes. It contained a scraper, two grease guns, a rubbish bag and dry wipes. The estimated cost of the lost equipment was US$100,000.

UPDATE: You may have seen in the news that this happened again on 1 November:

bit.ly/FloatingToolbag

Einstein's sink

Einstein's celebrity has led to the display of several objects connected to the physicist. Einsteinian artefacts include his blackboard, in the Museum of the History of Science in Oxford; his pipe, in the Smithsonian; and a photo of the physicist in fluffy slippers in the collection of the Historical Society of Princeton. One of the more curious items is Einstein's sink. Visitors to the Oort Building, at the University of Leiden, can visit a grubby looking sink in the De Sitterzaal lecture room. University legend runs that Einstein (along with, at other times, Lorenz, Ehrenfest and Onnes) washed his hands in the basin. The sink has its own Wikipedia page, is listed as the 38th most popular attraction in Leiden by TripAdvisor and, when the sink was threatened with being lost in a 2015 renovation, was saved by a petition of sink enthusiasts.

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 **floating and sinking** 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.

Credit: IOP

Water tanks in waterlogged ground can be a big problem

Having done a bit of fishing and kayaking myself, the need to understand floating and sinking in a basic way is obvious to me; but what about that tiny number of students who have no interest in canal-based activities? The paper *"Demonstrating buoyancy in waterlogged ground"* by Stephen Hughes is a fascinating real-life application. It describes how a 22 ton concrete water tank was lifted out of waterlogged ground. Apparently fuel tanks embedded in the ground can be crushed by groundwater. Groundwater buoyancy can be a serious problem when a large excavation for the foundation of a high-rise building is left empty before building work starts.

The paper describes a number of instances where pressure from groundwater has been an issue and then describes a low-cost series of experiments that students can do to investigate the physics involved. There's quite a lot of scope here with the experiments being simple enough for younger students to perform while the maths involved could be of interest to older students. The whole context is interesting, surprising and relevant.

Another article worth reading for some insight into floating and sinking is a short one from Jon Ogborn titled *"Archimedes' boat: making holes in water"* which was part of the Physics Education 'Insights and Conundrums' series. There can be an issue with connecting the macroscopic explanation of floating and sinking to what is happening microscopically. Making a connection between displacing fluid and the pressure that involves, and pressure from the movement of particles, can be difficult. This article discusses the idea of punching holes in water and the weight of the water that would fill the holes. It seems a very simple idea, but Ogborn suggests that this approach might be used as a build up to learning about Archimedes' principle.

The next article concerning floating and sinking comes from the 'What Happens Next?' collection and was written by Felix Isaac and David Featonby. I find this a fascinating demonstration, best performed by students themselves so they can feel the forces involved.

You take a rectangular and regular container, preferably transparent so there can be no hidden goings on. The container is almost filled with water – it needs to have around 5 cm of water

in it at least. The container is then balanced on a pencil or similar object lying lengthwise on a bench. Obviously the water needs to not be slopping around to balance, and when a steady state is reached, students can push a finger into the water at one side of the container, as far away from the pivot as possible. They can use an object if they prefer. Either way, they will really feel the forces at play. The bizarre bit is that the carefully balanced container doesn't tip over. You can feel the force of the water pushing against your finger; you can feel the force you are exerting; but the container doesn't move at all.
The next step is realising that the force is being transmitted throughout the fluid, so although you feel a force on your finger, the container is feeling that force everywhere inside it. Balanced water!

"Demonstrating buoyancy in waterlogged ground"
bit.ly/PEWaterloggedGround

"Archimedes' boat: making holes in water"
bit.ly/PEArchimedesBoat

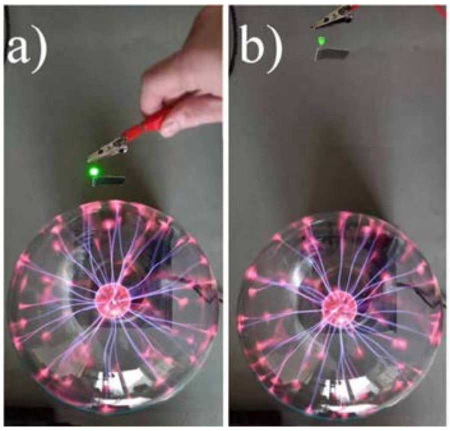
"Balanced water! The question"
bit.ly/PEBalancedWater

Recent highlights

"The spinning toilet brush–a classroom experiment on the mechanical equivalent of Joule's heat" is an open access paper that could be used to add a little humour to a lesson. The title says it all really, but the authors have done a painstaking job of trying to recreate Joule's famous experiment using a toilet brush. The article even has a good image of the original experiment to use.

The paper *"A simple practical to measure energy stored when stretching a spring"* by Mark Harrison describes how to show that the energy stored in a spring that obeys Hooke's Law is proportional to the square of the spring's extension. It does this using equipment you'd expect expect to find in most school physics labs. While the paper isn't open access, there is a five-minute video abstract that anyone should be able to access.

If you've been enticed towards plasma balls but don't know how to use them in your teaching then *"Transmission of electromagnetic waves from a plasma globe to a light emitting diode"* is going to be a great read for you. I never realised that you could light an LED just by bringing it up to the



Credit: IOP

plasma globe. My favourite use of plasma balls was putting a coin on top and then bringing another coin up very close to the first and getting tiny sparks. This paper describes much more useful ideas including looking at shielding of EM radiation.

"The spinning toilet brush–a classroom experiment…"
bit.ly/PEToiletBrush

"A simple practical to measure energy stored when stretching a spring"
bit.ly/PEStretchingSpring

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

Quick Links

Open access

"Is the Archimedes principle a law of nature? Discussions in an 'extended teacher room'"

What teachers think about Archimedes' principle

bit.ly/PELawOfNature

Free article

"Once more about the Cartesian diver"

One of many Physics Education papers on Cartesian divers

bit.ly/PECartesianDiver

"Use of an Arduino to study buoyancy force"

Get up to date with your floating and sinking with an Arduino!

bit.ly/PEArduinoBuoyancy

Open access

"The evolution of Physics textbooks used in Ireland 1860–2022"

Worried about your textbooks? You should be, according to this paper.

bit.ly/PEPhysicsTextbooks

"School visits to a physics research laboratory using virtual reality"

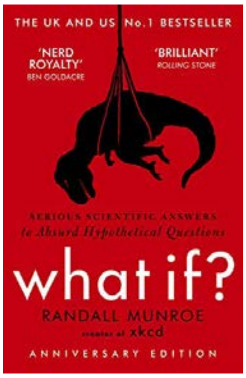
Virtual reality could let students visit anywhere on earth (and beyond) at low cost

bit.ly/PELabVisitsVR

Book corner

In this new slot, we share book recommendations from the physics teaching community. Kicking us off, David Cotton writes about 'What If?' by Randall Monroe.

what-if.xkcd.com



Credit: Randall Munroe

What if there was a book that proposed absurd problems and answered them with well thought-out science and calculations? Well there is, written by engineer Randall Munroe of xkcd.

'What if?' addresses questions like "How long could a nuclear submarine last in orbit?" The answer involves an exploration of the physics of pressure and temperature, and there is even a calculated approach to getting the submarine out of orbit by reversing the Trident missiles in their housings. A range of other, similarly bizarre questions are given this treatment.

My own favourite, which I use with my students when teaching gas laws, is "A mole of moles": what would happen if you were to gather a mole (unit of measurement) of moles (the small furry mammal) in one place? Monroe starts his answer with some ballpark maths to tell us that a mole of moles would be on a planetary scale. Then, using calculations, we find that, if released on the Earth's surface, the moles would be 80 km deep.

A former NASA robotics engineer, Monroe now draws comics full time and runs the xkcd.com website, where readers can ask absurd hypothetical questions. This book is a collection of his favourite answers from the site. There is also a 'What If? 2', which was published last year.

I have seen many students return happy from Christmas holidays with this book. I would recommend it for your physics students and your family.

physicsworld

Stories from our magazine for the global physics community.

Visit **physicsworld.com**

Agostini, Krausz and L'Huillier win 2023 Nobel Prize for Physics

This article, by Physics World online editor Hamish Johnston, profiles the three physicists who shared this year's Nobel Prize for "experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter".

Pierre Agostini (Ohio State University, USA), Farenc Krausz (Max Planck Institute of Quantum Optics and the Ludwig-Maximillians University of Munich, Germany) and Anne L'Huiller (Lund University, Sweden) share 11 million kronor – about US$1 million. L'Huillier's award is particularly notable because she is only the fifth woman to receive the Nobel Prize for Physics.

Quoted in the article is Nobel Committee for Physics member Mats Larsson, who said: "I think the most exciting thing is that, over a very long period, [the laureates] have been working very hard both to understand the fundamental physics and then to develop the technology to really open the world of electrons, which are the workhorse for all of us and we never had access to earlier."

bit.ly/PWNobelPhysics23

...and the Peace Prize also goes to a physicist

Physics World News Editor Michael Banks profiles Iranian physicist Narges Mohammadi, who was awarded the 2023 Nobel Peace Prize "for her fight against the oppression of women in Iran and her fight to promote human rights and freedom for all". She is the third physicist to be recognised with the award.

Mohammadi began campaigning for women's rights at university in the 1990s. As a graduate she worked for the Iran Engineering Inspection Corporation, but was also a prolific journalist and human rights campaigner. In 2009 she was sacked and arrested. She has since been convicted several times and is currently serving a ten-year jail sentence. In 2022 she published a book based on interviews with women who had experienced solitary confinement.

The Nobel Committee remarked that that this year's Prize also recognises the "hundreds of thousands of people who, in the preceding year, have demonstrated against Iran's theocratic regime's policies of discrimination and oppression targeting women".

bit.ly/PWNobelPeace23

more...

IOP Publishing has also put together a page featuring papers published by this year's Nobel Laureates, including the winners for Chemistry, whose work on quantum dots has featured in journals from IOP Publishing: **iopscience.iop.org/page/nobel-prize**

Saskia Burke, an assistant scientist/metrology technician at the National Physical Laboratory (NPL) writes about the measurement of density.

npl.co.uk

more…

Saskia is one of the technicians featured in the Gatsby Charitable Foundation's 'Technicians: We Make the Difference' website and campaign, which showcases the many exciting technician careers available to young people, which you don't need a degree to get in to. Saskia undertook a three-year apprenticeship with NPL, rotating through departments for dimensional, mass and nuclear metrology. To find out more, visit **technicians.org.uk**

Measuring density

Density is measured by the amount of mass in a certain volume. Its unit, kg/m^3 is traceable back to the National Physical Laboratory (NPL), which holds the standard kilogram and metre – and all other primary standards of measurement. We also have a department that carries out density measurements and calibrations for customers.

Density is measured with a hydrostatic weighing apparatus. Based on Archimedes' principle, this process involves weighing an object on a weighing balance in air and then in water. Since we know the density of both air and water, we can compare the different results for mass to work out the density.

An object will float if it's less dense than its surrounding air or water, and will sink if it's more dense. Real-world applications where precise measurements are needed for this include helium balloons and life jackets.

However, density also plays a part in how the centre of mass of an object is measured. If an object has a uniform density, then the centre of mass will be in the centre of the object. But if the density isn't uniform (if the object has hollow elements or is an odd shape) then the centre of mass won't be in the centre of the object.

This is an important parameter for space-based physics experiments as it affects linear and angular momentum, which keep spacecraft components floating through space in the direction and path needed. At NPL, we calibrate the centre of mass for spacecraft components, such as the batteries used to power the onboard instruments.

Samir Moezzi, Physics Advisor at CLEAPPS, looks at some useful teaching activities on floating and sinking.

primary.cleapss.org.uk

Lava, cocktails and a fire extinguisher

CLEAPSS has a primary section which hosts a wide range of activities on floating and sinking – many of which are more than suitable for secondary science. They could be used in lessons, in a science/STEM club, or even as student-led demonstrations during open evenings.

The iconic lava lamp celebrates its 60th anniversary this year. The 1960s design classic has for decades entranced users with the mesmeric floating and sinking movements of hot wax and water. What more excuse is needed for students to make their own simple lava lamp using oil and water? Search our primary resources website for 'lava lamps' for simple-to-use instructions.

Other primary website highlights on the floating and sinking theme include our 'density cocktail'. This is a colourful activity that enables students to use six different liquids to learn about density. It encourages good observation, thinking skills and equipment manipulation.

Credit: Shutterstock

We also have a teacher demonstration activity that uses carbon dioxide produced in a reaction between bicarbonate of soda and vinegar to extinguish a flame. This could make for an excellent starter activity if teaching secondary students about density.

Please search the website for these activities plus a whole lot more.

Lisa Clatworthy, editor of Education in Chemistry, the Royal Society of Chemistry's magazine for teachers, shares some chemistry-inspired activities.

edu.rsc.org/eic

In search of solutions

Sink or swim in your science lessons with these chemistry-inspired activities

Challenge your leaners with a set of practical problem-solving activities. From RSC Education's *In search of solutions* collection, these activities are designed to engage and motivate learners, as well as help them develop key skills and encourage them to consider a career in science.

Each activity presents learners with a context and problem to solve. Get your students to work in groups to design and then do their own experiment. They'll need to work as a team and the open-ended approach will engage learners with the process of scientific enquiry, developing key practical skills, such as writing a hypothesis, selecting appropriate equipment, controlling variables and evaluating results.

Full kit lists and safety instructions are included with each activity, and they're all free to download from the RSC Education website.

Try these four activities on the theme of floating and sinking:

- The ten-gram boat race explores surface tension: **rsc.li/3LYB6OX**
- The ups and downs of chemistry encourages learners to explore solubility and density: **rsc.li/3ZXzoTQ**
- Building a chemically powered boat finds a use for junk materials as learners create a gas-powered boat: **rsc.li/46wdsln**
- A bubble race takes the chemically powered boat a step further as learners have to use bubble power to drive a boat further for longer: **rsc.li/3ZZsEEX**

Find more *In search of solutions* activities at **rsc.li/3M47HTT**

Sylvia Knight, Head of Education at the Royal Meteorological Society, describes the spectacular phenomenon of brinicles or 'underwater stalactites' – driven by floating ice and sinking salty brine.

rmets.org


Credit: windy.app

A brinicle

A sinking sensation

Brinicles – columns of ice which extend down through the polar ocean – captured the imagination of many when David Attenborough's Frozen Planet team first captured one forming in 2011.

When sea ice forms, any impurities such as salt are forced out. The ice itself isn't salty and, being less dense than the surrounding water, floats. As the ice forms, it therefore makes the surrounding water saltier, lowers its freezing point and increases its density. This supercooled brine therefore sinks and, in specific conditions, sinks in a plume.

As the brine comes into contact with the less salty water below, ice forms instantly around the plume, creating a hollow tube or 'brinicle' which insulates and contains the sinking plume. Transfers of latent heat and salt reinforce the process and in very still, shallow water this enables the brinicle to thicken and extend down to the sea floor. The colder the air, the more saline the water contained within the brinicle.

In some ways the formation of a brinicle is a very specific (and spectacular) example of the more general formation of polar sea ice which, by making the surrounding water saltier, causes it to sink and drives the thermohaline circulation of the world's oceans.

As the climate changes and the surface ocean warms, less sea ice forms, having significant impacts on the global circulation of water and the wider climate system.

CREST AWARDS

crestawards.org

The CREST Awards are the flagship education programme from the British Science Association (BSA), providing enrichment activities to inspire, engage and connect young people aged 5–19 with STEM.

Our free CREST project resources and challenge packs incorporate a range of science activities and experiments which span numerous themes to suit varying skills and age groups. Find out more: **library.crestawards.org/**

BSA offers Engage Grants to help schools take part in CREST Awards. Engage Grants are designed to help schools run CREST Awards with students who are underrepresented in STEM. The next round of applications opens in January. Find out more: **crestawards.org/engage/grants**

BRITISH SCIENCE ASSOCIATION

Wonderlab: The Bramall Gallery at the National Railway Museum, York

Wonderlab: The Bramall Gallery is an unmissable new interactive experience for schools at the National Railway Museum, York. Recommended for KS2 and KS3, pupils will put their engineering skills to the test with 18 hands-on activities, from a human wind tunnel to experimenting with wheel design.

Children will discover how fire makes an engine move or how the right shape can make a train go faster in our live Science Shows: Fire Powered and Streamlined by Design. The gallery enriches learning across STEM themes including magnets, forces, energy, states of matter and design and technology.

A visit to Wonderlab: The Bramall Gallery complements a trip to the National Railway Museum, where your class will make meaningful connections between the past, present and future of railway heritage and engineering as they discover the wonders of the museum.

railwaymuseum.org.uk/learning

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Upcoming events...

British Science week

8–17 March

Free activity packs are available

britishscienceweek.org/activity-packs/

49th Stirling Physics Teachers Meeting

23 May 2024

Booking details will be available via **iop.org** soon

Inspire inquisitive minds to think big, challenge facts, ask questions and invent solutions with the UK's top annual science and engineering competition.

Entries close on 27 March 2024

thebigbang.org.uk/competition

Physics Central 2324

January – July 2024

New dates have been published for Physics Central 2324 in the new year.
To check the latest, visit:

spark.iop.org/events

Technicians
We make the difference

Technicians: We make the difference

This campaign (featuring the IOP Apprentice Award winner Saskia Burke, see pages 3 and 17) was set up by the Gatsby Charitable Foundation, which has been championing technician careers since 2016. Visit the website for teaching resources, careers case studies and a role-finder. There is also a section aimed at parents.

technicians.org.uk

ASE 2024 Annual Conference

Thursday 4 January

8.45
Building careers into lesson planning

Investigating the effectiveness of spaced learning in physics lessons

9.45
Physics-related apprenticeships: what are they and where can they take us?

14.15
Unlocking pathways: opportunities in physics-related technical routes

Reflections from the Institute of Physics' Teacher Educator Pilot

15.15
Physics and tea!

Friday 5 January

9.45
Climate anxiety and climate change

Maths confidence: an overlooked issue for secondary science ITT?

14.15
Top tips for inclusive science teaching

15.45
Why are physics teachers leaving teaching? What we know from research

Saturday 6 January

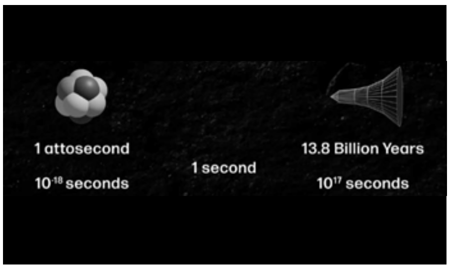
14.15
Institute of Physics Education Research Club: bringing teachers and research together

Seen elsewhere...

Attoseconds explained

This year's Nobel Prize was awarded for the creation of attosecond pulses – but what are they and what do they enable physicists to do? This short video provides a good introduction:

bit.ly/Attoseconds



Floating solar

Wind energy isn't the only renewable that's making use of floating technology. This profile from the BBC shows how floating solar panels enable access to bigger spaces:

bbc.in/47fGdmH

Credit: Shutterstock

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