Classroom physics

June 2022 | Issue 61

The magazine for IOP affiliated schools

Balloons in physics lessons

Limit Less in the classroom, on social media and in careers

Engineers who teach physics

Drawing force diagrams

IOP Institute of Physics

This issue

Credit: Dotted Yeti/Shutterstock

Balloons are one of the most versatile teaching aids known to physics - from the sub-atomic to the galactic scale

Get inspired by balloons

"Life is like a balloon; you must put something into it to get the best possible results."

If you look for inspirational quotes on the internet, this one is likely to pop up sooner or later. It is attributed to William Cranch Bond, a 19th century amateur astronomer who would become the first director of Harvard's observatory and whose achievements included co-discovering Hyperion, the eighth satellite of Saturn, and some of the first photographs of celestial objects.

It's not clear whether Bond used balloons in his work or what prompted the quote. But, by putting all sorts of things into balloons – air, various gases, hexagonal nuts (see p 16) – physicists have learned a lot about the world. They burst them (p 16), use them to enable a free fall jump from the edge of space (p 14) or explore the Earth's magnetic field (p 13). And from a teaching perspective, they are one of the cheapest, most versatile and effective tools to have in the classroom.

This issue is bursting with ideas for teaching physics with balloons. Our pull-out (p 9-12) focuses on using them to explore forces, but you can also use them to detect radioactivity (p 14 & p 17) or teach about beta decay (p 16). If your school is looking for a challenging project to involve a group of students, why not work towards launching your own high altitude balloon (p 7) – it's more doable than you might think and the results can provide data for many lessons on the ground.

Whilst it is important to bear in mind that some students have allergies and phobias connected with balloons, the only other challenge is to think of a topic in physics that can't be taught with the aid of a balloon.

Balloons are associated with happy times – have fun!

Caroline Davis
Classroom Physics editor

Please fill in our reader survey (see back page) at **smartsurvey.co.uk/s/CP2022**

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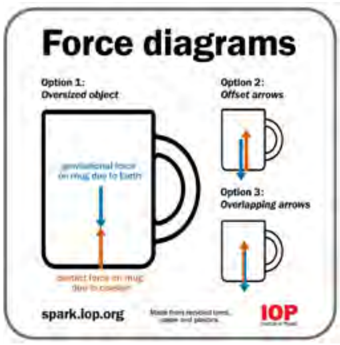
With this issue...

IOP Affiliated Schools and Colleges will receive:

a **coaster made from recycled materials** showing three different ways of drawing arrows for co-linear forces



Follow the IOP Education Department on Twitter **@IOPTeaching**

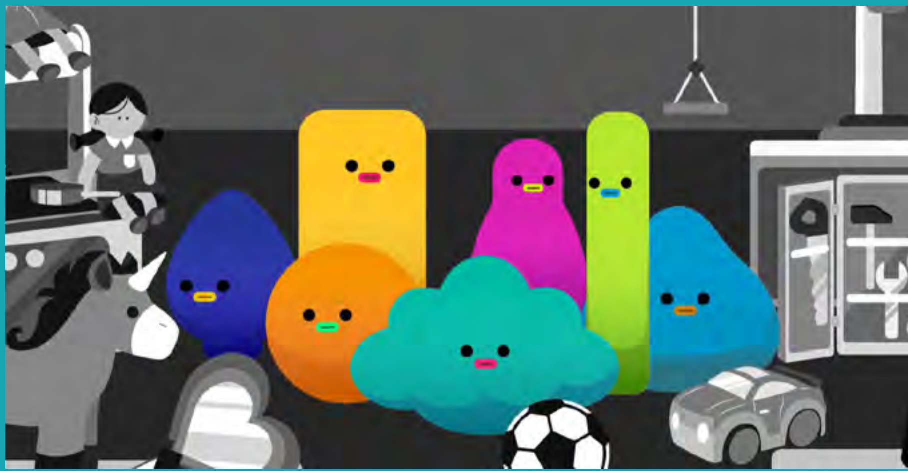
Read Classroom Physics online and access previous editions at **spark.iop.org/classroom-physics**

Limit Less

In the UK and Ireland, fewer than one in four post-16 physics students are girls. Black, LGBTQ+ and working-class students also face enormous barriers to studying one of the most enriching and fascinating subjects available. It doesn't have to be this way. No-one should feel that physics is not for them. The Limit Less campaign is calling for change.

To find out more visit **iop.org/Limit-Less**

Limit Less



Show your support for our manifesto for change at **campaign.iop.org/manifesto**

...in the classroom

This June, we're shining a spotlight on the IOP's resources for teachers to promote inclusive learning, including activities, posters and more. These are designed to encourage pupils and teachers to think carefully about the often unintended consequences of our words and actions and challenge the stereotypes that limit how we view ourselves and others from an early age.

Inclusive Teaching: 10 Tips for Teachers

Developed from our research into gender and behaviour patterns.

spark.iop.org/inclusive-teaching-10-tips-teachers

Challenging Stereotypes

An animation investigating unconscious bias and the difference between sex and gender.
spark.iop.org/challenging-stereotypes

Inclusive Careers Guidance

Explores where gender expectations can creep into careers guidance and suggests ways to reduce these inequalities.

spark.iop.org/inclusive-careers-guidance

iop.org/school-resources-address-gender-imbalance or search for "inclusive teaching" on **spark.iop.org**. Follow **@IOPTeaching** on Twitter for updates

...and Limit Less on social media

Social media is a key influence on young people. So we have put together a good practice guide with advice and guidance on how to ensure content is accessible, inclusive and accurate.

The document is divided into sections:

- **How to promote good physics**
- **Challenging stereotypes in physics**
- **Infographics and accessibility**
- **Helpful links**

Read – and share – the guidelines
iop.org/SocialMediaGuide

...and Limit Less careers

Our new suite of resources and lesson plans is designed to support teachers in the UK and Ireland to bring physics careers into their classrooms whilst encouraging students to make their choices, unburdened of the influence of negative stereotypes

Aimed at 12-15 year-olds and their families, the digital pack contains a booklet with profiles of people from diverse backgrounds who have pursued physics post-16.

The pack also contains a Limit Less careers lesson PowerPoint presentation and lesson plan notes. It uses the profiles from the careers booklet, asking students to challenge their own preconceptions about physics and showcasing the opportunities opened up by doing physics.

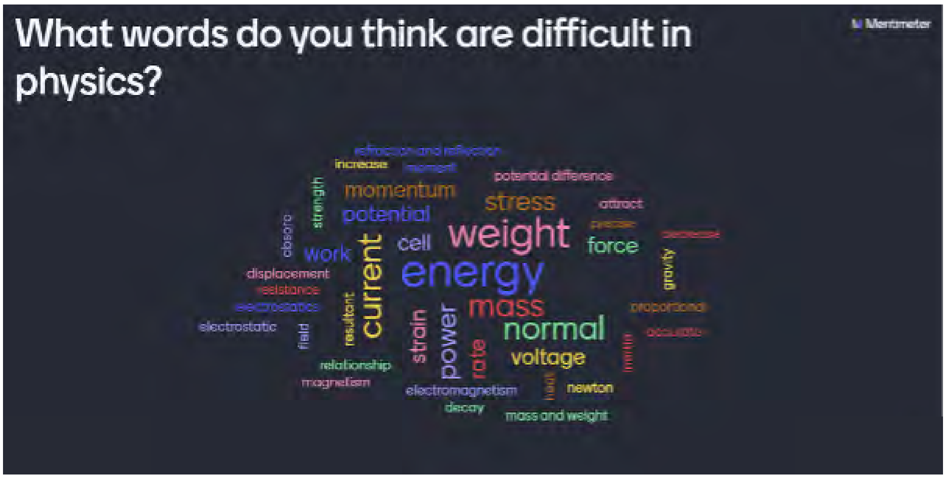
There's also a short guide for teachers with info about jobs and physics, and links to further resources to help raise the confidence of your students, supported by the key messages of the Limit Less campaign.

The resources can be downloaded from **iop.org/careers-physics/careers-resources**

Email **campaigns@iop.org** for physical copies of the booklet

Everyone Coaching Physics: language and literacy

Our Everyone Coaching Physics sessions are aimed at those involved in teacher development from across our nations and regions.



Credit: Mentimeter

Attendees' responses at a recent Everyone Coaching Physics session

We welcome CPD leaders, lone teachers supporting their department, mentors and initial teacher trainers - in fact anyone who supports at least one other human in their quest to become a better physics teacher. We discuss ideas and best practice in coaching physics, looking at how the most recent education research relates to physics teaching and learning.

A session in March looked at the importance of literacy for science teaching and how reading and telling stories may be used as a way of encouraging it. Although numeracy is important, an Education Endowment Foundation report in 2017 found that: "In correlational studies of science learning, the strongest and most consistent predictor of pupils' scientific attainment has undoubtedly been how literate they are."

We distinguished between 'literacy in science' and 'scientific literacy' and discussed whether science teachers, are also language teachers, as the words we use have a precise scientific meaning which often differs from the way the words are used in everyday contexts. One example is the word 'cell'. Asking a group of people what they understand by 'cell' is an interesting exercise - it may be mistaken for its homophone 'sell', be the room in a prison or cells in honeycombs. And that is in addition to the chemical and biological contexts. 'Radiation' and 'electricity' were also identified as 'difficult'.

We looked at the EEF's suggestion that oral language interventions should be based on the idea that comprehension and reading skills benefit from explicit discussion of either content or processes of learning, or both, and that oral language interventions should support learners' use of vocabulary, articulation of ideas and spoken expression.

more...

The final Everyone Coaching Physics session will be on 29 June at the Physics for Everyone event at the University of Birmingham. Visit **talkphysics.org/events** for more information

Log on to TalkPhysics for links on literacy in physics at **bit.ly/TPliteracy**

IOP response to the Schools White Paper

In April, Lisa Jardine-Wright, IOP Vice-President for Education and Skills, wrote an open letter to Nadhim Zahawi, the English Secretary of State for Education in response to the government's policy paper, *Opportunity for all: strong schools with great teachers for your child.*

Whilst Dr Jardine-Wright welcomed many of the provisions set out in the paper, she expressed concern that the plans do not tackle the major problems facing physics education. Describing the significant advantages to both the economy and to individuals that having a strong physics education system provides, she wrote, "Despite this undoubted value of the subject, physics education remains in crisis and many students, often those in more deprived areas, are denied the opportunities that studying physics provides - 70% of A-level students come from just 30% of more advantaged schools."

Her letter called for action in three key areas:

- Create fairer and more inclusive classroom cultures by implementing measures to fight negative stereotypes and prejudices that limit student opportunities
- Implement a systematic approach to subject-specific CPD to ensure that there are enough, well-equipped physics teachers to provide high quality physics education and consequent opportunities for all students
- Establish strong governance mechanisms for the new arms-length body as it develops and ensure both educational and subject matter experts play a pivotal role in shaping its outputs and activities.

Hari Rentala, IOP Head of Learning and Skills, said, "Implementing our recommendations will help teachers provide the best possible physics education for everyone. We call on the UK government to take this opportunity to address some of the deep-rooted challenges facing physics education in England."

more...

The white paper is available online at **bit.ly/CP22whitepaper**

Read the IOP open letter at **iop.org/SchoolsWhitePaper**

Calling teachers with an engineering background

We're looking for established teachers of physics who have an engineering background (degree or workplace experience) to help with a new government initiative to tackle the shortage of physics teachers.

Last year, fewer than a quarter of the target number of trainee physics teachers, were recruited in England. So this year, the government has launched a teacher training course entitled Engineers Teach Physics, aimed specifically at engineers and materials scientists. Trainees can be either new graduates or career changers, and a pilot will begin in autumn this year.

The IOP has been part of a group of organisations advising the government about how this might work, alongside teacher training institutions and engineering bodies.

Louis Barson, IOP director of innovation said: "If we aspire to be a 'science superpower' and solve our greatest challenges, it is vital that we provide universal access to high-quality physics education and training. This partnership with engineering could help tackle the physics teacher gap."

Credit: Department for Education

The government hopes to increase the number of engineers entering teaching to help solve the chronic shortage of physics teachers but also to bring an engineer's perspective into the classroom

Dr Rhys Morgan, director of education at the Royal Academy of Engineering, said: "We hope that this new programme aimed at engineering graduates will help to address long-term teacher shortages in physics. Engineers as teachers will also bring physics to life with real-world contexts and applications."

The programme will be trialled by the University of Birmingham, the National Mathematics and Physics SCITT, University of East Anglia, Yorkshire Wolds Teacher Training, University of Wolverhampton and the University of Manchester.

more...

Further details can be found at **getintoteaching.education.gov.uk/subjects/engineers-teach-physics**

We're looking for current physics teachers to mentor and support new trainees. If you're happy to give your time, please contact

chris.shepherd@iop.org

New misconceptions from teenager trends

Students often have naïve ideas based on their life experiences and encounters. In fact, I recently noticed one of my own, says former teacher Jess Howell, now manager of the IOPSpark website.

Sitting on my balcony, I wondered whether my neighbour below could see my legs dangling down as he sits in his living room – initially I thought not, then I realised that his field of view includes rays entering the window from above and not just in front of him. I hadn't connected this basic concept to my everyday life because I've never had a balcony before.

On IOPSpark, we've built a bank of naïve ideas – or misconceptions - extracted from hundreds of studies. However, the world around us is constantly changing, including the science curriculum itself. We asked teachers to tell us about new misconceptions they have spotted and have begun to publish them.

Credit: Lalandrew/Shutterstock

Many students think metals are poor conductors/good insulators because of the design of modern water bottles

A great example was noticed only recently despite the author's 20+ years of experience: students thinking that metals are poor conductors/good insulators because of the new trend for insulated water bottles, where the outside layer is often made from metal.

Tell us about any new misconceptions spotted amongst your students, we'd be very keen to publish them!

more...

Explore the collection **spark.iop.org/misconceptions**

Add your own **spark.iop.org/share-your-students-misconceptions**

Credit: Jamie Costello

"Dawn, looking east over the North Sea" - taken by one of Sutton Grammar School's HAB missions

The highs and lows of HABing

This image was taken in April 2011. I was lucky to be working with an exceptional group of students who were very keen to photograph a sunrise and so we had set off in the middle of the night to launch from Cambridge.

During this launch, the team had a problem with the GPS system just before lift-off. The problem was solved just in time, but, in the rush, everyone forgot to calculate a fresh landing site prediction. Unfortunately, the weather had changed from the planned launch time and the new predicted landing site was in the North Sea. This was one of the few launches not to have a cutdown facility for emergencies.

So, the balloon was off, and all we could do was follow its doom. The pupils tracked the device until it went below the horizon, then it was lost.

When this happens, there's always hope. All HAB kits are purposefully covered in contact details for such eventualities. Weeks later I received an email from a very helpful man in Holland. He had found the payload and was very pleased to send it back. The photo memory card was a bit messy but the pictures were recoverable. I still have the payload case at school as a memento.

High Altitude Ballooning – not as difficult as you might think

For several years, Jamie Costello, assistant headteacher and physics teacher at Sutton Grammar School, ran APEX - a backcronym for Altitude Photography Experiment, launching High Altitude Balloons (HABs) with different teams of students. He explains why this was such a career high.

Taking pictures from the edge of space is, literally, out of this world, but also great fun. My advice: "dare mighty things" and let me help you get started.

The HAB community has grown enormously since I first launched in 2008 and there is plenty of support available. Start with the UK High Altitude Society (UKHAS) but other experts are easy to find and super helpful - it is amazing how much goodwill there is towards physics teachers and their students.

Starting in September, you could plan for a launch in late spring/early summer. First, assemble a team. The abilities of the group will determine how much teacher involvement will be needed - and time commitment is required - but rest assured, your efforts will be rewarded.

Safety always comes first: appoint a student H&S officer. Helium canisters, civil aviation guidelines for HABs and possible high voltage circuit boards all require specialist supervision and your input. You'll need a photographer, a GPS tracker, a coder, telemetry lead, balloon and parachute coordinator, a casing specialist and a finance officer. You may also wish to appoint a CEO and PR rep. Make your team feel important and invite the headteacher to the odd meeting.

Dedicated A-level pupils with a background in programming and electronics may simply get on with it but buy a ready-made kit for a GCSE group. The HAB community will often track your balloon for you.

When you launch, make a weekend of it. Go out for a meal the day before, soak up the excitement. If you have never seen a balloon launch before, it's something you'll never forget. And the fun doesn't end there. With a GPS tracker and other data, you can discuss your achievements with your classes back at school: distance/time graphs, temperature gradients, radiation levels, even the humidity of the stratosphere. There'll will be so much physics to discuss... I suspect you'll want to launch again.

more...

UKHAS Beginner's guide to High Altitude Ballooning: **ukhas.org.uk/general:beginners_guide_to_high_altitude_ballooning**

Using balloons to understand colour

The colour an object appears can be a complex product of the spectral properties of the object, the light source and any materials that reflect, transmit or diffuse the light on its journey from source to object.

As different people's eyes can have slightly different spectral responses, it is possible to have observer metamerism – where two different spectra provide a perfect colour match for one individual (eye or person), but not another. Colour experiences truly are in the 'eye of the beholder' and matrimonial disharmony over colour matching in interior design can be physiologically based.

All these aspects, and more, are taken into account when attempting to get machines to measure colour as it is seen by humans.

Sensations of colour in humans are generated by triplets of cone cells in the retina responding to short, medium and long wavelength bands over the visual range. Thus 'normal' trichromatic human colour vision requires just red, green and blue lights to create an enormous range of colours - a trick used in phone, computer and TV screens. By adjusting the proportions of these 'primary' colours, most colour sensations can be induced - for example red and green light combined can make a colour that appears identical to monochromatic spectral yellow.

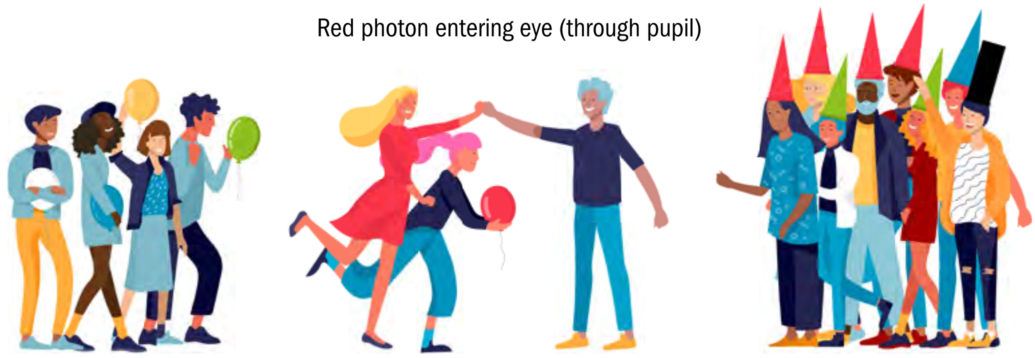
Balloons are great for modelling these concepts.

By Andrew Hanson, Outreach Manager at the National Physical Laboratory who worked for many years in measurement of colour

Demo 1: act out the human visual pathway

'Photons' waiting to enter the eye

Red photon entering eye (through pupil)



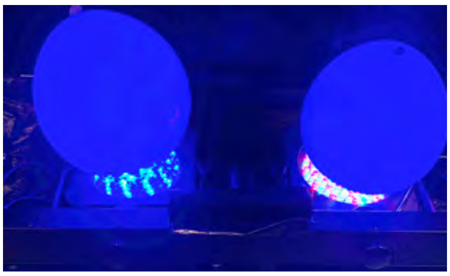
The retina
Cones excited by red, green and blue plus a rod (right) excited by any light

Red cones are excited by red photons and yellow photons excite red and green cones

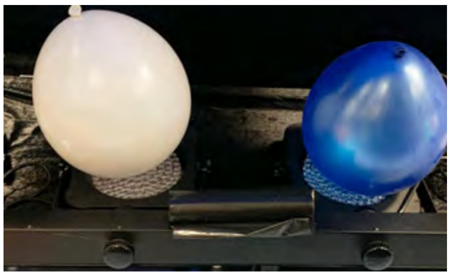
Demo 2: what colour are these balloons?

This involves two coloured balloons illuminated by controllable RGB LED lamps (your school drama department may be able to loan you some suitable ones). A darkened room is ideal, but a reasonably well-lit one is fine. When choosing balloons, avoid green as it is near impossible to get a good colour match with LED lamps. Red balloons provide the most vivid demonstration, but blue balloons are best in terms of inclusivity as a significant proportion of the population have colour vision deficiencies that make it difficult to distinguish between shades of neutral colours as well as reds and greens.

The set-up is shown above. The two balloons are secured with double-sided tape onto the – fortuitously cool – lamps.



Two balloons illuminated by different RGB lamps with room lights turned down



The same balloons illuminated by room lights (RGB lamps switched off)

The lamp on the left produces blue light only, the one on the right produces red, green and blue (=white) light.

When the lamps are switched off and room lights are on, we see that one of the balloons is in fact white. It only appeared blue because it was lit by a blue light. Interestingly, the LED lamp on the right appears to be blue. This is not because it is emitting blue light (it is off), but because it is being illuminated by room light reflected off the blue balloon above.

more...

Watch Andrew's Royal Institution talk *The physics and psychology of colour* **https://youtu.be/af78RPi6ayE**

Download our *Seeing Pink Elephants* activity **spark.iop.org/seeing-pink-elephants**

For further reading, Andrew recommends *The Physics and Chemistry of Color: The Fifteen Causes of Color* by Kurt Nassau.

Physics education research

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

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

Credit: Prostock-studio/Shutterstock

Interactive engagement where students discuss what they are learning with peers and/or instructors has been shown to produce better learning outcomes.

Finding a balance between teacher talk and interactive engagement

In recent years, there has been considerable support for a view that lessons should be dominated by teacher-led activities and that instructional strategies such as Direct Instruction alone provide the answer to more effective teaching. Work from physics education research over the last 20+ years has established a convincing and robust evidence base to challenge this view, and perhaps prompt physics teachers to reflect on the best balance between teacher talk and active student participation to support learning.

In 1998, Richard Hake published a study called *Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses.* It aimed to try, as best as was possible, to compare two different teaching methods, defined as follows:

- **Interactive Engagement** - methods designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors.
- **Traditional** - courses reported by instructors to make little or no use of interactive engagement methods, relying primarily on passive-student lectures, recipe labs and algorithmic-problem exams.

Conceptual and problem-solving tests were used to assess learning gains for classes by one or other of the teaching methods. The outcomes across high school, college and university populations aligned. Those taught by the Interactive Engagement methods did significantly better in their tests. In 2016 this work was revisited, drawing together studies over a 20-year period and involving nearly 50,000 students (Von Korff et al., 2016). The findings were the same, seeing larger learning gains for those taught by the Interactive Engagement methods. This advantage was seen across multiple settings irrespective of class size and prior achievement.

Ultimately, the power of research should be in how it informs practice rather than offering an uncontested 'right way'. The evidence base across these two papers is about as strong as you are likely to find on a subject level. The study was in the US but the content covered is well mapped to UK curriculums and so at the very least it provides considerable food for thought to those reflecting on how they do and should teach physics.

With this in mind, we will offer the final word to Arnold Arons, who offers some guidance on navigating these challenges in his book *Teaching Introductory Physics* (1996):

...research is showing that didactic exposition of abstract ideas and lines of reasoning (however engaging and lucid we might try to make them) to passive listeners yields pathetically thin results in learning... ...I am, of course, not advocating unclear exposition. I am pointing to the necessity of supplementing lucid exposition with exercises that engage the mind of the learner and extract explanation and interpretation in his or her own words.

more...

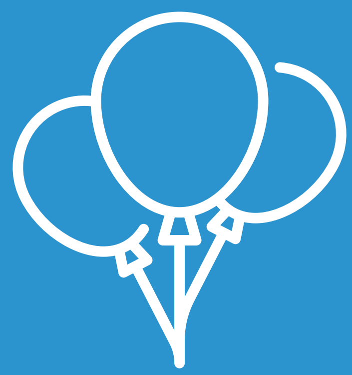
Von Korff, J. et al (2016). *Secondary analysis of teaching methods in introductory physics: A 50 k-student study,* American Journal of Physics **doi.org/10.1119/1.4964354**

Hake, R. R. (1998). *Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses,* American Journal of Physics **doi.org/10.1119/1.18809** (requires subscription)

Pull out and keep!

Teaching forces and motion

Balloons



Inside this issue:

Force arrows

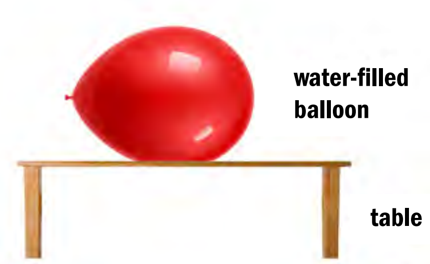
Drawing force diagrams requires an understanding of how forces arise - an idea that many students struggle with.

Some of your class may have come across the phrase that 'for every action there is an equal and opposite reaction'. However, this version of Newton's third law can be misleading. The word 'reaction' implies that the force on one object appears in response to the other, rather than two forces arising at the same time when two objects interact. For example, two objects might interact gravitationally, electrically, magnetically or by being brought into contact. In all cases, each object exerts a force on the other one (of the same size but in the opposite direction).

When introducing force diagrams, labelling arrows in a way that explicitly states what other object is responsible for the force will help your students link forces to the interaction (and object) that caused it. A downward arrow labelled 'gravitational force due to Earth' is more informative than one labelled 'weight' and calling the upward force on an object resting on a surface a 'contact' or 'support' force is most definitely preferable to calling it a 'reaction force'.

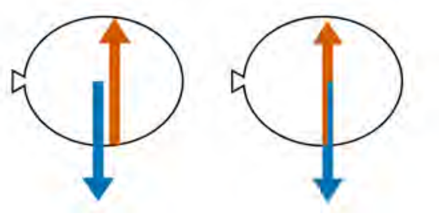
When labelling force arrows, encourage your class to include what object the force is on, and what other object the force is due to (eg 'contact force on the balloon due to table').

Drawing forces that act along the same line can require a compromise. Let's think about different ways to represent co-linear forces acting on the balloon in this scenario:



The gravity arrow should begin at the centre (of mass) of the balloon and point downwards while the contact force arrow should start at the bottom of the balloon, at the point at which it makes contact with the table, and point upwards:

To accommodate both, the two arrows can either be drawn much smaller than the object (above), offset (below left) or in a way that makes it clear that they overlap (below right)



Also important is sharing reasons for omitting any forces. Our balloon is water-filled and so its density is higher than the surrounding air. Buoyancy effects are small; we can ignore upthrust, but this would not be true for an air-filled balloon.

This pull-out contains activities that provide opportunities to develop force drawing skills. The first is the simplest of vehicles: a rocket balloon. The second is our favourite charged-balloon demonstration: moving an aluminium drink can without touching it. Also included is a worksheet on ideal gases.

Dr Taj Bhutta is the IOP's strategic lead for curriculum and content

Avoid a bad reaction

Reaction force is a confusing term. It can mean:

- the force on an object in contact with a surface, or
- one of an 'action-reaction' pair in Newton's third law.

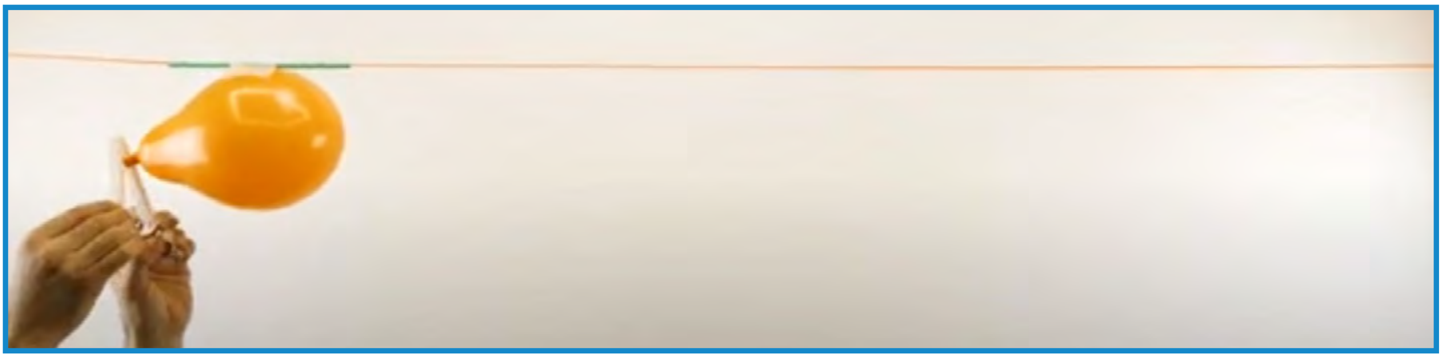
Avoid it. Instead use 'push of table' or contact force. For Newton's third law, refer to forces arising in pairs as the result of an interaction.

more...

Videos to support the teaching of forces
spark.iop.org/forces-cpd-videos

Demonstration: Rocket Balloon

In this demonstration students see a simple rocket in action. You can use it to illustrate Newton's third law of motion.



Launching a rocket balloon

Equipment

- Balloon
- Drinking straw
- Clothes peg or other clip
- Several metres of string
- Sticky tape
- Scissors

Preparation

Locate suitable fixed points to enable you to tie the string across the room (eg cupboard handles).

Procedure

1. Pass the string through the straw.
2. Attach the two ends of the string to the fixed points in the room.
3. Inflate the balloon and use the clothes peg to close the mouth.
4. Attach the balloon to the straw using sticky tape.
5. Undo the peg to release the air.

Teachers' notes

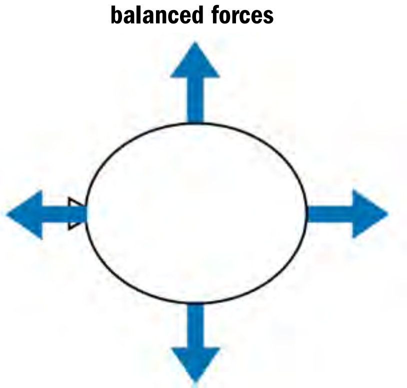
Students may refer to 'action and reaction' force pairs when describing the motion of the rocket. Emphasise that these can be misleading terms. They imply that one of the forces in Newton's third law appears in response to the other. Discuss what's happening inside the balloon to illustrate how the forwards force on the balloon arises at the same instant as a backwards push on air. Emphasise that, as with all Newton's third law force pairs, the two forces arise at the same time and act on different objects (balloon and air).

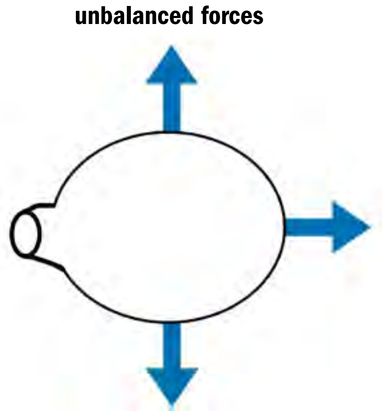
Explanation

When the peg is attached, the balloon remains inflated because the air particles inside it are colliding with the inside surface. They push equally to the left, right, up and down and so the forces on the balloon are balanced (as are those on the air inside it).

When the peg is removed, the air particles no longer push on the open end of the balloon. The forward force on the front end of the balloon is no longer balanced by a backward force and so the balloon accelerates forwards. Similarly, if we consider the forces acting on the air in the balloon, we can see that there is a resultant force acting on it to the left, and so the air accelerates backwards.

Forces on balloon due to air pressure





more...

Download force diagrams and watch the video at **spark.iop.org/rocket-balloon**

Arrow tips for students

- Draw object by itself
- Start each arrow where force acts
- Draw arrow in direction of force
- Add labels to describe what object the force acts on and what it is due to

Class activity: Attracting can

This activity introduces students to the idea of charged objects exerting forces on uncharged objects

Equipment

Each student will need:

- Empty aluminium soft drink can
- Rubber balloon
- Cloth or woollen clothing

Procedure

Ask students to:

1. Inflate the balloon and tie its neck.
2. Place the empty can on its side on a flat surface.
3. Hold the balloon close to the can. They should see that nothing happens because the balloon is initially uncharged.
4. Rub the balloon on their clothing or a piece of cloth so that it becomes charged.
5. Bring the balloon close to the can. They should see the can start to move towards the balloon.
6. Move the balloon gradually away from the can so that the can rolls along.

Teachers' notes

Charged objects attracting other objects may be familiar from, for example, a comb attracting hair. You could rub the balloon and show that it also attracts a student's hair. To help them visualise charging processes, introduce electrons as negatively charged particles that move between the materials.

If students use the phrase 'static electricity', explain that it can be a misleading one. The charging process for the balloon involves the transfer of charge between cloth and balloon, and the process for the aluminium can involves charges moving within the can. The charging processes may be different, but in neither are the charges 'static'.

more...

Download force diagrams and watch the video
spark.iop.org/attracting-can

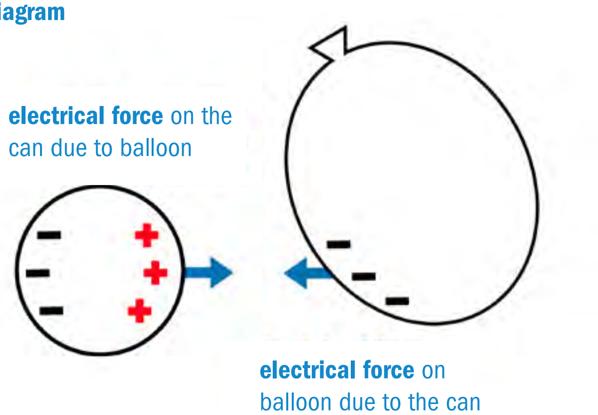
A charged balloon will attract a drinks can and make it roll

Explanation

The balloon becomes charged when rubbed because it is made of a material that attracts electrons more strongly than the cloth. Electrons are transferred from the cloth to the balloon and so the balloon gains a negative charge overall. Explaining that the cloth is left with a positive charge will help students appreciate that charge is conserved, but there is no need to discuss atomic structure or the nature of the positive charge in the objects.

The charging process for the aluminium can is different. The two objects do not come into contact. Instead, electrons in the can are repelled by the balloon and so move to the part of the can furthest away. The back of the can becomes negatively charged and the front positive, but overall the can remains electrically neutral. The reason the aluminium can starts rolling is because the back of the can is further away and so the repulsive force on the back of the can is smaller than the attractive force on the front.

Force diagram

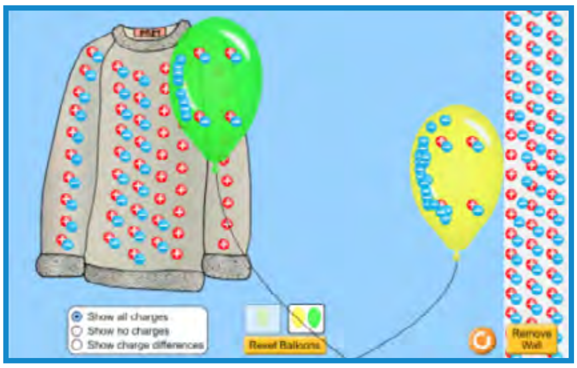


Air pressure forces

Inflating a balloon inside a bottle with a secret hole in it is a great way to show your class that air pressure forces are real. The YouTube channel **Action Lab** has a great video for this demonstration:

bit.ly/ALairpressure

Charged balloon simulation

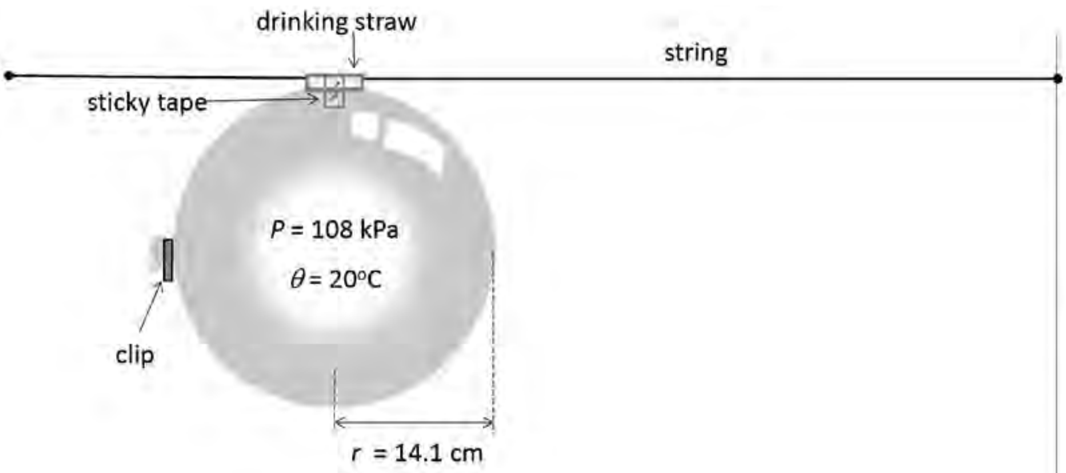


The PhET name and logo are registered trademarks of The Regents of the University of Colorado

PhET simulations have a great interactive for charged balloons. Your students can make predictions about force at a distance for various charge configurations
phet.colorado.edu/en/simulations/balloons-and-static-electricity

Worksheet (age 16+):
Ideal gases

A teacher sets up a demonstration to illustrate how a rocket works using a spherical balloon of radius 14.1 cm.



Useful equations and constants

Volume of a sphere:
$V=\frac{4}{3}\pi r^3$

Ideal gas law:
$PV = nRT$

Average kinetic energy of a gas particle:
$\langle E\rangle = \frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

Molar gas constant:
R = 8.31 m^2 kg s^{-2} K^{-1} mol^{-1}

Boltzmann constant:
k= 1.38 x 10^{-23} J K^{-1}

1. Copy the diagram and calculate:

   a. the volume V in m^3 occupied by the air inside the balloon
   b. the temperature T in kelvin of the air inside the balloon

   Add this information to your diagram.

2. The air inside the balloon behaves like an ideal gas.

   a. Show that the balloon contains about half a mole of air.

   b. The mass of one mole of air is 28.0 g. Determine the density of the air inside the balloon in kg m^{-3}.

   c. Explain why this is higher than the density of the air outside the balloon.

Studying A-level or Higher or Advanced Higher physics?

Download your free study aid from the Institute of Physics at **iop.org/pocket-physics** or order a print copy by emailing **education@iop.org**

3. According to the kinetic theory of gases, the pressure P depends on the root-mean-squared speed of the gas particles inside the balloon.

   a. State two assumptions made in deriving this result.

   b. What is meant by the term *root-mean-squared speed?*

   c. Air is made up of mostly nitrogen gas. Determine the root-mean-squared-speed of nitrogen molecules in the balloon (the mass of a nitrogen molecule is 4.65 x 10^{-26} kg).

   d. Other gases inside the balloon, such as oxygen, have a different root-mean-squared speed. Suggest why.

4. The teacher removes the clip. Explain why the balloon now starts to accelerate to the right.

5. After the demonstration, the balloon is deflated. Calculate the new volume occupied by the air that was once inside the balloon. You may assume that the temperature of the air remains constant and that atmospheric pressure is 101 kPa.

Balloon stories

Faraday's balloon

Now a familiar aspect of childhood parties, rubber balloons were invented in 1824 to serve physics. Whilst working at the Royal Institution, Michael Faraday required a flexible container for storing hydrogen. He developed a container made from caoutchouc, a type of rubber that, in the era before vulcanisation (the industrial process of hardening rubber by heating it with sulphur), was naturally sticky. Faraday reported that the hydrogen balloons made from caoutchouc were buoyant with 'considerable ascending power'.

Physicists in balloons

Jacques Charles, after whom the law linking the volume and temperature of a gas is named, was a ballooning pioneer. He launched the world's first crewless hydrogen balloon and, in 1783, was the first to fly one. The hydrogen for both flights was produced from the reaction of a quarter of a tonne of sulphuric acid with a similar mass of scrap iron. The resulting gas was directed, through lead pipes, into a silk balloon, painted with a solution made from dissolving rubber in turpentine. Charles began his flight close to the current site of the Eiffel Tower and, it is reported, that when the balloon landed, it frightened a group of peasants who tore apart its remains with pitchforks.

Joseph Gay-Lussac was also a pioneer of balloon flight, making an ascent with the physicist Jean-Baptiste Biot. The pair reached an altitude of 23,000 feet enabling them to demonstrate that the Earth's magnetic field does not vary significantly with height.

It is argued that Charles's Law should be attributed to Gay-Lussac. Charles had carried out experiments before Gay-Lussac, but he did not publish his results. Gay-Lussac's acknowledgement of Charles's unpublished work led to the relationship becoming known as Charles's Law.

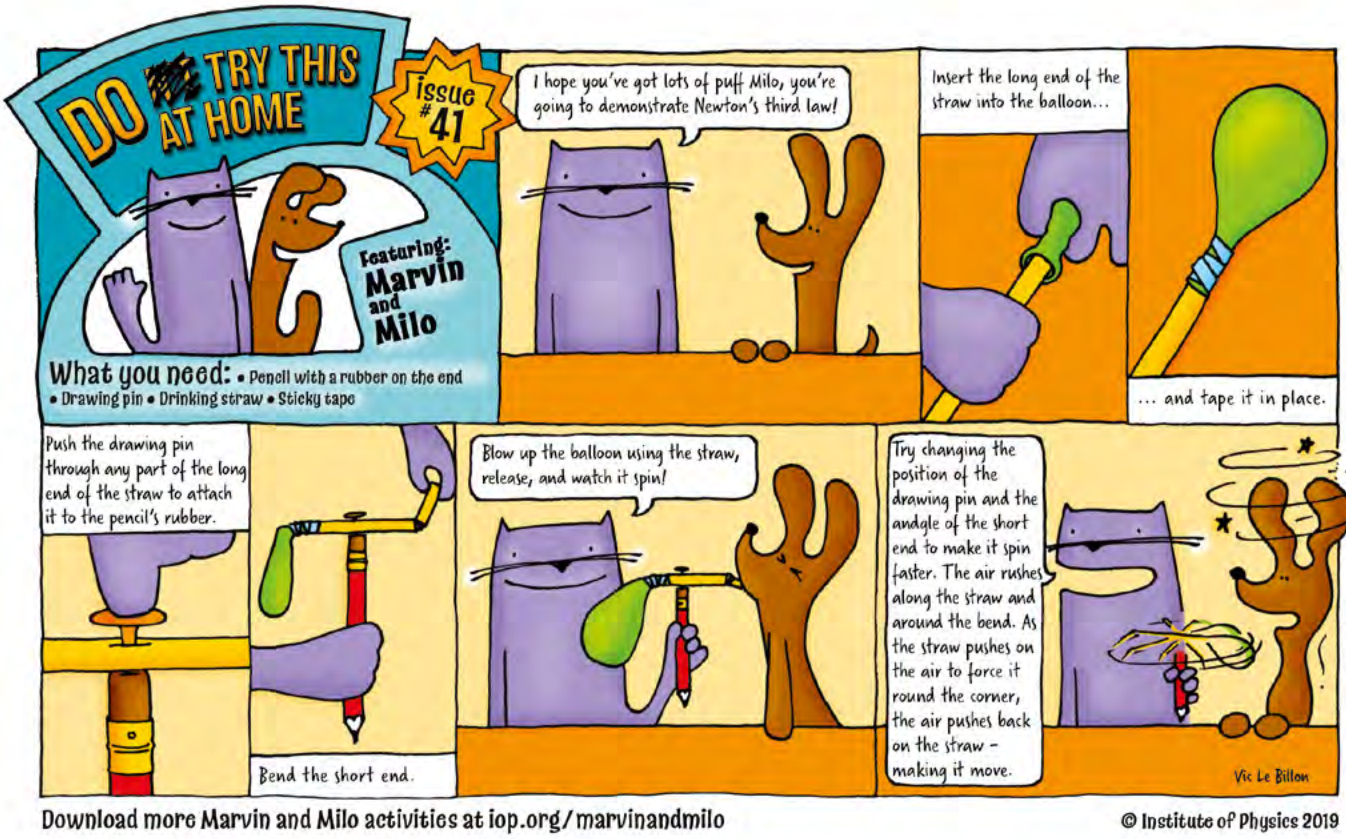
Vacuum airships

A curious proposal from the history of air travel is the vacuum airship or null ship. Just as objects with densities lower than water will float in it, a vacuum will be buoyant in the atmosphere because it has a lower density than air. An aircraft based on this principle was first proposed in 1670 by Lana di Terzi. He designed a flying boat with a hull and sails lifted by four evacuated copper spheres. The design challenge of such aircraft is the need for a material strong enough to contain a vacuum but of a sufficiently low density to allow it to float. Advances in low density materials suggest that if an aluminium honeycomb core is used to support a boron carbide skin, the dream of vacuum airships might be realised soon!

spark.iop.org/stories-physics

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

Follow him on Twitter **@RBrockPhysics**



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 **using balloons in physics lessons** from the archive and the current volume. These papers should provide support for developing a topic for your scheme of work that could include environmental issues, mathematical modelling and hands-on experiments.

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.

Inflation and charging

The not-so-obvious starting point for this article is radioactivity. Far more obvious is the charging of inflated balloons on woolly jumpers. These charged balloons, when left, may attract radioactive particles that are ionised. By leaving the balloons for a fixed amount of time the levels of radon may be compared in different locations, as described in the paper *Radioactive balloons: experiments on radon concentration in schools or homes.* This activity could be an interesting opener when looking at radioactivity and linking it to students' own experiences. The website **ukradon.org/information/** may also be helpful. I once showed a class a radioactivity monitoring badge and asked them what it was. I expected them to have no idea, and then would follow a story about my visit to a nuclear power station. Surprisingly, half the class put their hand up and told me straight away what it was. The rest of the lesson was them telling me stories about the radon found in local houses.

bit.ly/PEDradon

Lots of puff

Back in 1993, John Fox wrote an article called *The baffling balloons!* It was about a simple demonstration of two balloons inflated to different sizes and connected by a pipe, with a tap, to each other. The baffling part was that when the tap was opened what was expected to happen did not happen. Sometime later David Featonby revived this demonstration as part of his What Happens Next? workshops and expanded on it in *Balloons hold the key to inflation.* In the paper, Featonby revisited the author's explanation of how you can get the balloons to behave however you like by pre-inflating some of them. This means that you can repeat this demonstration a number of times and still keep students thinking. This could be a fantastic introduction to stretching, Hooke's Law and Young's modulus. There is even a Marvin & Milo activity for a simplified version.

bit.ly/PEDbafflingballoons

bit.ly/PEDballoonskey

bit.ly/PEDballoonsrevisited

spark.iop.org/unbalanced-balloons

Credit: © Red Bull Stratos

The helium balloon used by Felix Baumgartner to jump to Earth from the stratosphere

On the edge

Today, high altitude ballooning is possible even in schools (see Jamie Costello's article on page 7), but jumping from a balloon on the edge of space is a bit extreme. In 1960, Colonel Joseph Kittinger made the first jump from here and recently there have been further attempts to repeat the feat. There is a lot of interesting physics that this could lead to, not always the obvious. Relativity for instance; when the jump started, with nothing nearby to compare his movement to and no air to produce any whooshing sounds, it was difficult to gauge how quickly he was falling. Looking up at the apparently receding balloon confirmed that he was actually moving. This could also be used in a climate change topic. How big is the atmosphere? How far away is space? More recently we have events that take things further, like the supersonic freefall of Felix Baumgartner accomplished with the Red Bull Stratos project on 14 October 2012. These are not the only attempts at this jump and students can research other attempts or look into ballooning more generally and some of the physics associated with it.

bit.ly/PEDredbull
bit.ly/PEDbaumgartner
bit.ly/PEDsupersonicfreefall
bit.ly/PEDkittinger

Physicseducation

Credit: Jose Angel Astor Rocha/Shutterstock

The Crookes radiometer

Comparison of forces for the Crookes and Hettner radiometers

The Crookes radiometer is a fascinating device and students may come across them in shops. The mechanism by which they work could be an interesting avenue for discussion but it would be useful to do some experiments with them. Unfortunately, the inside of the glass envelope needing to be a partial vacuum makes that very difficult for schools. This article introduced me to the Hettner radiometer. This has the black and silver parts of the vanes next to each other horizontally rather than back-to-back, implying that some of the mechanisms suggested for making the vanes turn cannot be correct because the Hettner radiometer still turns. This paper and a few images taken from it could make for an interesting discussion with older students. I wonder if a homemade radiometer would turn inside a partially evacuated bell jar?

bit.ly/PEDcrookes

Teaching about electric current and resistance with a ‘blinker’

This paper will be interesting to anyone thinking about how they currently teach electricity. There is a school of thought that, initially, students might approach finding out about electricity empirically, so that they can find the rules for current, potential difference and series and parallel parts of circuits before they get too bogged down in what exactly it is they are measuring. However, as many schools now use multimeters as they cost less than separate meters, this can be tricky as students are using the same meter with no way to work out why. The blinker described in the paper flashes at different rates depending on the current passing through it and is relatively easily and inexpensively constructed. Using the blinker for students aged 11-14 makes the voltmeter setting distinct until they understand what the multimeter does.

bit.ly/PEDblinkers

Quick Links

Falling faster than g, exponentially
Great for teaching centre of gravity

bit.ly/PEDfasterthang

Gliding for Olympic success
Sliding as a sport - a look at the physics

bit.ly/PEDsliding

From reactor to patient: an example of radioactive diagnostics and effective half-life in thyroid cancer treatment
If you are teaching medical physics

bit.ly/PEDradiodiagnostic

A low-cost spectrometer to analyse the purity of honey
You will bee interested in this

bit.ly/PEDpurehoney

Teacher interventions and student strategies for circular motion problems: a matrix representation
Could we use matrices to teach?

bit.ly/PEDcircmotion

Designing physics board games: a practical guide for educators
Using games in your teaching

bit.ly/PEDdesignboardgames

Don’t shoot the piano tuner

A lot of useful ground can be covered by linking sound to music. In music, an A is always an A, or one of a family of As, but in physics, an A is not always the same. Musical notes can have a range of frequencies, not just a specific one. Students may find it interesting to learn about pitch and frequency and the well tempered scale. A quick online search will reveal guitars with wiggly frets rather than straight, or fan-aligned frets rather than parallel ones. Students might wonder what’s going on if they think that a note always has to be a specific frequency, but when they realise it’s more about perception and intervals than measures and absolutes, many of these strange musical devices will make more sense.

bit.ly/PEDpiano

salfordacoustics.co.uk

southampton.ac.uk/engineering/outreach/explore_sound.page

talkphysics

David Cotton, editor of our online discussion forum, chooses his favourite TalkPhysics discussion threads on **using balloons in physics lessons.**

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

Teaching physics with balloons

Balloons can be used in teaching many different areas of physics and the *Teaching physics with balloons* workshop has been delivered at many IOP teacher CPD events. Have a look at resources from Joanna Kent's session at a 2020 lockdown CPD event which includes risk assessment as well as lots of great ideas for the classroom and at home.

bit.ly/TPballoons1

A-level balloons

Maria Kettle from the University of Cambridge's department of engineering delivered a session on *A-level physics with balloons* at an East Midlands regional day in 2018. She showed how a hexagonal nut in a balloon can demonstrate centripetal force. The rate at which you twirl the balloon can also demonstrate how pitch is related to frequency when teaching sound.

bit.ly/TPballoons2

Beta decay

The idea of teaching beta decay with balloons has been discussed on TalkPhysics and can also be used when showing students fusion in stars. I have a demonstration that uses balloons to demonstrate beta plus decay and its role in the proton chain. This is a way some stars convert hydrogen into helium in their cores.

bit.ly/TPballoons3

IOP coach Sue Woolhouse uses balloons to show alpha and beta decay in one of the IOP DOMAINS matter and nuclear CPD videos.

Using balloons to demonstrate beta decay

spark.iop.org/matter-and-nuclear-cpd-videos#radioactive1

physicsworld

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

Credit:inkanya Anankitrojana/Shutterstock

Balloon bursts approach the speed of sound

Bursting balloons is good fun, but there is fascinating physics lurking in how the fabric of the balloon is ripped apart. Two French physicists studied the bursting process using a high-speed camera and discovered that there is a critical point in the inflation of a balloon beyond which it will create beautiful flower-like patterns when it bursts. The research could boost our understanding of how materials fail when subjected to high degrees of stress.

French artist Jacques Honvault is famous for high-speed photographic images, including a spectacular shot of a balloon fragmenting just after it is popped. This image fascinated physicist Sébastien Moulinet of the École Normale Supérieure in Paris, because the fragmentation pattern is very similar to the patterns of cracks when a material such as glass is struck by a hammer.

Read the full article at
bit.ly/PWballoonburst

The physics of Oreo splitting, metamaterial chocolates taste better

In case you have never eaten one, an Oreo is a sandwich of two round biscuits with a sweet creme filling. Many folks will separate the two biscuits and eat the filling first. Crystal Owens at the Massachusetts Institute of Technology is probably one of those people, because she and her colleagues have published a paper about the physics of how that separation occurs.

Oreo fans will know that the cookie almost always comes apart leaving most – if not all – of the filling on one biscuit. And now Owens and her team have created an "oerometer" to find out why.

Their device is a rheometer that grasps the two biscuits and gives the cookie a twist until it separates in two. The team then quantified how much filling was on each biscuit.

Read the full article at
bit.ly/PWoreosplit

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

Credit: Dan Bright

Get positive about batteries

Join the Royal Society of Chemistry's new global experiment and take charge of a brighter energy future

Batteries are part of our everyday lives. Whether they're disposable alkaline or rechargeable lithium-ion, batteries power everything from toys and remote controls to phones and electric vehicles. They're so commonplace, your students might not think much about them. The Royal Society of Chemistry though is asking them to think, take a closer look and take charge in its latest global experiment.

Take charge: global battery experiment asks 9–14 year-olds to do their own investigation, share their data on the website and find out what other global experiment scientists have discovered. Getting involved is really simple.

There are two investigations: one uses everyday materials and can be done anywhere; the other needs a voltmeter and is ideally done in a science lab. Simply pick one, download the instructions from the *Take charge* website and away you go – in your lessons or science club.

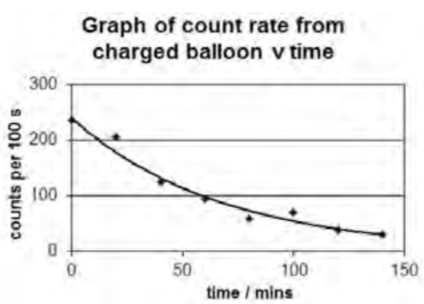
As well as the investigations and data share, *Take charge: global battery experiment* is also asking students to become sustainability champions. It's challenging them to think about, adopt and share energy saving practices.

Taking part in the global battery experiment will help your students better understand how batteries work and how they can help our transition to more sustainable sources of energy. And participating in *Take charge* might inspire one of your learners to become the next big thing in batteries and energy storage solutions.

more...

To get involved, visit **rsc.li/takecharge**

CLEAPSS is an advisory service supporting science and technology in schools. Its advice and guidance is recognised by Ofsted and the HSE for safe practice for practical work in schools. Visit **cleapss.org.uk**



Using a balloon to demonstrate radioactive half-life

If a rubber balloon is inflated, electrostatically charged by friction and hung from the ceiling for a while, it will collect radon decay products on its surface from naturally occurring radon-222 in the air.

The radioactivity is mainly Pb-214 and Bi-214, both from the Rn-222 decay chain, and some from Pb-212, in the decay chain of Rn-220. Pb-214 has a half-life of 26.8 minutes, Bi-214 19.7 minutes and Pb-212 10.6 hours. Try this out yourself before demonstrating it to students. The success depends on the area you live in and the construction of buildings. In low-radon areas with controlled ventilation buildings, particularly modern buildings, this does not work. In contrast, in higher radon areas and older buildings where the ventilation is not controlled, you can get appreciably high count rates from the balloon. The example decay curve (left) was prepared from measurements taken by CLEAPSS staff.

Instructions

- Inflate a rubber balloon, friction charge it with a piece of woollen material and suspend it from the ceiling for between 45 and 60 minutes.
- Deflate the balloon, put it on a piece of thick card then place on a tray. Put an end-window GM detector such as a ZP1481 just above the balloon so that the GM window is close, but not touching the balloon.
- Take a count for 100 seconds and repeat this about every 20 minutes. This will give a decreasing count rate, roughly halving every 50 minutes.

more...

For more information on this and other experiments relating to radioactive half-life, search for GL128 on **science.cleapss.org.uk**

Another version of this activity available is on the SSERC website at **bit.ly/CPssercballoon** with an accompanying YouTube video at **bit.ly/SSERCradonballoon**

Answers for ideal gases 16-19 worksheet on page 12

1.

a) $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\,(0.141^3) = 0.0110\ \text{m}^3$

b) $T = (273 + 20)\ \text{K} = 293\ \text{K}$

2.

a) $n = \frac{PV}{RT} = \frac{(101 \times 10^3) \times 0.0110}{8.31 \times 293} = 0.487\ \text{mol}$

b) Mass of air inside balloon M = 0.487mol x 28.0 g mol^{-1}= 13.6 g

Density = M/V = 0.0136 kg/ 0.0110 m^3 = 1.24 kg m^{-3}

c) Answer could include some or all of the following points:

- The temperature of the air inside and outside the balloon is the same
- The air inside the balloon is compressed by the stretchy surface of the balloon and so the same mass of air outside the balloon will occupy a larger volume
- The outward force on (every section of) the balloon surface due to the internal pressure must be equal to the sum of the inward force due to stretched surface and external air pressure.

3a) Any two from:

- Gas particles are in continuous random motion
- Collisions of gas particles are (on average) elastic
- Time between collisions is much greater than duration of collisions
- Volume of gas particles is negligible compared to volume occupied by the gas
- Forces only act on gas particles during collisions and/or we can ignore gravity and attractive or repulsive forces between gas particles.

b) The root-mean-squared speed is the square root of the (mean) average of the square of the speed of the gas particles.

c) $\sqrt{\langle c^2 \rangle} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.38 \times 10^{-23})293}{4.65 \times 10^{-26}}} = 511\ \text{ms}^{-1}$

b) All gases that make up the air inside the balloon are at the same temperature. Molecules with a larger mass m (eg oxygen) will have a lower root-mean-squared speed.

4. When the peg is removed, the air particles can no longer exert a pressure force on the open end of the balloon. The air pressure force on the other end of the balloon is no longer balanced and so the balloon accelerates in that direction (away from the open end).

5. If initial pressure and volume are P_1 and V_1 respectively, and final pressure is P_2 then final volume:

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{108 \times 0.0110}{101} = 0.0118\ \text{m}^{-3}$$

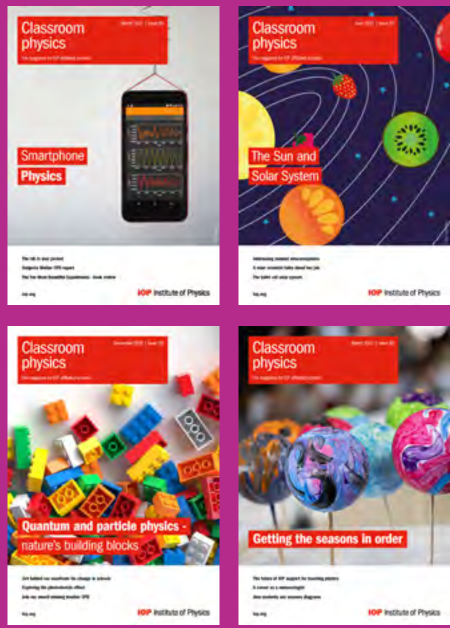
Classroom Physics reader survey

We're inviting readers to share your views on this publication. Your feedback will help us to improve the support we can offer you and ultimately help students in the UK and Ireland towards the best possible experience of physics. We are grateful for your time. Please note that your responses will be treated in strict confidence and will be anonymised.

The survey should take 5 – 10 minutes to complete.

Closing date: 29 July 2022

smartsurvey.co.uk/s/CP2022



Physics for everyone – a day of physics updates, inclusion and education research

29 June 2022 at the University of Birmingham

We're delighted to invite you to this brand new venture! We've joined up with the School of Physics at the University of Birmingham to create this event for teachers, technicians, CPD leaders, teacher trainers, education researchers and more. We are pleased to have Professor Louise Archer, professor of sociology of education at the Institute of Education, starting the day with a keynote session. Then there will be be three strands:

- The cutting edge of physics
- Skills, careers and levelling up - physics in context
- Physics education research

There is no charge to attend the event which is fully funded by the IOP and University of Birmingham.

Register at **talkphysics.org/events**

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For support running CPD, contact our Professional Practice Group **Education-ppg@iop.org**

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