IOP | Institute of Physics
Education *Supporting Teachers*

Classroomphysics

The newsletter for affiliated schools

March 2016 Issue 36

Student activity

View the transit of Mercury from school

This May will provide a wonderful opportunity to observe a transit of Mercury – weather permitting, of course.

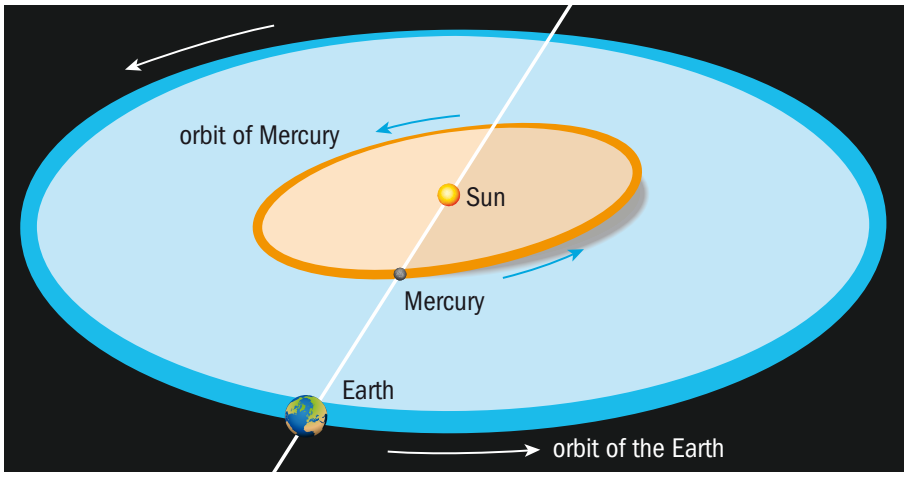
The last transit of Mercury occurred in 2006 on a November evening so was not observable from the UK or Ireland. But the next one will start just after midday on 9 May and complete slightly before 8pm British Summer Time, providing a great opportunity for school observation.

Remind students that they must never look directly at the Sun. For groups, the best way to observe the transit is to project the Sun onto a shaded white surface using a telescope (refer to CLEAPSS Guidance Leaflet PS17, via cleapss.org.uk). Alternatively, if a telescope isn't available or if clouds decide to spoil the view, live streams will be available over the internet.

Transits occur when an astronomical body partially obscures the view of the Sun from the Earth. While eclipses of the Sun by the Moon occur a few times each year, the transits of Mercury and Venus (the only two planets between us and the Sun) are rarer. Transits of Venus occur in pairs only every century or so (the next one is due in 2117), while transits of Mercury occur between 3.5 and 13 years apart.

Although Mercury passes between the Earth and the Sun at least three times a year, its orbital inclination is such that it usually passes above or below the Sun from our point of view. Earth crosses the plane of Mercury's orbit twice a year, in early May and the beginning of November. If Mercury happens to be in the right position, between the Earth and Sun at these times, a transit will be seen. There are 13 or 14 such events each century.

Historically, planetary transits have played an important role in determining the scale of the solar system. Today, transits outside our solar system are used in the hunt for habitable planets that orbit stars other than our Sun. Although most of these exoplanets are too far away to image directly, even with our best telescopes, the temporary reduction in the host star's brightness when an exoplanet transits allows astronomers to detect the planet and estimate its size. Your students can learn more about how astronomers use transits to investigate exoplanets using activity 1 of our *Exoplanet Physics* teaching resource.



The orbital planes of Earth and Mercury and the positions of the planets during a transit.

Brocken Inaglory/Wikimedia Commons

Transit of Mercury (inset) across the Sun on 8 November 2006. Some sunspots are also visible in the image, for example on the left-hand side.

For more information: Guidance on observing the event safely, along with literacy, numeracy and computing resources relating to the transit of Mercury, are available to download from the Royal Astronomical Society at ras.org.uk/education-and-careers/for-schools-and-teachers. Five exoplanet-related practical activities, including one on the transit method for detecting planets outside our solar system, are available to download at iop.org/exoplanets.

The latest physics education news, resources and classroom ideas – from the IOP education team

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Model Mercury's transit and work out how long it will last.

Editorial


Welcome to *Classroom Physics*, which has a space theme for this spring issue.

Firstly, we're delighted to include a special edition set of *Marvin and Milo Tim Peake* postcards. Inspired by Tim's Principia mission to the International Space Station, Marvin and Milo demonstrate five simple space-related experiments.

Next, we're excited about the transit of Mercury in May (p1). Although these transits aren't that rare, with about 13 per century, the most recent one was 10 years ago. So it will be the first opportunity to view it for many of your students. We include a reminder about our exoplanets resources and a related teaching tip (p8).

With this issue, you'll also receive details of a space science masterclass at the National Space Centre, plus a great booklet of resources about climate change.

Thank you to the 288 teachers and technicians who filled in our Affiliated Schools survey. We were pleased to hear how much you value *Classroom Physics* (more than half of you keep it for at least a year) and we saw that you find the teaching tips particularly useful. So we'll include as many as we can in each issue. We'll also remind you of existing IOP-recommended teaching resources.

Your comments also highlighted that not all schools are aware of the benefits of their IOP Affiliation. These include access to *Physics Education*, our journal of articles about teaching physics and reviews of textbooks and software; a subscription to *Physics World* and access to the online version; discounts on IOP teacher conferences such as the Rugby meeting (see iop.org/rugby), and access to the IOP Education Forum, which supports our educational activities. For full details visit iop.org/affiliation.

Finally, this is Manchi Chung's last edition as editor. She has co-edited 15 issues but is excited to be heading up a new IOP project bringing together our digital resources in a single, physics-driven place on the web.

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Early career teachers

Survey reveals salaries for newly qualified teachers

The average starting salary for a new physics specialist teacher is about £2600 above the minimum on the national payscale, according to a new IOP survey.

Based on 225 responses from science and physics specialists who took up newly qualified teacher positions in England and Scotland between 2012 and 2015, our survey found that physics and physics with maths teachers started on an average salary of £24,800.

The minimum point on the national payscales for England, Wales, Scotland and Northern Ireland was around £22,200 for September 2015.

Chris Shepherd, IOP Teacher Support Manager for early-career teachers, said: "New teachers tell us they don't know what to expect when they go for job interviews. So we wanted to find out what new physics teachers were offered, how this reflected their career background and whether they tried to negotiate their salaries."

The full range of starting salaries for physics specialists ran from £15,500 (a female human biology graduate starting her career in a state school) to £49,000 (a mid-career male engineering graduate in an independent school).

We also wanted to find out how NQT salaries are agreed. One in eight respondents said their schools made it clear that the salary offer was non-negotiable. Yet a similar number of respondents reported an increase in salary following negotiation. Men were more likely to have negotiated than women.

A third of respondents felt it was unacceptable to negotiate, while many others felt they did not have enough information available to know whether to negotiate and, if so, how to go about it.

"There is a wide variation in starting salaries," Chris commented. "This reflects the wide variation in background of new physics teachers but also the wide variation in school policies. We firmly believe that teachers should be properly recognised and rewarded for the work they do."

For more information: We have advice for student teachers who are looking for their first qualified teacher position at bit.ly/1QIfksn.

Professional development

£2000 Fellowship will bring your idea to life

If you have an idea about physics teaching that you have always wanted to develop, then the Anthony Waterhouse Fellowship can help you bring your idea to fruition.

You need to be a practising teacher working in a UK school or college catering for students in the age range 11 to 19 years. The Fellowship provides you with a grant of £2000, plus up to an additional £1500 for travel expenses, materials and software expenses or to pay for services that will help you develop your idea into something that other teachers can use.

By the end of your research project, we would like your idea to be made available to the wider physics teaching community, for example via an article in our journal *Physics Education*. As part of the support we provide to Fellowship recipients, the Institute can provide links to physics education researchers and a network of experienced teachers.

For more information: visit www.iop.org/waterhousefellowship. Deadline for 2016 Fellowships is Monday 18 April 2016.

Alan McKeegan

Alan McKeegan (left) of Wade Deacon High School in Widnes was awarded an Anthony Waterhouse Fellowship in 2015. He wanted to explore the effects of peer mentoring on increasing the number of students choosing Physics A-level, focusing in particular on Pupil Premium pupils.

He gave us this update: "We have identified a group of students and these have had regular mentoring by both older students within the school and, for some, PhD students from a local university. The students involved have also had a visit to the University of Manchester in an attempt to raise their aspirations. Parents have been fully briefed throughout and they will be invited in at the end of the project for a celebration event."

Teacher and technician awards

IOP recognises crucial work of physics teachers

Attracting and retaining talented physics teachers is crucial for future groundbreaking work in physics, according to IOP president Roy Sambles. Speaking at the IOP Awards Ceremony last November, Prof. Sambles paid tribute to the fundamental work of physics teachers to cutting-edge research.

He said: "The kind of world-changing work that we're here to celebrate tonight can only continue if we have enough bright people undertaking frontier physics research. This in turn needs a supply of dedicated teachers to inspire them. Encouraging more girls to study physics, particularly coming from mixed-sex schools, is a constant concern."

In England, the awards are based on metrics and nominations by their schools, while in Scotland, Wales and Ireland they are based on nominations. This year's winners are: Andrew Ogilvie (Bannerman High School, Glasgow), Frank Cotter (Christian Brothers College, Cork), Martyn Notley (City of Bristol College, Bristol), Rachel Jones (Ysgol Eirias, Conwy), Mark Dixon (Bancroft's School, Woodford Green) and Jon Brown (Magdalen College School, Oxford).

For more information: visit iop.org/teachersawards.

IOP

This year's IOP Teacher Awards winners.

SALTERS–CLEAPSS National Awards for Science Technicians

The SALTERS' Institute

Make sure your school's science technicians are recognised for their work by nominating them for an award. The IOP is among the supporters of the Salters–CLEAPSS Awards, which aim to highlight the importance of technicians in enabling high-quality practical work to take place.

The awards are open to science technicians in schools and colleges catering for students up to age 18, and who have a total of five or more years' experience in schools and colleges, either full-time or part-time. In 2016, the emphasis is on promoting and supporting the professional learning and upskilling of technician teams.

The winning team (which can be an individual or a group of technicians) will receive £2000, while four runners up will receive £500 each. The awards will be presented at the annual Salters' Institute Awards Ceremony in December.

The closing date for initial entries is Friday 20 May 2016.

For more information: see saltersinstitute.co.uk/prizes/technicians-awards.

Improving gender balance

Learning by teaching: primary outreach

Secondary-school students in Worcester and North Yorkshire have been developing and running workshops in primary schools as part of the IOP's Improving Gender Balance project.

Jenny Search, IOP Girls in Physics project officer said: "Leading workshops is a great way for students to increase their confidence and skills in communication, as well as helping them to reassess their own assumptions. At the same time, the workshops are an important intervention for the younger children."

A workshop designed by three female year 9 students from Richmond School, North Yorkshire, set out to understand how younger students perceive gender and careers.

The girls began by asking the class to draw doctors and teachers and then label them by gender. Over 80% drew male doctors and female teachers. A male primary student explained, "Men are normally doctors and women are nurses."

When the primary students were asked to sort jobs into male and female, many identified firefighters, scientists and police officers as male. They classified receptionists, babysitters and fashion designers as female. The voice of gender equality fell to the few (usually girls), with one primary student commenting, "Whatever men can do, women can do."

Jenny suggested other ideas for primary workshops could focus on STEM activities, linking your secondary school science club with a neighbouring primary and supporting your students to run a junior science club or outreach session.

IOP

Asking students to develop workshops can help increase their confidence and communication skills.

For more information: Find out more about primary perceptions – and challenging them – with NUT's Breaking the Mould at bit.ly/NUTgender. IOP primary physics teaching resources are available at www.supportingphysicsteachers.net.

Teacher event

Physics is sweet at ASE conference

Our highlight from this year's Association for Science Education conference has to be Dan Cottle's workshop Fruit & Sweet Physics.

Using food in the classroom is always popular. The teachers attending this year's conference, at the University of Birmingham in January, were no exception. The room was full to bursting and overcrowding became a health and safety risk!

Dan, who is the IOP's Physics Network Co-ordinator for Birmingham, shared lots of simple ideas for using fruit, potatoes and sweets in physics lessons, demonstrating topics from inertia to measuring the speed of light. He also set up the much-loved jelly-baby wave machine, which is used to demonstrate the propagation of transverse waves.

This year's ASE conference was attended by over 3000 delegates. The IOP ran 27 workshops, attracting hundreds of science teachers and their supporters. These included sessions from our Improving Gender Balance team, a very practical workshop on our resource *Thinking on Your Feet: Football and Physics*, and a panel discussion on school-based CPD which included delegates from the Ogden Trust and NCTL among others.

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Standing room only at the jelly-baby wave machine.

As well as workshops, we ran a drop-in space where teachers could pick up resources and meet the IOP Education team, who were happy to offer advice.

There were also sessions from our Stimulating Physics Network, highlighting the work we've done with link schools. These workshops were run jointly between a Teaching and Learning Coach and a teacher in their link school.

For more information: Learn how to build your own jelly-baby wave machine at bit.ly/1KW8aUO. Find our *Football and Physics* resources at www.iop.org/football.

Watch Dan's workshop online

talkphysics.org

Last year, Dan Cottle ran a webinar called Real Physics with Fruit and Sweets. You can see the video by logging in at www.talkphysics.org and searching for "Real Physics". There are accompanying teacher discussions and lots more suggestions for lesson ideas.

Professional development

Connecting teachers with education research

A new one-day conference, set up by a grassroots teacher organisation, aims to make keeping up to date with education research affordable. The maths and science researchED event will take place on Saturday 11 June in Oxford. It is aimed at teachers who would like to connect their practice more closely to research, and has a day rate of just £20.

Tom Bennett, who founded researchED in 2013, said: "I saw a real hunger in the teaching profession for greater access to better research in their field. So researchED was born. The unique blend of teachers, academics and everyone in between made it a powerful blend of ideas and voices. These conferences don't promise the answers to your every research question: rather they promise to help you start finding ways to begin to answer it for yourself."

The day will include world-class speakers (including the IOP's Head of Education, Charles Tracy), discussion sessions and CPD including plenty of physics workshops, many from the IOP. Judging by previous conferences, it is likely to be busy, thought-provoking, and enlightening.

For more information: on researchED, visit www.workingoutwhatworks.com. For details of the conference and to book your place, visit www.oup.com/education/researchED. Follow Tom Bennett: @tombennett71.

Student competition

Encouraging your students to be the inventors of the future

Brilliant ideas sometimes stem from an abstract, isolated thought. More often they come from trying to come up with a solution to a specific problem.

The invention of the stethoscope 200 years ago is a nice example. The French physician René Laennec attended a young female patient suffering heart problems. He felt uncomfortable about placing his ear to her chest but, fortunately, inspiration struck. He recalled watching children sending signals to each other using a long piece of wood and a pin. He realised that an instrument intervening between her chest and his ear would amplify the sound of her heartbeat, saving both his blushes and her life.

Your Life Campaign

The Formula 100 competition invites students aged 11–13 and 14–16 to submit a video of 30–60 seconds answering the question: What would you invent and why? The competition is run by the Your Life campaign, an industry-led and government-supported drive to increase uptake of physics and maths at A-level and equivalents.

The winning entry in each category will win £1000 for the school and an iPad for the student. Other prizes to be announced.

For more information: visit yourlife.org.uk/formula100/registration.

Resource

Levelling up TalkPhysics

Watch out for the new version of our digital community for physics teachers, technicians and trainers. The improved TalkPhysics will still have the current functionality, such as finding and sharing physics content and resources, special interest groups and support and advice from a network of more than 9500 users.

But our new platform and rebrand will enable better search functions, easier navigation and an enhanced events calendar. You'll also be able to:

- Join webinars from the IOP's Physics Network Co-ordinators.
- Discover local STEM CPD in your area – and add your own workshops to the events calendar
- Help your peers solve classroom problems and get recognised for your expertise
- Follow a regular resources blog
- Catch up on physics news

The new TalkPhysics is due to launch in spring 2016.

For more information: Register now by visiting www.talkphysics.org and clicking on "Register". Registered users will be automatically upgraded to the new version.

Resource

Aim for the stars with the NSO telescope

The Stimulating Physics Network (SPN) and the National Schools' Observatory (NSO) have launched a new webpage, presenting a selection of NSO activities involving the world's largest robotic telescope.

The Liverpool Telescope is situated in the Canary Islands. Owned and operated by the Astrophysics Research Institute of Liverpool John Moores University, schools across the UK and Ireland can access this state-of-the-art instrument online for free. Help is on hand via a dedicated support site with teacher and student guidance.

Designed with non-specialist teachers in mind and supporting the study of physics up to age 16, the activities come complete with web-based guidance on astronomy and on using the associated software. NSO staff can be contacted for support, and SPN schools can benefit from the one-to-one support of their Teaching and Learning Coaches. Teachers can create a free account and from this they can control students' accounts and supervise their use.

Students can obtain bespoke images from the telescope and analyse them with software. They are led step-by-step through this process, from deciding what to observe to how to process the images. Using the telescope draws on mathematics, coding and engineering and helps to develop wider skills such as team working and problem solving.

NSO

The Dumbbell Nebulla (M27) taken through the Liverpool Telescope.

There are also opportunities for longer term involvement with the NSO, including projects such as Asteroid Watch where schools can help to classify asteroids and comets.

For more information: access the activities at schoolsobservatory.org/spn. Create an NSO teacher account: schoolsobservatory.org.uk/user/register.

Professional development

Free regional CPD

Look out for your local Stimulating Physics Regional Teacher Day. There are 10 of these held around England every year, offering free workshops and masterclasses for all physics teachers and school lab technicians.

A recent SPN Teacher Day in Leeds attracted 65 teachers. As well as workshops, there were talks from the head of physics at the University of Leeds and an expert in physics in the fashion industry.

Upcoming Teacher Days:

- Highgate Regional Day (London & SE): 16 April 2016
- South West Annual Physics Day: 24 June 2016
- A Day for Everyone Teaching Physics: (DYHNE) 30 June 2016

For more information: Find events near you at www.stimulatingphysics.org/regions.

STIMULATING PHYSICS NETWORK

Confidently Delivering the New A-level Physics Practicals

Come and learn how to build students' practical and investigative skills in the context of the compulsory practical activities specified by the new physics A-level. Dan Cottle's hands-on session will have activities to try out and refreshments will be provided. At King Edward VI Five Ways School, Birmingham, on 17 March. To book, and for more events like these, visit www.stimulatingphysics.org/regions.

Geocaching

Spring's digital highlight: an engagement tool for teaching the EM spectrum. Geocaching is a free, app-based hide-and-seek game played by millions around the world. Challenge students to find (or to set each other) a cache as an introductory lesson or homework activity. Get more information at www.geocaching.com/play and free alternatives from any app store.

Activities this spring across the regions

- North West Teaching and Learning Coach Christine Mayson visited the University of Cumbria to enrol the latest early-career teachers to SPN's mentoring programme.
- Teachers from across the South West attended an electricity and magnetism workshop at The Arnewood School Academy.
- More than 50 teachers attended our 2016 Improving Gender Balance conference in York.
- Ferryhill Business Enterprise College in County Durham became our latest Partner School.

Twitter
Follow us **@TakeOnPhysics** for advice, ideas and events for teachers of physics.

Events

EVENTS FOR TEACHERS

Maths for GSCE Physics Booster Course
Charterhouse School, Surrey
5 March
This hands-on workshop will concentrate on subject knowledge and developing understanding, using the Institute's Supporting Physics Teaching resources. Details and booking: contact Katharine Wilkinson (science@charterhouse.org.uk).

Isaac Physics Workshop
King's College London
11 March
For A-level Physics and A-level Maths teachers, this one-day workshop will cover problem-solving with vectors, calculus and exponentials. Details and booking: isaacphysics.org/events/11032016kclms.

Physics Booster Course
Charterhouse School, Surrey
12 March
This hands-on workshop will concentrate on subject knowledge and developing understanding, using the Institute's Supporting Physics Teaching resources. Details and booking: contact Katharine Wilkinson (science@charterhouse.org.uk).

Space across the Science Curriculum
Space Studio West London
24 March
Delegates who attend this full-day event will have the chance to choose workshops. Costs £45 + VAT (lunch and refreshments are included). Details and booking: nsa@spacecentre.co.uk or call 0116 258 2147.

National Space Academy Showcase Event
Cardiff University
19 April
The showcase event will highlight how the Academy's programme works and includes a free CPD session delivered by Robert Woodman (National Space Academy Lead Educator). Details and booking: nsa@spacecentre.co.uk or call 0116 258 2147.

Secondary Science CPD: The Energy Mix
EDF Energy Education Centre, Somerset
4 May
This day will include interactive workshops and a tour of the Hinckley B nuclear site. Please note, places are limited and a security form will need to be completed before 31 March. Details and booking: Sarah Bleach (sarah.bleach@petroc.ac.uk).

Specialist Physics CPD Session
National Space Centre, Leicester
26 May
The programme will explore "space related" strategies for teaching A-level Physics, as well as the mathematics involved in space physics. Costs £150 + VAT (lunch and refreshments are included). Details and booking: nsa@spacecentre.co.uk.

28th Annual Rugby Meeting
Rugby School, Warwickshire
9 June
This annual meeting for physics teachers will feature lectures given by leading research physicists and physics education experts, hands-on workshops, and an opportunity to browse the exhibition. Details and booking: www.iop.org/rugby.

South West SPN Annual Physics Day
University of Exeter
24 June
Details and booking: www.stimulatingphysics.org/regions-southwest.htm.

A Day for Everyone Teaching Physics
The Sjøvoll Centre, Durham
30 June
A day of lectures, updates, workshops, manufacturers, publishers and more; includes sessions for those who are new to the subject, as well as experienced teachers. Details and booking: bit.ly/SPNdurham.

EVENTS FOR STUDENTS

Lab in a Lorry, Wales
Ysgol Clywedog 2–3 March
Westbourne School 8 March
St Cyres School 9–10 March
Bangor University 15–16 March
Swansea 22–23 March
Bassaleg School 12–15 April
Queen Elizabeth High School 26–29 April
This touring mobile lab gives students aged 11–14 years old the chance to explore interesting hands-on experiments. Details and booking: labinalorry@iop.org.

Your Universe Festival
University College London
10, 11 & 12 March
This festival will include tours, talks and telescopes will be available to look at the Sun, Venus and the Moon (weather permitting). Details and booking: Dr Francisco Diego (secondary-schools@star.ucl.ac.uk).

British Science Week
Nationwide
11–20 March
There are lots of resources to support the planning of your school's science week. Details: www.britishscienceweek.org.

Big Bang Fair
Birmingham NEC
16–19 March
The four days are packed with exciting and stimulating hands-on science, technology, engineering and maths. The focus is on inspiring young people to pursue STEM subjects as their career. Details and booking: www.thebigbangfair.co.uk.

STFC Particle Physics Masterclasses
Various locations and dates
These events consist of a mixture of talks and practical sessions centred on particle physics. Details and booking: bit.ly/1WJKN20.

Royal Institution Engineering Masterclasses
Various locations and dates
These events introduce young people to engineering, allowing them to gain insight into its creativity, practice and relevance. Typically contains six Saturday morning sessions. Details: bit.ly/1SexhTE.

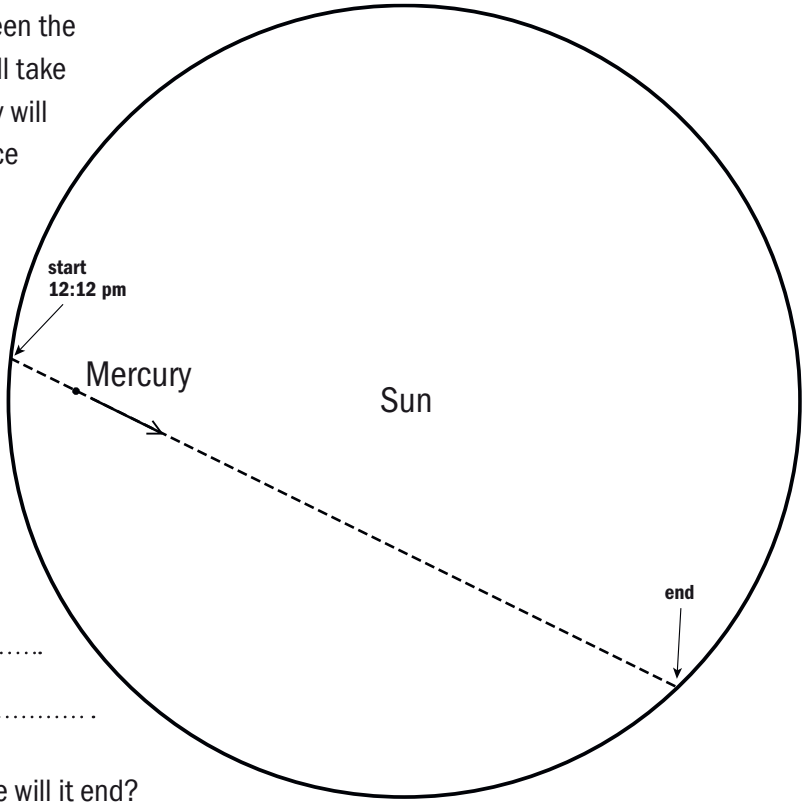
Isaac Physics Masterclasses
Various locations and dates
These free workshops aim to develop each student's confidence and problem-solving skills in a core area of physics. Details and booking: isaacphysics.org/events.

Worksheet: notes and solutions

Question 1.
(a) Time = distance / speed
= 1,080,000 km / 40 km/s
= 27000 seconds.
(b) Time = 27000 / (60 x 60) = 7.5 hours. The transit will end at 7.42 p.m.
Question 2. The teaching tip (page 8) may help students answer both parts. Start by discussing the table: is there a pattern? Explain that transits are not observable everywhere on Earth as they may occur at night-time. Part (b) could also be set as a research question for homework.
(a) Number of orbits Mercury completes in an Earth year = 365 days / 88 days, i.e. just over 4. This corresponds to Mercury overtaking Earth 3 or 4 times a year, depending on the start positions.
(b) Mercury's orbit is tilted (when compared to the orbital plane of the Earth).

Transit of Mercury: 9 May 2016

A transit takes place when a planet comes between the Sun and the Earth. The next transit of Mercury will take place on 9 May 2016. During the transit, Mercury will appear as a small dark dot moving across the face of the Sun. The dotted line on the diagram here shows the path that Mercury will follow.



1. During the transit, Mercury will be travelling at a speed of 40 km/s and will move a distance of 1,080,000 km.

(a) How long will it take in for Mercury to transit the Sun?

……

……

(b) The transit will start at 12.12 p.m. – what time will it end?

……

……

2. Here are some dates for past and future transits of Mercury:

Year	1999	2003	2006	2016	2019	2032	2039	2049
Day	15 Nov	7 May	8 Nov	9 May	11 Nov	13 Nov	7 Nov	7 May

(a) Mercury takes 88 days to orbit the Sun. How many times do you think Mercury overtakes the Earth in one year?

……

……

(b) Each time Mercury overtakes the Earth, a transit is possible. However, as shown above, transits are quite rare. Research and explain why we do not observe transits of Mercury more often.

……

……

Teachers: see page 6 for notes and solutions

Paper plate physics: transit of Mercury

Begin by explaining that Mercury moves around the solar system in the same direction as Earth (anticlockwise when viewed from above the north pole of the Sun), and its orbital period of 88 days corresponds to about four orbits per year.

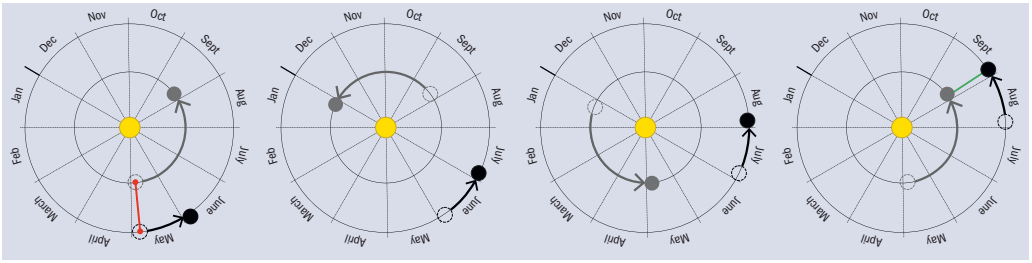


Figure 1. Mercury (grey) and Earth (black) align every four months. The first two alignments are shown.

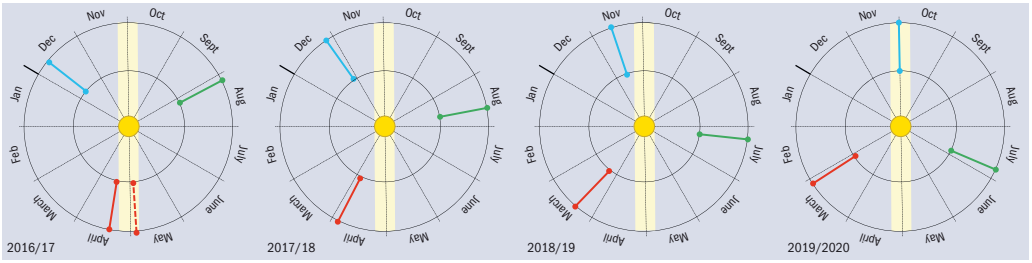


Figure 2. Transits only occur when an alignment happens close to the May–Nov line (yellow). In the first cycle, there is one transit at the beginning of May 2016 (dotted red line). There is no transit in May 2017 or in any month for another 3.5 years until halfway through the fourth cycle there is a transit in November 2019.

Apparatus per student pair:

- Paper plate
- Protractor
- Compass
- Scissors
- Plasticine or cork board
- Pencil and coloured pens
- Two counters or coins

Instructions

Ask your student pairs to:

- Draw the Sun at the centre of the plate.
- Draw two circles: one at the outer edge to represent Earth's orbit, and one closer to the Sun to represent Mercury's orbit.
- Divide the plate into 12 equal segments and label the months of the year, moving anticlockwise around the edge of the plate.
- Place both counters just to the right of the line dividing April and May to represent the position of the planets for the 2016 transit.
- Draw a line between the planets to indicate this alignment.
- Going anticlockwise, move the Earth counter one segment and Mercury four segments. Will there be a transit in that month – i.e. does Mercury come between the Earth and Sun?
- Repeat a total of 12 times, moving Mercury four segments for every one segment Earth moves. Each time there is an alignment, mark the position in a different colour (see figure 1).

After moving the Earth through one complete cycle, they should have alignments marked at the beginnings of May, September and January. Conveniently, the pattern repeats every year. This simple model indicates that there should be three transits a year.

Improving the model

Explain that Mercury's orbit is in fact tilted, and that they are now going to investigate what effect this will have on the frequency of transits. Ask them to:

- Make a small incision just to the right of the alignment line in May, using Plasticine or a cork board on the other side of the plate to do this safely with a pair of scissors.
- Cut anticlockwise along Mercury's orbit, stopping at the line dividing October and November.
- Make another incision the other side of the October–November line and continue cutting until they reach the April–May line.

By leaving the card attached at these two positions, they should be able to tilt the orbit of Mercury (as shown in figure 3). In September and January, Mercury will now pass either above or below the Sun when viewed from Earth. Transits occur once a year, in May.

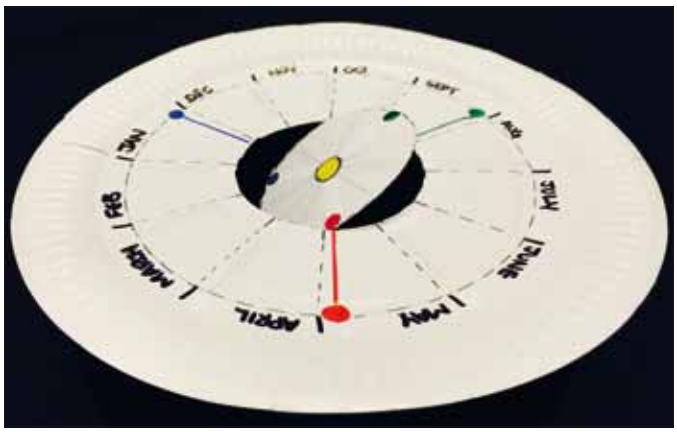


Figure 3. Completed tilted model with alignment marks.

A better model

Show your class the dates of past and predicted dates for transits (see table on page 7). Discuss the successes and failures of their model. It explains why transits occur in May, but doesn't predict November transits or explain why transits do not happen every year.

Remind them that Mercury's period is 88 days, which is equivalent to 365/88 = 4.15 orbits rather than exactly 4 orbits a year. Mercury overtakes Earth earlier than predicted (see figure 2), so alignments occur earlier and shift to an earlier time each successive year. Over a number of cycles the alignment positions will gradually move round until once again an alignment occurs in either May or November and a transit is observed once more. There is also the additional complication that Mercury follows an elliptical path not a circular one and, by taking this (and other factors) into consideration, astronomers can successfully predict future transits.

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