PHYSICS NEWSLETTER

—

18th Edition - Discoveries

Welcome to the 18th edition of the Physics Newsletter, the final edition produced by the current physics team! The theme of this edition is inspired by the spring and all of its new beginnings.

A big thank you to all the people who contributed to this edition of the newsletter: Alice, Ruth

Contents

A Final Note from the Editor

I've really enjoyed making these newsletters over the last year. They are certainly time-consuming and fiddly to produce, but each time I've sent off the finished product it has always felt well worth the effort. I am very proud of everyone who has contributed to the newsletters that we've made together and I hope that each one has brought some joy to both its writers and readers. If even one person has learnt something new or been inspired, then these newsletters have done their job.

Thank you especially to Ruth and Raga for contributing to every newsletter - I quite literally could not have done it without you!

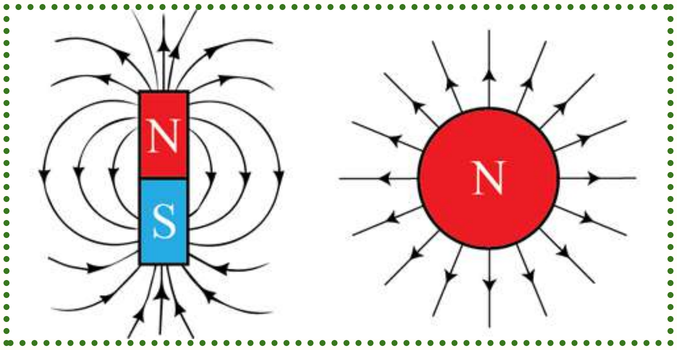
Alice

Keeping up to date...

Physics in the News - Magnetic monopoles

Imagine a magnet and you would most likely think of a basic bar magnet with a "red" north pole and a "blue" south pole. But is it possible to split that magnet until you get something different? If you keep splitting it you would only get smaller and smaller dipole magnets, but what about a magnetic monopole? The idea of a magnetic monopole was first theorised by Paul Dirac, who also first theorised the existence of antiparticles, in 1931.

A monopole in the form of a single electric charge already exists in the form of electrons, yet a particle with a single magnetic charge has been considered hypothetical so far.
Electrons have a property called spin (angular momentum) which creates a magnetic field around an atom. When there are several spins arranged specifically in a material, such as spin ice, they seem to behave like magnetic monopoles.



There are a few methods to detect the existence of magnetic monopoles. For example, researchers at CERN have been attempting to find evidence of magnetic monopoles with the ATLAS experiment. They collide protons which annihilate and result in virtual photons, which then produce magnetic monopoles. The criteria for these magnetic monopoles are particles that have a high mass of roughly 4 TeV and are 4700 times more ionising than a proton. Due to their highly ionising properties these monopoles would have a low penetration and would lose energy quickly. The detectors at CERN therefore contain large cameras which can provide evidence of collisions and trap the highly ionising monopoles quickly.

Another research method utilises Faraday's Law, which is that when you pass a magnet through a coil a current is induced in the coil. In the case of passing a magnetic monopole through a coil, a particular type of current is induced that can be indicative of the existence of magnetic monopoles.

Recently, physicists at the University of Oxford and Cambridge have discovered magnetic monopoles in haematite, a type of iron oxide. They used the technique of diamond quantum magnetometry, where a fine, highly sensitive needle made of diamond with a single spin was used to measure the magnetic field of haematite. The results were that this natural occurring magnet has the behaviour of magnetic monopoles.

While the magnetic monopoles have not been fully separated, there are significant implications of magnetic monopoles. This discovery can lead to the advancement of computing technology, as transistors can become faster and more efficient. A more ubiquitous technique might be its potential use in MRI. For MRI scanning, a very high magnetic field is needed to detect changes in spin of hydrogen atoms, but with magnetic monopoles the magnetic field needed may be less.

Sai Raga Navili 13P

References:

https://physicsworld.com/a/magnetic-monopoles-seen-in-the-lab/
https://www.quantamagazine.org/the-biggest-discoveries-in-physics-in-2023-20231221/#:~:text=Video%3A%20In%202023%2C%20physicists%20found,JWST's%20potentially%20cosmology%2Dbreaking%20discoveries

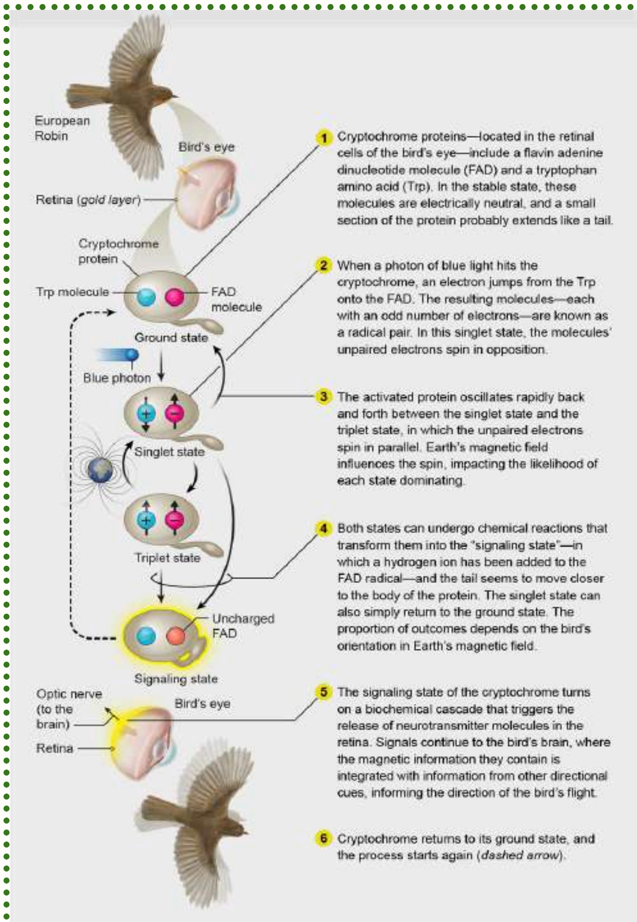
The Physics Behind... Bird migration

In the UK, spring marks the departure of birds such as the European robin, who have sought shelter from the cold winters in Eastern Europe. Unlike us, these migrating birds do not have the luxury of GPS, so how are these birds able to find their way?

Many birds are able to sense the Earth's magnetic field and use it for migration. These birds are viewed as having an in-built 'living compass' which allows them to follow the path of the earth's magnetic field. A standard compass consists of a permanently magnetised needle which rests on a pivot and is able to lie in the same direction as the magnetic field, allowing us to determine true north. However, it is incredibly unlikely for a bird to be permanently magnetised (unfortunately they are not magnetic), so how can these birds determine the earth's magnetic field?

Magnetoreception is the sense which allows an organism such as birds to detect a magnetic field. This sense is linked to the eye for two main reasons. The first is that the magnetic compass of a bird is light dependent and is disturbed by the absence of light. Another is the discovery that a brain region called Cluster N, which receives and processes visual information is the most active part of the brain when certain migrating birds use their magnetic compass. If Cluster N is dysfunctional, the birds are incapable of using the Earth's magnetic field to orient themselves. This suggests that a process taking place in the retina of the eye, where light is focused, is responsible for the birds' magnetoreception. We can imagine this as the bird being able to "see" the magnetic field, perhaps with areas of vision appearing lighter or darker when they look in the direction of a magnetic field.

To explain how this process might occur, a scientist named Klaus Schulten put forth the theory that radical pairs, which are short lived chemical intermediates (a substance formed as a middle step of a reaction), might be the cause. To explain radical pairs, we have to consider a property of electrons called spin, which causes them to have magnetic moments (behave like microscopic magnets). Electron shells are separated into orbitals, each orbital consisting of two electrons. One of these electrons has an up-spin and the other of the pair has a down-spin. This means when we have a molecule with an even number of electrons, the opposite spins are able to cancel each other out. However, in radicals, we have an odd number of electrons, resulting in a spin and therefore a magnetic moment. This means they are very sensitive to the earth's magnetic field.



Radicals are very chemically reactive and are often formed in the presence of UV light. One theory to explain magnetoreception in birds is that radical pairs are created when a light-sensitive protein called cryptochrome (found in the retina of birds) absorbs blue light. This causes an electron to jump from one amino acid to another, leaving behind two molecules with an odd number of electrons. The internal magnetic fields between these two molecules leave the spins 'waltzing' between like and opposite spins. This waltz can be affected by weak magnetic fields, such as the earth's magnetic field. Six types of cryptochromes have been found in migratory birds, and in the last twenty years scientists have been unable to find a molecule which is able to sense the earth's magnetic field as sensitively. Whilst cryptochrome is present in non-migrating birds such as chickens, it is much more magnetically sensitive in migratory birds which suggests that evolution optimised cryptochrome in migratory birds for navigation.

However, this is just a theory as cryptochrome has only ever been studied in isolation, not when it is actually in the eye. Just because cryptochrome is sensitive to magnetic fields does not mean it is the primary method of detecting the earth's magnetic field for migratory birds. Some other theories include:

- Magnetised rock in the beak of some birds
- The use of angle of inclination as a "stop sign"

Which of the theories do you think is most likely to be true? Or perhaps it is a combination of all these methods which allow birds to migrate successfully!

Emilie Silk and Tanisha Rumana

References:

https://www.scientificamerican.com/article/how-migrating-birds-use-quantum-effects-to-navigate/#:~:text=A%20bird%20detects%20the%20axis,bird's%20ability%20to%20orient%20correctly.
https://www.ox.ac.uk/news/science-blog/how-birds-sense-magnetic-field-earth-help-them-navigate
https://www.newscientist.com/article/2281998-we-may-finally-know-how-migrating-birds-sense-earths-magnetic-field/
https://www.bbc.co.uk/news/science-environment-57582451
https://www.vox.com/down-to-earth/22901324/birds-migration-navigation-earth-magnetic-field

Women in Physics: Jocelyn Bell Burnell

Dame Jocelyn Bell Burnell was born in 1943 in Northern Ireland. As a child, she developed a keen interest in astronomy and went on to study physics at university, gaining a PhD at Cambridge in 1969.

But what she is most famous for is her discovery of pulsars. In 1967, as a graduate student at Cambridge, she helped to construct a large radio telescope. She and her advisor, Antony Hewish, were looking for quasars, a special type of supermassive black hole at the centre of some galaxies that emit radio waves. However, while reviewing hundreds of metres of printed data, she spotted a series of extremely regular radio pulses. She established that the signal was pulsing with great regularity, at a rate of about one pulse every one and a third seconds. These pulses looked nothing like the long, wavering signal of a quasar. Bell Burnell, Hewish and the rest of their team joked that the source of these pulses was the LGM (Little Green Men), referring to the idea that they might be an attempt at extraterrestrial communication.

For a few months, they monitored the pulses using more sensitive equipment and discovered several more regular patterns of radio waves. They determined that the pulses were being produced by a pulsar (aptly named by the press who found the term pulsating radio source a little too long). Pulsars are highly magnetised neutron stars that rotate rapidly and emit beams of electromagnetic radiation out of their magnetic poles. This radiation can only be observed when a beam of emission is pointing directly towards Earth, which is why the emissions appear as pulses.

In 1974, the Nobel Prize for Physics was awarded to Hewish and Martin Ryle, another British radio astronomer, for the discovery of pulsars. This caused quite the controversy as many prominent fellow astronomers felt that she had been snubbed, as summarised in this quote: *'She helped build the array she used to make the observation. She is the one who noticed it. She is the one who argued it's a real signal. When a graduate student takes that kind of lead in her project, it's hard to play it down.'* - Feryal Özel, an astrophysicist at the University of Arizona.
Years later, Bell Burnell said herself that *'the fact that I was a graduate student and a woman, together, demoted my standing in terms of receiving a Nobel prize.'*
Even during the press interviews, she faced sexism as all the astrophysics questions were aimed at Hewish while Bell Burnell was asked demeaning questions such as how many boyfriends she had. Despite these challenges, Bell Burnell is a highly respected figure in physics today and has been awarded a grand total of 13 awards in physics, including the Michael Faraday Prize which is awarded for excellence in communicating science to UK audiences. She has inspired countless

people across the world to pursue a career in astrophysics and remains a symbol of what women can achieve even when under the thumb of the patriarchy.

A young Jocelyn Bell Burnell, excited to be reading data from the radio telescope in the background.

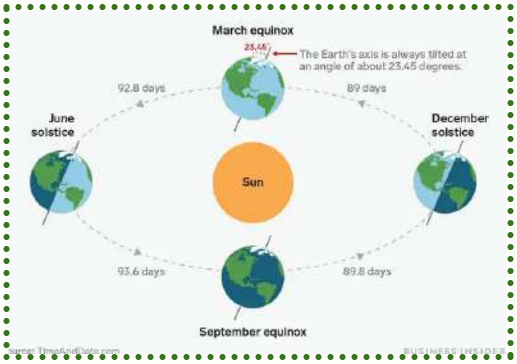
The Vela Pulsar Jet, imaged in 2013 by the Chandra X-ray Observatory Centre.

Ruth Rafeeq 13MP

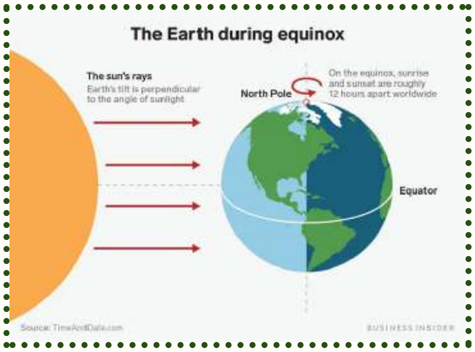
References:

Jocelyn Bell Burnell | Astrophysicist who discovered the pulsar | New Scientist
Jocelyn Bell Burnell - Wikipedia
Jocelyn Bell Burnell | Biography, Nobel Prize, Contributions, Astronomy, & Facts | Britannica
What are pulsars? | Space

Physics in the Real World: The Spring Equinox



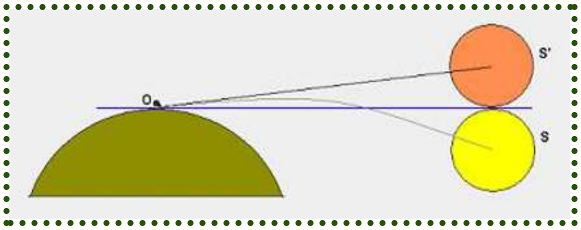
Recently, you may have noticed that the days are getting longer. Waking up in the morning is still quite a struggle, but it seems that there's more sun to coax you into consciousness. This year, the spring equinox - or *vernal* equinox, from the latin *ver* for spring - was on Wednesday, 20th March at 3:06 am. The equinox marks the sun's crossing above Earth's equator, as it moves from the southern to northern hemisphere.



Of course, it isn't really the sun that is moving - it's us. The earth is tilted on its axis so for most of the year, light from the sun is shared unequally across the earth's surface. However in March (and September), the earth's two hemispheres receive nearly equal amounts of the Sun's rays. In fact, the second part of the name - *equinox* - comes from the Latin *aequus* (equal) and *nox* (night).

The equinox comes with some interesting effects.

Firstly, the day and night aren't actually equal at the equinox. In reality, we experience a day that is a few minutes longer than night at the spring equinox. Refraction in the atmosphere bends the Sun's rays, causing the Sun to appear above the horizon even as it moves below. Due to refraction, we see the sun about half a degree above its true geometrical position whenever the sun nears the horizon. Although this may seem like a small effect, half a degree is comparable to the size of the sun seen from the earth (known as the sun's angular diameter).



(Here the true position of the sun, S, is shown in yellow and the result of refraction, S', is shown in orange.)

Atmospheric refraction advances the sunrise and delays the sunset, adding nearly another six minutes of daylight at mid-latitudes all year. Lower temperature, higher humidity and higher barometric pressure all increase atmospheric refraction and lengthen the sunrise.

Therefore, on the equinox, the length of day and night are only nearly equal. It is the centre of the sun that takes 12 hours to rise and set. The point at which day and night are truly equal is not the equinox, but the equilux a few days after the autumn equinox, and a few days before the spring equinox.

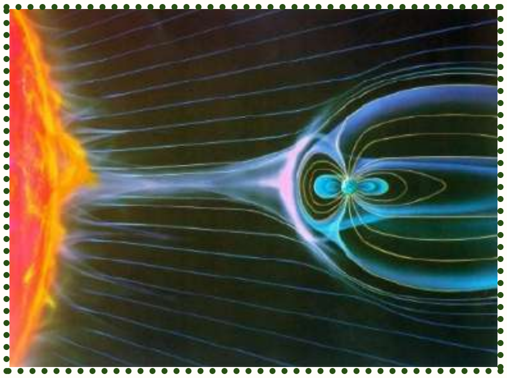
In contrast to the equinox itself, which happens at the same instant worldwide, the exact date of an equilux varies with latitude. Similarly, the earliest sunrises and latest sunsets vary with latitude. At and near the equator, the daylight period is over 12 hours long every day of the year so equilux cannot occur.

Perhaps unexpectedly, the equinox affects not just the length of the day, but the tides.

At the equinox, the Sun is exactly aligned with the celestial equator (an imaginary line in the sky above Earth's equator). Since the equator of the Earth is lined up with the sun, the gravitational effect of the Sun on the Earth is greater during the equinoxes.

As a result, the Sun exerts a stronger force on the Earth, which produces a higher gravitational pull on the tides, causing a tidal 'bulge'. These are known as 'equinoctial tides' as they occur during the equinox. This effect was described by Isaac Newton in 1686, who first explained the gravitational forces between the Sun, the Moon and the Earth.

The most exciting effect of all, and one to keep a lookout for, is that the Northern Lights (Aurorae) tend to occur more frequently around the equinoxes.



Although this is still poorly understood, it is thought that the alignment of the Sun and the Earth increases the strength of the magnetic field between their magnetic poles. When one of the Sun's poles is tilted towards the Earth, charged particles ejected from the sun can travel along the magnetic field lines until they interact with the Earth's magnetic force field (magnetosphere). A 'solar wind' made of charged particles collides with nitrogen and oxygen molecules in the Earth's atmosphere, resulting in the massive, dancing bands of the aurora.

You can watch the movement of the shadows in this animation from NASA:
https://youtu.be/FmCJqykN2J0

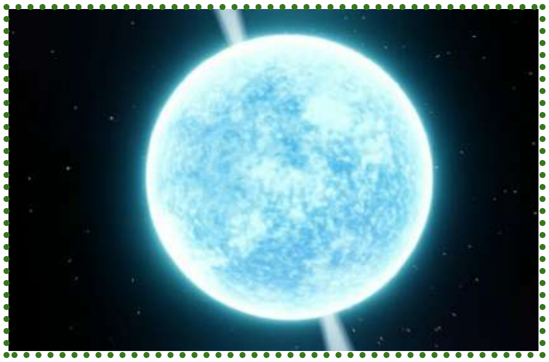
Alice Bill Wilks 13CL

References:

https://www.sciencefocus.com/planet-earth/spring-equinox
https://www.businessinsider.com/when-is-first-day-of-spring-march-equinox-2019-03?r=US&IR=T
https://earthsky.org/astronomy-essentials/everything-you-need-to-know-vernal-or-spring-equinox/#:~:text=Bottom%20line%3A%20The%202024%20March,we%20experience%20it%20on%20Earth%3F
https://earthsky.org/astronomy-essentials/equal-day-and-night-on-the-equinox-march/#:~:text=Atmospheric%20refraction%20and%20the%20equinox&text=What%20does%20atmospheric%20refraction%20mean,than%20night%20at%20the%20equinox.

Physics Mystery: A neutron star or a black hole?

Some of the most interesting things in space originate from the death of a star. Throughout their lives, stars have to fight against the gravitational force pushing in on them. Nuclear fusion, the process of two lighter nuclei forming a heavier nucleus, is constantly happening in a star's core, allowing it to use the energy released to heat up the gas within it, causing an outward pressure that balances out the force of gravity. When they run out of light nuclei to fuse, they get crushed by gravity and die. If a star is massive enough, a supernova will occur. After this point, the star could become a neutron star, with its immense mass pushed into a tiny volume. Due to the extremely high density, protons and electrons merge into neutrons very tightly packed together. The proximity of the neutrons allows the star to use neutron degeneracy pressure to push out against gravity again. However, once a star is heavy enough, its mass causes the gravitational force to completely overpower the degeneracy pressure and it collapses into a black hole.



So, if a star has a high enough mass, it can collapse into a black hole after it dies but exactly how much mass must it have? The Tolman-Oppenheimer-Volkoff (TOV) limit is the theoretical boundary between what constitutes if a star will become a neutron star or a black hole and is currently calculated to be around 2.2-2.6 times the mass of our sun. However, there is a problem with this. The heaviest neutron star ever found is a mere 2.08 times the mass of the sun while the lightest black hole is 5 solar masses. This leaves a giant 'mass gap' around the TOV limit, making it very difficult to ensure its theoretical value is correct. This is why looking for real stars or black holes within this mass cavity is important.

On the 18th of January, an article was published talking about a mystery object 40,000 light years away discovered orbiting a pulsar (a type of neutron star). Found using a radio telescope, no visible light was detected from the object. Pulsars emit pulses of radio jets extremely regularly. When small changes in the period of the pulses were measured, it was clear there was another massive body not visible to our telescopes. These changes in pulse timings were used to calculate the orbit and therefore the mass of both objects in the binary system, revealing the mass of the pulsar's companion to be between 2.1-2.7 solar masses, directly within the mass gap, near the predicted TOV limit. However, when accounting for the angle of the system's orbit compared to us, this number is closer to 2.7 times our sun's mass. Black holes do not directly emit visible light and, due to their small volume, neutron stars do not give out much visible light, meaning the object could be either. Moreover, efforts to find any emitted radio jets from the companion have come up short.

1,920 × 1,080

However, there is one way to possibly tell the difference between the two options. The paper predicts that the object was formed from the merger of two separate neutron stars into either one heavier star or a black hole. If an object was to be created this way, a black hole would spin much faster than a neutron star. Going back to the pulsar, we know how much the pulsar's radio jets will change depending on how its companion is spinning, which can be used to find if the mystery object is a black hole or neutron star. Unfortunately, the anomalies in pulse timings that would need to be measured are just too small to do with our current equipment. Maybe a few years later, we will be able to find these elusive heavy neutron stars and light black holes, finally proving if our calculated mass limit for a star to become a black hole is right!

Ananya Balaji 13W

References:

https://youtu.be/8PHt7NcwllA?si=3XTYVpwQ0pn_weYa
https://www.manchester.ac.uk/discover/news/lightest-black-hole-or-heaviest-neutron-star-manchester-astronomers-uncover-a-mysterious-object-in-milky-way/
https://www.space.com/mystery-object-lightest-black-hole-heaviest-neutron-star
https://www.space.com/22180-neutron-stars.html

Bonus: Get ready for April Fools (it's never too early)

What is the name of the first electricity detective?

Sherlock Ohms and John Wattson

Two atoms were walking across a road when one of them said, "I think I lost an electron!"
"Really!" the other replied, "Are you sure?" "Yes, I'm absolutely positive."

Why is electricity an ideal citizen?

Because it conducts itself so well.

"I was studying frequency in my physics class. Now my brain Hertz."

Einstein developed a theory about space.

And it was about time too.

What did the Nuclear Physicist have for lunch?

Fission Chips.

Where does bad light end up?

In prism.

Dates to know:

1. **Beamline for Schools Competition: submissions from January to April 2024**

   An international competition for designing an experiment to be performed at a high energy particle accelerator. For Beamline for Schools 2024, the three winning teams will realise their experiments at CERN and DESY. All winners will be supported by a team of professional scientists.

   https://beamline-for-schools.web.cern.ch/sites/default/files/Invitation_BL4S_2024.pdf

2. **Isaac Physics Mentoring Scheme: any time from September**

   For Years 11 to 13, this is a super-curricular opportunity (great for your personal statement!) where you get set weekly problem solving activities. At the end of the school year you will receive a certificate with the number of questions completed.

   https://isaacphysics.org/pages/mentor_menu?stage=all

3. **University of Oxford Physics Department events**

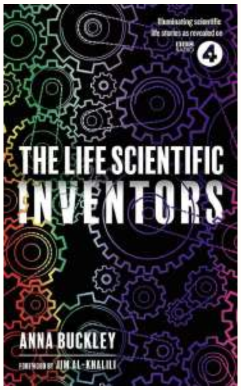
   For Years 10 and 12 - have a look (for lots of taster days and programmes)!

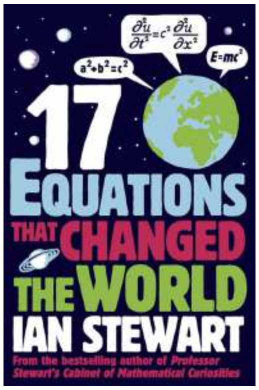
   https://www.physics.ox.ac.uk/engage/schools/secondary-schools

4. **Engineering society is every Thursday in Room 27 at 1pm!**

Get involved!

Here are some titles on theme with ‘Discoveries’ from the Physics lending library at the back of Lab 10.

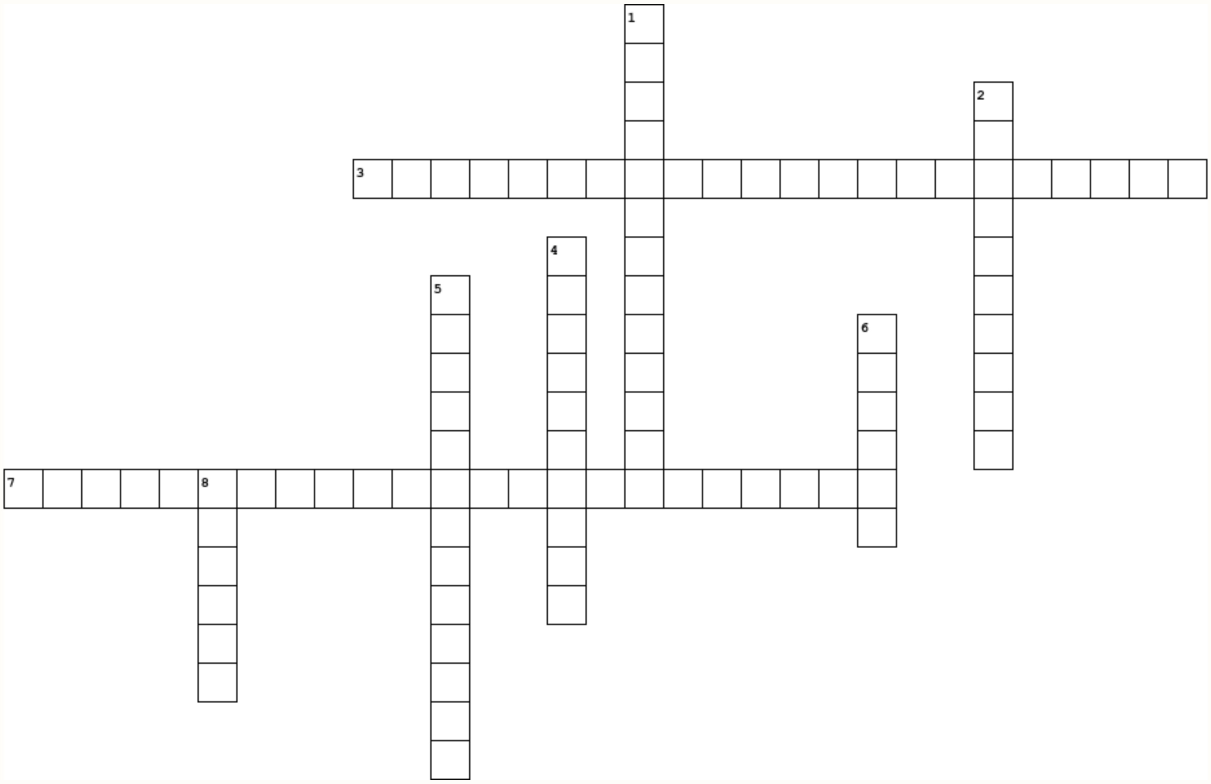




Crossword

A very special mention to Fatima Tabib 10C, Fathima Imthiyaz 13M, Vidhushaa Senthilkumar 9Z, and Sathviga Gopinath for completing the last crossword (some even without looking at the word bank!). I hope you enjoy this one too!

Physics in the News



Across

3. used to accurately model how sound waves travel underwater

7. detected a burst of neutrinos, evidence for neutron star at heart of supernova remnant

Down

1. the type of wave theorised to be caused when two supermassive black holes merge

2. the kind of star that was caught eating stars and planets

4. scientists want to build an even larger particle accelerator to find this type of matter

5. the process that powers the sun

6. one of the first companies to coordinate tourism flights to Earth's orbit

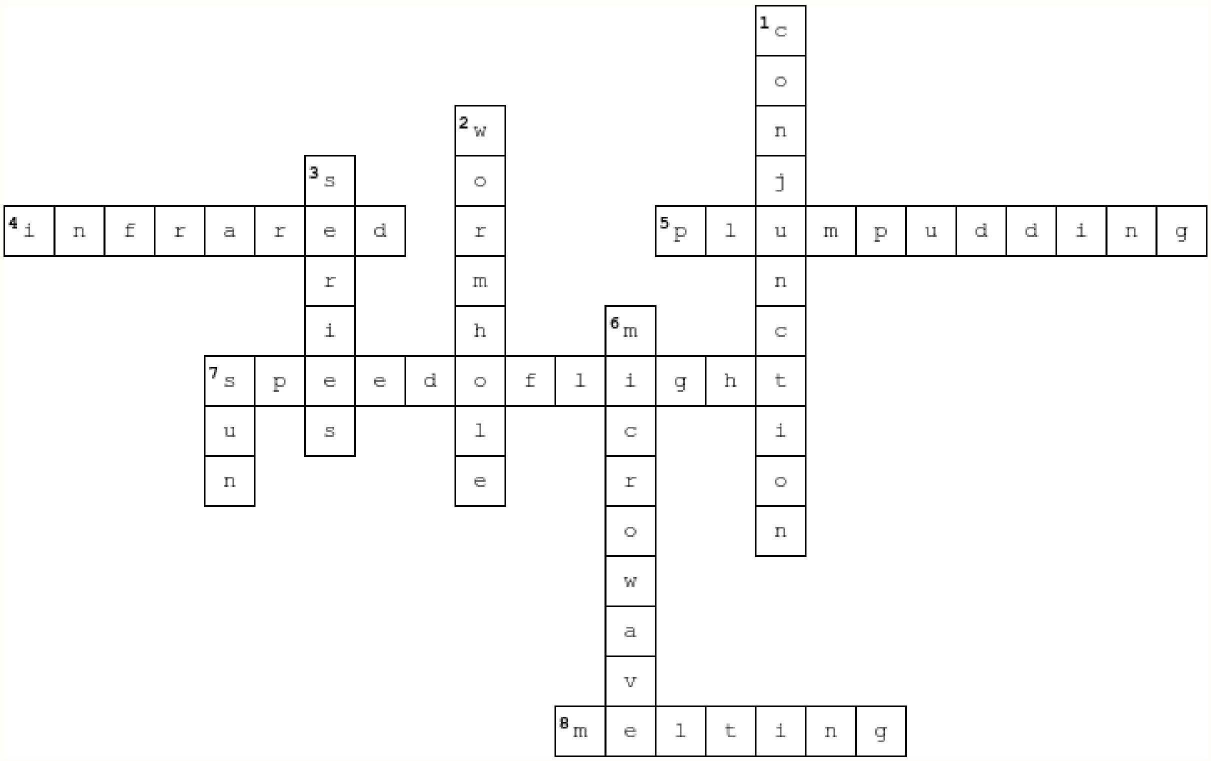
8. the adjective used to describe spacetime in a theory eliminating the need for dark matter

artificial intelligence • dark matter • gravitational • James Webb Space Telescope • nuclear fusion • SpaceX • white dwarf • wobbly

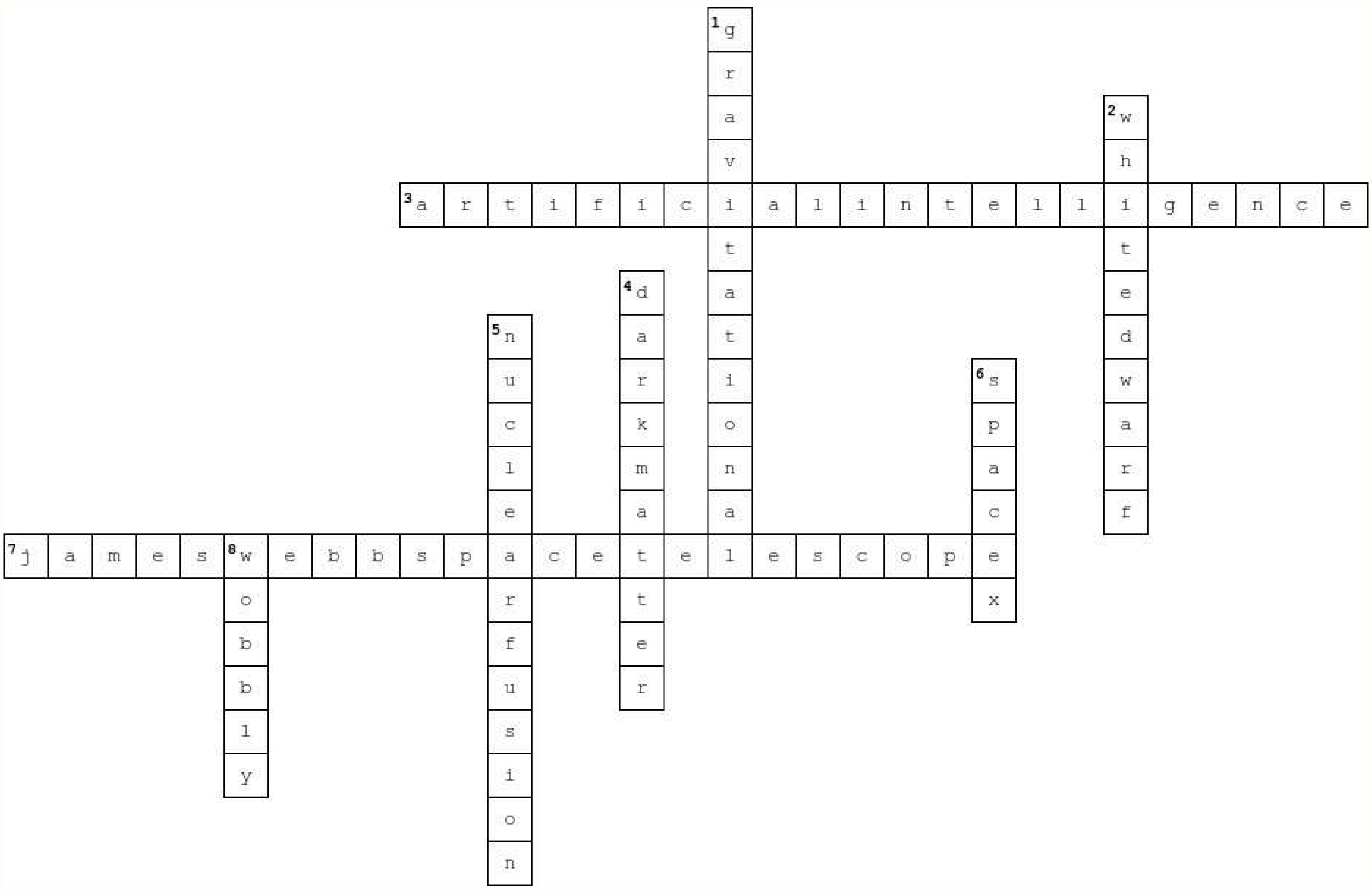
Some links to articles I used to make the crossword that you might find interesting:
https://www.myscience.uk/news/2024/physics
https://www.theguardian.com/science/2024/mar/09/controversial-new-theory-of-gravity-rules-out-need-for-dark-matter
https://www.sciencedaily.com/news/space_time/sun/
https://science.nasa.gov/missions/webb/webb-finds-evidence-for-neutron-star-at-heart-of-young-supernova-remnant/

Thank you so much to everyone who has enjoyed the crosswords! - Ruth :)

Answers to the previous crossword:



… and to this crossword (no peeking!) as it is the last edition:


1 gravitational
2 whitedwarf
3 artificialintelligence
4 darkmatter
5 nuclearfusion
6 spacex
7 jameswebbspacetelescope
8 wobbly