PHYSICS NEWSLETTER

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15th Edition - Hot and Cold

Welcome to the fifteenth edition of the Physics Newsletter. With summer in full force, we have decided to base this newsletter on all things hot and cold! We really hope that you find this issue both interesting and accessible - and that it inspires you to do some research of your own.

A big thank you to all the people who contributed to this edition of the newsletter: Ananya, Sai Raga, Alice, Ruth, Eesha and Emilie.

If you would like to be featured in any of our upcoming newsletters, just email Alice (17billwilks551@kechg.org.uk)!

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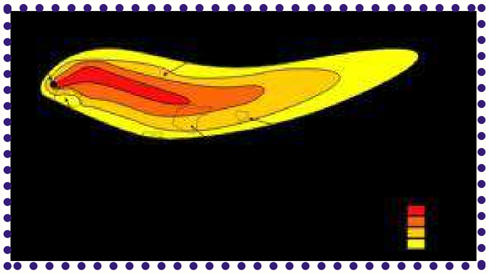
Keeping up to date...

Physics in the News - Why is the Arctic so Radioactive?

Dirty, dusty and filled with radioactive material, glaciers contain places with high concentrations of fallout radionuclides (FRNs) - concentrations a hundred or even a thousand times more than the concentration of soil in your garden. This is due to the organic material deposits in glaciers, which collect FRNs from nuclear disasters and testing of nuclear weapons. However, the danger of these deposits is triggered when glaciers melt; this causes radioactive material to spread into the rivers and seas. Contaminated water from these glaciers can harm ecosystems and could be potentially consumed by humans.

Also known as “organic scavengers”, cryoconite is a sediment composed of dust, dirt, microbes, algae and fungi, which is trapped in glaciers due to precipitation and wind. This organic component of cryoconite is what traps the radioactive material in a sticky biofilm; even unnatural substances such as pesticides, microplastics and industrial soot. The biofilms formed by microorganisms are stuck together and are also attached to the surface of the ice. Due to all these factors, cryoconite is dark in appearance, and therefore absorbs light from the sun and does not reflect back light like ice. This means cryoconite is warmer and the ice around the cryoconite melts, the water also traps radioactive substances.

So, how did this radiation get there in the first place? Well, when nuclear explosions occur, whether that be from weapon tests or incidents at nuclear plants, something called radioactive fallout is propelled into the air. Radioactive fallout contains different radionuclides (unstable nuclei that release radiation when they decay) and different radionuclides have different masses and half lives. A radioactive substance's half life is the time taken for half of its unstable nuclei to decay, so materials with longer half lives take longer to disappear and are more dangerous. Lighter radionuclides get carried much further distances by atmospheric wind currents. This means that lighter radionuclides with longer half lives are more likely to travel and seriously affect adjacent areas.



This picture shows the 'fallout pattern' after a radioactive explosion. As you can see, most of the fallout falls close to ‘ground zero’, but areas far from the source are also at risk.

Many of the radionuclides found within the Arctic glaciers were released by the 1986 accident at Chernobyl. One such nuclide was Caesium-137, which has a long(ish) half life of 30.1 years.

Explosions at Sellafield, a nuclear plant in England, and multiple weapon tests also released radionuclides, such as Technetium-99, which were carried to the Arctic.

The same is happening in the Southern hemisphere as well. Disintegrating satellites have deposited around 1kg of radioactive nuclei into the atmosphere, some carried away to glaciers. Similarly, the collapse of a Russian Mars probe has led to increased radioactivity in Patagonia, Chile.

Cryoconite's sticky property which allows it to collect FRNs may cause dangerously high concentrations of radioactive material, but scientists have considered using this property for a functional purpose of cleaning disaster zones. If cryoconite is implemented in areas such as Chernobyl, radioactive material can be collected which means the areas will be safe for the ecosystem. Additionally, even if the glaciers melt, unless they are directly consumed or used, the radionuclides could be diluted by the time they reach any large bodies of water, therefore the level of threat from glaciers releasing radioactive material when melting is not too major. So you don't really need to worry about the glaciers, rather the nuclear disasters themselves.

Ananya Balaji, 12W and Sai Raga Navili, 12P

Our sources:

https://physicsworld.com/a/trapped-in-ice-the-surprisingly-high-levels-of-artificial-radioactive-isotopes-found-in-glaciers/ (Main article for the inspiration)

https://www.sciencealert.com/there-s-a-bunch-of-nuclear-fallout-embedded-in-glaciers-and-they-re-starting-to-melt

https://www.livescience.com/65230-nuclear-fallout-trapped-in-glaciers.html

https://blogs.egu.eu/divisions/cr/2020/05/29/did-you-know-the-surface-of-melting-glaciers-is-one-of-the-most-radioactive-places-on-earth/

https://www.epa.gov/radtown/radioactive-fallout-nuclear-weapons-testing

https://inis.iaea.org/collection/NCLCollectionStore/_Public/33/071/33071236.pdf

https://www.sciencedirect.com/topics/medicine-and-dentistry/caesium-137#:~:text=Co%20produces%20gamma%20rays%20with,half%2Dlife%20of%2030.1%20years

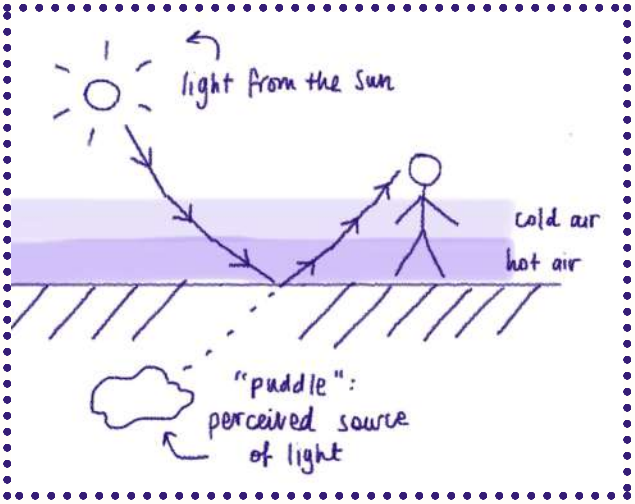
The Physics behind... Shimmering Roads

This road isn’t wet. It’s hot.

Known as a mirage, this phenomenon occurs on almost all hot surfaces. In this case, which is probably very familiar, the surface of the road in the distance appears to shimmer, and looks like it is covered in puddles. (You might have seen this on a motorway!) On a hot summer day, energy is transferred to the road surface as heat (or infrared radiation) emitted by the sun. The air above the road heats up by conduction and becomes less dense. This affects the speed at which light travels through it.

Because light travels faster through less dense materials, it travels faster through the warmer air (warm air has a lower refractive index). When the light travels between different densities of air, it bends; this produces the two effects that we’re interested in.

When the air is heated, it becomes less dense and rises, cooling as it gets higher. As this air moves away from the hot road, the colder, denser air above it moves in to take its place. This air is then heated and this process repeats, creating a cycle known as a convection current. Because the warm and cold air are constantly moving and swapping places, light doesn't travel in a straight line. The bending of the light is what produces the shimmering effect!



The ‘puddles’ arise from a separate phenomenon. On a really hot day, the warm air and cold air form distinct layers, with the warm air closest to the ground. Light travelling from the cold air to the warm air is reflected at the boundary between the layers and bends upwards towards your eyes. Our brains assume that light always travels in a straight line, so it looks like this light is coming from the ground. When you look at the road in the distance, you view it from just the right angle for the warm layer of air to act as a mirror. Light is reflected towards you and the blue of the sky looks like puddles of water. Moving closer, the puddles disappear because all of the angles involved in reflection and refraction change.

Isn’t that cool?

Here are the references I used:
https://medium.com/@AddsTake/the-physics-of-road-heat-mirages-5e15d46e15d5
https://earthsky.org/earth/what-causes-a-highway-mirage/
https://www.mentalfloss.com/article/52514/why-does-road-look-wet-hot-days

Alice Bill Wilks, 12CL

Women in Physics: Chien-Shiung Wu

"I wonder whether the tiny atoms and nuclei, or the mathematical symbols, or the DNA molecules have any preference for either masculine or feminine treatment" - a quote from Wu, an experimental physicist who was a pioneer in nuclear physics.

Chien-Shiung Wu was born in China in 1912 and received a bachelor’s degree in physics in 1934, before moving to the US to obtain a PhD at the University of California. She was offered a job teaching at Princeton in 1943 despite women not being allowed to study at Princeton at that time. She also worked on the Manhattan project where she helped develop the process for separating uranium into uranium-235 and uranium-238 isotopes. After the war, Wu worked for Columbia University’s physics department where she carried out research in the nuclear physics field.

In 1956, scientists Tsung-Dao Lee and Chen-Ning Yang asked Wu to design an experiment to prove whether the Law of Conservation of Parity was universal or not. Parity is an intrinsic symmetry property of particles that is characterised by the behaviour of their wave functions under reflection through the origin of their spatial coordinates - quite the mouthful! In simpler terms, parity refers to the relationship between a particle (or process) and its mirror image. For example, a particle spinning clockwise produces a mirror image spinning anticlockwise. The conservation of parity stated that identical particles have the same parity and scientists believed that the conservation of parity would apply in all situations. It would be impossible to distinguish right from left and clockwise from anticlockwise in particle interactions.

However, there was a problem. Two types of K-meson (a type of subatomic particle) called tau and theta were identical in every way except for the fact that they decayed into products with different net parity. Seeing as all other properties were the same, tau and theta should be the same particle but the law of conservation of parity stated that the parity of a system cannot change under particle decay. So the question was, are tau and theta different particles or are they the same particle, with the consequence of parity not being conserved? Lee and Yang suspected that parity might be violated in weak interactions, of which beta decay is an example. As an expert in the field, Wu was asked to carry out an experiment to check if parity was conserved during beta decay. She took the task to heart, designing a very complicated experiment, planning everything herself. She designed the machines for the experiment, wrote the laboratory procedures, and created the guidelines for measuring the results.

Wu with Lee and Yang

Wu decided to use a sample of radioactive cobalt, which would undergo beta decay, and cooled it to an extremely low temperature (just above absolute zero!) using super-cooling equipment. This slowed the atoms down so Wu could observe their movement. She knew that if conservation of parity applied, there should be an equal number of atoms spinning left and right. But it was not equal and the law of conservation of parity was disproved. Wu's experiment provided evidence that atoms have preference for the direction in their spin - in beta decay, atoms prefer to spin to the left. Yang and Lee's theory was confirmed and they were awarded the Nobel Prize for Physics in 1957, but Wu was not included.

However, Wu was a celebrated physicist despite not being awarded the Nobel Prize, as she was the recipient of many other awards. For example, she was the first to be awarded the Wolf Prize in Physics and the first woman elected as president of the American Physical Society.

If you want to read more about Chien-Shiung Wu and parity, check out the references below.
https://oumnh.ox.ac.uk/learn-chien-shiung-wu
https://theglindafactor.com/chien-shiung-wu/#:~:text=Wu's%20experiment%20disproved%20the%20Law,confirmed%20Yang%20and%20Lee's%20theory.

https://physicsworld.com/a/credit-where-credits-due/
https://www.britannica.com/science/parity-particle-physics

Ruth Rafeeq, 12MP

Physics in the Real World: Exploring the Potential of Bioelectronics and Microcurrent in the Medical Field

Source: https://www.todaysmedicaldevelopments.com/article/what-is-bioelectronic-medicine/

What are bioelectronics?

Bioelectronics, also known as electroceuticals, are an innovative technology that harnesses electrical signals to influence neural pathways and regulate biological processes within the body. This emerging area of research holds great promise for improving bodily functions and treating various medical conditions by restoring and manipulating the body's electrical signals. There are three main forms of electrical stimulation: microcurrent, peripheral nerve, and neuromuscular stimulation, each with its unique applications.

Understanding the Role of Electrical Signals:

Electrical signals play a crucial role in the functioning of our bodies. Charged particles, such as ions, that are present in biological tissues enable the transmission of electrical signals and the passage of pulses through nerves. These signals influence vital processes like muscle contraction and cell communication. Bioelectronic devices are specifically designed to facilitate the exchange of electrical signals within the body.

Microcurrent Therapy - A Subtle Electrical Approach:

Microcurrent therapy involves the application of extremely low-level currents, at amplitudes of one millionth of an ampere. Unlike directly stimulating nerves, microcurrent is applied transcutaneously, meaning it is delivered through the skin surface. Microcurrent therapy has found success in wound healing and inflammation reduction. It promotes mitochondrial health and ATP production by mimicking the flow of electrons that facilitates these processes, and helps restore the body's normal electrical currents. Given its tiny magnitude, microcurrent is subsensory, meaning it remains imperceptible to patients during treatment.

Factors Influencing Microcurrent:

The effectiveness of microcurrent therapy relies on several factors. One crucial factor is the resistance of the biological tissue being treated. According to Ohm's Law, which states that current is inversely proportional to resistance, higher tissue resistance results in smaller currents. Other parameters such as frequency and waveform also play a role. The goal of microcurrent stimulation is to develop precise medical technologies that can be personalised to individual patients' conditions, ensuring optimal treatment outcomes. However, further research and development are necessary to transform this vision of optimisation into a reality.

Expanding Applications of Bioelectronic Therapies:

Bioelectronics exhibits tremendous potential for treating a wide range of conditions such as Crohn's disease and diabetes. For example, Galvani, a prominent company in this field, has developed a neuromodulation system targeting Rheumatoid Arthritis. The system sends pulses to the splenic nerve, which in turn sends signals to the spleen, effectively switching off the inflammatory state of splenic immune cells. This mechanism leads to an alleviation of pain and reduction in inflammation. A remarkable aspect of bioelectronics is its adaptability, where a significant portion of developed hardware and software can be repurposed for treating various conditions with minor adjustments. This presents substantial economic benefits compared to the development of new compounds for each condition (which is how traditional pharmaceutical treatments work).

Future Directions and Challenges:

The future of bioelectronics appears promising as the field continues to advance. A key goal is to map the neural network comprehensively, enabling a deep understanding of how electrical signals interact within each part of the body. This neural data needs to be decoded and presented in a user-friendly manner, which poses a significant challenge. Additionally, establishing a robust evidence base for the efficacy of bioelectronic technologies is crucial for their commercial and clinical acceptance. Reliability and reproducibility of results are essential to gain widespread recognition. Witnessing the breakthroughs in physics and engineering applied to medicine is an exciting journey, and the path ahead holds immense potential for further advancements in this field.

If you are interested in learning more about bioelectronics, I would suggest having a look at these podcasts and articles:
001: What is Bioelectronics? (Part 1) - The Bioelectronics Podcast
002: What is Bioelectronics? (Part 2) - The Bioelectronics Podcast
The Engineer Oct 2022: Bioelectronics; Nervous Energy (magazine article)
Bioelectronics ‘jump-start’ the next wave of device therapeutics - McKinsey & Company

Eesha Walji, 12CL

Dates to know:

1. **UK CanSat Competition registration: June to October 2023**

   The UK CanSat Competition involves designing and building a simulation of a satellite, within the volume and shape of a soft drink can, as well as a parachute to ensure it can survive landing. Teams should be 4-6 people, all over the age of 14.

   https://www.stem.org.uk/esero/secondary/competitions-and-challenges/cansat

2. **OxBright Essay Competition 2023 registration: entries close on 30th September 2023**

   The OxBright Essay Competition is designed for 15-18 year olds. Your essay can be about Engineering, Maths or Computer science (but unfortunately not just Physics).

   https://www.oxbright.org/resources/essay-competition/

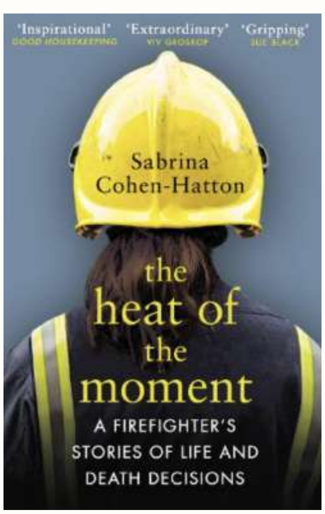
3. **Next physics society: September 2023**

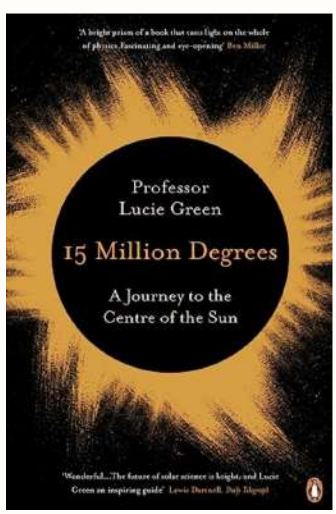
4. **Next newsletter: October 2023**

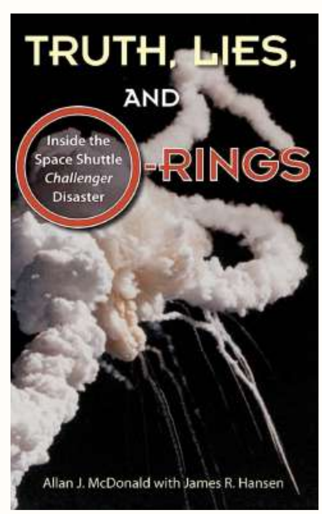
Get involved!

Did you know that there is a Physics lending library at the back of Lab 10? If you decide to borrow a book, send in your book reviews for a feature in the next newsletter!

Some of the titles on theme with 'hot and cold':

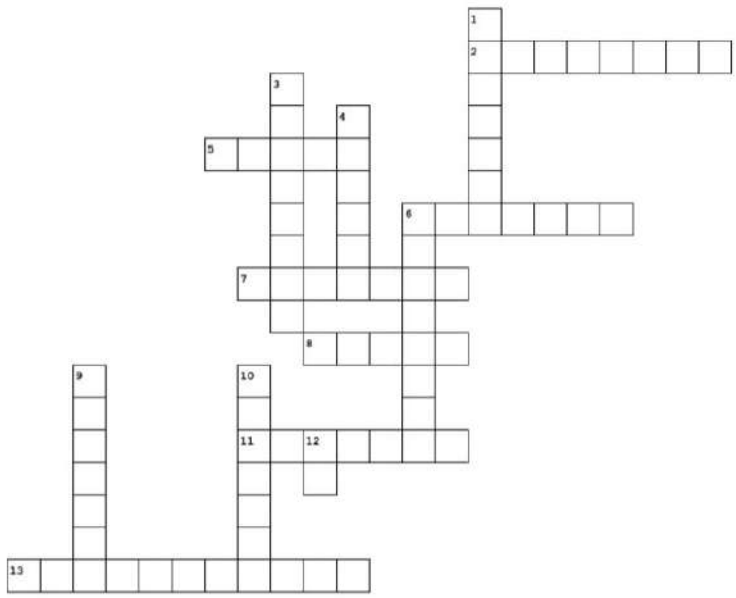






Crossword!

Famous Physicists



Across

2. famous for his theories of relativity
5. first woman to win a Nobel prize
6. invented the world's first electrical generator
7. created diagrams of particle interactions
8. said force is proportional to extension up to a certain limit
11. there is a type of radiation named after him
13. discovered the first radio pulsars

Down

1. one of the first to discover nuclear fission of uranium
3. first woman to discover a comet
4. made major discoveries while in lockdown from the plague
6. produced the first X-ray images of DNA
9. famous for his work in electromagnetism and differential equations
10. worked for NASA to send astronauts to the Moon (hint: Hidden Figures!)
12. her experimental setup proved a theory about subatomic particles

Answers to this crossword in the next newsletter!