KES Physics Newsletter

Autumn Term 2021

Figure: The Lagoon Nebula (NGC 6523) - ESA/Hubble

Note from the Editor

Hello all! Thank you for reading this terms edition of the KES Physics newsletter. We've each worked hard to write a little about what we've been working on this term, and hope you find it interesting!

Wishing you a very happy winter break!

- Rob -

Bradley Holloway

At KES 2012 - 2019

Alumni Astrophotography

In these images, we see two kinds of object. *Galaxies*, and *Nebulae*. Galaxies are large clumps of stars, some containing more than 100 billion stars. Nebulae are the whisps of gas and dust, left behind when stars die. These nebulae also act as birthing grounds for new stars, formed from the ashes of those that came before.

If you want to see more of Bradley's photography work, you can follow his Instagram page: bradhvisuals

Are you interested in Astronomy? Want to see what's up there in space but don't know where to start?

During the Winter season, some of the brightest deep sky objects can be visually observed without any specialist equipment. Two of these targets are The Great Orion Nebula and Andromeda Galaxy. I recommend downloading an app called Stellarium which gives you a map of the night sky to help locate what you would like to see. Some factors that we astronomers have to consider are light pollution and moon light. These both wash out the night sky making observing and photographing much more difficult. A website called www.lightpollution.info is a great place to get started to find nearby dark sky locations.

The great Orion Nebula is relatively easy to spot but will just appear as a brighter star to the unaided eye. But with binoculars, observing becomes a lot easier. The Andromeda Galaxy is a more difficult target to spot, it does require darker skies to see and ensuring your eyes have fully adjusted to the dark. Andromeda still appears as a faint haze but is slightly more visible with binoculars.

Astrophotography is very different to and more technical than visual astronomy. It usually requires a lot of equipment, but there are a number of alternatives requiring no more than a mobile phone and a tripod. Phones now have the ability to do long exposures and using this with a tripod, you can get some widefield shots with some stars showing up. This is exactly how I started it all.

Messier 45 - Pleiades Star Cluster with surrounding reflection nebulae. Interstellar dust surrounds this cluster being reflected by hot blue stars.

Messier 42 - The Great Orion Nebula. A bright and active star forming region rich with hydrogen gas and dust. It is one of our closest star forming regions at 1,500 light years away.

Messier 31 - Andromeda Galaxy. A close up to our neighbouring galaxy, seeing the dust lanes within. Two dwarf galaxies M32, M110 are also visible in the image.

Dr Paul Jarvis

Studied Physics, Chemistry, Maths, Biology

Read BA and MSci Natural Sciences at Cambridge University

Ph.D. in Geology from Bristol University

Currently a Physical Volcanologist at GNS Science in New Zealand

At KES 2001 - 2008

When I started at KES 20 years ago, I had this crazy idea that I wanted to become a volcanologist when I was older. I don't really know where this came from or how it started. Maybe I was inspired by a film or a documentary. Anyway, everyone thought I was crazy. Even my head of year, who was an otherwise supportive and excellent teacher, laughed when I told him. So, I stopped wanting to be a volcanologist. At A-level, I chose the three sciences and maths, before going on to specialise in physics at university, without really knowing what I wanted to do. It was only once I was in the fourth year of my degree and saw a PhD opportunity advertised that involved research on the physics (fluid and thermo-dynamics) of magma that I discovered I could still go into volcanology. So, in hindsight, I've realised two lessons: 1) listen to career advice, but don't let the opinions of others stop you from achieving your goals; and 2) your GCSE, A-level or degree choices don't restrict your future career options as much as you might think.

I've been thinking about this a lot recently because I have just started a new job as a Physical Volcanologist for GNS Science in New Zealand. GNS are a national research organisation who, among other things, are responsible for monitoring and researching the volcanoes of New Zealand. My new role is to study and research the physics of volcanoes, studying everything from how magma moves through the Earth's crust, to volcanic ash clouds and lava flows. Essentially, this is the job I dreamed of when I was a kid and it hasn't really sunk in that this is what I now do every day.

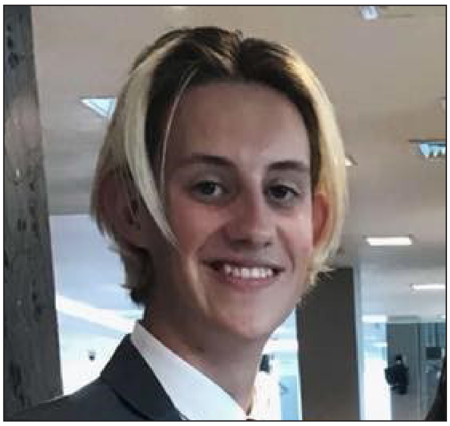
New Zealand is also the ideal place for this job. There are 12 active volcanic areas in the country covering the full range of different styles of eruptions. For the first time, I can also be involved in monitoring these volcanoes. This will involve examining the data we collect about these volcanoes, e.g., the number and location of earthquakes, the amount of gas being emitted, to try and determine if magma is moving beneath the volcano and if an eruption may be likely.

In the coming issues, I'll be telling you about the volcanoes of New Zealand and the science I'm doing to try and understand them. I hope you'll find it as interesting as I do.

a)

b)

Photos of some of New Zealand's volcanoes. a) In the distance are the volcanoes of Ruapehu (right) and Tongariro (left). In the foreground is Lake Taupo, which fills the caldera of the Taupo "supervolcano" (credit: summitpost.org). b) Whakaari /White Island almost constantly emits volcanic gases (credit: stuff.co.nz).



Fin Cooney

Studied Physics, Maths, History, Further Maths (AS)

Reading Physics at Loughborough University

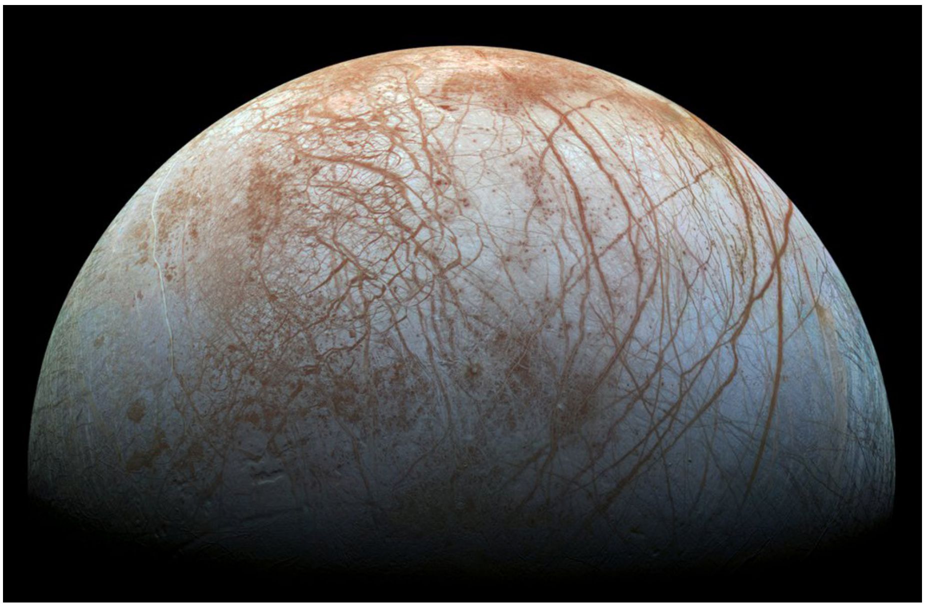
At KES 2011 - 2018

This semester, for the first time, I was able to choose optional modules for my studies. Physics at Loughborough is a rigid course up until third year meaning that all modules are compulsory. Being able to pick my two optional modules, Thin Films, Surfaces & High vacuum, and Dynamical Systems, was refreshing; studying areas you're interested in makes you a lot more motivated.

Surfaces, Thin Films and High Vacuum sounds like quite a diffuse module but the three topics are actually all intertwined to the area of physics covered. In the module we learn about the properties that thin films have and how they can be attached to surfaces. Doing this can give materials extremely useful properties. High end knives for example will have thin films attached to the blade to keep them sharper for longer. The high vacuum part of the module comes from the fact that a thin film cannot just be fused together. Molecules in the air can get trapped under the film causing imperfections in the material.

Dynamical Systems is an interesting module. It's essentially showing us how we can express moving systems in a mathematical form. We can express moving points in a space as functions. We then also looked into more complex things like bifurcation and multidimensional maps.

My individual project for third year is looking into a mission concept for a probe venturing to Europa, a moon of Jupiter. The concept will involve the design of the craft as well as simulating the trajectories of the craft in MATLAB. This has meant I've had to teach myself things like orbital mechanics and interplanetary injection (it's literally rocket science). These are exceedingly interesting topics and I'm glad I've got this project as the only other route to learn about space exploration is on the Aero-Engineering course here. The maths actually isn't as bad as you'd think for rocket science - after quantum it seems like a walk in the park. The hard parts conceptualising the movement of the planets. Luckily in our solar system the planets orbits are coplanar which makes interplanetary travel slightly easier for us. Thought this is true, conceptualising the elliptical path of, and where, the planet will be as the craft approaches it is tricky and involves lots of calculation. Again, the maths is not so hard, it's more the amount of calculation as well as putting it to code.



Europa's Surface (Image - Nasa/JPL)

Alex Broad

Studied Physics, Maths, Psychology, Further Maths (AS)

Read BSc Physics at Swansea University

Read MSc Physics at UCL

Physics Ph.D. student at UCL

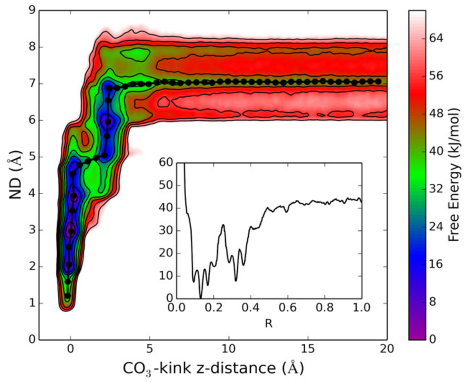
At KES 2012 - 2014

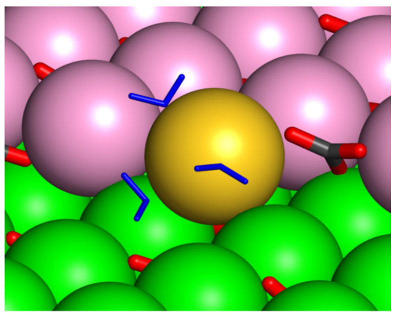
Ever wondered about the local thermodynamics at calcite growth sites? No? Well, me neither. Or, at least I didn't until a few months ago when I realised it was a very important in building a comprehensive understanding of crystallisation.

The reason we want to do this is because crystallisation forms the basis of biomineralization i.e., the processes through which living things use crystallisation to growth structures such as bones and teeth. Understanding biomineralization could have huge impact on materials design. We're obviously a long way off such advances yet, but my work should be a (tiny) step in the right direction.

For a bit of context: calcite grows via the formation of growth islands, like a tiny step 1 atom thick, which expand by the nucleation of new steps. Once a new step begins to form it grows via the corner that forms along the side of a step. The corners are also known as kink sites or growth sites. While some effort has been made to simulate step sites, no real effort has been made for growth sites, despite how fundamental they are in crystal growth (hence the name growth sites).

My work has mostly involved calculating free energy surfaces (where free energy is a combination of energy and entropy and is related to probability density) for calcium and carbonate approaching kink sites. An example of this is in the left-hand-side of the figure. Here, the x-axis shows the distance between the gold calcium ion and the kink (corner) site, and the y axis is known as the coordination number. The coordination number is a function that describes the number of water molecules attached to the atom, except it is designed to be continuous (ignore the fact that having 5.7 water molecules attached isn't physical). The colour plot shows the free energy surface, and the dotted line shows the minimum free energy path (the most likely route) that describes the attachment of the gold calcium ion to the site. The calcium ion approaches the kink site, loses a few water molecules, crosses a large barrier in moving closer, and finally sheds a couple more water molecules. The image on the right shows the gold ion in the position that minimises the free energy. The other calcium ions are shown in green for the bulk crystal and pink for the step. Carbonate is shown in grey and red. The three water molecules that stick to the calcium are shown in blue.





Robert Clemenson

Studied Physics, Chemistry, Maths, Further Maths

Read BA Physics and MMathPhys Mathematical and Theoretical Physics at Oxford University

Physics Ph.D. student at Sussex University

At KES 2008 - 2015

Hello all! This has been as busy a term as any for me. I've had lots of teaching, research work, as well as planning for my year long research trip in the United States (starting in January).

An important focus in my research this last term, has been on so called 'Casimir Forces'. This curious quantum mechanical effect can (with great difficulty) be demonstrated experimentally by taking two uncharged parallel plates in a vacuum, and measuring the attractive force pulling the plates together. This is often described as 'the Casimir effect'. The origin of this attractive force is quite fascinating, and changes the very notion of what we mean by 'nothing'.

It turns out, empty space is not really empty at all. There is a constant fizz of elementary particles popping in and out of existence. You may ask "surely this violates conservation of mass? You can't just make something from nothing!" - Which is a very fair point! However, quantum mechanics teaches us that you *are* allowed to violate conservation of mass and energy, as long as you don't do it for very long. As these particles pop in and out of existence very quickly, they don't break any rules.

In the context of my research; I have been studying models of the Universe that involve a fourth spatial dimension. The size of this fourth dimension is stabilised through this Casimir effect, similarly to the two parallel plates in the experiment - held together by this fizz of virtual particles.

As a particle physicist, it's convenient to represent this fizz of particles using Feynman diagrams. If you're doing your A levels, you'll be familiar with these squiggles.

The diagrams show particles entering from the left, interacting in the middle (by exchange of force carrying particles), and leaving on the right (See figure 1 for an example).

In this fizz of nothingness, there is nothing to begin with, and nothing to end with. However, we have a lot of freedom for what we can sandwich in the middle. Figure 2 for example shows one 'vacuum bubble diagram' involving electrons, however there are infinitely many of these diagrams we can write down.

We can talk more about these bubble diagrams another time, including how they have been giving theoretical physicists a headache for decades in relation to the cosmological constant problem.

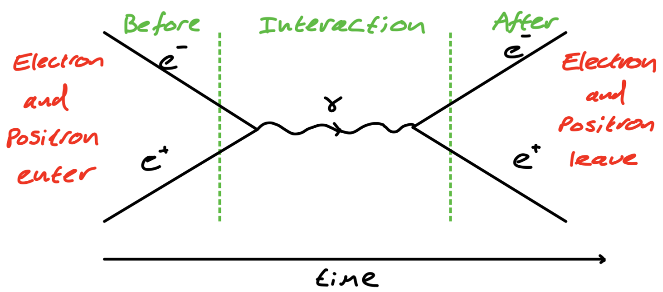


Figure 1

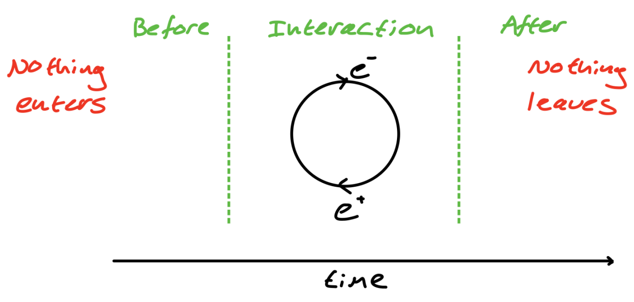


Figure 2

Life After University

If you've been reading this newsletter for a while now, you may have gotten the impression that people just drop off the face of the Earth after they finish their degrees.

In this section we hope to bring you occasional updates from former KES students who have completed their formal education in Physics or Engineering, and have gone on to have fullfilling and exciting careers.

Timothy South

Studied Physics, Government and Politics, Maths, Further Maths (AS)

Read MEng Aerospace Engineering at Bristol University

Currently a Software Developer at the Crown Commercial Service

Hello, it has been a while since I've done one of these, but Rob asked and so I shall deliver. You will see my education was in aerospace engineering, but I do not find myself in that industry at the moment. In fact, I am a software developer at the Crown Commercial Service (part of the government). I spend most of my time developing and supporting websites that my organisation manages.

Is this what I thought I would be doing when I left university? No. Was my dream job working on websites? No. So how did I end up here? The truth is that getting a job after university is not easy. I finished Uni in June 2019 but didn't start working at CCS until November the same year.

Before going to university, I had never done any programming, though I was good with spreadsheets, but it's one of the key skills I was taught at university and the main one I use in my day-to-day life (so I haven't completely wasted £60,000!).
When I finished university, I could only programme in MATLAB but now I use Ruby, JavaScript, Python and many more in my work and all of these I have learnt while working.

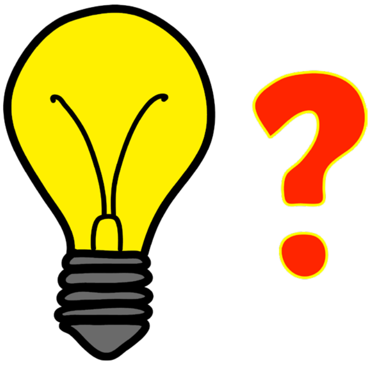
Now the struggles of job hunting, and the "cost" of university might sound scary, but one of the best things they don't tell you about work, probably because this is not the case for your teachers, is when you finish work, you're free to do what you want. No study, no homework, no job hunting, just freedom to enjoy yourself (and I do). It's a strange feeling after years of feeling a bit guilty when not doing schoolwork that I can play games and watch football with a clear conscience.

So, how should I conclude all this. Well, I guess my first point is that if you're not sure what you want to do when you finish your education, don't worry about it. However, you should be sure in what you enjoy doing and you should hopefully be able to find a job that can accommodate this. My second (and final) point would be that your education never stops. You'll always be able to learn new things and improve your skills even when they are part of your job description.

The most important skill you can have, is a love of learning!

Problem Page

Here are a few problems you can take a look at over the winter break



Light Bulb Problem

Imagine you have 100 light bulbs in a row, all initially off. Each is labelled in order with a number 1 to 100.

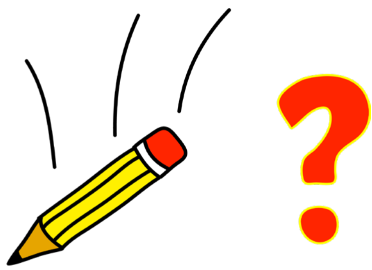
Now suppose you flick the switch on all the bulbs whose number is a multiple of 1 (i.e. all the bulbs are now on), then you flick all the multiples of 2 (so now 2,4,6,8,... are off again), then 3, and so on until you get up to 100.

Which bulbs will be left on after this process is finished? (Don't try and do this by going through and working it out with brute force! Try and think of a way of explaining this for any number, potentially much bigger than 100!)

Handshake Problem

If there are 'n' people in a room, and each person wants to shake hands with every other person in the room. How many handshakes in total take place?

How about, if we imagine some bizarre handshake, taking part between multiple people simultaneously (we will call it a k-shake. Where each shake requires 'k' people to take part). How many possible k shakes are there in a room of 'n' people?



Falling Pencil Problem

When I drop a pencil from around waist height, how much does the Earth move in reponse?

Questions and Answers

Submit your questions to Mrs Lake, or through the Cosmic Conundra contact page

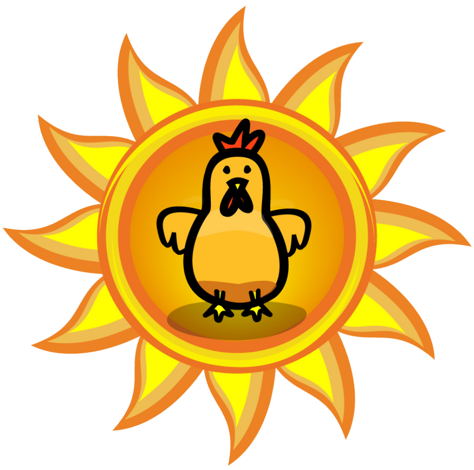
How long would it take to cook a chicken on the sun?
(Year 7)

I estimate it would take around 1.82 millisecond (1.82 thousandths of a second).

The calculation is pretty straightforward! Chicken is considered cooked when its internal temperature reaches 165 Fahrenheit (= 347 Kelvin). The surface temperature of the sun is around 5778 Kelvin. Taking the heat capacity of chicken to be 3.521 Joules per kg per Kelvin, and the thermal conductivity of white meat to be 509.3 Joules per second per Kelvin. If we assume an average chicken weight about 4.4 kg. We can use E = mcT to calculate the energy needed to heat the chicken to 165 Fahrenheit. Then using the heat transfer equation Heat Flow = thermal conductivity x Contact area x Temperature difference, we find a time of about 1.82 milliseconds.

There are much more sophisticated ways you to treat this, but for a 'back of the envelope calculation' this does the job!

Robert Clemenson



What happens if you fall into a black hole?
(Year 7)

This is a question I've answered before, so I'm going to (rather cheekily) give the same answer I have previously written!

The weird thing is, it's all really a matter of perspective. Let's consider a very very big black hole (say, over 1 million times the mass of our sun - this would in fact be called a *supermassive black hole*). The reason I want to think about big black holes, is that these are actually a lot more gentle to fall into. It's the small scrappy black holes that will rip you apart by *spaghettification* (the technical term for having your body pulled into a long length of human spaghetti by a hungry black hole).

So for a supermassive black hole, we don't have to worry about being spaghettified at the even horizon. Now let's suppose you and I are sat inside a spaceship some distance from the black hole, and you decide to dive head first into the beast (that seems a bit silly, why would you do that??). What happens next is now totally dependant on who's making the observation. So let's discuss these two cases.

From my perspective: I see you plummet towards the horizon of the black hole, but as you get closer and closer to passing through the horizon, you begin to slow down (as if in slow motion). You keep getting slower and slower, never quite passing through the horizon of the black hole. All the while, you become flatter and flatter, becoming smeared across the horizon. But still, I never see you fall through. To me, time appears to have frozen for you - so from my perspective you never even fell into the black hole!

From your perspective: You feel yourself falling towards the horizon of the black hole, and accelerating (not slowing down as I saw happen). You pass through the horizon as if it wasn't even though, and you look up back towards my spaceship as you do, and see the Universe jolt up in speed - supernovae, galaxies colliding, the entire Universe may pass you by in an instant. The rest of the tale is not as pleasant.. As you fall towards to singularity of the black hole, tidal forces on your body increase, and you are ripped apart. Death by black hole.

Robert Clemenson