KES Physics Newsletter

Autumn term 2018

Timothy South

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

Reading Aerospace engineering at Bristol University

At KES 2008 - 2015

So here it is… my final year… we're on the home stretch now! So, this term has been a little different than others in that, while I have not had very many lectures, it's been quite hectic.

My one lecture series this term is Engineering Design for Marine and Wind power and it's fairly interesting. In this, we mainly look at offshore wind turbines and tidal power (which is just underwater turbines). While the content is not very technical, we get all our lectures from people who work in the industry and they talk on a wide range of topics from the finance and cost of building a wind farm to the logistics of installing an offshore turbine. It's quite interesting and the content is different from most of my other units so far, so it's a nice change.

Now for the more interesting part of my term which is the group design project where we are designing a satellite. CIMR, which stands for Copernicus Imaging Microwave Radiometer, is an ESA satellite concept which will measure the sea ice concentration over the poles and we basically have to design it in 12 weeks (as appose to the 7/8 years it will probably take!). What's novel (and challenging!) about this satellite is that it does its measurements by using a large reflector which spins above the spacecraft (leading to a lot of "interesting" problems). For this project, I am the Structures Engineer, Systems Engineer and Project Manager. As the Structures Engineer, I have had to design the structures for the main bus and the rotating boom (which holds the reflector). As the Systems Engineer, I keep an eye on budgets, particularly the mass and the cost budget, the sub-system architecture as well as keeping all the sub-systems communicating. As the project manager, if The Apprentice has taught me anything, I just take responsibility for when everything goes wrong. In all seriousness, this is the unit I've been most looking forward to since joining University as I get to put a lot of the skills I have learnt over the years into practice and, hopefully, get an end product out of it. This project presents a challenge that needs solving and the reward in solving this challenge is why I chose Aerospace Engineering.

Zak Goble

Studied Physics, Maths, Economics, Further maths (AS)

Reading Physics at Manchester University

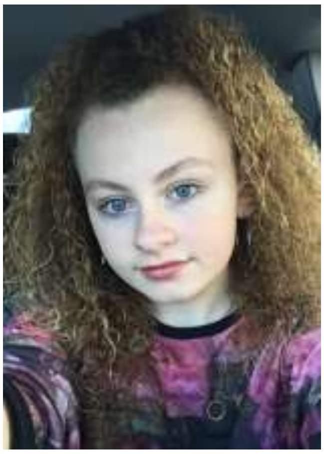
At KES 2010 - 2017

I'm Zak, a second year physics student at the University of Manchester.

This term, I'm studying maths of waves and fields, electromagnetism, quantum mechanics, Lagrangian dynamics and programming. Maths of waves and fields is our most painfully boring subject, in that it's just page upon page of algebra, but our lecturer is a guy called Jeff Forshaw, who's known for being the science correspondent on BBC programs like Doctor Who (Rob's well jelly I've got him), so he makes it worth getting out of bed for. Electromagnetism is the study of how electric and magnetic fields work together to produce light, which sounds cool enough already, but our lecturer drops some fire banter by firing consistent shots at Brian Cox (who we only get in first year unfortunately!) Quantum mechanics is the study of what *really* happens to particles and other small scale objects; you learn very quickly that Newton's laws of motion don't actually work on an atomic scale. Our lecturer for quantum is an overly eccentric and hyperactive Chinese man called Yang, and his erratic behaviour cracks us up every lecture. Compared to where you would solve for a system's equation of motion (i.e. find its acceleration) at A level, using the conservation of total energy or considering the net force acting on the system, Lagrangian dynamics is a new, more mathematically stimulating way of solving of doing it. The majority opinion in our class is that our lecturer is a genuine robot. He's never once made a mistake, in speaking or in writing, and he's yet to express emotion. Somebody swore they saw him drinking oil once. These four courses have been pretty sweet, overall.

Programming, on the other hand, is the worst thing I've ever done in my life. Worse than doing childcare (or 'psychology', to give it KES's official name) at AS level. It's the study of computer language and writing codes, and I genuinely don't remember ever being less happy than when I'm coding. It's the only course in the degree so far that hasn't had an exam, only coursework, which sounds great in theory, but with the amount of work you have to do, you'll be having nightmares about faulty code within days.

For those in year 13 applying to do physics at Uni, look forward to that.



Trinity Wills

Studied Physics, Maths, Art

Reading Mechanical engineering at Hertfordshire University

At KES 2011 - 2018

Sooooo hello everyone taking the time to read this, I'm Trinity but you probably best recognise me as the girl with the mad curly hair. I'm currently coming to the end of my first semester at the University of Hertfordshire, studying mechanical engineering. Overall these first few months of University have certainly been interesting and have taught me a lot. Not just in the sense of the content of the course but also about myself. Initially I was fearful I had chosen the wrong course, I was doubtful I was capable, but the more time has passed I have realised this is definitely what I want to do. I would compare one of our most recent assignments to a nonsensical Lego set. We were tasked to create a "craft" that would travel in a semi-circular path in 3.5 turns of a crank handle using only the parts and tools provided. At first, I thought it was ludicrous, how was we going to put all this stuff together to make something that fulfills the specifications? With no previous experience we were left to experiment. We had to try and create systems of belts and pulleys and even incorporate maths (yup maths, calculus is still a thing at uni too, sorry). After A LOT of trial and error we eventually created a final design, as crude as it was, but it worked! So, if you like the process of problem solving and design then engineering is the right subject for you. Also, girls don't let the fact that engineering is a predominantly male subject hinder your decision of choosing it, people may underestimate you but use it as an incentive to prove them wrong. Don't ever think you're too dumb for uni, I'm supposedly an intelligent engineering student but on my second day I managed to lock myself out of my car with my keys, phone, jacket and bag all on my passenger seat. I was nearly two hours away from home and I was parked a 20-minute walk away from anything. After realising I had absolutely no way of contacting anyone I had to make the awful decision of smashing the window of my new car. The journey home down the M25 with no window was fun. So, if you're worried and apprehensive about starting university don't be, I have every faith you won't be as clumsy as me. Also, any prospective engineers reading this, please design a car key that is Trinity-proof, thanks in advance.

Have a good day everyone!

Trinity x

George Watkins

Studied Physics, Chemistry, Maths

Reading Astrophysics at Queen Mary University of London

At KES 2008 - 2015

I am just finishing the first semester of my fourth year at QMUL, studying for an MSci. For the past three years, I have studied a range of modules across different branches of physics, with a focus on astrophysics. These include condensed matter, electromagnetism, waves and optics, thermodynamics, relativity, and quantum mechanics.

This term, I have been studying celestial mechanics, stellar structure and evolution, general relativity, and statistical data analysis. My relativity module has been very interesting. Especially recently, where we have been discussing gravitational waves. We have worked out how to determine the gravitational waves emitted from a binary system from finding the orbital frequency and energy density of the system, and then using the "quadrupole equation".

Alongside these modules, I have been working on my final project. The project involves using and analysing data from the Kepler mission to derive various parameters of exoplanets. Kepler uses the transit method, meaning that it records the brightness of several stars, and monitors for periodic dips in their brightness. These dips are the result of a planet passing between us and the star.

So far, I have written code which reads in raw Kepler data for the incident flux (brightness) from a star, and the time at which it was recorded. Once the orbital period has been determined, the whole time series graph (with ~60,000 points) can be "folded" so that the centre point of each transit is at zero. This is useful for averaging the start and end times, and the depth of the transit, which are then used to calculate the planet radius, semi-major axis (orbital radius) and inclination.

I am currently working on implementing an improved model, which takes into account limb darkening. Essentially, the edges of stars are not as bright as their centres. This will give better estimates of the parameters of the planet worked out from the simple model I am currently using. I am also working on implementing a way to either fully automate or provide a better estimate for finding the orbital period of the planet. Obviously, it would be much better to have a general method that can find a good estimate for multiple planets, rather than relying on manual adjustment.

Robert Clemenson

Studied Physics, Chemistry, Maths, Further maths

Reading Physics at Oxford University

At KES 2008 - 2015

This term, I have had lectures in: Fluid mechanics, atomic and laser physics, symmetry and relativity, dynamical systems, and biophysics.

Before I say anything more about this term, I should probably talk a little about my summer spent at Caltech! Without going into too much detail, I had a fantastic time! We were very successful in implementing the planned modifications to the dusty plasma experiment, I attended my first ever scientific conference, and worked with some very clever and interesting people!

At the moment, I am trying to organise more summer research for 2019. I've found a theoretical physics Professor also at Caltech, who is willing to work with me on some aspects of quantum field theory (CFT/AdS duality to be specific. Sadly, not enough room to give too much detail on the topic!). We haven't yet confirmed any dates, and it'll depend how I get on with the vast amount of reading he's sent me, but I will tell you how it goes later on in the year.

The lecture course I have most enjoyed this term, has undoubtedly been symmetry and relativity. (For a little more about 'symmetry', see my entry in the 2018 spring term issue). This course covered a lot of the special relativity we'd seen in first year, but formalised many ideas, and introduced geometric objects called 'tensors'. Tensors are kind of like generalizations of matrices to higher ranks (though they are a little more complicated than that). E.g. a rank-0 tensor is just a scalar, a rank-1 tensor is a vector (think column vector), a rank-2 tensor is a matrix (sorry to those that haven't seen matrices before), and a rank-3 would look like a 'cube matrix' with an entry in every cell of a 3x3x3 cube (for the 3-dimensional case).

In these lectures, we looked at how to build theories that respect the fundamental symmetry of (flat) space-time, 'Lorentz covariance'. This basically means: 'all the laws of physics are the same according to all non-accelerating observers'. An example of the kind of theory you can build from a surprisingly small number of simple considerations, is electromagnetism.

The last few months have seen my colleagues and myself do some really interesting science. In the summer, we undertook a fieldwork campaign to Sabancaya volcano, Peru. Sabancaya has been erupting explosively since November 2016, producing between approximately 15-30 ash-producing explosions a day, similar to that seen in Figure a. Whilst the majority of these explosions are pretty small, larger ones lead to potentially hazardous ash fall in nearby towns and villages. Additionally, the large amount of ash that has accumulated means the surrounding area is akin to an "ash-desert", and during periods of high wind, significant quantities can be remobilised into the atmosphere creating a hazardous environment.

Paul Jarvis

Studied Physics, Chemistry, Maths, Biology

Read BA and MSci Natural Sciences at Cambridge University

Ph.D. in Geology from Bristol University

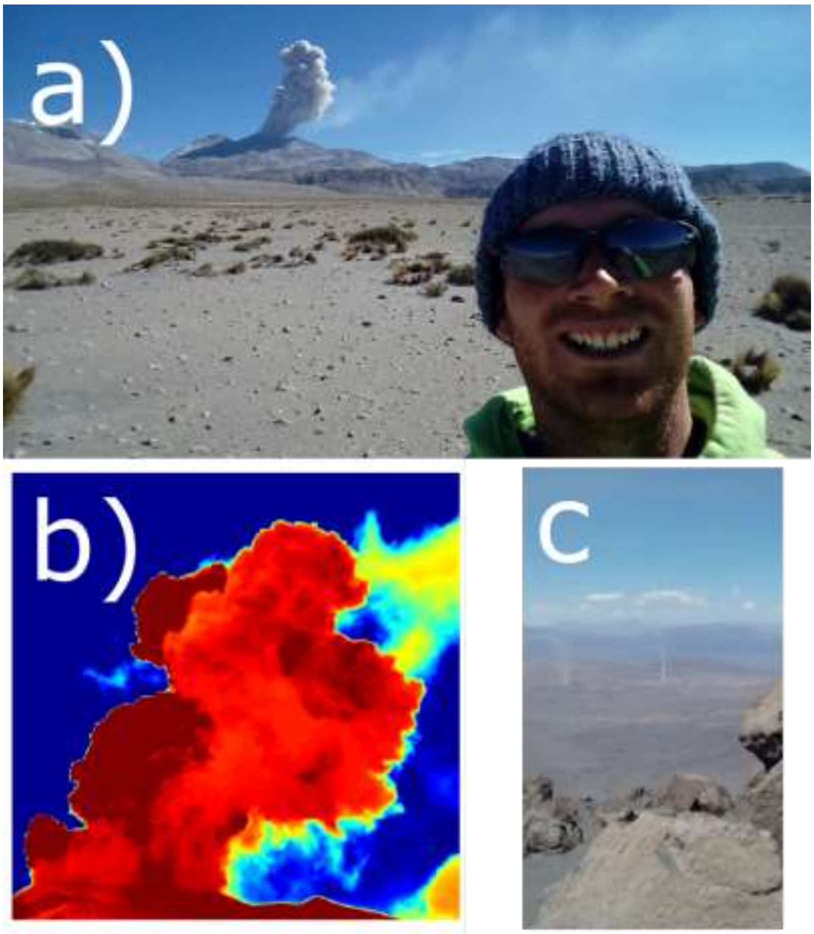
Currently a post-doctoral research assistant at the University of Geneva

At KES 2001 - 2008

Our work had several objectives. Firstly, we captured high-resolution videos of the explosions, using both visible light and infrared cameras (see Figure b). From these videos, we are able to estimate quantities including how fast the material was ejected from the vent and the height the plume reached in the atmosphere. We are now using these measurements to calculate the effect of the wind on the plume, as well as infer how the explosion occurred.

Secondly, we also installed an array of acoustic sensors near the volcano. When the explosions occur, they create infrasonic waves (sound waves below the frequency of human hearing) in the atmosphere. The sensors detect changes in atmospheric pressure as the waves travel past and convert the detected signal into an electrical current which is then transmitted to the local volcano observatory. There the signal can be interpreted to determine the size of the eruption. This is important for local volcano monitoring as now information about a large explosion can be obtained very quickly allowing rapid (real-time) hazard assessment to be performed.

Finally, we made observations of the remobilisation of the already deposited ash in the local area. One way this happened was through dust-devils (Figure c). These form when turbulent vortices in the wind pick up ash which then rises upwards in a vertical vortex, potentially up to heights of hundreds of metres. We saw many of these every day.



Additionally, one day, we were caught in a dust storm meaning we couldn't see further than a few hundred metres and had to abandon work for the day. These storms can fill the atmosphere with more ash than any single explosion, so present a large hazard to human health and overhead aeroplanes. We measured the wind speed, temperature and humidity, whilst also collecting samples of the resuspended ash to see if we can relate the wind speed to the size of the suspended particles, and thus assess which weather conditions leads to the largest quantities of resuspension, and therefore the most danger.

Overall, working at Sabancaya was an incredible experience and getting to spend more than two weeks working on an active volcano fulfilled a long-held dream. When I was at KES, one of my teachers once asked me what I wanted to do when I grew up and I responded that I was going to be a volcanologist. He laughed, I think because he thought it was a very narrow field. In fact, it is a hugely multidisciplinary field. I specialised in physics and maths at university and use these skills to analyse the data we collected and calculate quantities such as the pressure in the volcano that causes the explosions, or the wind speed required to remobilise ash. My colleagues use geological and chemical knowledge to analyse the samples and together we build up a picture of the whole system.

Fin Cooney

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

Reading Physics (with a foundation year) at Loughborough University

At KES 2011 - 2018

I'm Fin, a foundation year physics student at Loughborough University, and I haven't been bothered to think of a decent introduction, so I've plagiarised Zak's.

I am currently doing a foundation degree, which, for those of you who don't know, means I am effectively going back over the important bits of A Level Physics and Maths and also starting the first bits of my actual degree. Although this sounds like a lot of hassle it's definitely an option to consider. My grades meant that I could have gotten into university however not the university I liked the most (Loughborough) so I chose to, rather than go to a Uni I didn't want to go to and do a three year course, instead do an extra year at Loughborough. The foundation course means that you can still go to an A list university if you fall short of your grades, if you're willing to do the adjoining year.

Although there is work to do and course material that is taught at A-level and I therefore don't know, there is also a lot of content that I do already know – this is very handy as it frees up a lot of time for me. Having more time than most at Uni, due to the fact that I have fewer lectures than most, I decided to run for hall Social Sec, which I won. This responsibility leaves me in charge of organising lots of events for the whole hall. I now often have to organise things like punch parties and balls for the hall, so basically a lot of phoning and emailing people on most days. I would highly recommend going for Committee once you get to Uni, it's a great way to make new friends and you will probably get a ton of perks like free entry and VIP to events.

Overall it's been a sick first semester. I highly recommend signing up for everything you can. Dog walks, parties, sport and committee are great ways to make new friends which you're going to want lots of, so give everything a go when you get to Uni and most of all enjoy it.

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

My PhD involves using molecular simulation in order to understand the mechanisms which control the growth of organic crystals in the presence of different additives. By 'organic crystals', I am mostly referring to Calcite, which is the most common biomineral on Earth. And by 'biominerals', I mean materials which are produced by living systems. Calcium based minerals form many hard structures in biology (bones, teeth, shells etc.) and the molecular processes behind crystallisation are at the heart of how structures such as these grow. Organic crystals grow from supersaturated solution, and the presence of different atoms and compounds in these solutions will change properties of these crystals, such as the shape of the resulting crystals and their mechanical properties. These molecular processes and subtleties involving different atoms/compounds present in solution result in huge differences on the macroscopic scale. Biological systems (such as us) have been able to exploit these processes in order to shape skeletons and much more. It may be unsurprising, therefore, that the number of types of possible processes involved is huge, with a practically infinite scope of possibility. Filling the gap between the microscopic details and the macroscopic properties is the key to understanding how many biological systems grow. With this understanding, we may be able to grow our own systems with desirable mechanical and structural properties.

My part in this is to make and run atomistic simulations of these crystals in order to bridge the gap between microscopic and macroscopic. The problem is that even our most powerful computers may take hours (or days) to simulate a roughly nanometre-sized system for only a few nanoseconds. Finding clever shortcuts is key to getting any useful information from these simulations. I've been examining how the presence of holes in Calcite crystals effect the crystal size and stress distributions, in order to compare with experiments. More recently, I've been examining how the presence of various hydrocarbons in a water solution affects how difficult it is for particles to attach to a Calcite crystal surface. The aim is to show that hydrocarbons disrupt the dense water structure near the crystal surface, thus making it easier for particles to reach the surface. If all goes well I may be able to publish a paper on it, but we'll see...

Problem Page

1) [All years] Imagine you have 100 light bulbs in a row, all initially off. Each is labelled with a number: 1,2,3,4,5,…,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, 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!)

2) [Year 11 +] Find the numerical value of the following: (Where the pattern continuous infinitely)

$$x = \sqrt{1 + \sqrt{1 + \sqrt{1 + \sqrt{1 + \cdots}}}}$$

(Hint: Try squaring both sides)

3) [Year 12 +] How and why does the melting of the polar ice caps affect the length of a day?

4) [Year 12 +] 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?

5) [Year 12 +] How does opening to door of a fridge in a perfectly insulated room affect the temperature of the room?

Once you have attempted all the problems, ask Miss Heggie for the solution sheet!

Questions and Answers

What careers can you go into with physics? - Salary comparison

After graduation, the largest single pathway taken by physicists is 'further study'. (I.e. a PhD, or a postgraduate master's degree). The next most common career paths are: Education (e.g. physics teacher), finance, scientific and technical industries, government (e.g. working for the civil service), energy and environment, electronics/IT and software. Other examples are: healthcare, the law, government research. Average starting salaries for graduates: Physics and Astronomy £26,312, Aerospace Engineering: £27,820, Electronic Engineering £26,416, General Engineering £29,068. (The average graduate salary over all degrees is around £23,000) – *Rob*

How would you quantumly entangle large quantities of mass such as a coin or even a person?

Entanglement exists between two objects where, thanks to the details of quantum mechanics, the total wavefunction of the two objects is inseparable. This means that, when you make a measurement on one object, the quantum state of the other is automatically determined by what is measured on the first object, regardless of how far the two objects are separated. As for actually entangling two objects experimentally, there are several methods for doing this, including firing two entangled photons at two different objects, or thermally exiting the two objects so that the wavefunctions between the two objects overlap. These methods may work well for individual atoms, but would not prove useful for huge objects such as coins or people, which exist at such large length and energy scales that their quantum details are no longer measurable. I suspect that supercooling the objects would reduce this problem. Firstly, the quantum states (such as atomic excitation or vibration energy states in atomic bonds) become more defined at low temperatures. Secondly, the atoms in an object at near zero temperature will have larger wavelengths and I suspect it may theoretically be possible to get these wavefunctions to overlap between two coins or people. This would probably require temperatures enormously close to absolute zero, which would be far beyond the reaches of modern technology. The objects would also have to be isolated (put in a vacuum) as well as supercooled, so I'd personally limit this procedure to a coin at best. *- Alex*

How can you get relevant physics work while at University?

It depends what we mean by 'relevant'! There are loads of summer internships open to physics students in the world of finance (Jane Street is an example of one of the more competitive schemes). Once you are at University, you will be able to go to internship/careers fairs to find out more about specific companies offering schemes for undergraduates. If by 'relevant', you mean physics based work (i.e. research), then there are also a lot of opportunities. Many Universities offer schemes to their own undergraduates, where the student can apply to work with a Professor in the department over the summer (sometimes on a predesigned project, sometimes with more freedom) and receive some funding for living expenses. There are other schemes though, which are open to students from any University. My general advice is; if you don't ask, you don't get! Read about the research that goes on in your department (or other departments), and contact the researchers whose research appeals to you. But make sure you have some idea of what you're talking about, don't rush to contact anyone. Take your time reading about their research, and thinking about whether it really excites you or not! ***- Rob***

What are the ideal qualifications and preparation to be an astronaut?

To be an astronaut you'll first need a degree in either science or engineering. You'll then also need to do a lot of research on something (and preferably something that has space applications). If you also have experience in flying a jet aircraft, they might even let you pilot the spacecraft! For this reason, most astronauts either have a PhD or Pilots license. I think the best bit of preparation you can do now is learning Russian as that is (currently) a requirement to go on the ISS. So keep working hard now and, if you're very, very lucky, it might pay off in the future. ***– Tim***

Submit questions for next terms issue to Miss Heggie!