KES Physics Newsletter

Summer term 2019

Here it is, my final KES Physics Newsletter entry. Rob has asked if I will write a double page this term and I obliged so I'll either be going out with a bang or a long hard slog of a read. Anyway, my entry this term will form of two parts; first I am going to talk about my final year project (FYP) and second, I will give a little review on my entire University experience.

So, the title of my FYP was *"Modelling gamma ray attenuation in a small radiation detector for aerospace applications"*. The title itself basically sums up what I was doing but I'll try and explain it as best I can. The Small Radiation Detector (SRD) is, as the name suggests, a radiation detector of low volume. It can detect the strength of gamma radiation and the count rate. Because it is so small it can be flown on weather balloons and is used to investigate the radiation in the Earth's lower atmosphere. However, the nature of gamma radiation means that it has a probability of being stopped by any material it passes through, this is what is meant by attenuation. Therefore, the purpose of my project was to create a way of investigating how the material environment of the detector can affect the measurements it makes.

Timothy South

'Rocket Scientist'

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

Reading Aerospace engineering at Bristol University

At KES 2008 - 2015

I guess the first question you may be asking is "Didn't you do an Aerospace degree? What's this got to do with that?". Well, to be honest, I think the only real link between my project and aerospace is that the detector is sometimes flown. On the plus side, this project was very much physics based which, I suppose, is much more appropriate for this newsletter!

As for what I actually did, originally the intention was for me to use existing software, but I couldn't get it to work so, in the end, I developed my own code and method to measure the attenuation in the detector. The way the code works is as follows: CAD models are imported into the MATLAB workspace, MATLAB being the programming tool I use. A

"gamma-ray" (literally just a line) is then passed through the model and the code, using vector calculus, can calculate which parts and the distance the ray has passed through. With this information, the code can work out how much the gamma ray is attenuated and present these results. As you can see, although the project itself is based more in physics, the work I did was much more mathematical (much more to my style!).

Overall, I think my final year project went quite well. I was able to achieve my objectives, write a report on the project and present my FYP in poster form to a panel of academics without much issue. Hopefully, this will be reflected in the marks when I get them.

Now for a little retrospective about my time at University starting with what I wish I had done differently. University is an opportunity for two things; Learning and socialising and while I think I did alright with the first one, I don't feel I took advantage of the second. One of the things I enjoyed about my last two years is that I was part of the space society and table tennis society. These were great fun, but it shouldn't have taken me two years to decide I wanted to take part in student activities. When you go to University, don't make the mistake I did of not taking the opportunity to go and try new things. You will regret it.

That was a bit negative so let's quickly move on to a more positive retrospective on my time at University. One of the best and most important things I learnt while at university was programming. It as a skill that I have used in many different circumstances and is one I enjoy using. As for my favourite unit, that would have to be my space units. From my previous entries, you may know I like space so to learn about it in more detail has been one of the most enjoyable parts of the course. If you asked me was studying Aerospace Engineering a good choice I would absolutely say yes. It has allowed me to make new friends, gain new skills and work on interesting and challenging projects. I would definitely recommend studying engineering for any of you who enjoy the more practical or mechanical side of physics.

So here it is, my final few lines in the KES physics new letter… To all of you who are studying physics or are about to go to university, make sure you do one thing. Go Beyond, Plus Ultra! Thanks for reading.

Zak Goble

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

Reading Physics at Manchester University

At KES 2010 - 2017

I'm Zak, and I got five A's at AS level. Take that, Rob.

For no particular reason other than because Rob told me to, I will be introducing the topic of complex numbers.

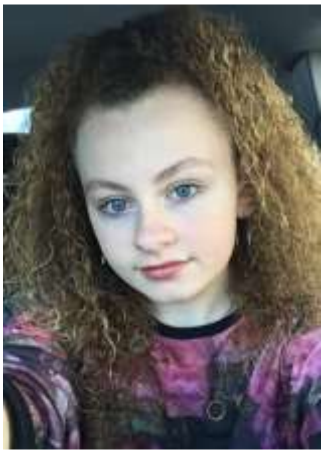
All throughout both GCSE, *and* normal, A level maths, teachers will tell you that some quadratic (and higher, even order) equations have no solutions. Take $x^2 + 1 = 0$, for example. You'd take the one over to the other side, and then proclaim that the equation has no solutions because you can't take the square root of a negative number. Job done. Or is it?

To create solutions to these types of equations, mathematicians invent a thing called i, or 'the' imaginary number, which is defined as the square root of minus one. The solutions to the equation in the paragraph above are therefore plus or minus i. This can be applied to more complicated equations, such as $x^2 + 4x + 8 = 0$. Using the quadratic formula on this would give solutions of $x = -2 \pm 2i$. The term without an i is called the *real* part of the solution, while the term with the i is called the *imaginary* part. The equation may not have any *completely* real solutions, but it can be solved with complex ones.

But what's the point? Why invent a thing that is completely meaningless in the real world, and whose only purpose is seemingly to make solving equations more complicated? The answer is that, when it comes to fields like calculus, using imaginary numbers actually *simplify* problems a lot. They take lots of hard-and-annoying-to-deal-with sine and cosine functions and turn them into exponentials, which are much more friendly. While it's not particularly insightful to attempt to comprehend imaginary numbers in the real world, they act more as mathematical tools than anything else. It's the equivalent of inventing an iPad and giving it to a problem child. The child shuts up, stops being so difficult, and then solves your equation for you. (Ok maybe not, but you get the gist.)

I hope you enjoyed that completely unrequested and pointless maths lesson in this physics newsletter.

Zak



Trinity Wills

Studied Physics, Maths, Art

Reading Mechanical engineering at Hertfordshire University

At KES 2011 - 2018

Hi again! Somehow, I survived the first year of Uni! All assignments submitted, all exams taken. Overall, I think it's been a productive year. I got to use big machinery and keep all my fingers, I learnt how to apply the laws of thermodynamics in open and closed systems without crying, and best of all, after all this time I think I no longer dread calculus (I know, I'm shocked too). Probably the biggest thing I've learnt this year is that mathematicians, physicists, engineers etc have an immense love for elaborate language for not so elaborate things. Even the words "Differentiation" or "Integration" sound scary at first but really, they're just a bunch of simple steps put together. My top study tip for when you're struggling to understand a certain topic is to pretend you're the person who created that concept. When faced with complex equations or concepts etc, you might find them daunting at first and perhaps even feel inclined to give up if you don't understand it instantly. However, you must remember that all these intricate equations, lengthy definitions and extensive theories all began as simple inquisitive thoughts of one or a few individuals. Einstein and Newton weren't superhuman intelligent mutants, they were just people like you and me. (If you really think about it they both just possessed the tendency to be super nosey because they had a need to know how and why the world worked.) If people like Einstein and Newton are capable of creating theories etc, then we are all capable of understanding them. All theories, formulas and concepts etc originate from simpler, easier to understand things. During A-levels I was convinced that I was too unintelligent for physics and maths or going to Uni, but now I'm positive that I'm capable and we are all capable. All the embellished fancy language can be intimidating and discouraging but once you break things down into pieces of information you do understand you see that all the jargon was simply a decorative label to make things more complicated than they really are. So, what I'm really trying to say is we're all as intelligent as Einstein and Newton etc (Yay! Go us!) we just may not have mastered the art of waffley nonsensical terminology yet. Eat a dictionary and you'll be set. Also, don't give up just because it gets tricky. Until next time, Trinity xx

Robert Clemenson

Studied Physics, Chemistry, Maths, Further maths

Reading Physics at Oxford University

At KES 2008 - 2015

As is always the case, third term at Oxford was very exam-centric, and didn't leave much room for a lot of new learning or interesting problems. Though I did take a course in numerical methods for solving partial differential equations (which are invaluable in modern physics research, as many of these equations are not exactly solvable, and require various approximations and computational techniques to crack). Other than this, there really isn't much to report!

As mentioned in both previous newsletters this year, I am currently working at Caltech in the area of 'AdS/CFT duality'. I expect it's about time I give you some idea of what these terms mean! To start with, the acronym I have used fully translates to 'anti de-Sitter space – conformal field theory duality'. More meaningfully, this represents a very promising approach to finding a quantum theory of gravity.

The year 12's may remember the discussions we had in May about Feynman diagrams, and how the more complicated Feynman diagrams (those with more vertices) contribute successively less to the overall probability of a given particle interaction (Interaction -> Some incoming set of particles going to some outgoing set of particles). Well, this is not always the case! For some theories, the more complicated diagrams become successively more important, and the perturbative method of Feynman diagrams breaks down.

AdS/CFT duality refers to a very special correspondence between certain d-dimensional theory's that possess so called 'conformal symmetry', and equivalent theories in (d+1)-dimensional anti de-Sitter space (space of constant negative curvature). A consequence of this duality is a kind of weak-strong coupling correspondence, where a CFT with this annoying divergent Feynman diagram property previously mentioned, will correspond to a theory in AdS without this property, allowing us to use Feynman diagrams as we would like.

Working on these Feynman-like diagrams while walking the same hallways as the man himself (Richard Feynman - my all-time physics hero) is proving to be a thrilling experience!

Last month I took part in an extremely cool experiment where we used a particle accelerator (Swiss Light Source synchrotron, Switzerland) to try and understand how gas bubbles can escape (or not) from magmas. A synchrotron is a particle accelerator where a magnetic field is used to bend particles into a closed path. A really useful feature of synchrotrons is that, when charged particles are accelerated, they emit electromagnetic radiation. In particular, when the particles are electrons moving close to the speed of light, the emitted radiation are high-energy x-rays which can be used to perform 3D (tomographic) imaging at fast acquisition rates.

For our experiments, we used the X-rays to image volcanic rocks changing as they are heated and melted, forming magma. In the figure, you can see how the rock sample changed during heating. Starting on the left, you can see the initial sample as a 2 mm diameter cylinder. The image has been rendered such that the rock/magma appears red whereas the surrounding capsule is grey.

We then heated the sample with two powerful lasers to a temperature where the rock started to melt. In the second frame, the rock has started to expand and flow, filling the space inside the capsule as it melts. In the third frame, the magma has started to rise through the conduit where we can see large bubbles inside the magma, whilst the lower part of the capsule is now fully filled. Finally, at the end of the experiment, the magma has expanded out of the capsule.

Paul Jarvis

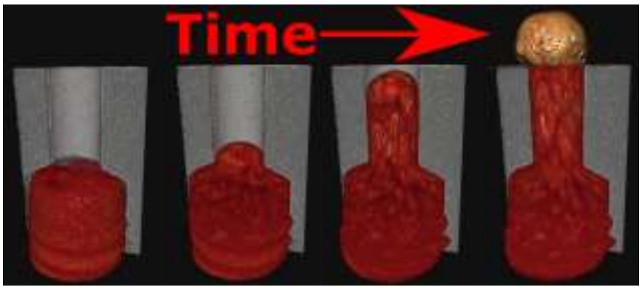
Studied Physics, Chemistry, Maths, Biology

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



The most interesting aspects of these experiments are the role that the bubbles play as the magma expands. The bubbles form and grow as dissolved water in the magma comes out of solution. It is crucial for us to understand how bubbles behave in magmas as many explosive eruptions are driven by pressure from trapped bubbles. Hopefully, these experiments will provide some insight into how bubbles form, expand and coalesce in magmas of different compositions.

Fin Cooney

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

Reading Physics (with a foundation year) at Loughborough University

At KES 2011 - 2018

This term has been vastly dominated by revision for the 4 exams that I have just sat. As mentioned in my last piece, I am sitting four modules; Physics, Maths, Electronics and Mechanics. My exams went well, and I am confident I am going to progress to next year – I would still definitely recommend foundation to any of you. The course is challenging in some areas and allows you to brush up for a year on everything. The other advantage is you can get into a top university with poorer grades.

While my Maths, Physics and Electronics modules were very similar to my A Levels, mechanics offered a refreshing new subject that went off on tangents from the previous knowledge I had. The main thrust of Mechanics was based around things like beam theory and polar moment of inertia problems. These topics gave me more of an understanding of civil engineering and further ideas about mechanics. I now also know that I do not want to switch course to Physics and Engineering as I had been thinking about it.

This term I also played a leading role in planning our Halls Day and Summer Ball as part of my work as Social Secretary. Both went off without a hitch, however planning two events in the space of two weeks for 300 people each got very stressful at times. I would still recommend staying in halls at least for first year to anyone. You meet so many new people and will have a fantastic time. I would also like encourage everyone to consider running for Hall Committee (if your Uni has them).

Social Sec has allowed me to branch out a lot, getting me DJ gigs, a job as a rep for most Loughborough events, the chance to meet new people and I honestly feel it has allowed me to move up another rut on the Loughborough University ladder – I also have received many free drinks and tickets.

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

I'm currently nearing the end of the first year of my PhD and, since my last entry, I have embarked on a series of new projects. Perhaps the most exciting of these projects (in my opinion) is one which borders on the more mathematical and philosophical side of computational materials physics. The premise is fairly simple: imagine a single molecule drifting from one side of a room to another. The molecule will, as you might expect, bump into many other molecules, which will slow it down, speed it up, change it's direction etc. This process is, in reality, extremely complex, and is a result of interactions between countless atoms. Therefore, any simplification to such a process is of great use. This is easily achieved by ignoring all the other atoms in the room and treating the molecule in question as moving 'randomly' through space. The collisions with other atoms merely become a random force on the molecule, and the problem is massively simplified. The issue with this, however, is that we have neglected how the rest of the room changes as the molecule moves. Consider now a different example of a crystal growing in a solution. Molecules in the water stick to the surface of the crystal and ultimately become part of it. It is easy to fall into the trap of thinking of this as a random process. However, should lots of atoms attach themselves to the crystal very quickly, the number of atoms near the crystal will momentarily be reduced until more atoms drift through the water. Therefore, the faster the crystal grows at present, the slower it is able to grow in the future. In other words, the growth rate of the crystal has a 'memory'. The effects of memory on nucleation and growth rates has often been overlooked, and my aim is to understand when and how memory is important in predicting complex non-equilibrium processes. I've started by simulating a random walk along a two-dimensional free energy map and projecting the process onto one dimension. I find that, under certain conditions, the movement along one dimension starts to have a memory. This memory can result in huge changes to the behaviour of the system. If such effects are neglected in practice (as they often are) then the predictions that we make of nucleation and growth rates may turn out to be very wrong. Ultimately, my aim is to design methods which give better results for free energy barrier crossing methods via the addition of memory.

Problem Page

1) [All years] This problem has some relevance to an important concept in the quantum mechanics of many particle systems. Where particles being 'identical' carries a much stronger meaning than in our everyday usage of the word. This can go a way to helping us explain the electron shell model of the atom. (But enough physics for now)

Suppose I have two pairs of dice. Pair number 1 consists of two completely identical blue dice that we will call dice 1A and dice 1B, with pair number 2 being one blue dice called 2A and one red dice called 2B.

When I roll either of the pairs of dice, I do so with my eyes closed, opening my eyes only once the dice have settled.

Find the probability that the sum of the number landed on by dice 1A and 1B in pair 1 is 6. Do the same for dice 2A and 2B in pair 2.

Now consider the case where we roll each pair separately, and they land such that the sum over the two dice *is* 6. Find the probability that the dice landed in the configuration 1A = 2, and 1B = 4. Repeat this, but for pair 2, with 2A = 2 and 2B = 4.

(Hint: Pay close attention to that fact that the dice in pair 1 are identical. Would we be able to distinguish 1A = 2 with 1B = 4 and 1A = 4 with 1B = 2?)

2) [Year 12 +] A satellite in circular orbit initially at 40,000 km (measured from the centre of the Earth) loses energy at a constant rate $mk\,Js^{-1}$, where m is the mass of the satellite, and $k = 14.7\,Js^{-1}kg^{-1}$. Assume the satellites orbit remains circular. Find the time taken for the satellites orbital radius to decrease by 10,000 km. Now find the time taken for the satellite to crash to Earth (Answer: around 2 months).

You will need:

$$Total\ energy\ of\ satellite = \frac{M_{sat}{v_{Sat}}^2}{2} - \frac{GM_{Earth}M_{Sat}}{r_{Sat}}$$

(You can just take the formula as a given. Don't worry about the potential energy term having a negative sign. You will see this later.)

3) [Year 12 +] When a person jumps on the surface of the Earth, the Earth itself moves very slightly in the opposite direction to the person (from Newton's third law). Find the distance moved by the Earth when a 100kg person jumps 1m in the air. State any assumptions you make.

Note from the editor:

At the end of the third year of this newsletter, I would like to thank Paul, Alex, Zak, Trinity, Fin, and George for their articles this year. With a special thank you to Tim, whose humorous and entertaining contributions we will all miss!

I would also like to convey our thanks to the KES science department, and in particular to Miss Heggie, for their continued support and enthusiasm for this project.

We would be thrilled to hear from students about what they liked, and what they would like to see more/less of next year. This year, we added the Q&A and problem page sections, which I hope you have found stimulating.

Best of luck to those of you leaving KES this year! If you would like to get involved with the newsletter, please get in contact with us through Miss Heggie!

I look forward to writing to you all again in December!

Robert Clemenson