KES Physics Newsletter

Summer Term 2020

Note from the Editor

Hello all! I am very pleased to introduce you to the updated KES Physics Newsletter. All of the contributors have worked hard to put something together, despite the unusual circumstances facing us all. So as always I would like to thank Harry, Paul, Alex, Callum, Zak, Trinity and Fin for their contributions over the past year.
We all wish you an enjoyable summer, and hope to hear from those Year 13's leaving KES to pursue further study in STEM about how they can get involved with the newsletter!

- Rob -

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 Covid-19 pandemic has affected everyone. One of the biggest questions now is how can people return to work, school and social venues whilst keeping themselves and others safe. This will require multiple mitigation measures e.g. hand washing, face masks and social distancing. But how effective are these? To answer this, we need to understand how respiratory infections are transmitted. Most often, viruses are transferred within fluid droplets that form within our respiratory tract, and are expelled whenever we breath, talk, sneeze or cough. Once emitted, there are three primary transmission mechanisms:

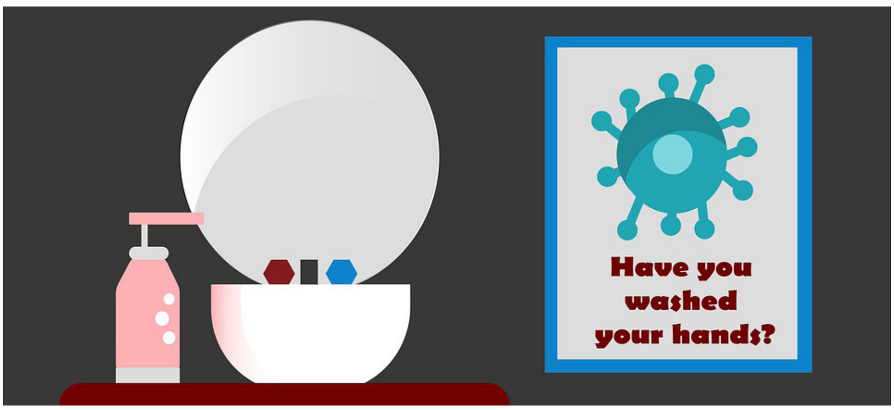
- ***Droplet*** – Droplets expelled from one individual directly deposit on another's mouth, nose or eyes

- ***Contact*** – Droplets deposit on surfaces and are ultimately transferred, normally via hands, to another person's respiratory system

- ***Airborne*** – Expelled droplets rapidly evaporate, becoming sufficiently small to remain airborne for up to hours and can be inhaled by others

Much research is ongoing to determine which mitigations are the most effective against each of these mechanisms. Hand washing is the most important mitigation against the contact mechanism, involving both chemistry (soap breaks down the bonds which bind material to your skin, as well as damaging the virus) and physics (the removed debris becomes trapped in bubbles which, due to the motion of your hands, rapidly become removed). Meanwhile, social distancing is a key defense against the droplet mechanism. When breathing or talking, most large droplets will travel less than 2 m. However, those expelled by coughing or sneezing can travel much further. This is where face masks become important (see this video on Twitter for a demonstration). Sneezing or coughing through a mask drastically reduces the velocity of expelled droplets and thus the distance they reach. Finally, airborne transmission is problematic indoors, where there are few air currents which remove dispersed, small droplets. Hence, keeping homes, offices and schools well-ventilated is vital.

Much research is still needed to understand how to prevent transmission of Covid-19. More information can be found in this freely-available article: https://doi.org/10.1017/jfm.2020.330. However, it is clear that all of us have to be mindful of our behaviour if we are to keep ourselves and other safe.



Callum Shingleton-Smith

Studied Physics, Maths, Chemistry, Computing (AS)

Reading Physics (with a foundation year) at Royal Holloway University of London

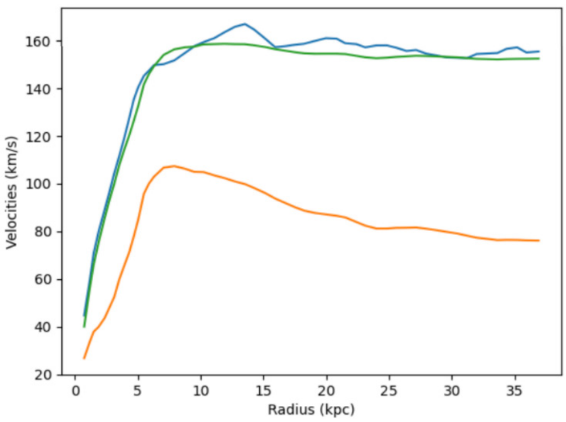
At KES 2012 - 2019

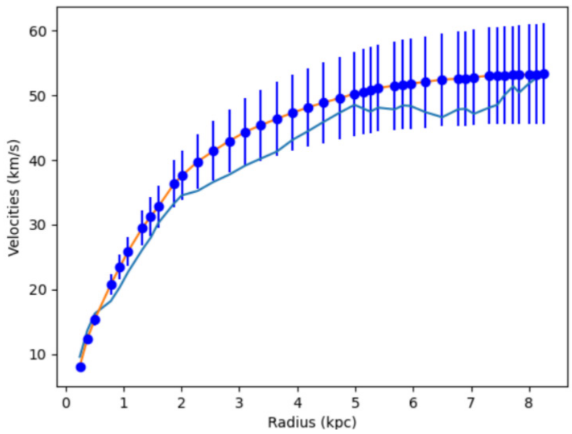
Term 3 has been an interesting experience; teaching has been purely online (although this term was originally meant to focus on the practical aspects of my course). Though running experiments physically in a lab has not been possible, we have been using online simulators and software instead, this has had its benefits and drawbacks. Term 3 also contained an individual research project which made up a large chunk of our overall grade for the year.

This term was less than a month long with lectures being held Monday-Thursday, I have been kept busy with the assignments for each of the three modules (electronic engineering, astrophysics and programming). The recording of online lectures has been useful for revision and my uni has set up an online resource for asking lecturers questions directly – this has come in very handy for the project.

The electrical engineering module has been a relatively basic introduction to circuits and their safe operation, we have been using multisim which is a free online tool where you can design and create circuits. The programming module has been very useful for getting used to the python modules that I will be using for the Physics course next year: numpy and matplotlib allow for the calculation and precise plotting of data points – I will use these frequently next year when collecting data from my experiments. Finally, the last part of term 3 taught astrophysics in which the teaching was centred around the main project. My project involved researching dark matter in galaxies and understanding how predictions for velocity rotation curves of galaxies can be improved by considering dark mass within galaxies.

The first graph below shows the original model that predicts the rotation curve for a galaxy (orange line) and the improved model (green line) which you can see is much closer to the data measured from real galaxies (blue line). The second graph is a result of further improvement to my model by improving a constant used to calculate the amount of dark mass – as can be seen here the real data falls within the error bars which I have calculated with uncertainties. My final conclusions from my experiment is that the presence of dark matter can explain the apparent missing mass in galaxies and therefore improve predictions for the rotation curves.





Robert Clemenson

Studied Physics, Chemistry, Maths, Further Maths

Read BA Physics at Oxford University

Reading MMathPhys Mathematical and Theoretical Physics at Oxford University

At KES 2008 - 2015

It feels pretty strange to be writing this, given I've now finished my time as an undergraduate. I can honestly say that the last four years have been simultaneously the best, most challenging, and most interesting of my life (so far!).

With the double whammy of an exam heavy final term and a total lack of in person lectures, I thought I might be so bold as to give a few choice pieces of advice for students starting university this year to ignore!

One of the most important lessons I've learnt in the last four years, is that **it's ok to find things difficult.** Physics and Maths are hard, and these things take time to get to grips with. Never shirk away from the hard problems! It's far better to feel inadequate for struggling with a difficult problem, than to be happy just answering the easy questions.

Make the most of your Professors and tutors. Pick their brains, read the recommended textbooks (not just the lecture notes), do the exercises. Even theoretical physicists have to be 'hands on' in practicing their trade. Reading through a calculation is not the same as doing it for yourself (as I have discovered and rediscovered many times over during exams).

Don't waste the long summer holidays between university terms. There are companies and universities all over the world looking for student interns to come and work with them. Developing the skill for writing a good enquiry email to send to Professors and employers is vital (and surprisingly hard to perfect). Stemming from a couple of well researched and worded emails, I was lucky enough to spend two wonderful summers at the California Institute of Technology (Caltech) as part of their SURF program.

Talk to other physicists, mathematicians, classicists, historians, ... Making friends with the people on your course, and (just as importantly) people on other courses is a horizon broadening experience. Talk about the things you don't understand, ask for insights, and work on problems together.

Don't write off certain areas of physics. It's pretty common (I in part blame The Big Bang Theory) for theoretical physicists to poke fun at experimentalists, and engineers. The truth is, anyone who knows anything about science knows that actually, this is like comparing apples to oranges. Engineers and experimentalists possess skillsets, and smarts totally alien to theorists. Don't let the 'banter' seriously influence your perceptions of these fields!

Lastly, to the Year 12's and below: **Apply to Oxford!** The only thing all Oxford undergraduates have in common, is a willingness to work hard. Sometimes people are worried they won't fit in, or think they will be written off because of their school or background. This is not true. Each of us writing in this newsletter is a former KES student. Coming from a state comprehensive should be no barrier to you giving Oxford or Cambridge (but preferably Oxford, sorry Paul) a go!

I look forward to writing to you all again next year, when I'll be joining the Theoretical Particle Physics group at Sussex University as a PhD student!

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

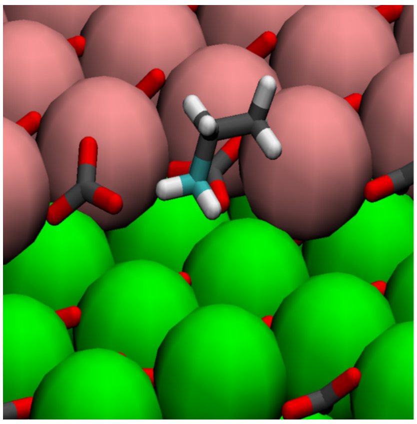
At KES 2012 - 2014

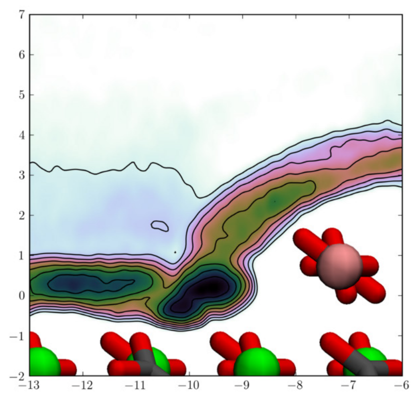
Quick update from last time: the paper I sent to be published was accepted, so I'm finally the main author of a published paper! To briefly recap, I wrote a paper on how magnesium nanoparticles are able to increase the fracture toughness of calcite by compressing the lattice and introducing a complex stress distribution throughout the crystal. The whole magnesium-calcite thing comes from a case study of the skeletons in a very particular type of starfish. This may not sound very relevant to us, but understanding how animals craft bones from raw materials in even the simplest cases is another steppingstone towards understanding biomineralisation.

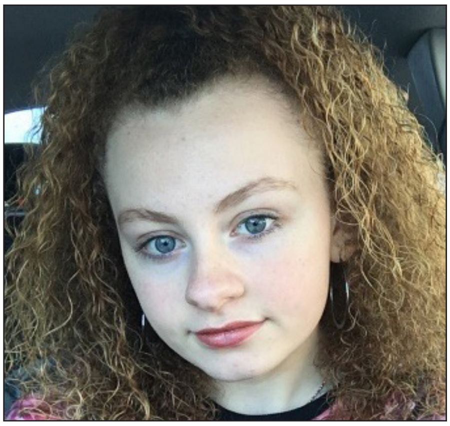
Moving on to the present, I'm sure lockdown has been a bit of a block for most people's research, but I'm lucky enough to be one of the few whose research hasn't suffered at all recently. So I've spent my abundance of free time to try and understand how amino acids get into calcite. Since amino acids are a huge building block in life, it is important to understand how they can get into minerals and shape their final properties.

Some recent experimental work has found that certain polyamine molecules are able to occlude in calcite similarly to amino acids. This has led to the conclusion that amine groups are important in occlusion into calcite. This is interesting, as people typically thought that it was the carboxyl groups in amino acids that primarily cause occlusion.

To test this, I've ran a long series of simulations where I essentially push some amino acids towards calcite from water and get their binding strength. The attached picture shows ethylammonium (or a lysine side chain) binding to calcite. The picture on the left shows an image I found from my simulations, where the binding of the molecule is most clearly seen; the map on the left shows a similar image rotated 90 degrees. The colour map shows the 'free energy' of the ethylammonium around calcite. Free energy is essentially the negative logarithm (base e) of the probability density multiplied by the thermal energy, kT (as in PV=NkT). What's interesting here is that, not only is the free energy difference (shown in the blue region in the colour plot) very large, but there is essentially no barrier preventing ethylammonium from getting to the crystal. This explains why it can get into calcite so easily. This is all very interesting, and should hopefully form the basis for my next paper.







Trinity Wills

Studied Physics, Maths, Art

Reading Mechanical Engineering at Hertfordshire University

At KES 2011 - 2018

OKAY…SO…WELCOLME TO LEVEL 374 OF YEAR 2020. I think it's fair to say this year has been a little unexpected for all of us (brace yourself we are only just over halfway through) Anyway I hope everyone is taking care and doing okay despite the madness!

This August I was set to begin a placement year which essentially means I was supposed to spend a year working in industry to help learn on the job skills and then return to university for my final year. Unfortunately, thanks to the Rona, the company I was meant to be working for had to cancel therefore I have no choice but to complete my final year earlier than expected. On a more positive note I did manage to achieve decent grades this semester even with all the uproar and changes to exams and teaching (fingers crossed heading for a first-class degree).

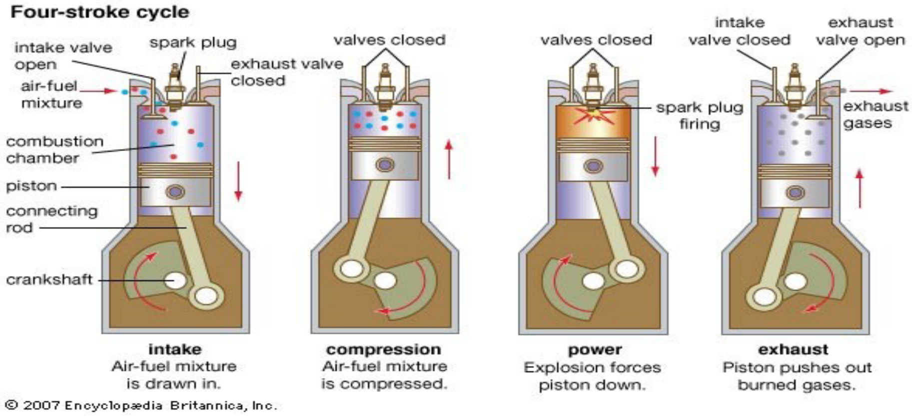
I think with all this extra time spent at home it's given us all more time to think and I've spent a lot of time thinking about why I chose to follow the path of engineering and debating if I've made the correct choice. I first decided to go into engineering as I have a great interest in cars and trying to understand how they work.

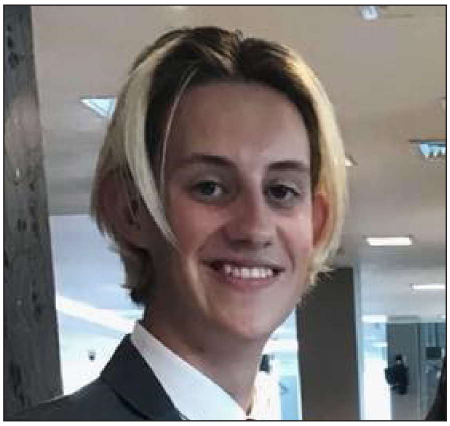
Have you ever wondered exactly how a car moves? How is the petrol and diesel fuel converted into motion? You might have heard of an internal combustion engine, but what does this actually mean? Below you can see an image illustrating the process of a four stroke engine. When you look under a bonnet of a car you can see the engine block but what is going on in there? There are many parts to the engine block, but I will just explain how the fuel is converted to energy to help the wheels turn.

As you can see below the first stroke is the intake stroke. This means an air-fuel mixture is drawn into the combustion chamber. In the second stroke the valves are closed and the air-fuel mixture is compressed by the piston moving up the chamber. The third stroke is the ignition or power stroke. In diesel engines the air-fuel mixture will ignite without the need of spark plugs, but petrol engines require them to help the mixture ignite (basically creating mini controlled explosions in your engine…so damn cool).

The explosion forces the piston down and in turn causes the crank shaft to rotate. The crankshaft therefore enables linear motion to be converted into rotational motion which can then be used to power the wheels. The fourth stroke is the exhaust stroke where the piston pushes out the burned gases. So…yeah… here's my little explanation on how internal combustion engines work!

I hope to be designing cars one day so look out Jaguar, Audi and Rolls Royce I'm coming for you! Take care everyone!





Fin Cooney

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

Reading Physics at Loughborough University

At KES 2011 - 2018

The Invention of Calculus

During the mid 17th century, two scientists separated by land and sea were simultaneously developing the field of calculus; specifically, the area known as infinitesimal calculus. These two mathematicians were Sir Isaac Newton (pictured lefr) and Gottfried Wilhelm Leibniz (pictured right) and they both independantly developed our ideas and concepts on the topic of calculus as we know it today.

Prior to the work by Newton and Leibniz, calculus was used as a throw away word for any area of mathematics. There had been some prior work completed on the area that today is known as calculus. For example, Fermat had previously founded his interior extremum theorem – this allows us to find the maxima and minima of differentiable functions. Newton's teacher, Isaac Barrow had also contributed to the cause by founding new ways to calculate the areas under and tangents at points on curves.

Newton expanded the concept of calculus by furthering the idea of differential and integral calculus. At the time he was challenged to explain the nature of the orbits of planets by a contemporary. On further studying of the problem he put together his theory of gravity in order to explain the phenomenon. Gravity explained the orbits, but there was one problem; when his theory of gravity was shown on earth the objects, when dropped, did not fall at a constant speed. What Newton went on to realise was that gravity caused acceleration.

His key finding in terms of calculus was that the time derivative of velocity is acceleration.

If you have ever wondered why there are two notations for the derivative of a function such as f'(x) and dy/dx, then wonder no more. The reason for this is due to the fact that Newton invented the derivative as we know it today; separately and simultaneously, Leibniz also invented this but used a different notation. It is believed that Newton invented the f'(x) variation.

Newton was a stark introvert and rarely published papers. He had to be bullied into publishing his works such as Opticks and Principia. His papers on calculus were published in a similar fashion many years after he first put pen to paper on them. Leibniz on the other hand was part of the scientific community and a well known mathematician.

It's hard to quantify the scale of the impact that these two people had on mathematics. Calculus is now the epicentre of most maths and is used in everything from business to agriculture, from travel to video games – the breadth of applicability is staggering.

Zak Goble

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

Reading Physics at Manchester University

At KES 2010 - 2017

I'm Zak, and I'm so bored that I've just completed RuneScape. Literally got level 99 in everything.

Everything.

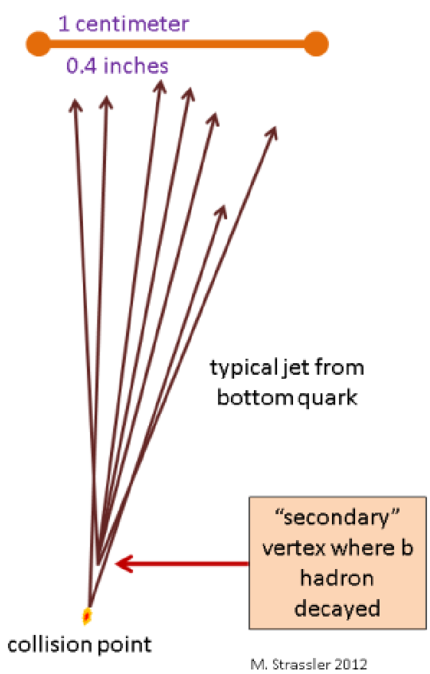
As ever, while there are only two terms per year at Manchester, and Rob, in his infinite wisdom, requests three articles per year, I'm going to have to dig around the bottom of the physics barrel for some content. This one will be lab-y.

Our task in lab at the beginning of this year was to analyse data from the Large Hadron Collider (LHC) beauty experiment at CERN. The real data. Two of our lab demonstrators worked on the actual experiment in Switzerland and were able to provide us with a record of all of the different interactions of the particles involved in the collisions in the 27km ring. Our job was to use this to find evidence for global CP violation, which is an imbalance in the amount of matter and antimatter in the universe.

Due to the high amount of weird and wonderful particles coming out of the LHC proton-proton collisions, we had to select our data carefully. We were only looking for B meson (properly wham and rare particles) decays into kaons (one of the proton and neutron's strange second cousins), and hence had to reject any event that had a high probability of containing other particles, such as pions (spicy mini protons) and muons (fat electrons). What remained was only a tiny proportion of the total number of LHC particle events. We were then tasked with pairing each B meson to each of the kaon decay products by looking at the known rest mass of the B meson, the energy and momentum of the kaons, and then using conservation of energy and momentum to match them. The comparison of the number of B- decay events to B+, and the relative difference between them, was what provided the information about matter-antimatter imbalances.

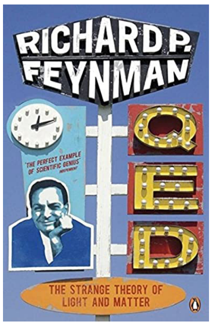
As any post-school physicist will tell you, the result you get at the end of an experiment means absolutely nothing without uncertainty, which is a quantified estimate of how reliable your result is. In this experiment, we couldn't be sure if our particles were definitely kaons and not pions, and whether or not certain kaons perfectly matched to certain B mesons in reconstructed decays. All these things considered and quantified, our result could have been miles out.

What we did find, however, was that there is more matter than antimatter in the universe – but only very slightly. Not anywhere near enough to explain the fact that everything around us seems to be made of matter, given that not everybody is constantly exploding and annihilating each other – and nobody knows why. The physics that fully explains CP violation is yet to be discovered. Uncovering this secret is currently one of the main goals of the LHC.



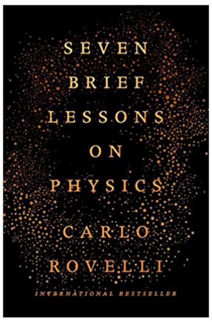
Book Recommendations

Click the images of the books for links to their Amazon pages



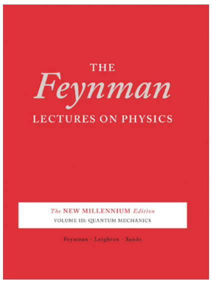
QED - The Strange Theory of Light and Matter
- Richard Feynman -

This book is readable for students in all years, and brilliantly introduces the theory describing how light and matter interact at the level of fundamental particles.



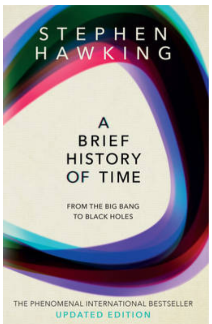
Seven Brief Lessons on Physics
- Carlo Rovelli -

The 'brief' in this books title, should be taken more literally than in Hawking's book below. This book gives wonderfully succinct, and beautifully written descriptions of the most fundamental components that make up our universe. Space, time, matter, and more. Well worth a read.



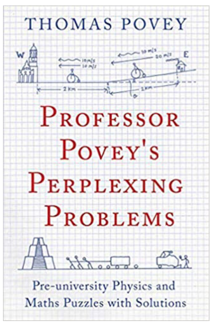
The Feynman Lectures on Physics
- Richard Feynman -

These lectures cover a great deal of university level physics, and provide deep insight into all topics introduced. This is a perfect set of lectures for Year 13's going to university this year. Best of all, the books are totally free online at: www.feynmanlectures.caltech.edu



A Brief History of Time
- Stephen Hawking -

This book is at the right level that a student in any year will get something good out of it. Hawking covers all things from quantum theory, and the beginning of the Universe, to black holes and the future of physics. An absolute classic.



Professor Povey's Perplexing Problems
- Thomas Povey -

Professor Povey's book is a brilliant collection of Physics and Maths puzzles, best suited to students between Year 10 and Year 13. There are lots of examples of the kind of problems students may be expected to answer in Oxford/Cambridge physics admissions interviews.