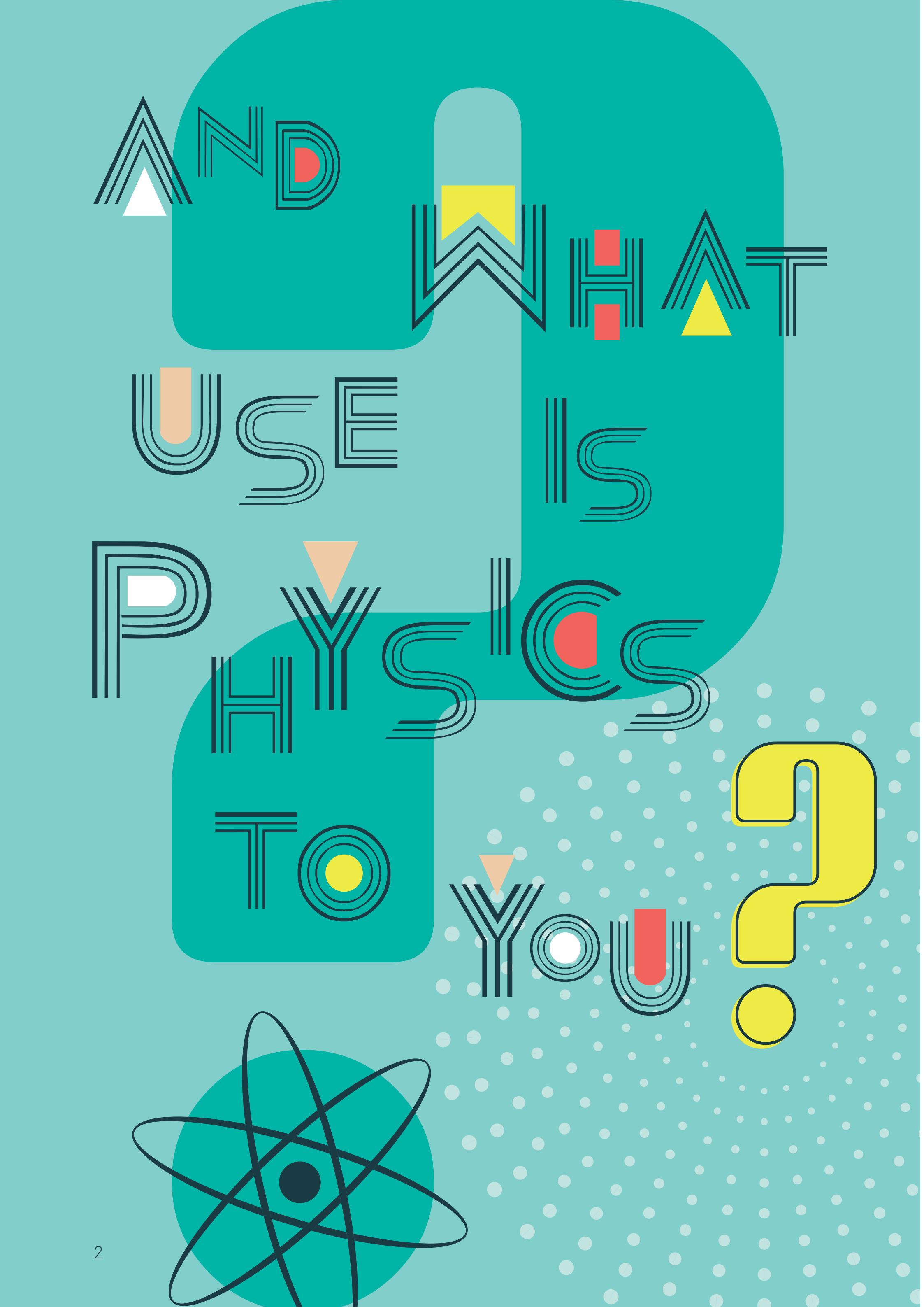
WHAT IS SO EXCITING ABOUT PHYSICS?

A booklet explaining why you don't want to miss out on studying physics. Produced by **Cavendish Inspiring Women**

CiW



We've put together this booklet to give you a glimpse into what physics is about, why it's exciting and why you definitely can't afford to miss out on studying it beyond GCSE. We've had some fantastic contributions from a range of truly inspiring young women with backgrounds in physics, which I hope you'll enjoy reading as much as I have! For me, what stands out the most is the amazing range of different problems which physicists work on – from learning **how the human brain develops (see page 24)** to **making computer games (page 23)**, as well as those who have left science to **work as a barrister (page 12)** or in the world of **business and finance (page 14).**

I hadn't even considered studying physics at A-level until I was sixteen and I would never have believed that I would go on to do a physics degree. But once I realised **how fundamental physics is to the world around us** and the type of questions which physicists try to tackle, I was hooked. I simply couldn't imagine not wanting to learn more and to answer some of the questions I had, like: **'why can't you travel faster than the speed of light?'** and **'what is the smallest particle possible?'.** If those questions don't interest you, there are many more questions which physics can help answer- from understanding **how the economy works** to **improving performance in sport.**

I hope this booklet will open up that world for you – the opportunities really are endless and every one of us has a huge amount to contribute.

Sarah Morgan
Physics PhD student

This booklet has been produced by **Cavendish Inspiring Women (CiW),** a group led by physics PhD students at Cambridge University.

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King

THORLABS

So What Actually is Physics?

In brief, **physics is about questioning how the world around us works** and looking for answers through a combination of experiments and theoretical work. Of course, that means that **physics can be applied to a huge range of different systems**- all the way from bacteria to planets!

What's more, **physics can also be applied to numerous areas outside of science**, including visual effects for films, modelling the economy, journalism and many more... the list is endless.

What Does a Physics Career Look Like?

There are several different routes into physics- for example an apprenticeship or physics A-level. **A physics degree normally takes three or four years and opens a huge number of doors** – in finance, business, consulting, research, teaching... to name just a few. Those who want to carry out research in physics sometimes also go on to study for a PhD.

People who have studied physics go on to do a whole range of different jobs, in fact **there are very few things that you can't do with a physics degree!**

Importantly, studying **physics opens doors** because the skills which you learn, including problem solving and numeracy, are very **highly in demand by employers from a whole range of job sectors.** Studying physics (either at A-level or at university) certainly doesn't mean that you have to go into a physics related job.

INTERVIEW

SHEILA KANANI

Education, Outreach and Diversity Officer
Royal Astronomical Society
@SaturnSheila


Photo: Nush Cole, Royal Astronomical Society

When did you first become interested in science?

I think I've always been quite interested in science, but I didn't realise until I was at secondary school. When I was eight I wanted to be a vet or an inventor and remember dreaming of making prostheses for cats that had lost limbs!

Why astronomy in particular?

Two things led me to have an interest in space. One was my physics teacher who told me, age twelve, that I was naturally good at physics and that made me want to do it more (who doesn't enjoy doing something they are good at?!).
The other was the Tom Hanks film *Apollo 13*; I saw it in the cinema and remember coming out, staring up at the moon and deciding then that I wanted to go into space.

Why should people bother with astronomy?

Astronomy can get people enthused about science, and science is so important for everything in life! Science isn't just about learning the bones of the body or the names of the elements, science teaches you how to enquire, how to investigate ideas, teamwork, report writing, practical skills, time management and problem solving!

Where was the most exciting place you've worked and why?

As a research scientist all the places I've worked have been exciting! From the Mullard Space Science Laboratory which looks like X-mansion – you expect a fighter jet to suddenly appear from under the swimming pool (yes we did have a swimming pool!) – to the Australian outback where I was using an array of radio telescopes to search for exoplanets (at the Narabri facility of the ATNF) complete with kangaroos.
Finally, I love being in London, as I'm right by the shopping mecca of the West End!

'I was using an array of radio telescopes to search for exoplanets'

What do you do for fun?

I love making people laugh so I enjoy doing science comedy in pubs and theatres. New hobbies include upcycling, knitting and interior design. I guess my favourite thing to do though is go out for a meal – eating is what I do for fun!

INTERVIEW

ROMA AGRAWAL

Structural Engineer

@RomaTheEngineer

Photo: Nicola Evans, WSP

Tell us about your career path so far?

I grew up in Mumbai and always enjoyed maths and science. Then, at sixteen I moved to London to study for my A levels (Maths, Further Maths, Physics and Design & Technology). I studied Physics at the University of Oxford and had a placement one summer working with mechanical engineers. I really enjoyed it, so I decided to become an engineer. I joined WSP as a graduate structural engineer in 2005 and am now an Associate Director. I've been lucky to work on some fantastic projects over my career, including the Shard at London Bridge.

What are the best bits about being a female engineer?

People remember me. I often attend meetings with lots of men so the fact that I'm quite memorable helps me to stand out. Also being in a minority means that the media has been interested in my work, which has given me some fantastic opportunities – for example being a Leading Lady for M&S.

What's the greatest obstacle you've had to overcome so far?

Having confidence in my own abilities has been a challenge at times. I often wondered why I was admitted to Oxford to study Physics, as I didn't feel smart enough. Even today I have moments of doubt. I'm aware that I sometimes feel like this now, and with encouragement from others and self-belief, I can deal with it and ensure I'm not letting it stop me from moving forward.

What do you do in your spare time?

I enjoy Indian classical dancing, ballroom and Latin dancing.
I practice yoga once a week and love cooking and baking.
I also spend a lot of time visiting schools and universities and talking about engineering.

Who inspires you?

I'm inspired by people who go against the grain and achieve amazing things. An example is Emily Roebling, who was the daughter-in-law of the engineer who designed the Brooklyn Bridge. After tragedy struck and he died, and her husband was crippled in an accident on site, she took up the mantle and got the bridge built. A woman running a major engineering project was unheard of in the 1800s but she did it.

'I've been lucky to work on some fantastic projects including the Shard at London Bridge'

INTERVIEW

Emma Towlson

Complex Networks Research Scientist

How did you become interested in physics?

I have always had a need to understand, in every sense. Couple this with the excitement I feel from solving a puzzle or learning a new mathematical technique and my obsession with the beauty of and patterns within the natural world and I feel like it was inevitable that I would pursue science. I remember as a child standing outside with my dad in the early hours of the morning feeling a sense of wonder as we watched a lunar eclipse. I had a similar sensation when I first saw equations claiming to explain laws of the Universe – I knew I had to understand them.

What do you work on now?

I'm a university research scientist working on network science; specifically, I study brain networks. By describing individual components as nodes and their interactions as edges in a network, we can reduce a system of formidable complexity to a graph that we can hope to understand.

'I have always had a need to understand, in every sense'

Is network science really physics?

Absolutely! It's also maths, and (depending on the system in question), computer science, neuroscience, economics, social science, biology etc… a network must be understood in the context of the system from which it was derived. Statistical physics is crucial to the formalism of networks. The interdisciplinary nature of the area is something that really inspired me to get involved. I find it amazing to work on a project with a physicist, a business researcher and a psychiatrist and find patterns in data using ideas from each discipline – the power of sharing resources across academic subjects should never be underestimated.

What can network science be applied to?

The answer to this question is endless. I have seen network science successfully applied to recipes (identifying flavour networks distinct to different cultures), music, Twitter and Facebook, proteins, air traffic and the WWW to name but a few… networks are fundamental to our world. One particularly exciting current application is to apply it to the cell and identify disease modules.

What would be your advice to someone thinking about studying physics at A-level?

Do it. But seriously, studying physics will at worst open your eyes to some interesting facts and scientific ways of thinking, and at best open doors for your life you had no idea existed. I'd also heavily advise studying maths at the same time; the two are intimately linked.

ISABEL JAMAL

Barrister at 8 New Square Chambers

Tell us about your journey to becoming a barrister?

I always had an interest in becoming a barrister, but was very keen to continue my physics studies after school. Physics and philosophy was therefore the ideal degree for me as it allowed me to combine analytical essay writing with the mathematical and scientific rigour of a physics degree. After my degree I took a law conversion course at BPP law school and then completed my barrister training course for a year (now called the Bar Professional Training Course). I then completed a year of pupillage (an assessed apprenticeship) at 8 New Square chambers and was then accepted as a tenant there.

What do you do in a typical day?

As an intellectual property barrister I spend around 20% of my time in Court (either in a trial or making or responding to procedural applications). The rest of the time I am either preparing for those Court appearances (which involves drafting legal arguments or preparing for cross-examination of witnesses) or advising clients on their cases. That means that my typical non-Court day involves reading documents, drafting advice and legal documents and speaking to solicitors on the phone or in meetings to discuss cases. The hours are long, but I have some flexibility in how I work because I am self-employed.

'Prospective employers will always be impressed with a physics degree'

What has been the biggest challenge of your career so far?

The biggest challenge in my view is handling the pressure associated with advising upon the best course of action for your client, often in circumstances where time is short, the stakes are high and there is no clear 'right' answer. Much of the job is about making judgment calls and, as the barrister, I am often the ultimate decision-maker. Questions like 'are we going to win?', 'should we sue them?', 'how much should we offer them to settle the case?' are rarely easy to answer.

In what ways is having a background in physics helpful?

Physics is extremely helpful in my particular specialism as I deal with patent law, so I often have to learn about particular areas of science and technology associated with the patents (e.g. life sciences, mechanics, telecommunications) in order to argue the case for my clients. More broadly, physics also trains you to think through a problem logically. That training is invaluable in my profession as it helps to work through an argument clearly and coherently.

Would you recommend studying physics to others?

I would definitely recommend it. First and foremost, it is fascinating and extremely intellectually rewarding. Secondly, whatever career you decide to pursue afterwards, your prospective employers will always be impressed with a physics degree.

Gemma Godfrey

Business Leader, Broadcaster & Quantum Physicist

@GCGodfrey

Photo: The Fold London

'Who wouldn't want to know why the sky is blue?!'

What is your career and what's your favourite thing about it?

As a finance expert, the most satisfying aspect of the job is to empower people with the knowledge to make smarter decisions.

Why did you decide to study physics?

An inspirational teacher at school made the subject accessible, relatable and fun - who wouldn't want to know why the sky is blue?!

What was the best thing about doing a physics degree?

The variability of the subject matter and its broad applications. It equips you with lifelong skills that can be applied across a wide variety of industries.

What got you interested in the world of business and how has your physics degree helped you to get to where you are today?

An ability to challenge pre-conceptions, tackle problems to find innovative solutions and think outside the box has proved invaluable.

What do you do to relax?

Spend time with friends and family – especially my two year old son.

QUIZ

FIND YOUR PHYSICS ROLE MODEL

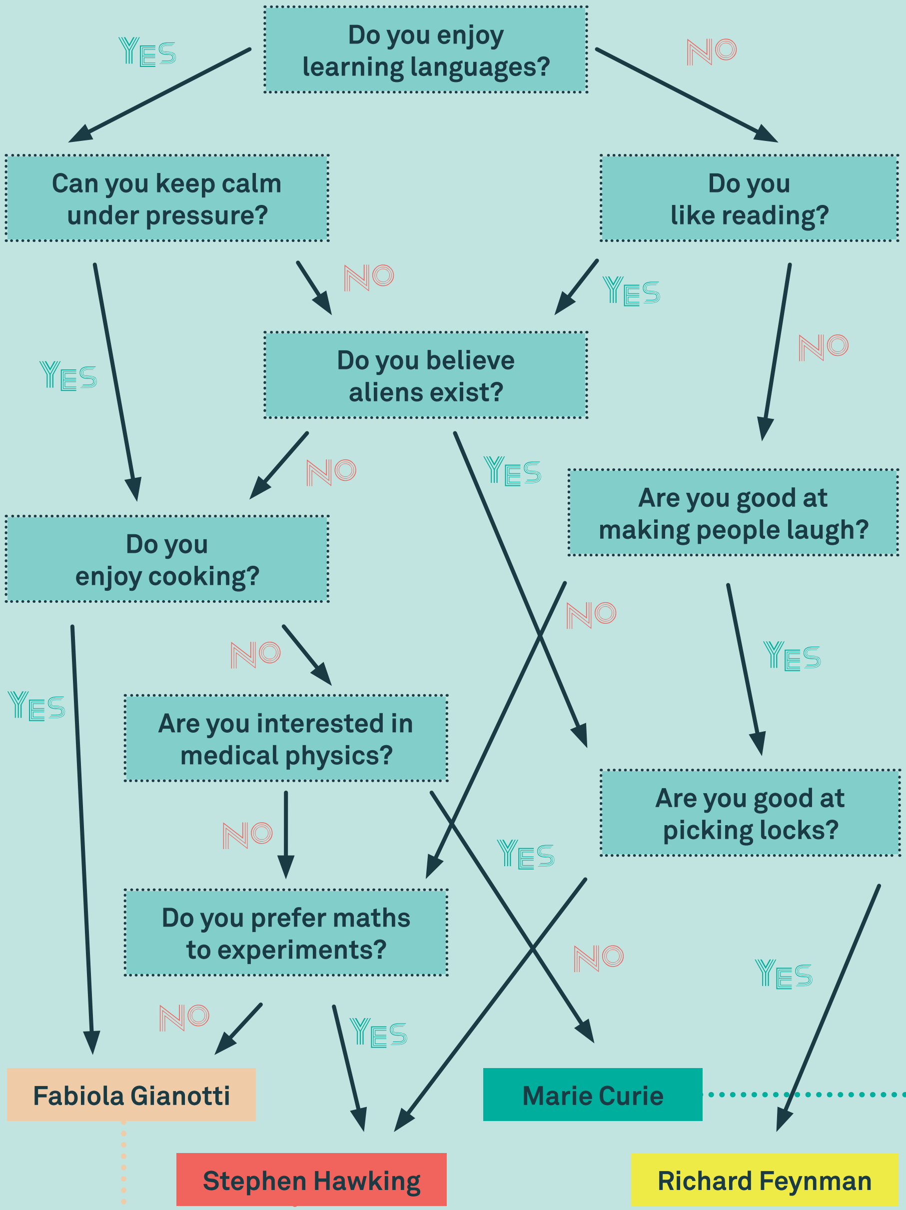



Photo: Musée Curie (coll. ACJC)

Marie Curie
Marie Curie was a Polish-born physicist and chemist, born in 1867. She discovered radioactivity and her research was crucial for the development of X-rays in surgery. She was also the first person to receive two Nobel prizes!

Fabiola Gianotti
The first woman to be appointed Director-General of CERN, Fabiola Gianotti is an Italian particle physicist with a passion for music, cooking and physics. As a trained pianist, she loves the links between science and art.

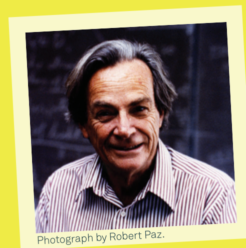

Photo: Mike Struik


Photo: Danor Aharon / Shutterstock.com

Stephen Hawking
Stephen Hawking is a theoretical physicist, world-famous for his work on black holes. Diagnosed with ALS (a form of Motor Neurone Disease) at just 21, he has overcome incredible obstacles to pursue his ambition to understand the laws governing the universe.

Richard Feynman
Richard Feynman was an American theoretical physicist, renowned for his sense of humour and keen sense of curiosity. A fantastic communicator and teacher, he certainly knew how to keep an audience entertained!

Photograph of Richard P. Feynman used with the permission of Melanie Jackson Agency, LLC and courtesy of the Archives, California Institute of Technology.


Photograph by Robert Paz.

The Bizarre World of Quantum Mechanics

Hannah Price, Research Scientist

Physics can stretch your imagination to the extremes. In my research, I study the very coldest places in the universe, far colder even than the depths of outer space. In fact, these places exist only in laboratories, where clouds of atoms are trapped and cooled to temperatures less than a millionth of a degree above absolute zero. As well as pushing back the limits of the possible, these experiments give us the perfect playground for exploring and understanding more about quantum mechanics.

Most of our daily experiences can be described intuitively with so-called classical physics. When we play sport, we can quickly calculate where a ball will land and run to catch it. Now, imagine that the ball is the size of an electron. At such small scales, we enter the weird world of quantum mechanics and all our intuition has to change.

For example, we can no longer know with any certainty where the ball will hit the ground. Instead, there is a probability that the ball lands here, but there's also a small probability that it lands over there behind the tennis courts. And that is just a small taste of what the quantum realm is like.

By going to tiny temperatures, we enhance quantum effects, making them so strong that they dominate even over the size of a huge atomic cloud. Because the effects are now on such a large scale, we get to see and image quantum physics in action directly, often for the very first time. We can even create exotic quantum states of matter, such as superconductors or superfluids, where particles flow without friction. As a theoretical physicist, I get to use my imagination, backed up with mathematics and computer

FEATURE

modelling, to dream up new experiments that we can do with these ultracold clouds of atoms, to learn more about the fundamentals of quantum physics.

While I enjoy the challenge of how mind-bending and bizarre the quantum world can be, I also love that understanding quantum physics is really useful.

Your computer, your smart phone, and all your other electronic devices, actually rely on electrons behaving as quantum particles. We can hope, therefore, that what we learn today about quantum mechanics and atoms in the universe's coldest places, will help us tomorrow to develop the improved technology and smarter materials for the rest of the world.

Atoms arranged in a system known as an 'optical lattice'. By changing the depth of the wells researchers can control the interactions between the atoms.

Photo: E. Edwards/JQI

Glimpsing into Outer Space

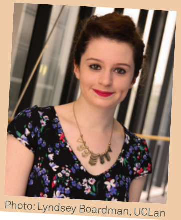
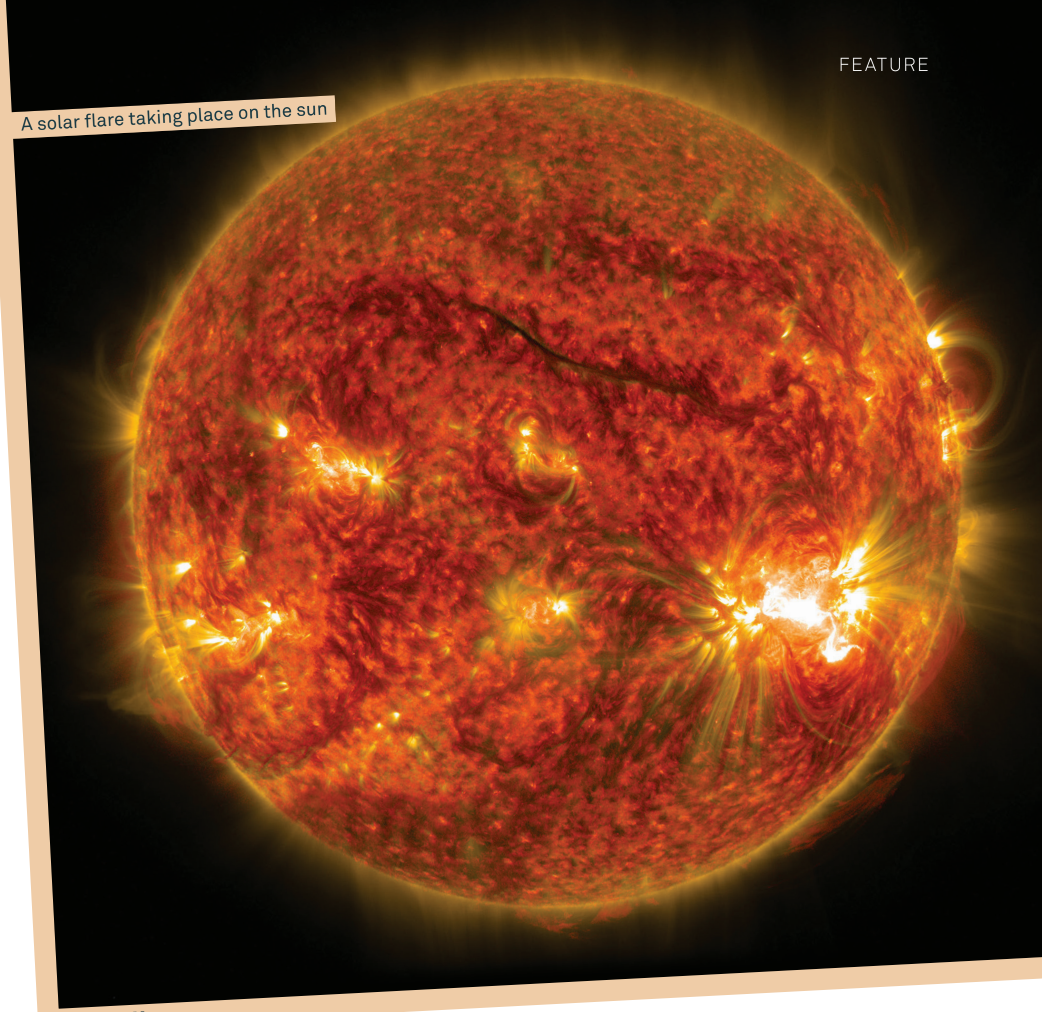


Photo: Lyndsey Boardman, UCLan

Jasmin Evans, Physics university student
@thequirkyquark

Science is all around us, it's everywhere... empty your pockets now and see what you find.
Loose change? Stars go through a process called fusion, where incredibly high pressures and temperatures cause nuclei to fuse together, starting with fusing hydrogen to produce helium and then making progressively heavier elements up to iron...
Even heavier elements like copper are formed when that star goes bang in a supernova explosion.
What else do you have? A mobile phone? The processes going on inside it are incredible, from the conversion of sound to digital impulses and back again, the circuit board controlling everything, the LCD screen that you look at and the microphone you speak into... the gadget you hold in your hand has more computing power than those aboard the Apollo spacecraft that landed man on the Moon.
If you look up on a clear winter's night, and see seemingly thousands of stars shining above you, stop and think for a moment. Every point of light is a star that could possibly have its own solar system orbiting around it, and one of those planets may harbour life. This is what I find so fascinating about space science and astronomy. We send robots to other planets in our own solar system, attempting daring landing sequences, relying on millions of lines of code to relay commands and of course rove the surface to explore.

The technology used to make these rovers and satellites is astounding, planning a successful mission requires the key tool in a physicists arsenal – problem solving. Part of the fascination of physics is starting with what seems like a very complex problem and finding ways to break it down, to work around the obstacles, apply knowledge, equations, theorems, diagrams and eventually come up with a solution.


A solar flare taking place on the sun
Photo: NASA/SDO

This can also be applied to everyday life; by thinking like a physicist you can approach problems and situations with a different outlook. Physics gives you an analytical approach with the ability to think outside of the box, which employers find very attractive in job candidates.

Historically, the lack of women in physics has been sadly very obvious... but you have the chance to change that!

Physics and mathematics help you to grow; you can do so much with a little self-belief, research and curiosity. Allow yourself to open your mind to what could be out there, and the possibilities will never cease to amaze you.

The Quest for Clean Energy from Fusion

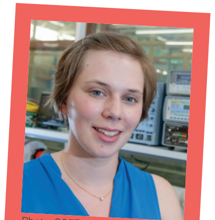


Photo: CCFE

Steph Hall, Scientist at Culham Centre for Fusion Energy

I work at Culham Centre for Fusion Energy (CCFE) where we try to recreate fusion, which is a process that happens in the Sun, here on earth. Fusion occurs when two hydrogen atoms collide to make helium and a large amount of energy and we can make it happen by heating hydrogen up to temperatures hotter than the Sun. CCFE is in Oxfordshire and has the largest fusion experiment in the world, called the Joint European Torus (JET), along with another machine called the Mega Amp Spherical Tokomak (MAST).

There are many fusion experiments around the world, all trying to produce more energy from the reaction than it takes to sustain it. When we can do that then we will have a source of energy that will have readily available fuel, very few waste products and will hopefully solve the energy shortage that we are currently facing.

I work on the real time protection system for MAST. The system is needed to protect the machine from the high powers needed to heat the hydrogen atoms to a point where they will fuse and produce energy. It is designed to react as quickly as possible if any power limits are breached so the machine is not harmed by the high powers in the equipment or the high temperatures of the hydrogen.

While working at CCFE I have learnt a lot more than I could have imagined and enjoy being part of a team committed to helping to produce a clean energy source. It is an exciting place to work as you are at the cutting edge of technology, solving problems that will one day lead to getting a fusion power plant up and running.

JET: the largest fusion experiment in the world.

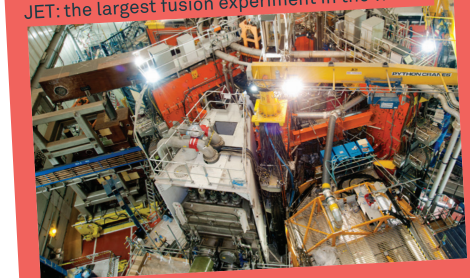


Photo: EUROfusion

FEATURE

From Particle Physics to Candy Crush

Tatia Engelmore, Data scientist at King

I found physics fascinating for as long as I knew what it was. At school I decided to become an experimental physicist because it seemed incredible that we could discover laws of nature by doing a simple experiment. I went on to university and then to do a PhD, during which I worked at a particle accelerator which smashed gold nuclei together at nearly the speed of light and collected data using detectors as big as a three-story building. We wrote code to analyse the massive amounts of data and tried to learn more about the mysterious force that holds a nucleus together.

While I still love physics, I decided I didn't want to continue doing it as a career after my PhD. It's a bit scary switching fields, but I knew there were lots of interesting jobs in the private sector if I could manage to get one. Fortunately when I graduated the field of data science was becoming big, and it seemed like a great fit for my skills and interests. It involves writing code and algorithms to pull out useful information from huge amounts of data, which is similar to what I had been doing before.

Shortly after I started my job search I got an offer from King, then a little-known gaming company but now famous as the creator of Candy Crush. My job involves analysing user data and predicting things such as whether a player will remain interested in the game, or if a user will want to install a new game on their phone if they see an ad. It's very cool to see the algorithms I write working! I like my job because it's challenging, and I get to use my maths and programming skills.

Overall, there are lots of things you can do with a physics degree. I have friends from university who also became data scientists or who went into finance, as well as those who now do physics research in industry or teach. It's a great path to many possible careers.

Making Sense of the Human Brain

Teresa Krieger, Physics PhD student
@TeresaGKrieger

Our brains are incredibly complex organs. To allow you to think, move, talk and dream, your brain contains 100 billion nerve cells which communicate with each other through electrical signals – that's close to the number of stars in our galaxy! In my research, I study how so many nerve cells are produced from just a few stem cells during the early development of a human embryo and how they connect with each other to exchange information.

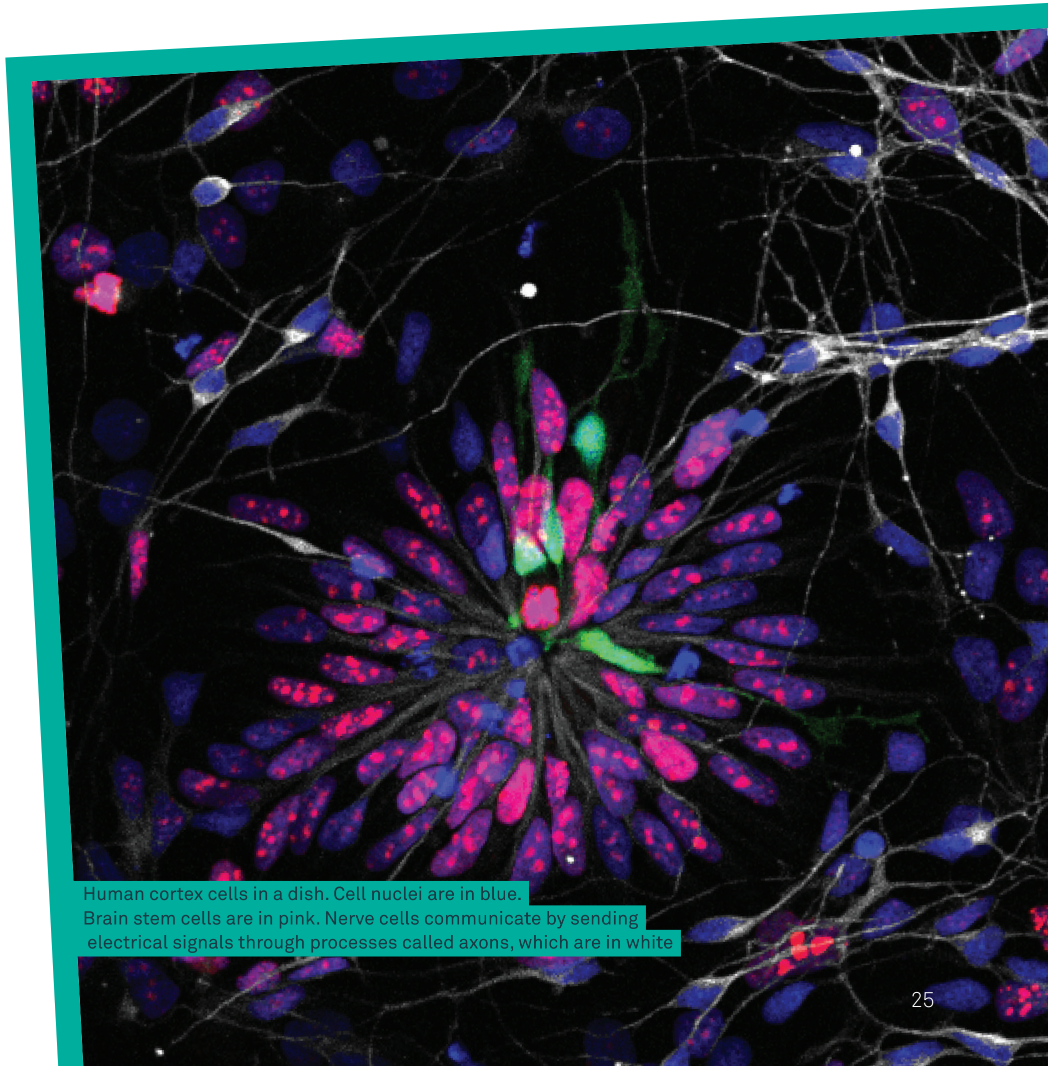
Brain development might sound more like biology than physics. In fact, I was lucky enough to study a little bit of both during my degree and I also worked as a research student in different labs to gain hands-on experience with running experiments and computational simulations. These days, I spend most of my time in a biology lab where I culture human stem cells in a dish, turn them into nerve cells and study their development.

I'm especially interested in the cortex, which is the outermost layer of the brain responsible for higher cognitive functions such as thought, language, and consciousness.

Biology has given us a lot of detailed information about how individual nerve cells work. However, since brains are so complex, it's almost impossible for us to understand the whole process of brain development in that much detail. And that's where my physics training comes in handy. Physicists have a lot experience making sense of complex systems. For example, during my degree, I learned how to divide a problem into manageable chunks, how to distinguish essential from unimportant information, and how to spot patterns in noisy data.

So in addition to my biology experiments, I also use these kinds of tools in my research. By labelling single brain stem cells with fluorescent proteins, so that they appear red or green under the microscope, I can track their cell divisions and movements over time. From watching a few hundred cells in the dish, I develop a hypothesis for how the human cortex develops. And then I write computer simulations to see if I can predict what happens in reality.

Above all, my physics degree has taught me how to solve tricky problems and deal with complexity. I'm applying this knowledge to study a biological process, but it's just as useful for other areas of research, engineering, finance, business management, and everything else!



Human cortex cells in a dish. Cell nuclei are in blue. Brain stem cells are in pink. Nerve cells communicate by sending electrical signals through processes called axons, which are in white

Bedside Blood Tests

Laura Huang, Research Scientist
at Sharp Laboratories of Europe, Ltd, Oxford

The ability to perform rapid diagnostic tests at a patient's bedside would be a great help in making sure that fast and appropriate medical treatment is given. It may sound like the realm of a doctor or biochemist, but a background in physics is very useful in designing and building new devices for the life sciences and healthcare sectors.

One device being developed where I work at Sharp Laboratories allows droplets of a water-based fluid (such as blood or urine) to be moved electronically. It works via a principle called 'electrowetting', which involves using electric fields to move the droplets with extremely high accuracy. This allows us to mix different droplets together and perform chemical reactions. Therefore the diagnostic tests that are normally done by hand in a test tube can now be done automatically instead, at a microscopic scale.

At the lab, we are very excited about the future for our device. It's a versatile platform which can carry out many tests simultaneously and the tiny liquid volumes being used means that it could save the NHS money as well as giving faster results for more immediate treatment.

EPSTOCK/ Shutterstock.com

Next Steps

Are you interested in finding out more about physics? If so, there are a number of places you could look... we've listed some of our favourites below:

A-level physics

Studying physics at A-level helps to keep your options open... even if you don't want to study physics at university, A-level physics is very well thought of by employers and universities and the problem solving skills you'll learn will stay with you for life. If you want to study physics at university then you'll also need A-level maths- physics and maths go hand in hand.

Specifically physics-related

Institute of Physics (IOP) www.iop.org
University physics department websites or visit in person
Think Physics www.thinkphysics.org, based in Northumbria
Research physics degrees at www.myphysicsccourse.org
Careers from A-level physics at www.physics.org/careers
Find out more about engineering at www.tomorrowsengineers.org.uk

Science more generally

FutureMorph www.futuremorph.org
Your Life www.yourlife.org.uk
Stemettes www.stemettes.org

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