FITZ EVENTS

FITZWILLIAM COLLEGE
UNIVERSITY OF CAMBRIDGE

Fitzwilliam College Summer School Programme 2024

Course brochure

Fitzwilliam College, a constituent college of the University of Cambridge, is delighted to offer its own in-person Summer School Programme for 2024. Through this programme, participants will experience the world-leading teaching offered at our institution, by the same academics responsible for our own undergraduate students. Reflecting the traditional Cambridge supervisions at the core of our undergraduate courses, our programme will help you develop your academic skills through challenging small-group problem-solving and discussion sessions.

Participants will have the opportunity to join various academic-enrichment activities during their stay, enhancing the core skills necessary for scholarly success at University. With practical experiments being a key part of several of our short Courses, students will gain first-hand experience of research in a practical setting. Early evenings will consist of academic enrichment activities, from essay writing to presentation and scientific communication skills, working with Cambridge academics to refine your techniques and grow your experience.

This brochure outlines the range of short courses on offer in 2024, detailing their core content, any prerequisite knowledge, and recommended reading lists.

I am delighted that Fitzwilliam College can offer you the opportunity to participate in this Summer School Programme. I hope you will enjoy exploring your chosen topic and grow your enthusiasm for learning. We look forward to welcoming you soon to our Summer School Programme!

Dr Peter Bolgar
Director of the Summer School Programme

Contents:

Physical Chemistry
(Chemistry)

Dr Andrea Chlebikova
Senior Project Chemist at Isaac Physics, Department of Physics, University of Cambridge
Senior demonstrator and lecturer, Yusuf Hamied Department of Chemistry, University of Cambridge
Special Supervisor at Newnham College

Andrea Chlebikova came to Cambridge as an undergraduate in October 2011, studying Natural Sciences at St Catharine's College, specialising in chemistry. She continued to pursue a PhD in atmospheric chemistry, focusing on methods of predicting rate constants based on molecular structure. Andrea has previously been part of the organising team for the Cambridge Chemistry Challenge, as well as being a UKMT volunteer in charge of marking mathematics challenges and olympiads. She became involved in undergraduate teaching at Cambridge in 2015 and has been supervising first-year chemistry to students of Natural Sciences as well as more specialised physical chemistry courses ever since. She is also involved with undergraduate admissions in multiple colleges. Andrea is in charge of designing and teaching the chemistry content on the STEM SMART programme run by the University of Cambridge, preparing students from disadvantaged backgrounds for studying STEM subjects at university.

College profile: [Andrea Chlebikova – Newnham College (cam.ac.uk)]

Module Structure and Syllabus:

Date	29th July Monday	30th July Tuesday	31st July Wednesday	1st Aug Thursday	2nd Aug Friday
	Introduction to Physical Chemistry	Thermodynamics	Chemical Kinetics	Spectroscopic Tools	Quantum Chemistry
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	Electrochemistry	Physical Organic Chemistry	Atmospheric Chemistry	LAB DAY	Final Presentations

Introduction to Physical Chemistry: What is physical chemistry and how does it fit in with the rest of the subject? In this first session, we will take a brief look at the history of chemistry and provide a context for what follows, discussing the significance of physical chemistry to our understanding of the subject as a whole.

Thermodynamics: We will meet the second law of thermodynamics and introduce the quantities necessary for approaching the question of what controls to what extent a chemical process goes ahead: enthalpy, entropy and Gibbs free energy. Our exploration of chemical equilibria will then focus on justifying the shifts seen based on Le Chatelier's principle.

Chemical kinetics: In this session, we will look at rates of reactions, what factors they depend on and how we can model them. We will start with an exploration of single-step processes and see how complexity quickly emerges for multi-step reactions.

Quantum Chemistry: This session focuses on building an understanding of compounds and reactions on a sub-molecular-level. How do chemists think about chemical bonding and changes to it in a useful way, despite the counterintuitive concepts quantum mechanics introduces?

Spectroscopic Tools: We will discuss techniques that allow chemists to study compounds and chemical reactions, and explore the physical chemistry behind them. This session will largely focus on infrared spectroscopy and links to the understanding of bonding developed in the previous session, but we will mention other tools and discuss the similarities and differences for various types of spectroscopy.

Electrochemistry: How can the physical chemistry concepts we have introduced be applied to electrochemical reactions? We will meet the theoretical foundations for understanding redox reactions using the Nernst equation, and see how it is used in biological contexts as well as batteries.

Physical Organic Chemistry: In organic chemistry, we learn many reaction mechanisms that show how a reaction goes ahead. In this session, we look at what evidence from physical chemistry studies is used for working out these mechanisms.

Atmospheric Chemistry: How can the ideas of chemical kinetics be applied to atmospheric reactions? We will look at both chemical processes happening at ground level (in the troposphere) and explore the ozone layer (in the stratosphere).

LAB DAY: This session will include a practical component and you will meet researchers from the Yusuf Hamied Department of Chemistry who will tell you about their research projects.

List of prerequisite knowledge:
Confidence with algebraic manipulation of expressions
A knowledge of differentiation will be helpful but is not necessary
Familiarity with chemistry of secondary-school level (e.g. representations of molecules and chemical bonding, recognise terminology such as “enthalpy”, some experience handling glassware)

Recommended reading list (optional):
Foundations of Physical Chemistry: No. 40 (Oxford Chemistry Primers) by Charles P. Lawrence , Alison Rodger and Richard Compton
Foundations of Physical Chemistry: Worked Examples No. 68 (Oxford Chemistry Primers) by Nathan Lawrence, Jay Wadhawan and Richard Compton

Palaeobiology: Evolution and Behaviour

Dr Ashleigh L Wiseman

Bye-Fellow, Fitzwilliam College, University of Cambridge
Leverhulme Trust/Isaac Newton Trust Early Career Fellow, McDonald Institute for Archaeological Research, University of Cambridge

Ashleigh is a biological anthropologist and archaeologist, having worked on archaeological and palaeontological sites across Europe and Africa since 2011. She is currently a Leverhulme Fellow at the McDonald Institute for Archaeological Research, University of Cambridge (2021-2024) working on reconstructing locomotion from hominin fossils, ranging from soft tissue estimation to simulations, stemming from her time as a postdoctoral researcher reconstructing archosaur locomotion (2019-2021). Her main research interests are understanding the origins of bipedality in our own evolutionary lineage, and using musculoskeletal modelling to investigate muscle mechanics during locomotion of extinct animals.

Research Profile: https://www.arch.cam.ac.uk/staff/dr-ashleigh-wiseman
Website: https://walkinginthepast.co.uk/

Dr Oliver E Demuth

Honorary Research Associate, University of Cambridge
Postdoctoral Research Fellow, Liverpool John Moores University

Oliver is a palaeobiologist and evolutionary biomechanist. Currently he is a postdoctoral researcher on dinosaur locomotion at Liverpool John Moores University. He started as a scientific illustrator and then studied palaeobiology at the University of Bristol and obtained his PhD from the University of Cambridge in 2023 where he studied the evolution of flight in birds. His main research interests are the evolution of locomotory behaviour in vertebrates, especially dinosaurs (birds and their extinct relatives). He combines musculoskeletal modelling and biomechanical approaches to reconstruct movement of extinct animals.

Dr Laura van Holstein

Junior Research Fellow, Clare College, University of Cambridge

Laura is an evolutionary biologist interested in the evolution of our own lineage, hominins. The evolution of the traits that set humans apart from other animals, such as cumulative culture and complex technology, have long been the focus of research. However, the processes that shaped our evolution, and particularly how they compare to those of other animals, have received far less attention. Laura addresses this question by placing our lineage in an unusually broad comparative sample—all mammals. Her research methods are based on comparative phylogenetic methods, palaeoanthropology, and ancient DNA. Laura obtained her PhD at the University of Cambridge (2022) and is currently a Junior Research Fellow at Clare College (2022-25).

Module Structure and Syllabus:

Date	29th July Monday	30th July Tuesday	31st July Wednesday	1st Aug Thursday	2nd Aug Friday
	A Billion Years of Evolution Dr Wiseman	Archosaurs: Rise of the Ruling Reptiles Dr Demuth	Birds and the Evolution of Flight Dr Demuth	Introduction to Human Evolution Dr Wiseman	Mammalian Speciation and Extinction Dynamics Dr van Holstein
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	Lab Session: Species Diversity Dr Wiseman	Using Fossils to Reconstruct Behaviour & Workshop: Evolutionary Biomechanics Dr Wiseman	Lab session: Inferring Behaviour and Ecology from Fossils Dr Wiseman	Technology & Culture – A Human-only Phenomenon? Dr Wiseman	Final Presentations Dr Wiseman

Aim of the course: Over these ten sessions, workshops and labs, students will be exposed to the methods that palaeobiologists use to reconstruct the past, ranging from ecology to behaviour. Much of this course will be interactive, providing students the opportunity to apply methods to fossil material to understand how the individual might have walked, what it likely ate, and to reconstruct its environment.

Day 1: A billion years of evolution
We journey through the last billion years of Earth's evolution. We will explore the dramatic transformations, pivotal events, and the emergence of diverse life forms that have shaped our planet. We will discuss major extinction events and examine why some animals were successful whilst others went extinct. This will be followed by a workshop using a palaeobiology database to plot changing species diversity over time.

Day 2: Archosaurs: Rise of the Ruling Reptiles
During this session we will examine the ruling reptiles of the Mesozoic era, and how their locomotory adaptations led to their remarkable success for more that 250 million years. This will be followed by a workshop in 3D digital modelling and how scientists use these techniques to learn more about fossils.

Day 3: Birds and the Evolution of Flight
Birds are one of the most successful animals, found across the world in the air, land and water. In this session, you will learn how they reached such diversity worldwide and what enables them to conquer their environment. This will be followed by a workshop on linking ecology, diet and body size with flight style.

Day 4: Introduction to human evolution
During this session, the last 5-7 million years of human evolution will be explored. We will step through time from our earliest ancestors (hominins) to today, learning about the key aspects that make us human: the ability to walk upright, large brains, use of technology, diet, and the ‘out of Africa’ worldwide colonisation.

Day 5: Mammalian Speciation and Extinction Dynamics
During this session, you will learn about the species concept, extinction dynamics and interspecific competition. We will ask the question: is human evolution 'weird' compared to that of other mammals?

Day 6: Lab Session: Hominin Diversity
We will explore casts of hominin specimens. In this session, we will explore how similar/dissimilar the individuals are, and consider if such diversity justifies the creation of a new species. We will debate our findings.

Day 7: Using Fossils to Reconstruct Behaviour, & Workshop: Evolutionary Biomechanics
In this session, we will learn how we can use different elements of a fossil to reconstruct past behaviour, with a focus on hominins. This will be followed by a workshop where we will learn the basics of biomechanics (the study of movement) and we will conduct some biomechanical testing of 3D digital fossils.

Day 8: Lab session: Inferring Behaviour and Ecology from Fossils
We will explore casts of fossils, with a focus on hominins. In this session, we will compare elements of the skeleton between different species and will learn what features to determine how the animal might have moved, its diet, and bring this all together to interpret it's ecology.

Day 9: Technology & Culture – A Human-only Phenomenon?
Humans were once thought to be the only species to use tools, but we now know that many different animals use tools. In this session, we will explore the evolution of technology and debate whether this makes humans unique. We will also debate: are humans the only species to have culture?

List of prerequisite knowledge:
Students will be required to bring their own laptop and will be provided with software to install as part of this course. This course will be taught at an introductory level and will be suitable to students of all backgrounds. It will especially suit STEM-track students.

Recommended reading list (optional):
N/A – to be provided during the course.

Medicine
(Biology)

Professor Matthew J. Mason
Professor of Comparative Physiology, Department of Physiology, Development & Neuroscience, University of Cambridge, Fellow at St Catharine's College

Dr Aaron D'sa
Specialist Registrar in Anaesthesia and Intensive Care Medicine at Addenbrooke's Hospital, Fellow at Fitzwilliam College, University of Cambridge

Dr Saeed Kayhanian
Academic Clinical Fellow in Neurosurgery at Cambridge University Hospitals, Fellow at Fitzwilliam College, University of Cambridge

Module Structure and Syllabus:

Date	**29th July Monday**	**30th July Tuesday**	**31st July Wednesday**	**1st Aug Thursday**	**2nd Aug Friday**
	Introduction to Physiology Prof Mason	Introduction to anatomy Dr Kayhanian	Physiology of anaesthesia; pharmacology of anaesthetic agents Dr D'sa	Medical ethics, law and human rights Dr D'sa	Introduction to intensive care; physiology and treatment of pain Dr D'sa
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	Introduction to sensory systems Prof Mason The auditory system Dr D'sa	Introduction to clinical trials Dr Kayhanian	Rescuing the injured brain Dr Kayhanian	Practical class day: including ECG and sphygmomanometry Prof Mason	Final Presentations Prof Mason

Introduction to Physiology: Discussion of hormones and homeostasis, the autonomic nervous system and cardiovascular physiology, all from a pre-clinical perspective but setting the context for understanding clinical practice.

Introduction to anatomy: An outline and discussion of human anatomy and the basis it forms for clinical practice.

Physics of anaesthesia: an introduction to aspects of physics relevant to anaesthetic practice. We will cover the way in which fluids and gases flow through tubes (including tubes in the human body!), and the use of electricity and electrical circuits to diagnose and treat conditions.

Pharmacology of anaesthesia: We will consider the different types of medicines which can be used to put a patient to sleep for an operation, and the way in which they can be administered. We will also investigate some medicines which have been used historically for anaesthesia and some of their risks and disadvantages.

Medical Ethics: We will look at what constitutes an ethical code, and some of the ethical and professional codes which have historically applied to medical practice and clinical research.

Human Rights: A review of the principles of human rights and how they can apply to medicine, and a review of some of the landmark cases involving human rights and medical practice.

Introduction to Intensive Care: An introduction to the types of treatments used in intensive care, and some of the conditions which are treated. We will look at how a ventilator works, why there are so many pumps and tubes, and some of the medicines which are used to treat patients in intensive care.

Physiology and treatment of pain: An overview of the way pain is sensed by an organism, how pain signals are carried to the brain, and how these signals can be processed. We will also consider some pain-relieving therapies, from simple home remedies to medication to electrical devices.

Introduction to Sensory Systems: Discussion of how electrical signals are generated and propagated in nerve fibres, and then how different types of sensory receptors transduce signals from the environment into these electrical signals which – ultimately – can be understood by the brain.

The Auditory System: We will consider the features of sound waves, and some of the delicate and complicated structures which convert sound waves into electrical signals in the brain. Students will also learn about some of the mechanisms which allow sounds to be located.

Introduction to clinical trials: The development of new therapeutics relies on testing with phased clinical trial approach. This course will discuss clinical trial methodology, with key examples from recent drug and therapeutic developments.

Rescuing the injured brain: an exploration of current and developing therapies for neurological disease.

Practical class day: An opportunity to learn about sphygmomanometry for the measurement of blood pressure, pulse oximetry, finger pulse measurements and electrocardiography (ECG). You will be looking at how these techniques work at rest, and you will then use them to investigate how your own cardiovascular system adjusts to the challenges of exercise and different postures.

Final presentations: where the students will give short presentations to the rest of the group about a topic which has caught their interest. There will be feedback given by Prof Mason, and the best presentation will be awarded a prize.

Nuclear Science and Technology

(Physics, engineering, materials science)

Dr Miles Stopher
Senior Tutor at Fitzwilliam College, University of Cambridge
Director of Admissions, Department of Engineering, University of Cambridge
Affiliated Lecturer, Department of Engineering, University of Cambridge

Dr Miles Stopher is Acting Senior Tutor at Fitzwilliam College, the Director of Admissions and an Affiliated Lecturer in the Department of Engineering. Previously he was Deputy Senior Tutor and Senior Lecturer of Engineering at Homerton College, Cambridge. He has supervised and directed studies in Engineering for almost 10 years, across a number of colleges at the University, including his alma mater, Jesus College. His research focuses on nuclear reactor design, with particular interest in the design of nanostructured materials for applications in extreme environments, such as the reactor core, radiation damage modelling, hydrogen embrittlement, and the engineering and safety of integral and passive small modular reactors. He lectures Nuclear Materials for Part III materials scientists at Cambridge, An Introduction to Materials Science for Engineers, and Nuclear Materials for Engineers on the MPhil in Nuclear Energy. He has also lectured on nuclear safety for engineers. Miles supervises Part IA and Part IB Mechanics, Materials and Structures to engineering undergraduates at Cambridge. Prior to his arrival at Cambridge, he worked on the design of the Royal Navy's Dreadnought-class nuclear-powered ballistic missile submarines.

Department profile: http://www.eng.cam.ac.uk/profiles/mas251

Module Structure and Syllabus:

Date	29th July Monday	30th July Tuesday	31st July Wednesday	1st Aug Thursday	2nd Aug Friday
	Introduction to Nuclear Energy	Fundamentals of Nuclear Science part i	Fundamentals of Nuclear Science part ii	Nuclear Safety and Waste Disposal	Nuclear Reactor Design
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	Fundamentals of Materials Science	Radiation Damage	Nuclear Fuel	Nuclear Cladding and Moderators	Final Presentations

Aim of the course: Nuclear Science and Engineering is an exciting area of research and industrial investment across the globe. From the decommissioning of current reactors to new, advanced fission and fusion reactors, there is huge demand for graduates with the knowledge and skills to work in the nuclear industry. This course will give an overview of the nuclear industry and discuss the many performance, reliability and safety issues within it, ensuring students understand the fundamental concepts of nuclear energy and technology. As such, this course covers topics across Materials Science, Physics, Chemistry and Engineering.

Introduction to Nuclear Energy: Nuclear Energy's role in the global energy infrastructure and strategy to tackle climate change.

Fundamentals of Nuclear Science: Common notation, types of radiation, binding energy, radioactive decay, half-life, and nuclear reactions.

Nuclear Safety and Waste disposal: Regulatory systems, probabilistic risk assessment, waste immobilisation and disposal.

Nuclear Reactor Design: Components, and types of reactor including pressurised water reactors, boiling water reactors, gas-cooled reactors and liquid-metal reactors.

Fundamentals of Materials Science: intrinsic and extrinsic properties, crystallography, microstructures and mechanics.

Radiation Damage: Displacement cascades, dislocation loops and void formation.

Nuclear Fuel: Uranium, plutonium, and future fuel design.

Nuclear Cladding and Moderators: Cladding - steels and zirconium, Moderators – graphite, Zirconium hydride, and liquid moderators.

Final presentations: short student presentations on a topic which has caught their interest. There will be feedback given, and the best presentation will be awarded a prize.

List of prerequisite knowledge:
There are no prerequisites for this course except for basic algebra and trigonometry.

Elements of Mathematical Economics

(Mathematics and Economics)

Vasileios Kotsidis

College Associate Lecturer at St. John's College

Vasileios Kotsidis uses tools from traditional and evolutionary game theory to analyse social interactions that (potentially) involve strategic motives. His research focuses on the scope and limitations of models based on methodological individualism in interpreting individual behaviour (human or otherwise) as it is manifested in social settings. It spans along three main directions: how individuals think, what they are motivated by, and what the researcher can infer. He obtained his PhD in Economics at the University of Nottingham. His doctorate explored some theoretical aspects of social (strategic) behaviour and investigated its empirical manifestations. He also enjoys practicing karate, studying on the philosophy of mathematics, and reading fantasy literature.

College profile: https://www.joh.cam.ac.uk/fellow-profile/2659
Department profile: https://www.econ.cam.ac.uk/people/cto/vk340

Module Structure and Syllabus:

Date	**29th July Monday**	**30th July Tuesday**	**31st July Wednesday**	**1st Aug Thursday**	**2nd Aug Friday**
	Elements of Mathematics I	Elements of Mathematics II	Elements of Statistics I	Elements of Statistics II	Rational Choice Theory I
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	Rational Choice Theory II	Stochastic Dominance	Dynamic Choice	Information	Revision

Elements of Mathematics I and II: These lectures introduce students to fundamental concepts of mathematics that have useful applications in economics.

Elements of Statistics I and II: These lectures provide the statistical foundations necessary for the analysis of economic processes and relations.

Rational Choice Theory I and II: These lectures introduce a formal theory of choice and examine some applications in economic transactions.

Stochastic Dominance: This lecture discusses conditions under which certain options outperform others, with reference to some key statistical properties.

Dynamic Choice: This lecture discusses formal choice in a temporal setting and examines financial decisions with varying time-horizons.

Information: This lecture investigates the ways in which rational agents can incorporate newly acquired pieces of information into their decision-making process.

List of prerequisite knowledge:

1. Understanding of limiting reasoning
2. Elementary trigonometry
3. Intuitive understanding of sets
4. Venn diagrams
5. Intuitive understanding of probability

Recommended reading list (optional):

The Calculus Lifesaver: All the Tools You Need to Excel at Calculus by Adrian Banner

Special Relativity and Quantum Mechanics
(Physics)

Dr Joao Rodrigues
Director of Studies, St Catharine's College, University of Cambridge
Bye-Fellow, Wolfson College, University of Cambridge

After many years working in Quantum Field Theory and Particle Physics, specifically in the parton structure of the nucleons, I changed my field of research to the climate of the polar regions. In the Polar Oceans Physics Group in Cambridge, I studied how the Arctic sea ice cover has changed in recent decades as a consequence of global warming. I examined sea ice thickness data collected by submarines and satellites and attempted to quantify the dramatic thinning of the Arctic Sea ice. At present, I teach several Physics and Mathematics courses for first-, second- and third-year students in the Natural Sciences and the Mathematical Tripos of the University of Cambridge.

College Profile: https://www.wolfson.cam.ac.uk/people/dr-joao-rodrigues

Module Structure and Syllabus:

Date	**29th July Monday**	**30th July Tuesday**	**31st July Wednesday**	**1st Aug Thursday**	**2nd Aug Friday**
	The Lorentz Transformation	Relativistic Kinematics	Relativistic Dynamics	Relativistic Optics	Appearance of rapidly moving objects
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	The historical development of QM	The postulates of QM and simple applications	The EPR paradox and the Bohr-Einstein debate	Bell's Inequality	Final Presentations

The Lorentz Transformation: We highlight the successes and difficulties of the pre-relativistic physics. The latter was very effective in predicting, for instance, the motion of the planets, but Einstein noticed what appeared to be an inconsistency between Newton's dynamics and Maxwell's electromagnetism. This led him to propose a new physical theory and a new transformation law for the coordinates of the same event in two different reference frames. Different observers may assign different times to the same event, a curious feature of what became known as the Lorentz transformation.

Relativistic Kinematics: The fact that time flows at different rates in different systems of reference has interesting consequences. We shall follow a fast-moving interstellar spaceship and compare the magnitudes of time intervals, distances and velocities measured by those in the ship with the corresponding measurements made by observers at rest. In this context, we shall examine in detail the well-known Twin Paradox.

Relativistic Dynamics: We introduce the notions of relativistic momentum and energy and study some examples of the conversion of mass into energy and vice-versa. We derive the famous formula $E=mc^2$ and explore its implications in some physical systems.

Relativistic Optics: The Doppler effect and the aberration of light were known phenomena in non-relativistic physics. We shall assess how Relativity modifies the classic formulas and explore some of the consequences of these changes.

Appearance of rapidly moving objects: When taking a photograph of a moving object, all rays generated at its boundaries arrive simultaneously at the camera. If the object has a non-negligible size, light rays must then leave its surface at different times. In most instances this causes a significant distortion on the appearance of objects that move at speeds close to the speed of light. However, perhaps surprisingly, some objects keep their shape in the photographs.

The historical development of Quantum Mechanics: The first quarter of the twentieth century is often regarded as one of the most productive periods in the history of science. We shall study the ideas of Planck, de Broglie, Heisenberg, Schrodinger, and others which culminated in 1925-1926 with the formulation of the Quantum Theory.

The postulates of Quantum Mechanics and simple applications: We introduce the notion of wave function, quantised energy levels and solve Schrodinger's equation for simple systems. We discuss how the equation can be applied to more complicated systems such as the hydrogen atom.

The EPR paradox and the Bohr-Einstein debate: The new ideas were not accepted without reluctance by some, among them Einstein. In 1935, together with Podolsky and Rosen, he wrote an article in which an apparent paradox suggested that the formulation of Quantum Mechanics was incomplete. We shall discuss their reasoning and the more modern version of the paradox due to Bohm.

Bell's Inequality: Almost 30 years after the EPR argument was formulated, Bell wrote what has been described as one of the most important scientific works of the 20th century, in which it was shown that Quantum Mechanics could not be completed with the so-called hidden variables. We shall have a good discussion of Bell's theorem and some of its variants, namely due to d'Espagnat.

List of prerequisite knowledge:

Newtonian dynamics: - Newton's Laws
- Notions of force, mass, momentum, energy and work

Optics: - The laws of reflection and refraction
- Notion of frequency, period, wavelength

Mathematics: - Elementary techniques of differentiation and integration
- Techniques for solving simple first and second order differential equations (desired but not strictly necessary)

Recommended reading list (optional):

Halliday and Resnick, *Fundamentals of Physics* (Relativity and Quantum Mechanics chapters only);
A Einstein, *The Principle of Relativity*;
R Feynman, *The Feynman Lectures on Physics*, Quantum Mechanics (Chapter 1 only);

Mathematics for the Natural Sciences – Option 1

(Mathematics)

Mrs Serena Povia

College Teaching Associate at St John's College

Supervisor at Magdalene and Jesus

Involved in Cambridge Admissions for the past 6 years in several colleges

STEMSMART Supervisor

I specialise in teaching Mathematics and Physics at the University level. I have been a supervisor in physics and mathematics for the Natural Sciences course for about ten years. My current teaching commitments are the Physics and Mathematics courses for the first year and the second year of the respective Tripos. I previously taught third-year courses too.

College Profile: https://www.joh.cam.ac.uk/fellow-profile/410

Module Structure and Syllabus:

Date	**29th July Monday**	**30th July Tuesday**	**31st July Wednesday**	**1st Aug Thursday**	**2nd Aug Friday**
	Differential Equations 1	Integration 1	Complex Numbers	Differential Equations 2	Manipulating Vectors
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	Introduction to multivariable calculus	Differential Equations 3	Integration 2	Differential operators	Final Presentations

Differential equations 1: Using physics, we introduce the need to use differential equations with some simple examples – possibly including systems of differential equations in nuclear decay.

Integration 1: A very flexible day on integration – it serves as a recap and extension for those who have done a lot of integration and as an introduction for those who have not seen much integration yet.

Complex Numbers: We need the formalism of complex numbers to solve harder physics problems. We introduce and use the cartesian and polar forms.

Differential equations 2: Simple harmonic oscillator physics requires a different style of solution that will use Complex Numbers.

Manipulating Vectors: Dot Product and Cross Product and a few applications in Physics.

Introduction to multivariable calculus: if we need to describe physical phenomena, we need to be able to express quantities in more than one dimension. We look at how to interpret a scalar function of two variables as a surface.

Differential equations 3: We cover simple examples of multivariable differential equations (for example wave equation, Laplace equation, Diffusion Equation)

Integration 2: We introduce simple forms of multivariable integration (surface, volume, centre of mass)

Differential operators: We focus on definitions of vector functions and simple applications of div, grad, curl. We cover very simple examples of physics that requires the use of vector operators.

List of prerequisite knowledge:
Simple derivatives (polynomials, trigonometric, ln), product and chain rules for derivatives, simple integrals (polynomials, trigonometric, ln).

Mathematics for the Natural Sciences – Option 2

(Mathematics)

Dr Stephen Sawiak

Fellow, Tutor and College Lecturer in Mathematics at Fitzwilliam College, University of Cambridge

I am a physicist working with MRI. My research is in the areas of clinical and veterinary neuroscience and systems and computational neuroscience. My primary research interest has been in morphometry, with structural imaging, diffusion tensor imaging and spectroscopy. I am particularly focused on preclinical applications. I have been teaching the first year Mathematics course for Natural Scientists since 2006.

College Profile: https://www.fitz.cam.ac.uk/person/dr-stephen-sawiak

Module Structure and Syllabus:

Date	**29th July Monday**	**30th July Tuesday**	**31st July Wednesday**	**1st Aug Thursday**	**2nd Aug Friday**
	Series, sums, convergence	Taylor series	Fourier series	Multiple integrals	Surfaces
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	Matrices, linear transformations	Probability distributions	*t*-tests	Other distributions	Final Presentations

Series, sums and convergence: Arithmetic and geometric series, mixed series, defining an infinite sum, determining convergence, limits.

Taylor series: Finding power series from first principles, combining series and applications to approximation.

Fourier series: Expressing functions in terms of a series of sine and cosine basis functions, applications.

Multiple integration: Integration in multiple dimensions, spherical and cylindrical coordinates.

Surfaces: Partial differentiation, stationary points in problems with more than one variable, introduction to the gradient operator.

Matrices and linear transformation: Introduction to matrix algebra, applications to linear transformations.

Probability distributions: Statistics (mean, median, mode, variance), the Normal distribution, hypothesis testing.

***t*-tests:** One-sample, two-sample and paired tests.

Other distributions: Binomial and Poisson probability distributions with applications.

List of prerequisite knowledge:

Basic differentiation and integration, some vector algebra (dot product) useful but not essential.

Sustainable Vehicles
(Engineering)

Dr Andrea Giusti
Bye-Fellow, Fitzwilliam College, University of Cambridge
Lecturer in Thermofluids, Department of Mechanical Engineering, Imperial College London

Andrea is a Lecturer in Thermofluids at Imperial College London, Department of Mechanical Engineering and Bye-Fellow at Fitzwilliam College, Cambridge. He studied Mechanical and Energy Engineering in Florence (Italy). He obtained a PhD in 2014 at the University of Florence, working on a project for the development of clean engines for airplanes. Following his PhD, Andrea joined the Engineering Department at the University of Cambridge as a Rolls-Royce Research Associate. He was appointed Lecturer by Imperial College in October 2018. In addition to the academic role at Imperial College, Andrea supervises undergraduate students at Fitzwilliam College. He is also Editor-in-Chief of the International Journal of Spray and Combustion Dynamics.

College Profile: https://www.fitz.cam.ac.uk/people/dr-andrea-giusti
Departmental Profile: https://www.imperial.ac.uk/people/a.giusti

The objective of this short course is to learn the fundamentals to develop an innovative conceptual design of a sustainable vehicle. The set of problems designed to support the learning will lead the student to a proposal of an innovative vehicle and a critical evaluation of its feasibility.

Module Structure and Syllabus:

Date	**29th July Monday**	**30th July Tuesday**	**31st July Wednesday**	**1st Aug Thursday**	**2nd Aug Friday**
	Engineering and Innovation	Sustainability and Life cycle assessment	Vehicle dynamics	Hydrodynamic forces	Internal combustion engines
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	Fuels and emissions	Electrification of cars	Future vehicle concepts	Ethics and intellectual property	Final Presentations

1. **Engineering and Innovation**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: ideal engineering system, S-shaped curve, transition to the super-system, micro-scale interactions, systematic innovation, nature-inspired innovation, examples.
    c. In-class problems: finding bio-inspired solutions for the improvement of the performance of a car.
    d. Assignment: definition of ideal car and identification of barriers to innovation.

2. **Sustainability and Life cycle assessment**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: the lifecycle of a component/system, climate crisis, the concept of sustainability, multi-criteria decision analysis, the various phases of the life cycle assessment, example.
    c. In-class problems: life cycle assessment of a car.
    d. Assignment: multi-criteria decision analysis.

3. **Vehicle Dynamics**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: forces on vehicles, wheels and forces exchanged on the ground, power requirements.
    c. In-class problems: identification of engine power requirements for a given performance.
    d. Assignment: computation of power required for different slope angles.

4. **Hydrodynamic forces**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: fundamentals of friction and drag, flow separation, streamlining, wing profiles, lift and downforce.
    c. In-class problems: computations of reduction of drag (case study).
    d. Assignment: sketch of an aerodynamic vehicle.

5. **Internal Combustion Engines**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: overview of internal engines, fundamentals of thermodynamics, torque, power, efficiency.
    c. In-class problems: coupling between an engine and a car; introduction to gear box.

6. **Fuels and emissions**
    a. Duration: 3 hours (2 hours of lecture; 1 hours of problems/discussion)
    b. Syllabus: classification of fuels, emissions from engines, biofuels, hydrogen
    c. In-class problems: quantification of carbon dioxide emitted by hydrocarbon combustion.

7. **Electrification of cars**
    a. Duration: 3 hours (2.5 hours of lecture; 0.5 hours of problems/discussion)
    b. Syllabus: hybrid cars, fully electric cars, fundamentals of fuel cells and batteries, energy, and power density.
    c. In-class problems: coupling between a car and an electrical powertrain.

8. **Future vehicle concepts**
    a. Duration: 3 hours (1.5 hours of lecture; 1.5 hour of problems/discussion)
    b. Syllabus: autonomous vehicles, urban air mobility, electric aircraft.
    c. In-class problems: conceptual design of a sustainable vehicle.

9. **Ethics and Intellectual property**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: patents, copyright, registered design, trademark, confidentiality, professional ethics, engineering ethics.
    c. In-class problems: patent search, patent reading.

List of prerequisite knowledge:
Fundamental concepts of mechanics (Newton's second law, friction force, velocity, acceleration along a straight line); the concept of energy and power; the concept of pressure. Optional: chemical reactions (reading reactants and products; balancing the reaction).

Recommended reading list (optional):
Any book on physics for high school.

Computer Science

Dr John Fawcett
Churchill College, University of Cambridge

Since completing his PhD, John Fawcett has been working in industry alongside lecturing, tutoring, supervising and directing studies in Computer Science at Cambridge. Over more than 15 years, John has seen around 500 students through to graduation. John has delivered courses in summer schools for over 10 years and is active in undergraduate admissions, including as Subject Convenor for the Computer Science undergraduate course. John served as University Senior Proctor in the 2021/22 academical year after being Praelector for 6 years at Churchill.

College Profile: https://www.chu.cam.ac.uk/fellows/dr-john-fawcett/

Module Structure and Syllabus:

Date	**29th July Monday**	**30th July Tuesday**	**31st July Wednesday**	**1st Aug Thursday**	**2nd Aug Friday**
	Computer Architecture	Operating Systems 1	Operating Systems 2	Starting Processes	Interprocess Communication
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	Network communication	Graphics 1	Graphics 2	Graphics 3, GPUs and accelerators	Final Presentations

Each of the following will use lecture time to introduce and explain new concepts, followed each day with practical programming exercises: learning-by-doing through scaffolded exercises giving room for learners to solve problems in their own ways.

Computer Architecture: the components inside a computer and styles of interacting with them. Programmed I/O. Interrupts. DMA.

Operating Systems 1: virtual memory for protection between processes. Address translation. Hardware acceleration.

Operating Systems 2: cooperative and preemptive multi-tasking. Scheduling algorithms.

Starting Processes: system calls, fork(), the shell.

Interprocess Communications: understanding Unix pipes, marshalling datatypes into bytes.

Network communication: sockets, server applications, a simple webserver.

Graphics 1: ray-tracing, Phong shading, imperfect and perfect reflections.

Graphics 2: triangularisation, Painters' Algorithm, Z-Buffers.

Graphics 3: texture maps, bump mapping, displacement mapping.

GPUs and accelerators: contrasting CPU pipelines with GPUs, understanding vectorizable workloads, OpenGL/CUDA coding.

List of prerequisite knowledge:

No computer science knowledge is assumed but programming experience is always useful. Later work on graphics assumes knowledge of vectors and basic geometry.

Recommended reading list (optional):

Computer Architecture and Organisation, S.P. Wang, published by Springer. ISBN 978-981-16-5661-3 (e-book 978-981-16-5662-0).

Philosophy in Cambridge: past and present

(Philosophy)

Dr Alex Carter

Academic Director for Philosophy and Interdisciplinary Studies, Institute of Continuing Education, University of Cambridge

Fellow at Fitzwilliam College, University of Cambridge

Alex Carter is the academic director for philosophy and interdisciplinary studies at the Institute of Continuing Education, University of Cambridge, where he has designed and delivered courses in philosophy, ethics and creativity theory. He also oversees the Institute's undergraduate research courses. Alex is also a fellow at Fitzwilliam College where he supports students' study skills. His own research interests are diverse and include Wittgenstein's later philosophy, the theology of Simone Weil and the philosophy of humour. Alex's PhD thesis explored some of the surprising aspects of Wittgenstein's views concerning freedom and fatalism. Alex is currently researching the relationship between humour and creative practice via the concept of 'serious play'.

College Profile: www.fitz.cam.ac.uk/people/dr-alex-carter
LinkedIn: www.linkedin.com/in/adcphilosophy/

Date	**29th July Monday**	**30th July Tuesday**	**31st July Wednesday**	**1st Aug Thursday**	**2nd Aug Friday**
	Philosophy in Cambridge	Cambridge's Natural Philosophers	Cambridge Platonism	Sidgwick's Utilitarianism	Philosophy, Science and Religion
Date	**5th Aug Monday**	**6th Aug Tuesday**	**7th Aug Wednesday**	**8th Aug Thursday**	**9th Aug Friday**
	Cambridge's Analytic Philosophers	Wittgenstein's Foundations of Mathematics	Oxford Philosophy	Cambridge and Free Speech	Final Presentations

Philosophy in Cambridge: We will explore a map of Cambridge to identify the key places where philosophical discoveries took place, including Fitzwilliam College itself. This will give students an overview of the course and allow students to go out and see the places we are talking about.

Cambridge's Natural Philosophers: Today, we think of Newton and Darwin as scientists. But in their own time, they were natural philosophers. We will consider the controversial and groundbreaking discoveries of these two natural philosophers; as well as the philosophical insights that inspired them.

Cambridge Platonism: In 17th Century Cambridge witnessed a resurgence of Plato's philosophy, spearheaded by Ralph Cudworth and Henry More. This session will give us the opportunity to (re)consider Plato's philosophy through the writings of these Cambridge philosophers.

Sidgwick's Utilitarianism: The Sidgwick site in Cambridge is named after the famous ethicist, Henry Sidgwick. He asked his contemporaries to consider what is right *from the point of view of the Universe*. But what does this mean? We will look at more modern attempts to revive Sidgwick's ideas.

Philosophy, Science and Religion: We will reflect on some of the themes considered in the preceding session. Historically, how do science and philosophy interact, and is it the same today?

Cambridge's Analytic Philosophers: This session introduces the 20th Century philosophies of Russell, Moore and Wittgenstein. All three philosophers sought to provide definitive answers to questions about the nature of reality.

Wittgenstein on the Foundations of Mathematics: We will look more closely at what Wittgenstein thought about mathematics through the lectures he delivered in Cambridge in the early 20th Century. These lectures may (or may not) have influenced other important figures in Cambridge, including Frank Ramsey and Alan Turing.

Oxford Philosophy: Cambridge edition: Wittgenstein's philosophy of language had a huge influence on philosophy in the second half of 20th Century. Oxford Philosophy, also known as Ordinary Language Philosophy (OLP), was rooted in Wittgenstein's claim that "The meaning of a word is its use in the language". But what does OLP get wrong about his claim?

Cambridge and Free Speech: We will turn to a contemporary topic in philosophical debates: free speech. What is free speech and is it simply the avoidance of restricting speech? We will look at the recent work by Rae Langton and Arif Ahmed on the topic.

List of prerequisite knowledge:

There is no required prerequisite knowledge for this course. A broad familiarity with the items on the list above will greatly enhance your understanding and enjoyment of the classes and good preparation by all students will contribute significantly to the success of the course. It is hoped that students will apply existing knowledge in other fields, e.g. physics, mathematics, law, in discussing the above topics.

Recommended reading list (optional):

• Floyd, J., 2002. Wittgenstein, mathematics and philosophy. In The New Wittgenstein (pp. 242-271). Routledge. (Ideal for those interested in the philosophy of mathematics).
• Russell, B., 2001. The problems of philosophy. OUP Oxford. (This is a good introduction to Bertrand Russell's philosophy and to philosophy in general)

Microbiology & Microbial Genetics

(Biology)

Dr Ashraf Zarkan
Research Fellow and Group Leader, Department of Genetics, University of Cambridge
Bye-Fellow, Fitzwilliam College, University of Cambridge

Dr Ash Zarkan is a microbiologist with a long-standing interest in infectious diseases and microbial genetics. Ash is an expert on antimicrobial resistance (AMR), and his research is focused on tackling the rise of AMR, especially in the human pathogen *Escherichia coli* (*E. coli*). His clinical focus is on urinary tract infections (UTIs) where *E. coli* is the major pathogen affecting 150 million people per year worldwide. He is an active member of the Microbiology Society, and he serves as an academic reviewer for a number of prestigious microbiology journals and grant funding bodies. Ash has lectured on several summer programmes in Cambridge on topics ranging from infectious diseases, immunity, vaccination, and antimicrobial resistance. He is an excellent and very engaging speaker. His interactive teaching style brings the excitement and experience of his research to his audience. Ash is very passionate about tackling the rapid rise of AMR and hopes to convey his passion to those who attend his courses.

Departmental Profile: https://www.gen.cam.ac.uk/staff/dr-ashraf-zarkan
Cambridge Infectious Diseases Profile: https://www.infectiousdisease.cam.ac.uk/directory/dr-ashraf-zarkan
LinkedIn Profile: https://www.linkedin.com/in/ashraf-zarkan/

Date	**Monday 29th Jul**	**Tuesday 30th Jul**	**Wednesday 31st Jul**	**Thursday 1st Aug**	**Friday 2nd Aug**
	10am – 12noon Intro Microbiology 1.30-3.30pm Group Exercises	10am – 12noon Intro Pathogens 1.30-3.30pm **Practical Session**	10am – 12noon Transmission & Prevention 1.30-3.30pm Group Exercises	10am – 12noon The Immune System 1.30-3.30pm **Practical Session**	10am – 12noon Antimicrobial Therapies 1.30-3.30pm Group Exercises
Date	**Monday 5th Aug**	**Tuesday 6th Aug**	**Wednesday 7th Aug**	**Thursday 8th Aug**	**Friday 9th Aug**
	10am – 12noon Antimicrobial Resistance 1.30-3.30pm Group Exercises	10am – 12noon Biofilms 1.30-3.30pm **Practical Session**	10am – 12noon Vaccines 1.30-3.30pm Group Exercises	10am – 12noon Microbial Genetics 1.30-3.30pm **Practical Session**	Final Presentations

Intro Microbiology: Introduces students to the microbial world and its diversity.

Intro Pathogens: Introducing students to the main types of pathogens.

Transmission & Prevention: Methods that are used for pathogen transmission (how do they make us sick?) and approaches for infection prevention.

The Immune System: The role of our immune system in combatting infectious diseases.

Antimicrobial Therapies: The range and mechanisms of antimicrobial medications against infectious pathogens.

Antimicrobial Resistance (AMR): what is it and why is it happening? What is the scale of the problem?

Biofilms: An overview of microbial biofilms and their role in infection and AMR.

Vaccines: Introduction to the principle and mechanisms of vaccines.

Microbial Genetics: Introduction to the main aspects of microbial genetic (DNA, RNA, replication…etc).

Pathogens Overview: Overview of some important pathogens and their role in infectious diseases.

List of prerequisite knowledge: There is no required prerequisite knowledge for this course. A broad familiarity with the items on the list above will greatly enhance your understanding and enjoyment of the classes and good preparation by all students will contribute significantly to the success of the course.

Recommended reading list (optional):

Anderson, D. *Introduction to Microbiology*. Mosby, 1980
Not complex but a bit old now. It covers a lot of what we will be covering in the course.

Jacob, Francois and Jacques Monod. *Genetic regulatory mechanisms in the synthesis of proteins.* "What is true for *E. coli* is true for an elephant.....".
A classic paper, www.sciencedirect.com/science/article/pii/S0022283661800727

Madigan, M et al. *Brock Biology of Microorganisms*. Pearson, 2014
A useful (albeit detailed) introduction to microbiology for readers with a good level of background knowledge.

Kenneth Todar's online textbook of microbiology, http://textbookofbacteriology.net/
A fairly detailed introduction for the interested amateur.

For pure fun (plus easy accessibility of the papers, because they're linked) have a look at the PNAS list of "classics". They're from a variety of sciences, including microbiology, so you'll have to do a bit of sifting/filtering: www.pnas.org/site/classics/pnas_classics.xhtml

Practical hours: 8 hours in total, 2 hours per session on Tuesday 30th July, Thursday 1st August, Tuesday 6th August & Thursday 8th August.