FitzEd Summer School 2025 - Programme 2

Course brochure

Enjoy browsing the detailed description of all of courses that we are going to offer as part of the FitzEd Summer School in Programme 2 (27th July - 9th August, 2025). For each course you will also find a list of prerequisite knowledge and corresponding problems to test your readiness for our courses. To help you catch up on prerequisites that you may not meet yet, we recommended an optional reading list for most of the courses.

Dr Peter Bolgar
Director of Summer School Programme

Contents:

FITZWILLIAM COLLEGE
UNIVERSITY OF CAMBRIDGE

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Psychology and Neuroscience, Option 2

Dr Katharina Zuhlsdorff
Bye-Fellow and College Lecturer at Downing College, University of Cambridge

Dr Zsófia Zavecz
Research Associate at the Department of Psychology, University of Cambridge

28th July - 8th August, 2025

Dr Katharina Zuhlsdorff is a visiting postdoctoral fellow at the Department of Psychology, University of Cambridge and a Bye-Fellow/Teaching Associate at Downing College. Katharina completed her PhD in the department on the topic of computational modelling of behavioural and neuroimaging data in patients with major depressive disorder and substance use disorder. Specifically, her research focussed on reinforcement learning and its underlying neural basis. Katharina's postdoctoral work has focussed on developing predictive models of dementia and depression using cognitive and MRI data and graph neural networks. This work has included the use of large-scale datasets such as the UK Biobank and Adolescent Brain Cognitive Development studies. Katharina has received awards from the Alan Turing Institute, Foulkes Foundation and the Angharad Dodds John fellowship from Downing College.

https://www.researchgate.net/profile/Katharina_Zuehlsdorff

Zsófia Zavecz is a postdoctoral research associate at the Department of Psychology, University of Cambridge. Her research areas are memory and sleep, with a particular emphasis on understanding the neural mechanisms of these processes. She was awarded a PhD in Psychology at the Eötvös Loránd University (Hungary) in 2020. In her doctoral work, she studied the differential association of implicit learning with sleep compared to explicit learning. She also used different techniques to examine the neural background of implicit learning, such as EEG, transcranial electric stimulation, and fMRI. After her PhD, Zsófia joined UC Berkeley (US) as a postdoctoral researcher, where she examined sleep as a protective factor against memory impairment in the face of Alzheimer's disease pathology. For her second postdoctoral position, Zsófia moved to Cambridge to apply cutting-edge neuroimaging methods to investigate the neural mechanisms of perceptual learning.

https://www.researchgate.net/profile/Zavecz-Zsofia

Module Structure and Syllabus:

This course offers a comprehensive introduction to key areas of psychology and neuroscience. It begins with fundamental concepts and methods in psychology, followed by specialised topics such as electrophysiology and sleep research, memory systems, and higher-order cognitive functions. Students will also explore computational neuroscience, neuroimaging, and psychopharmacology, with a hands-on approach to problem-solving, essay writing, and research presentations. The program emphasises active learning through supervised sessions and group discussions, culminating in final presentations of individual research projects.

Date	28th July Monday	29th July Tuesday	30th July Wednesday	31st July Thursday	1st Aug Friday
	Introduction to the fundamentals of psychology and neuroscience Dr Zavecz	Electro-physiology and sleep research Dr Zavecz	Memory systems and their disorders Dr Zavecz	Supervision Day 1 Dr Zavecz	Higher order cognitive functions and neuro-psychological disorders Dr Zavecz
Date	4th Aug Monday	5th Aug Tuesday	6th Aug Wednesday	7th Aug Thursday	8th Aug Friday
	Introduction to computational neuroscience and machine learning Dr Zuhlsdorff	Applications of neuroimaging and psycho-pharmacology Dr Zuhlsdorff	Guided Presentation and Essay Writing Dr Zuhlsdorff	Supervision Day 2 Dr Zuhlsdorff	Final Presentations Dr Zuhlsdorff

Introduction to the fundamentals of Psychology and Neuroscience: The objective of the first lecture is to introduce the fundamental notions of psychology and neuroscience and to provide an overview of the wide array of the methods that can be deployed in psychology and behavioural science research.

Electrophysiology and sleep research: In this lecture, the students will be introduced to the fundamentals of human physiological signals, with a focus on EEG and brain activity. Relatedly, applications of these to sleep research will be discussed with basic sleep research topics introduced.

Memory systems and their disorders: This lecture will focus on introducing different memory systems including their assessments methods, neural background and disorders where these memory functions are impaired (such as dementia).

Supervision Day 1: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will be expected to solve the problems before your supervision and bring along your answers to the session for discussion. You will also have a chance to ask questions about anything that was unclear at the lectures.

Higher order cognitive functions and neuropsychological disorders: This lecture will introduce higher order cognitive functions, including executive functions, attention and language skills and neuropsychological disorders where these cognitive functions are impaired.

Introduction to Computational Neuroscience and machine learning: This part of the course will focus on introducing students to the behavioural and neural mechanisms of learning and models used for quantifying learning such as reinforcement learning models. Furthermore, different types of machine learning methods will be discussed, as well as how they can be applied to behavioural and neuroimaging data.

Application of neuroimaging and psychopharmacology: Students will be introduced to a variety of neuroimaging methods such as structural and functional magnetic resonance imaging and magnetic resonance spectroscopy. Their application in psychological and clinical neuroscience will be discussed. The second half of the day will cover mechanisms underlying neurotransmitter signalling in the brain, how these give rise to behaviour, and how they can be targeted by pharmacological interventions.

Guided Presentation and Essay Writing: Guided, individual work on your research projects led by the course instructor. You will work on your essay and presentation with the course instructor in the classroom available to give instant advice.

Supervision Day 2: Small group (3-4 participants per group) sessions led by your course instructor where you will receive feedback on your essay and presentation drafts. Bring along the drafts to the supervision and develop your work following the course instructor's feedback.

Final presentations: You will present your research to other participants on the course and the course instructor.

List of prerequisite knowledge:
There is no prerequisite knowledge for this course. Strong analytical skills and a keen interest in Psychological and Behavioural Sciences will be particularly helpful. The course will be suitable for students interested in Psychology, Cognitive Neuroscience, Computational Neuroscience, Neuroimaging, Behavioural Neuroscience, Neuropsychopharmacology, and Neuroscience.

Test your knowledge of the prerequisites! Can you answer the questions below?
1. Can you list 3 neuroimaging or electrophysiological methods to study brain activity? What is the difference between them and what are the strengths and weaknesses of each?
2. How does the information spread in the brain?
3. List 5 main cognitive functions of the brain and disorders they might be impaired in.

Recommended reading list (optional):
Principles of Neural Science – Kandel
Fundamentals of Human Neuropsychology – Bryan Kolb and Ian Q. Whishaw
Reinforcement learning: an introduction – Sutton and Barto
An Introduction to resting state fMRI functional connectivity – Bijsterbosch, Smith, Beckmann

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Business Economics

Professor Christos Genakos
Professor of Economics and Policy, Cambridge Judge Business School
Director of the MPhil in Technology Policy Programme
Director of Studies in Management and Fellow in Economics at Fitzwilliam College
BSc (National and Kappodistrian University of Athens), MSc (University College London), PhD (London Business School)

28ᵗʰ July-8ᵗʰ August, 2025

Prof Genakos' research focuses on applied microeconomics, with an emphasis on industrial organization and quantitative techniques for competition analysis and regulation. He has published in many leading international peer-refereed journals and has advised many leading firms and international organizations on regulation, antitrust and pricing related issues. He is a College Lecturer in Economics, and directs studies in Management.

College Profile: https://www.fitz.cam.ac.uk/person/professor-christos-genakos
Judge Business School Profile: https://www.jbs.cam.ac.uk/people/christos-genakos/

Module Structure and Syllabus

Business economics covers the economic foundations of managerial decision making. In this module, we explore the importance of economics and how it relates to our everyday lives. Our task is to develop familiarity with microeconomic models to better understand concepts such as costs, demand, profit, competition, pricing, compensation and market entry strategy and to acquire the more subtle ability to apply them to real and simulated situations with a focus on learning how to "think like a manager" applying this thinking process to improve managerial decisions.

Date	28ᵗʰ July Monday	29ᵗʰ July Tuesday	30ᵗʰ July Wednesday	31ˢᵗ July Thursday	1ˢᵗ Aug Friday
	Introduction to business economics	Demand, Supply and Market Equilibrium	Firm Production Process: Technology and Costs	Supervision Day 1	The analysis of competitive markets
Date	4ᵗʰ Aug Monday	5ᵗʰ Aug Tuesday	6ᵗʰ Aug Wednesday	7ᵗʰ Aug Thursday	8ᵗʰ Aug Friday
	Market power	Game theory and competitive strategy	Guided Presentation and Essay Writing	Supervision Day 2	Final Presentations

Introduction to business economics: Define economics and its relation to the other sciences, explore the importance of economics and how it relates to our everyday lives, review fundamental concepts in economics and economic thinking.

Demand, Supply and Market Equilibrium: Understand and be able to work with the basic theory of demand and supply and market equilibrium. Apply supply and demand analysis as a qualitative forecasting tool to explain the effects of interventions in competitive markets.

Firm Production Process: Technology and Costs: Explain alternative ways of measuring input productivity and the role of the manager in the production process, distinguish between the short and long run input decisions, explain how economic costs differ from accounting costs, explain the difference and the economic relevance of fixed costs, sunk costs, variable costs and marginal costs, understand economies of scale and economies of scope.

Supervision Day 1: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will be expected to solve the problems before your supervision and bring along your answers to the session for discussion. You will also have a chance to ask questions about anything that was unclear at the lectures.

The analysis of competitive markets: understand the basic model of perfect competition and applications of this framework in evaluating the gains and losses from government policies.

Market power: understand the monopoly model and basic notions of price discrimination as well as the social costs of monopoly power and how regulation can limit market power.

Game theory and competitive strategy: key ideas of game theory in static and dynamic games and applications of these ideas in modelling oligopoly markets.

Guided Presentation and Essay Writing: Individual work on your research projects led by the course instructor. You will work on your essay and presentation with the course instructor guiding you through your research.

Supervision Day 2: Small group (3-4 participants per group) sessions led by your course instructor where you will receive feedback on your essay and presentation drafts. Bring along the drafts to the supervision and develop your work following the course instructor's feedback.

Final presentations: You will present your research to other participants on the course and the course instructor.

List of prerequisite knowledge:
Algebra: taking derivatives and differentiation.

Test your knowledge of the prerequisites! Can you answer the questions below?
Why do brown eggs cost more (and sell less) than white eggs?
Why do airlines charge much more for tickets purchased at the last minute, while West End theaters follow the opposite practice?
Is it always beneficial to act first and charge a price for your product when you are competing with other firms in a market?

Optional Reading:
Dasgupta (2007) *Economics: A Very Short Introduction*
Dixit (2014) *Microeconomics: A Very Short Introduction*

Chemistry

Dr Andrea Chlebikova
Senior Project Chemist at Isaac Physics, Department of Physics, University of Cambridge
College Teaching Associate at Sidney Sussex College
Special Supervisor at Newnham College
Course lecturer, Yusuf Hamied Department of Chemistry, University of Cambridge

Dr Peter Bolgar
Bye-Fellow at Fitzwilliam College, University of Cambridge
Director of Studies and College Lecturer at Magdalene College, University of Cambridge
Lecturer (Teaching) at University College London

27th July - 8th August, 2025

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: Dr Andrea Cheblikova | Sidney Sussex College Cambridge

Peter Bolgar is a teaching Bye-Fellow in organic and bio-organic chemistry at Fitzwilliam College. He completed his undergraduate degree in Natural Sciences at Cambridge, followed by a PhD in supramolecular chemistry at the same place. His research focused on the synthesis and characterisation of sequence polymers that are able to form sequence-selective duplexes, similar to nucleic acids. Peter now specialises in teaching chemistry at the university level, lecturing a range of courses from the first, second and third year of the undergraduate curriculum. He is involved with undergraduate admissions at Magdalene College. Peter is a member of the UK Chemistry Olympiad Committee, and he mentors students for the International Chemistry Olympiad both nationally and internationally.

College Profile: https://www.fitz.cam.ac.uk/person/dr-peter-bolgar

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Module Structure and Syllabus:

This course lets participants explore advanced topics in physical and organic chemistry, each of which are fundamental to your studies of a chemistry degree. The course is built on concepts that you will be familiar with from school curriculum. We will quickly extend your knowledge in the fields of atomic and molecular orbital theory, thermodynamics, kinetics and organic reactivity to give you a significant head start in your university education. You will be able to practice your experimental skills as well through a practical class in physical chemistry. We are looking forward exploring the highlights of first year undergraduate-level Chemistry curriculum with you!

Date	28th July Monday	29th July Tuesday	30th July Wednesday	31st July Thursday	1st Aug Friday
	Physical Chemistry: Thermodynamics Dr Chlebikova	Physical Chemistry: Kinetics Dr Chlebikova	Theoretical Chemistry: Quantum Mechanics Dr Chlebikova	Supervision Day Dr Chlebikova	Organic Chemistry: Isomerism, Conjugation, Acids & Bases Dr Bolgar
Date	4th Aug Monday	5th Aug Tuesday	6th Aug Wednesday	7th Aug Thursday	8th Aug Friday
	Organic Chemistry: Introduction to Organic Reaction Mechanisms Dr Bolgar	Organic Chemistry: Introduction to Reaction Types Dr Bolgar	Guided Presentation and Essay Writing Dr Chlebikova	Laboratory Day Dr Chlebikova	Final Presentations Dr Chlebikova

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? We will also apply our new understanding to discuss spectroscopic techniques that allow chemists to study compounds and chemical reactions.

Supervision Day: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will be expected to solve the problems before your supervision and bring along your answers to the session for discussion. You will also have a chance to ask questions about anything that was unclear at the lectures.

Isomerism, Conjugation, Acids & Bases: You will learn about different types of isomerism and explore the topic of chirality and its relevance to everyday life. We will discuss principles influencing electron

distribution in molecules and then look at factors that govern the acidity and basicity of organic compounds. Appreciation of acidity and basicity trends will help you better understand the reactivity of organic molecules, and why one reaction might be favoured over another when multiple reactions could take place.

Introduction to Organic Reaction Mechanisms: Understanding organic reaction mechanisms is a key skill to have for any undergraduate chemist. Following the introduction of simple concepts such as electrophiles and nucleophiles, you will learn the framework that experienced chemists use to describes organic reactions. This will enable you to rationalise reactions that you haven't seen before and lead to your much deeper understanding of organic chemistry.

Introduction to Reaction Types: We will introduce the concept of oxidation levels to help you classify organic reactions. This will be followed by a discussion of the most common types of organic reactions and factors that govern them.

Guided Presentation and Essay Writing: Individual work on your research projects led by the course instructor. You will work on your essay and presentation with the course instructor guiding you through your research.

Laboratory Day: This session will include a practical component where you will have to plan and carry out a chemistry experiment. You will have to interpret the data you obtain and reach conclusions on the basis of your findings.

Final presentations: You will present your research to other participants on the course and the course instructor.

List of prerequisite knowledge:
Confidence with algebraic manipulation of expressions, including logarithms.
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).

Test your knowledge of the prerequisites! Can you answer the questions below?
1. Calculate the volume of 0.1 molar sulfuric acid necessary to neutralise 25.6 grams of calcium hydroxide.
2. Rearrange $k = Ae^{-\frac{E_a}{RT}}$ for T.
3. Draw a structural formula for propanoic acid and but-1-enol.

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

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Elements of Mathematical Economics

(Mathematics and Economics)

Dr Vasileios Kotsidis

College Assistant Professor at Gonville and Caius College

27th July - 8th August, 2025

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.

Department profile: https://www.econ.cam.ac.uk/people/cto/vk340

Module Structure and Syllabus:

This course explores some fundamental notions and results that are of special importance of economic analysis. It begins by considering elements of set theory, analysis, optimisation calculus, and statistics. It then applies them to construct a series of progressively more elaborate logical statements which form the basis of formal choice under risk. The result is a robust and analytically tractable approach to reasoning about uncertainty.

Date	28th July Monday	29th July Tuesday	30th July Wednesday	31st July Thursday	1st August Friday
	Elements of Mathematics I	Elements of Mathematics II	Elements of Statistics I	Supervision Day 1	Elements of Statistics II
Date	4th Aug Monday	5th Aug Tuesday	6th Aug Wednesday	7th Aug Thursday	8th Aug Friday
	Rational Choice Theory I: Uncertainty	Rational Choice Theory II: Information	Guided Presentation and Essay Writing	Supervision Day 2	Final Presentations

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 under uncertainty and examine some applications in economic transactions. They discuss, in particular, attitudes towards risk, stochastic dominance, and the incorporation of new information into decision-making.

Supervision Day 1: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will be expected to solve the problems before your supervision and bring along your answers to the session for discussion. You will also have a chance to ask questions about anything that was unclear at the lectures.

Guided Presentation and Essay Writing: Individual work on your research projects led by the course instructor. You will work on your essay and presentation with the course instructor guiding you through your research.

Supervision Day 2: Small group (3-4 participants per group) sessions led by your course instructor where you will receive feedback on your essay and presentation drafts. Bring along the drafts to the supervision and develop your work following the course instructor's feedback.

Final presentations: You will present your research to other participants on the course and the course instructor.

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

Test your knowledge of the prerequisites! Can you answer the questions below?
1. What does it meant to state that some function, f, is continuous?
2. What does it mean to state that some function, f, is differentiable?
3. Consider two sets, A and B. Suppose that A is a subset of B. What are then the union and the intersection of A and B?

Biology: 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

27th July - 8th August, 2025

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/

Module Structure and Syllabus:

Microbes are the dominant life-form on the planet; they have been around longer than anything else, and they are more numerous than anything else. In fact, it is no understatement to say that we are guests in a microbial world. In this course, we'll explore the microbial world and look at how our preconceptions are changing as a result of new discoveries. We'll see how microbes have a thriving social life, and how this is tied in with the propensity of some species to cause disease and the rising problems of antimicrobial resistance. Your Course Lecturer, Dr Ash Zarkan, hopes that his enthusiasm for the subject will be.... "infectious"!

Date	28th July Monday	29th July Tuesday	30th July Wednesday	31st July Thursday	1st August Friday
	Microbiology & Pathogens	Transmission, Prevention, and the Immune System and Practical Session	Microbial Genetics & Vaccine Development	Supervision Day 1 and Practical Session	Antimicrobial Therapies & Antimicrobial Resistance
Date	4th Aug Monday	5th Aug Tuesday	6th Aug Wednesday	7th Aug Thursday	8th Aug Friday
	Biofilms and Persisters	Pathogens Overview and Practical Session	Guided Presentation and Essay Writing	Supervision Day 2 and Practical Session	Final Presentations

Microbiology & Pathogens: Introduction to the microbial world and its diversity as well as the main types of pathogens.

Transmission, Prevention, and the Immune System: Methods that are used for pathogen transmission (how do they make us sick?) and approaches for infection prevention. The role of our immune system in combatting infectious diseases.

Microbial Genetics and Vaccine Development: Introduction to the main aspects of microbial genetic (DNA, RNA, replication…etc), and introduction to the principle and mechanisms of vaccine development, using COVID-19 vaccines as examples.

Supervision Day 1: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will be expected to solve the problems before your supervision and bring along your answers to the session for discussion. You will also have a chance to ask questions about anything that was unclear at the lectures.

Antimicrobial Therapies & Antimicrobial Resistance: The range and mechanisms of antimicrobial medications against infectious pathogens. Introduction to antimicrobial resistance, what is it and why is it happening? What is the scale of the problem?

Biofilms and Persisters: An overview of microbial biofilms and their role in infection and antimicrobial resistance. An introduction to bacterial persisters, their rule in infections and association with biofilms.

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

Guided Presentation and Essay Writing: Individual work on your research projects led by the course instructor. You will work on your essay and presentation with the course instructor guiding you through your research.

Supervision Day 2: Small group (3-4 participants per group) sessions led by your course instructor where you will receive feedback on your essay and presentation drafts. Bring along the drafts to the supervision and develop your work following the course instructor's feedback.

Final presentations: You will present your research to other participants on the course and the course instructor.

Practical sessions: 8 hours in total, 2hours per session from 1-3pm on Tuesday 29th July, Thursday 31st July, Tuesday 5th August & Thursday 7th August. The practical sessions will include two main experiments on (i) bacterial growth and identification and (ii) bacterial genetic transformation.

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.

Test your knowledge of the prerequisites! Can you answer the questions below?
1. What properties make a given species of bacteria 'pathogenic'?
2. Do bacteria communicate with one another? If so, how do they do this?
3. How do antibiotics work? Is there such a thing as 'the perfect antibiotic'?

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

Computer Science: Cybersecurity

Dr John Fawcett
Fellow and Director of Studies, Churchill College, University of Cambridge

27th July - 8th August, 2025

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:

We hear about data breaches at one company after another, of hacks, exploits, and companies' data being encrypted for ransom. What's going on? Why is everyone's security so easily defeated, and what can we do about it? This course looks at security on the Internet, security on mobile devices, and defensive coding techniques we can all use to write better software. We explore some techniques that can scan programs for vulnerabilities and we will see the tools used in industry today to manage risk in the cyber sector.

Date	28th July Monday	29th July Tuesday	30th July Wednesday	31st July Thursday	1st August Friday
	Attack vectors and categories of attack	Defensive coding	Defensive infrastructure	Supervision Day 1	Security on the Internet
Date	4th Aug Monday	5th Aug Tuesday	6th Aug Wednesday	7th Aug Thursday	8th Aug Friday
	Security on mobile devices	Key management	Guided Presentation and Essay Writing	Supervision Day 2	Final Presentations

Attack vectors and categories of attack: this lecture considers the many ways of attacking computer programs and the networks that interconnect them. You will learn how the representation of data in computer memories leaves poorly designed programs open to attack.

Defensive coding: this lecture explores how to write programs with security in mind and also looks at the modern tools that are available to help write secure software and to detect vulnerabilities before they hit production environments.

Defensive infrastructure: here, we learn that our best efforts are likely to be out-smarted so we build defence in depth by looking at how we can protect different parts of our systems from one another, what zero-trust looks like in practice, and how to test the security of our infrastructure.

Fitzwilliam College reserves the right to changes to the course content or the course instructor.

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Supervision Day 1: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will be expected to solve the problems before your supervision and bring along your answers to the session for discussion. You will also have a chance to ask questions about anything that was unclear at the lectures.

Security on the Internet: this lecture looks at the specific issues with Internet-facing systems and programs that run in web-browsers on untrusted devices.

Security on mobile devices: we look at how the hardware features of a mobile device allow us to build in additional security, and also how mobile devices introduce new challenges for the cybersecurity professional.

Key management: it is important to understand how cryptographic keys are used, what protection they can offer, and how to use them. Incorrect key management is a cause of cybersecurity incidents and so is a critical piece of the puzzle in building a secure system!

Guided Presentation and Essay Writing: Individual work on your research projects led by the course instructor. You will work on your essay and presentation with the course instructor guiding you through your research.

Supervision Day 2: Small group (3-4 participants per group) sessions led by your course instructor where you will receive feedback on your essay and presentation drafts. Bring along the drafts to the supervision and develop your work following the course instructor's feedback.

Final presentations: You will present your research to other participants on the course and the course instructor.

List of prerequisite knowledge:
Some experience with C or C++.
Experience with setting up cryptographic keys is helpful but not essential.

Test your knowledge of the prerequisites! Can you answer the questions below?
1. How is a string represented in a computer memory?
2. What is a "stack frame"?
3. What is the difference between encrypting and signing a message?

Mathematics for the Natural Sciences, Option 2

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

27th July - 8th August, 2025

Serena Povia specialises in teaching Mathematics and Physics at the University level. She has been a supervisor in physics and mathematics for the Natural Sciences course for about ten years. Current teaching commitment are the Physics and Mathematics courses for the first year and the second year. Sereba previously taught third year courses too.

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

Module Structure and Syllabus:

Date	28th July Monday	29th July Tuesday	30th July Wednesday	31st July Thursday	1st August Friday
	Differential Equations 1	Integration 1	Complex Numbers	Supervision Day 1	Differential Equations 2
Date	4th Aug Monday	5th Aug Tuesday	6th Aug Wednesday	7th Aug Thursday	8th Aug Friday
	Introduction to multivariable calculus	Differential Equations 3	Guided Presentation and Essay Writing	Supervision Day 1	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.

Supervision Day 1: Discussing your answers to a problem set in small groups (3-4 participants per group) led by me. You will be expected to solve the problems before your supervision and bring along your answers to the session for discussion. You will also have a chance to ask questions about anything that was unclear at the lectures.

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

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. We may have time to cover some examples of multivariable integration.

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

Guided Presentation and Essay Writing: Individual work on your research projects (essay and presentation) led by me.

Supervision Day 2: Small group (3-4 participants per group) sessions where you will receive feedback on your essay and presentation drafts. Bring along the drafts to the supervision and develop your work following the course instructor's feedback.

Final presentations: You will present your research to other participants on the course and the course instructor.

Prerequisites: derivatives (polynomials, trigonometric, exponentials, ln), product and chain rules for derivatives, integrals (polynomials, trigonometric, exponentials, ln), integrations by substitution, at least some knowledge of complex numbers.

Note: this course will be very closely targeted at students between lower and upper sixth, those who have not seen and worked on the following pre-requisites will find the course very hard. Those who have already completed pre-university studies might find at least half of the course too easy. A question sheet will be pre-circulated to participants two weeks before the course to ensure that the prerequisites are met.

Fitzwilliam College reserves the right to changes to the course content or the course instructor.

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Mechanical and Electrical Engineering

Dr Miles Stopher
Director of Admissions and Affiliated Lecturer, Department of Engineering, Cambridge
Senior Lecturer, Fellow and Director of Studies in Engineering, Homerton College
Bye-Fellow in Engineering at Jesus College and Fitzwilliam College

27th July - 8th August, 2025

Dr Miles Stopher is a Senior Lecturer in Engineering at Homerton College and the Director of Admissions and an Affiliated Lecturer in the Department of Engineering. He is a Bye-Fellow of Fitzwilliam College, having previously been Acting Senior Tutor. He has supervised and directed studies in Engineering for 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. 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:

Engineering has many branches, but the oldest and broadest is mechanical engineering. Mechanical engineers look at the design, analysis, and manufacturing of mechanical systems and machines that keep our world moving forward. Electrical engineering was born in the 18th century, known then as "the youngest of the sciences". Electrical engineers study electricity, electronics and electromagnetism, and their application in the design, development, and testing of systems. This intensive course offers a valuable insight into what it is like to study mechanical or electrical engineering at university, covering the most prominent specialisms within the fields. Students will study the foundational concepts on which such specialisms are built and apply them to real-world problems, acquiring the skills and knowledge necessary to gain a head start in studying engineering at university.

Fitzwilliam College reserves the right to changes to the course content or the course instructor.

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Date	28th July Monday	29th July Tuesday	30th July Wednesday	31st July Thursday	1st Aug Friday
	Mechanical Engineering: Aerospace	Mechanical Engineering: Combustion Engines	Mechanical Engineering: Nuclear Reactor design	Supervision Day 1: Mechanics problems	Electrical Engineering: Integrated Digital Electronics
Date	**4th Aug Monday**	**5th Aug Tuesday**	**6th Aug Wednesday**	**7th Aug Thursday**	**8th Aug Friday**
	Electrical Engineering: Renewable Electrical Power	Electrical and Mechanical Engineering: Robotics	Guided Presentation and Essay Writing	Supervision Day 2: Electronics problems	Final Presentations

Mechanical Engineering, Aerospace: Engineering has many branches, but the oldest and broadest is mechanical engineering. Mechanical engineers look at the design, analysis, and manufacturing of systems that keep our world moving forward. In the mechanical engineering section of this course, you will focus on how mechanical engineers are working towards sustainable solutions within three key industries: aerospace, energy and transport. On your first day, you will be taught the fundamentals necessary to understand several advanced concepts in aerodynamics, how they constrain aircraft design and the engineering challenge of reducing aviation's carbon footprint.

Mechanical Engineering, Combustion Engines: On the second day, you are introduced to the fundamental concepts of combustion and their influence on the design of internal combustion engines, such as those found in cars, and gas turbines, such as those found in jet planes. You will then learn cutting-edge approaches to apply low-carbon fuels in such engines.

Mechanical Engineering, Nuclear Reactor Design: On your final day of teaching for the mechanical engineering section of the course, you will learn the fundamentals of nuclear reactor design, both fusion and fission. You will study the range of designs in use today and those proposed for the future, focusing on the materials challenges presented by the extreme environments of such designs.

Supervision Day 1, Mechanics Problems: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will be expected to solve the problems before your supervision and bring along your answers to the session for discussion. You will also have a chance to ask questions about anything that was unclear during the lectures.

Electrical Engineering, Integrated Digital Electronics: Electrical engineering is the study of electricity, electronics and electromagnetism, and the design of systems based on the respective principles. This section of the course will introduce three exciting industries where electrical engineers play a key role in design, development and testing: integrated circuits, power generation and robotics. On day 1**,** you will study the fundamental technologies that serve as building blocks to modern digital circuits and their applications. You will learn the fundamentals of design and operation of the major digital integrated circuit technologies, discuss the importance of miniaturising digital circuits and their role in microprocessors, memories and programmable logic devices.

Electrical Engineering, Renewable Electrical Power: On your second day of teaching, you will learn about the key types of renewable electrical power, the electrical technologies that support them, how they are incorporated into existing electrical transmission and distribution networks and the impact of government policy and economics on their viability.

Electrical and Mechanical Engineering, Robotics: On your final day, we will look at the multidisciplinary field of robotics. You will learn what is involved in the design, construction and use of robots from a mechanical and electrical perspective, building on your knowledge learnt across the programme. You will study the fundamentals of robotics and the technologies and techniques used to design, assemble, and control robots.

Guided Presentation and Essay Writing: Individual work on your research projects led by the course instructor. You will work on your essay and presentation with the course instructor guiding you through your research.

Supervision Day 2, Electronics Problems: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will be expected to solve the problems before your supervision and bring along your answers to the session for discussion. You will also have a chance to ask questions about anything that was unclear during the lectures.

Final presentations: You will present your research to other participants on the course and the course instructor.

List of prerequisite knowledge:

The emphasis during the course will be on the physical understanding of the principles involved. Only elementary mathematical methods will be used. The key is the engineering and not the mathematics behind it. As such, I expect students to have a basic awareness of circuits and their components, alongside a basic understanding of mechanics (see below).

**Test your knowledge of the prerequisites! Can you answer the questions below?**

1. Name the components (A, B, C, D and E) in the circuit below:
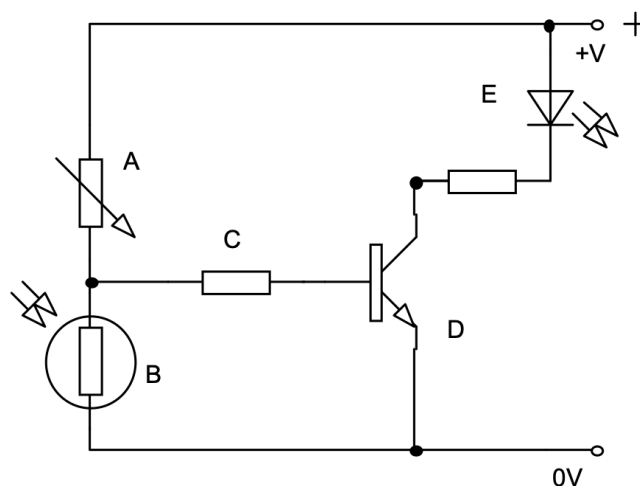
2. A train travels from town A to town B ,as shown in the scale diagram below.

   a) The distance the train travels between A and B is not the same as the displacement of the train. What is the difference between distance and displacement?
   b) Use the figure below to determine the displacement of the train in travelling from A to B.

c) There are places on the journey where the train accelerates without changing speed. Explain how this can happen.

Train route

Town B

N

Town A

Scale

1 cm represents 5 km
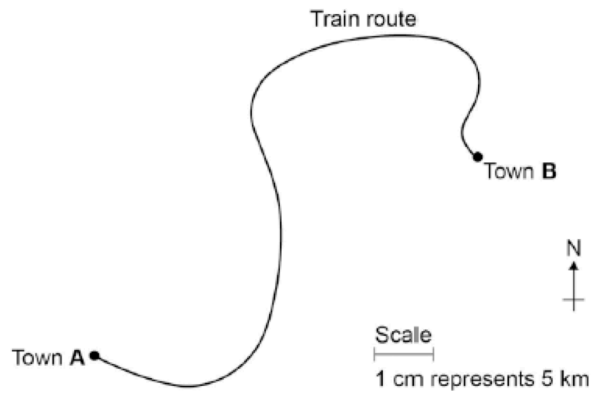
d) The Figure below shows how the velocity of the train changes with time as the train travels along a straight section of the journey. Estimate the distance travelled by the train along the section of the journey shown.

Fitzwilliam College reserves the right to changes to the course content or the course instructor.

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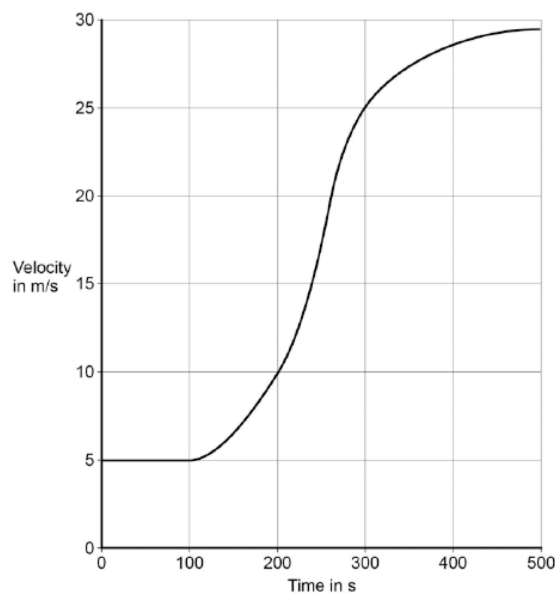
Medicine

27th July - 8th August, 2025

Professor Matthew J. Mason

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

Matt is a physiology lecturer in the Department of Physiology, Development & Neuroscience at the University of Cambridge. He teaches and examines Cambridge undergraduate medical students in physiology.

Prof. Matthew J. Mason | Department of Physiology, Development and Neuroscience (cam.ac.uk)

Dr Aaron D'sa

Consultant in Anaesthesia and Pain Medicine at Norfolk and Norwich University Hospital, Fellow at Fitzwilliam College, University of Cambridge

Aaron is an anaesthetist, and is involved in teaching undergraduate medical students physiology and neuroscience at the university. He has an interest in law and ethics.

Dr Aaron D'Sa | Fitzwilliam College, Cambridge | College of the University of Cambridge

Dr Saeed Kayhanian

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

Saeed is a neurosurgeon at Addenbrooke's Hospital and teaches anatomy to medical students at Fitzwilliam College. He has a research interest in brain injury and cell therapy for the treatment of neurological disease.

https://www.fitz.cam.ac.uk/person/dr-saeed-kayhanian

Dr Robert Abayasekara

Lecturer in Human Reproduction and Director of Pre-Clinical studies for Medicine, Admissions Tutor in Sciences, Fellow at Fitzwilliam College, University of Cambridge

Robert is a highly experienced medical and veterinary educator who has taught Endocrinology and Reproduction in Oxford, London and Cambridge.

Dr Robert Abayasekara | Fitzwilliam College, Cambridge | College of the University of Cambridge

Fitzwilliam College reserves the right to changes to the course content or the course instructor.

Module Structure and Syllabus:

The FitzEd Medicine course offers pre-university students an insight into medical science, current issues in healthcare and developments in medical technology. You will have the opportunity to extend your understanding of important topics in physiology and anatomy, discuss and debate important ethical issues, and even think about the design process for medical technology. The course will include small group teaching from experts, as well as sessions to guide key writing and presenting skills, and the opportunity to present your own project work.

Date	28th July Monday	29th July Tuesday	30th July Wednesday	31st July Thursday	1st Aug Friday
	Intro to Physiology Part 1 Prof Mason Hormones Dr Abayasekara	Intro to Physiology Part 2 Prof Mason Insulin Dr Abayasekara	How to build an anaesthetic machine Dr D'sa Ethics and Medicine Dr D'sa	Supervision Day Dr Abayasekara	Intro to sensory systems Prof Mason Auditory system Dr D'sa
Date	**4th Aug Monday**	**5th Aug Tuesday**	**6th Aug Wednesday**	**7th Aug Thursday**	**8th Aug Friday**
	Introduction to anatomy Dr Kayhanian	Rescuing the injured brain Dr Kayhanian	Lab day Prof Mason	Guided Presentation and Essay Writing Dr Kayhanian	Final Presentations Prof Mason

Introduction to Physiology Part 1: In this session, we will look at the important topics of electrochemical gradients, nerve conduction and the autonomic nervous system. This material will allow you better to understand some of the topics we will be covering later in the week.

Hormones: In this session we will explore the world of hormones by considering what are hormones, where they are synthesized, how they are transported and how they exert their actions.

Introduction to Physiology part 2: In this second session, we will be looking at cardiovascular physiology. We shall be considering in particular the importance and regulation of arterial blood pressure, as we will go on to look at the theoretical basis of the electrocardiogram.

Insulin: In this session we will examine a specific hormone, insulin and seek to understand its importance through appreciating the changes that occur when its secretion and/or action go wrong.

How to build an anaesthetic machine: We will look at what patients need during an operation, and how an anaesthetic machine assists. We will then think about how such a machine can be designed, and test out our hypothetical machine on a hypothetical patient!

Medical Ethics: We will review some difficult ethical scenarios which can arise during medical care, and think about how these can be approached.

Supervision Day 1: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will also have a chance to ask questions about anything that was unclear at the lectures. The supervision will be centred around considering how various structurally dissimilar hormones (e.g. angiotensin II, aldosterone, atrial natriuretic peptide and vasopressin) contribute to the regulation of blood pressure.

Intro to Sensory systems and the auditory system: In the morning, we will look at sensory physiology. We will consider the underlying concepts and then investigating in more detail the properties of the somatosensory, visual and auditory systems. In the afternoon session on the Auditory System, we will consider some of the properties of sound waves, and how they can be detected. We will look at the anatomy of the ear, and think about how it is adapted for its purpose.

Introduction to anatomy: We will take an overview human anatomy and its importance for the practice of clinical medicine. We will focus on important anatomical aspects in three case studies of the heart, upper limb and central nervous system.

Rescuing the injured brain: an exploration of current and developing therapies for neurological disease. In this session we will explore the common neurological diseases, look at the current treatments available and the emerging therapeutic modalities, and discuss how we can design and test new treatments.

Laboratory session: You will be visiting the Department of Physiology, Development & Neuroscience, where the medical students are taught here in Cambridge. In the Experimental Laboratory, you will take part in an exciting practical class in which you will be stimulating your ulnar nerve at the elbow, and recording the electrical and mechanical activity elicited in your hand. You will also be learning about blood pressure measurements and electrocardiography (ECG). The techniques you will gain experience with are useful diagnostically in medicine.

Guided Presentation and Essay Writing: Individual work on your research projects led by the course instructor. You will work on your essay and presentation with the course instructor guiding you through your research.

Final presentations: You will present your research to other participants on the course and the course instructor.

List of prerequisite knowledge: At minimum familiarity with GCSE-level biology.

Test your knowledge of the prerequisites! Can you answer the questions below?
1. What determines the pressure within a container of gas, what causes a gas to move, and what gases are biologically important?
2. Can you describe in general terms the anatomical route that blood takes from the left ventricle, around the circulation and back to the left ventricle? What causes it to flow, and what determines the direction it takes?
3. What substances does a cell need to survive? How can these substances be classified? Are there any required substances which do not enter the cell?

Recommended reading list (optional):
Have a look at some of the physiology videos on www.hippomedics.com, Prof. Mason's teaching channel. Those on electrochemical gradients, cardiovascular physiology and endocrinology will be most useful.

Physics: Special Relativity and Quantum Mechanics

27th July - 8th August, 2025

Dr Joao Rodrigues
Bye Fellow of St Catharine's and Wolfson Colleges

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

Dr David Homan
Research Associate at the Institute for Astronomy, University of Cambridge

I am a researcher at the Cambridge Institute of Astronomy. I work on large new telescope surveys that are designed to take measurements of millions of stars and galaxies. My research has focused on black holes, specifically the very large black holes that exist at the centres of galaxies. I study the extreme radiation emitted when these black holes draw in surrounding gas, dust, and stars. I obtained my PhD at the University of Edinburgh and afterward worked at the Leibniz Institute for Astrophysics in Potsdam, before coming to Cambridge. Over the years, I have worked on various undergraduate courses, lecturing and tutoring, covering a wide range of topics in Mathematics and Physics.

Departmental Profile: **https://www.ast.cam.ac.uk/people/david.homan**

Module Structure and Syllabus:
The motion of particles at speeds close to the speed of light is described by equations that are very different from those that we apply to study the motion of the objects in our daily life, such as the planets around the Sun. Special Relativity provides the theoretical framework to study those fast moving particles. We shall study phenomena such as the time dilation, length contraction and the famous twin paradox, which have no counterpart in the classical theory.

And let us explore the Quantum World. The atomic and subatomic particles behave in a way that for us, used to the certainties of Classical Dynamics and Electromagnetism, is unambiguously strange. Quantum Mechanics suggests there is an essential randomness in quantum phenomena and the best theory we have, based on the wave function and Schrodinger equation, can only predict the probabilities of events to occur. Such peculiarities of the theory were not appealing to everyone. We shall look at how Einstein objected to the standard formulation of Quantum Mechanics and how his ideas led to new developments.

Date	28th July Monday	29th July Tuesday	30th July Wednesday	31st July Thursday	1st Aug Friday
	The Lorentz Transformation

Dr Rodrigues | Relativistic Kinematics

Dr Homan | Relativistic Dynamics

Dr Homan | Supervision Day 1

Dr Homan | Relativistic Optics

Dr Homan |
| Date | 4th Aug Monday | 5th Aug Tuesday | 6th Aug Wednesday | 7th Aug Thursday | 8th Aug Friday |
| | Historical development and postulates of Quantum Mechanics

Dr Rodrigues | Schrodinger equation and applications

Dr Rodrigues | Heisenberg's Uncertainty Principle

Guided Presentation and Essay Writing

Dr Rodrigues | The EPR paradox and Bell's Inequality

Supervision Day 2

Dr Rodrigues | Final Presentations

Dr Rodrigues |

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.

Supervision Day 1: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will be expected to solve the problems before your supervision and bring along your answers to the session for discussion. You will also have a chance to ask questions about anything that was unclear at the lectures.

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.

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 and the harmonic oscillator.

Heisenberg's Uncertainty Principle. We derive Heisenberg's uncertainty relations and discuss their theoretical implications and how they prove the impossibility of simultaneous measurements of the position and the momentum of a particle. We introduce the notion of spin and angular momentum in Quantum Mechanics.

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.

Guided Presentation and Essay Writing: Individual work on your research projects led by the course instructor. You will work on your essay and presentation with the course instructor guiding you through your research.

Supervision Day 2: Small group (3-4 participants per group) sessions led by your course instructor where you will receive feedback on your essay and presentation drafts. Bring along the drafts to the supervision and develop your work following the course instructor's feedback.

Final presentations: You will present your research to other participants on the course and the course instructor.

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)

Test your knowledge of the prerequisites! Can you answer the questions below?
1. Igor is a cosmonaut in the International Space Station, orbiting the Earth at an altitude of 408 km at speed of 28000 km/h. What is his acceleration and what gravitational force does the Earth exert on him.
2. You apply a 4.9 N force to the free end of a spring, stretching it from its relaxed state by 12 mm. What is the spring constant? What force does the spring exert on you if you stretch it by 17 mm? How much work does the spring force do on your hand?

3. The wavelength of x rays produced in the Stanford Linear Accelerator is 0.067 fm; what is the frequency of these x rays?

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).