



FitzEd Summer School 2026 - 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 (26th July – 8th August, 2026). 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

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Medicine

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 Robert Abayasekara

Lecturer in Human Reproduction and Director of Pre-Clinical studies for Medicine, Admissions Tutor in Sciences, Fellow at Fitzwilliam College in the 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](#)

Dr Aaron D'sa

Consultant in Anaesthesia and Pain Medicine at Norfolk and Norwich University Hospital, Fellow at Fitzwilliam College in the 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>

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	27 th July Monday	28 th July Tuesday	29 th July Wednesday	30 th July Thursday	31 st July Friday
	Introduction to Physiology Part 1 Introduction to Anatomy Part 1	Introduction to Physiology Part 2 Introduction to Anatomy Part 2	Rescuing the injured brain	Lab Day	How to build an anaesthetic machine. Ethics and Medicine
Date	3 rd Aug Monday	4 th Aug Tuesday	5 th Aug Wednesday	6 th Aug Thursday	7 th Aug Friday
	Endocrine system	Reproductive system	Guided Presentation and Essay Writing	Supervision day	Final Presentations

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

Introduction to anatomy Part 1 and 2: 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.

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.

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.

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.

Endocrine system: 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.

Reproductive system: We will take a comparative physiology approach to understand the reproductive system, its development across ages in male and females and the early events to support embryological development.

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: 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.

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.

Biology: Microbiology & Microbial Genetics

Dr Ashraf Zarkan

Research Fellow and Group Leader, Department of Genetics, University of Cambridge
Bye-Fellow, Fitzwilliam College in the 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/>

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	27 th July Monday	28 th July Tuesday	29 th July Wednesday	30 th July Thursday	31 st July 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	3 rd Aug Monday	4 th Aug Tuesday	5 th Aug Wednesday	6 th Aug Thursday	7 th Aug Friday
	Biofilms and Persisters	Pathogens Overview and Practical Session	Guided Presentation and Essay Writing	Supervision Day 2 and Practical Session	Final Presentations

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

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 role 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, 2 hours 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



Psychology and Neuroscience

Decoding the Brain: a journey into the science behind thought, emotion and behaviour

Dr Aude Rauscent

Visiting Research Fellow, Department of Physiology, Development and Neuroscience
Bye-Fellow at Homerton College, Fitzwilliam College and Hughes Hall
Director of Studies for Psychological and Behavioural Sciences and Natural Sciences

Dr Alexandra Krugliak

Research Associate at MRC Cognition and Brain Sciences Unit, University of Cambridge
Supervisor, Trinity College, University of Cambridge



Dr Aude Rauscent is a Visiting Research Fellow in the Department of Physiology, Development and Neuroscience at the University of Cambridge and a Director of Studies in Psychological and Behavioural Sciences and Natural Sciences across several Cambridge colleges.

Aude obtained her PhD in Neuroscience and Neuropharmacology from the University of Bordeaux, where she developed an innovative experimental model to explore how the central nervous system adapts to environmental and morphological constraints, thereby maintaining appropriate behavioural responses. She later joined Professor David Belin's team at the French Institute of Health and Medical Research, investigating the neural and psychological roots of vulnerability to compulsive disorders.

Now based in Cambridge, Aude's research in the Cambridge Laboratory for Research on Impulsive and Compulsive Disorders (CLIC) focuses on understanding why some individuals are more prone than others to develop addiction and compulsive behaviours.

College profile: <https://www.fitz.cam.ac.uk/person/dr-aude-belin-rauscent>



Dr Alexandra Krugliak studied Psychology and Cognitive Neuroscience at The University of Maastricht (The Netherlands), before obtaining a PhD from the University of Birmingham (United Kingdom). Currently, Alexandra is a Research Associate at the MRC Cognition and Brain Sciences Unit at the University of Cambridge. Her main research interest is how the human brain represents the world around us based on perception, memory and learning, and how these processes change during healthy and pathological ageing. She combines neuro-imaging techniques such as Electroencephalography (EEG), Magnetoencephalography (MEG), and functional Magnetic Resonance Imaging (fMRI) with cutting-edge computational approaches to study neural

representations of visual and auditory perception both in healthy participants and in patients with Alzheimer's disease.

<https://neuroscience.cam.ac.uk/member/ak2063/>

Module Structure and Syllabus:

Have you ever wondered how the brain gives rise to thoughts, emotions, actions, and motivation? This course offers an exciting introduction to the fundamental concepts of Psychology and Cognitive Neuroscience. Through interactive lectures, you'll uncover how this extraordinary organ, made up of about 86 billion neurons, nearly as many as the stars in the Milky Way, controls perception, movement, and behaviour.

You'll also get hands-on insight into the advanced methods researchers use to study the mind and brain and develop essential academic skills: how to read scientific papers effectively, design and interpret experiments, conduct literature searches, introduce and justify a hypothesis, and build a strong, logical research narrative.

Date	27 th July Monday	28 th July Tuesday	29 th July Wednesday	30 th July Thursday	31 st July Friday
	Introduction to the fundamentals of psychology and neuroscience	The modular and integrative functional architecture of the brain	Towards an understanding of the individual vulnerability to develop psychiatric disorders	Supervision Day 1	Cognitive Psychology
Date	3 rd August Monday	4 th August Tuesday	5 th August Wednesday	6 th August Thursday	7 th August Friday
	Cognitive Neuroscience	Visual Perception	Guided Presentation and Essay Writing	Supervision Day 2	Final Presentations

Introduction to the Fundamentals of Psychology and Neuroscience: This opening lecture lays the groundwork for understanding how the mind and brain interact. Students will be introduced to key concepts in psychology and neuroscience, and they will discover the range of experimental methods scientists use to study behaviour, from observing actions to measuring brain activity.

The modular and integrative functional architecture of the brain: In this lecture, students will explore the fascinating architecture of the brain and uncover how its different regions work together to shape behaviour and thoughts. They'll then dive into the brain's chemical language (neurotransmitter systems) to learn how these powerful messengers influence everything from mood to movement, and what happens when things go wrong.

Towards an understanding of the individual vulnerability to develop psychiatric disorders: In this lecture, students will explore why some individuals are more susceptible than others to developing psychiatric disorders. They'll be introduced to the key psychological and neurobiological mechanisms that shape this vulnerability, and discover the experimental methods scientists use to study them.

Supervision day 1: The course instructor will lead discussions around a practical problem set in small groups (3-4 participants per group). Students will be expected to have thought about the problem before the supervision and bring hypotheses and answers to the session for discussion. During this very interactive session, students will also have a chance to ask questions about anything unclear in the lectures.

Cognitive Psychology: This interactive lecture will introduce the students to theoretical frameworks that contributed to our understanding of how humans think and process information.

Cognitive Neuroscience: In this lecture, the students will learn about methods to study the human mind with neuro-imaging methods and computational approaches. This lecture will cover traditional methods as well as current trends in Cognitive Neuroscience.

Visual Perception: In this lecture, the students will discover how visual information is perceived and processed in the brain. They will learn about the organisation of the visual systems in humans and animals, visual illusions, and the effects of lesions on visual experience.

Guided Presentation and Essay Writing: Guided, individual work on your research projects led by the course instructor. Students will learn how to read a scientific paper and be taught essay writing skills. Students will work on their essays and presentations with the course instructor in the classroom, who will be available to give instant advice.

Supervision Day 2: The course instructor will lead small group sessions (3-4 participants per group) where the students receive feedback on their essay and presentation drafts. Students should bring their essay/presentation drafts to the supervision and develop their work following the instructor's feedback.

Final presentations: The students will present their research to other participants in 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 suit students interested in Cognitive, Neuroimaging, Neuropsychopharmacology, and Neurobiology.

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

1. One brain area, one cognitive function? Comment.
2. How do the structures in the brain communicate?
3. Can you imagine tests to assess cognitive functions?

Recommended reading list (optional):

Principles of Neural Science - Kandel
Atkinson & Hilgard's Introduction to Psychology

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 Kapodistrian University of Athens), MSc (University College London), PhD
(London Business School)



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	27 th July Monday	28 th July Tuesday	29 th July Wednesday	30 th July Thursday	31 st July 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	3 rd Aug Monday	4 th Aug Tuesday	5 th Aug Wednesday	6 th Aug Thursday	7 th Aug Friday
	Market power and Strategic pricing	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.

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

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 and Strategic pricing: 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 theatres 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*

Elements of Mathematical Economics

Dr Vasileios Kotsidis

College Assistant Professor at Gonville and Caius College, University of Cambridge

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	27 th July Monday	28 th July Tuesday	29 th July Wednesday	30 th July Thursday	31 st July Friday
	Elements of Mathematics I	Elements of Mathematics II	Elements of Statistics I	Supervision Day 1	Elements of Statistics II
Date	3 rd Aug Monday	4 th Aug Tuesday	5 th Aug Wednesday	6 th Aug Thursday	7 th 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.

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

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 mean 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 ?



Physics: Astronomy and Astrophysics

Dr David Homan

Research Associate at the Institute for Astronomy, University of Cambridge



I work at the Cambridge Institute of Astronomy 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 taught various undergraduate courses including 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:

Astronomy aims to understand the Universe we live in through the application of the laws of physics. Newtonian mechanics and gravitation provide an excellent description of, for example, the motion of planets in our solar system. However, to understand the wide range of phenomena that we observe in our night's sky we must also move beyond Newtonian physics and draw from thermodynamics, quantum mechanics, and Einstein's relativity, among other fields of modern physics.

The course will commence with the classical basics, deriving an accurate description of the motion of planets around a star, or indeed of any orbiting body in a gravitational field. We will continue by studying the way stars are formed and powered, touching on topics such as nuclear fusion. This will also provide a good opportunity to explore the key role that observations play in astronomy, by discussing the way we can analyse the spectrum of the light coming from stars. The course will include hands-on experience with the analysis of astronomical data.

We will also explore some of the most extreme objects in our Universe, such as neutron stars and black holes, which achieve extremes of gravity and density that are impossible to mimic on Earth. The course concludes by considering one of the current limits of our knowledge: the presence of an unknown invisible component of our Universe that likely makes up most of all material, dark matter.

Date	27 th July Monday	28 th July Tuesday	29 th July Wednesday	30 th July Thursday	31 st July Friday
	Measuring the Universe	Orbital Motion	Powering a Star	Supervision Day	A Star's Life
Date	3 rd Aug Monday	4 th Aug Tuesday	5 th Aug Wednesday	6 th Aug Thursday	7 th Aug Friday
	White Dwarfs and Black Holes	Invisible Gravity	Essay Writing Day	Practical Day	Final Presentations

Measuring the Universe. Astronomers make measurements of our Universe in multiple ways, most importantly by observing electromagnetic radiation. One of the first hurdles to cross is to establish how far away the objects we can observe actually are. We will discuss different ways in which we

can measure distances in our Universe, in the context of the Cosmic Distance Ladder: from using the motion of the Earth around the Sun to using the expansion of the Universe itself.

Orbital Motion. Rotations and orbits are commonplace in the objects that make up our Milky Way, like exoplanets moving around distant stars. We will delve into the mathematical descriptions used to describe these kinds of systems and derive Kepler's laws of planetary motion from Newton's laws of motion and gravitation. Gravity defines many of the interactions we observe, and we will look at the expected and unexpected effects massive objects have on their surroundings, including the way gravity can deflect light itself.

Powering a Star. Looking at the night's sky, stars make up most of the objects we can see by eye. But what is it we really see when we look at a star? To answer this question, we will need to incorporate aspects of nuclear physics, thermal physics, and quantum mechanics. Together, important insights from these fields will help us understand the way stars are powered, the emission that comes from the stars surface, and the way we can tell what elements a star is composed of. Finally, we will have a look at stellar spectra, or how the emitted light can be broken down into different wavelengths.

Supervision Day. Discuss 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.

A Star's Life. Returning to what we learned about the physics of stars, this lecture day we will focus on following a star from start to end. Star formation is a complex process, and we will look at the many different types of stars it can result in. Topics to be covered are star clusters, the Hertzsprung-Russell diagram, and nucleosynthesis. We will conclude with a discussion of the variety of ways in which a star's life may end: slowly dying out or with an extremely bright explosion, in the form of a supernova.

White Dwarfs and Black Holes. Stellar remnants, the object that is left at the end of a star's life, provide laboratories for extreme physics that we cannot achieve on Earth. White dwarfs and neutron stars are extremely dense objects, packing a mass larger than our Sun's into a space down to only a few dozen km across. Even denser, black holes represent regions of space where gravity is so strong not even light can escape. We will look at the physics observed in these extreme objects and the range of astronomical phenomena they power.

Invisible Gravity. Black holes come in a variety of sizes, from the stellar-mass black holes discussed in the previous lectures, to objects billions of times the mass of our Sun. The gravitational effect of these super-massive black holes can have a large impact on their surroundings. And there are other sources of gravity that appear to be inherently invisible: 'dark matter' may in fact make up most of the matter in our Universe. We will discuss galactic rotation curves to understand why we believe dark matter exists and the different experiments currently at work to detect it.

Essay Writing Day. Students will work on their essays and/or presentations individually and will receive feedback from their course instructor. Discussion of the work will focus on guidance of the research itself, but the instructor will also provide help with presenting the work in a scientific manner.

Practical Day. This day is set aside for students to gain experience with real astronomical data. We will visit the Institute of Astronomy, look at a spectrum from our Sun, and put to use the knowledge gained in the lectures to analyse real-world observations.

Final Presentations. Students will present their research project to the other participants in the Programme and to their course instructor.

List of prerequisite knowledge:

Classical mechanics:

- Newton's laws of motion
- Concepts of acceleration, force, momentum, work

Mathematics:

- Trigonometry and geometry: familiarity with radians
- a basic understanding of derivatives and integration are required.

Light and waves:

- Relationship between wavelength and frequency

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

1. A star in our galaxy explodes in a supernova today. If it is at a distance of 50 lightyears, how old will you be when you can see this from Earth?
2. A spaceship is falling into a black hole. Assume the acceleration on the ship is constant, at 100 m/s^2 , and the starting velocity of the ship is zero. The speed of light $300,000 \text{ km/s}$. How long does it take for the spaceship to reach 1% of the speed of light?
3. The speed of a satellite moving in a circular orbit around the Earth is given by $v^2 = \frac{GM}{R}$ where G is Newton's gravitational constant, M is the mass of the Earth, and R is the distance from the satellite to the centre of the Earth. How high above the Earth's surface is the satellite, if it is moving at $11,000 \text{ km/h}$? [Note: you are of course allowed to look up the values for G , M , and the radius of the Earth]

Recommended reading list (optional):

- Feynman, R., *Six Easy Pieces* (1994): Chapter 5, Gravitation
A bird's eye view of one of the most important topics we will be discussing in this course. Light on the mathematics, great on insight.
- Bennett, M. et al., *The Cosmic Perspective* (10th ed., 2023): Chapter 18
An excellent introduction to white dwarfs, neutron stars, and black holes. More mathematical. If you like this, Chapter 14, on our Sun, will also be interesting.
- Any physics textbook on Newton's laws
A review of your high school textbook on Newton's laws, as well as chapters covering work and energy would be beneficial before starting this course.

Future-Focused Robotics: Bridging Mechanical and Electrical Systems

Dr Rachel Thorley

Fellow in Engineering, Churchill College, University of Cambridge

Rachel read Engineering at Newnham College before completing a PhD in Geoengineering for Carbon Sequestration at the University of Sheffield. She is a Fellow in Engineering at Churchill College, where she supervises undergraduate engineers in Mechanics, as well as teaching Structures, Design, and Engineering Communication. Rachel has supervised a range of industrial placements focused on developing control systems for environmental monitoring, off-grid eco homes, and low-cost wind turbines for sustainable energy. Prior to joining Churchill, she lectured in Engineering at the University of Sheffield, specializing in the practical aspects of both Electrical and Mechanical Engineering. Her research interests lie in innovation and sustainability, translating interdisciplinary concepts into real-world solutions. She is also an active member of a local makerspace, bringing expertise in rapid prototyping and digital manufacturing.



College profile: [Dr Rachel Thorley - Churchill College](#)

Module Structure and Syllabus:

Robotics is rapidly transforming industries—from healthcare and manufacturing to transportation and entertainment—making now the perfect time to build the knowledge and hands-on experience this field demands. This module provides a comprehensive introduction to the electrical, mechanical, and control aspects of robotics, focusing on the design and prototyping of robotic systems. You will learn how to integrate electronics, mechanical structures, and control algorithms, exploring what is involved in the construction and use of robots from a multidisciplinary perspective.

Through a blend of lectures, hands-on lab sessions, and group design projects, you will discover how to select and assemble hardware components, program control systems, and refine prototypes based on performance testing. By the end of the module, you will be able to design, build, and troubleshoot simple robotic devices, laying a solid foundation for further engineering study and real-world applications. In addition, the module incorporates an essential thread on communication skills. You will gain experience in clearly and accurately presenting ideas in written, verbal, and graphical forms, ensuring you can engage effectively with diverse audiences—an invaluable skill in both academic and professional engineering environments.

Date	27 th July Monday	28 th July Tuesday	29 th July Wednesday	30 th July Thursday	31 st July Friday
	Applications of robotics. Engineering fundamentals: careers & communication	Mechanical Engineering Fundamentals. Build and race a car	Electrical Engineering: Circuits & Microcontrollers	Supervision Day 1: Mechanics problems	Robot build: Integrating mechanical and electrical.
Date	3 rd Aug Monday	4 th Aug Tuesday	5 th Aug Wednesday	6 th Aug Thursday	7 th Aug Friday
	Robot build: Control theory and sensors	Computer Aided Design (CAD). Structural engineering team challenge	Guided Presentation and Essay Writing	Makerspace Visit, Rapid Prototyping & Guest Lecture	Final Presentations

Applications of robotics: This session explores the diverse ways robotics is reshaping industries worldwide. From healthcare robots assisting surgeons, to autonomous vehicles improving transport safety, to automated drones optimizing agricultural production. By examining both the practical applications and ethical implications, students gain a holistic understanding of how robotics can drive innovation while recognising the responsibilities that come with it. This session also looks at fundamental skills in engineering, building confidence in technical communication, both oral and graphical, that underpins successful engineering careers and gives a strong foundation for teamworking projects over the course.

Mechanical Engineering: This session covers the core theories and broad scope of mechanical engineering, focusing on how fundamental principles—such as statics, dynamics, and materials science—underpin the design and analysis of machines. Students will learn to evaluate forces, stresses, and motion in both traditional mechanical systems and emerging robotic applications. Students will put their theoretical knowledge to use, within a practical activity, building and racing cars. By working on small-scale prototypes, they gain hands-on experience in applying mechanical engineering principles to real-world robotics challenges.

Electrical Engineering: Circuits: This session introduces the fundamentals of electrical engineering through the lens of robotics. Students will gain hands-on experience using breadboards to build and test simple circuits, laying the foundation for more complex systems. Students will also be introduced to Arduino microcontrollers and use programming to control actuators.

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

Robot build: Integrating mechanical and electrical: This session brings together key learning from the mechanical and electrical parts of the course., applying their knowledge of circuits, components, and mechanical systems. Through hands-on prototyping, they will begin assembling and testing a simple robot, laying the groundwork for a responsive, integrated system.

Robot build: Control theory and sensors: Sensors are a critical component in robotics, enabling robots to perceive and respond to their environment. In this session, students will explore a variety of sensor types, examining their uses, limitations, and the science behind how they work. To connect sensing to real-world action, the session also introduces fundamental control theory. Students will explore the difference between open-loop and closed-loop systems, and how feedback can be used to improve a robot's performance. They'll also gain a basic understanding of how control systems help connect sensor input to responsive, intelligent movement, applying this knowledge practically as they continue building and testing their robots.

Guided Presentation and Essay Writing: This session supports students in preparing their essays and presentations, with guidance from the course instructor. Alongside developing their written and visual materials, students will have dedicated time for final assembly, testing, and debugging of their robotic builds. This hands-on troubleshooting allows them to refine both the performance of their projects and the clarity of their communication. By resolving any last-minute issues and polishing their work, students will be well-prepared and more confident going into the final presentations.

Computer Aided Design (CAD) & Structural engineering team challenge:

This session introduces students to the fundamentals of Computer-Aided Design (CAD), a key tool used by engineers to design and test ideas digitally. Students will gain hands-on experience with CAD software before putting the Makerspace visit, where they will see rapid prototyping in action. There will also be a fun structural engineering challenge, to combine technical learning with creativity, problem-solving, and teamwork.

Makerspace Visit, Rapid Prototyping & Guest Lecture: This session combines a visit to a local makerspace and a guest lecture from Dr David Hardman, the Henslow Junior Research Fellow in robotics. At the makerspace, students will explore rapid prototyping tools such as 3D printing and laser cutting, and gain hands-on experience designing and fabricating simple components. They'll learn how these technologies accelerate the design process and support innovation in robotics and engineering. The session also includes a guest lecture on cutting-edge robotics research, with time for Q&A on current challenges and future career paths in the field.

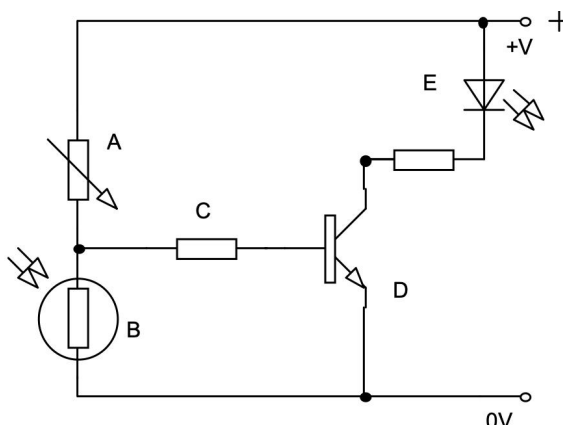
Final presentations: Students will present their research to other participants on the course and the course instructor.

List of prerequisite knowledge:

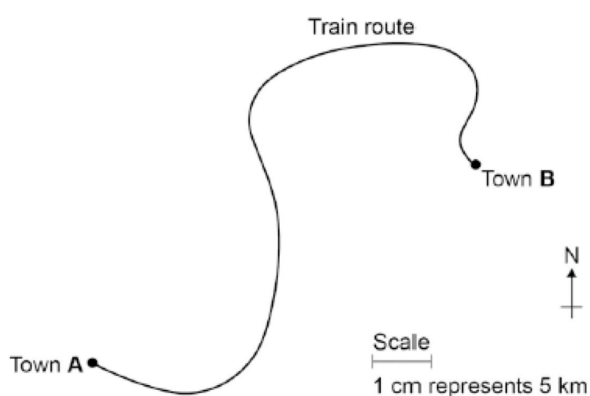
The emphasis during the course will be on the physical understanding of the principles involved. Only elementary mathematical methods will be used. The key is the engineering and not the mathematics behind it. As such, I expect students to have a basic awareness of circuits and their components, alongside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

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

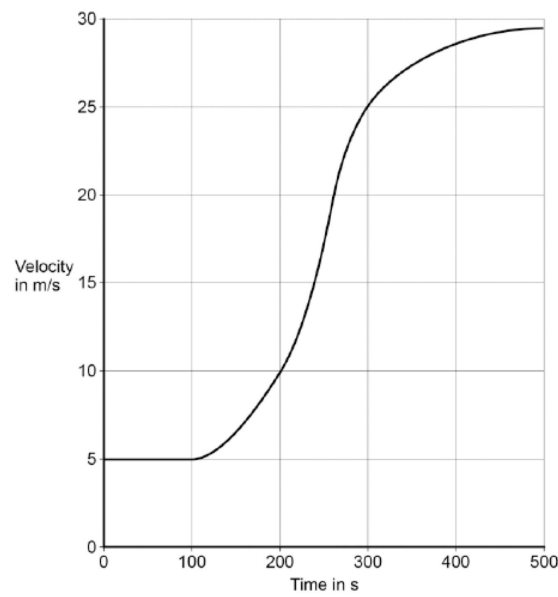
1. Name the components (A, B, C, D and E) in the circuit below:



2. A train travels from town A to town B, as shown in the scale diagram below.
- 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?
 - Use the figure below to determine the displacement of the train in travelling from A to B.
 - There are places on the journey where the train accelerates without changing speed. Explain how this can happen.



- 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.



Mathematics

Professor Anthony Ashton

Fellow, Tutor, College Professor, Director of Studies in Mathematics at Homerton College,
University of Cambridge

Lecturer, Department of Applied Mathematics & Theoretical Physics, University of
Cambridge

Anthony Ashton has been lecturing courses in the Mathematical Tripos since 2011. His teaching responsibilities fall across a broad range of subjects, from courses on Differential Equations and Probability in Part IA all the way to Analysis of PDEs in Part III. He is director of studies in mathematics at Homerton, where he oversees the progress of around 40 students each year. In 2017 he was awarded the Pilkington Prize, a prestigious prize awarded by the University of Cambridge to academics who have made an outstanding contribution to teaching and outreach within the University.

His research interests focus mainly on partial differential equations (PDE). More specifically, he works on spectral approaches to elliptic boundary value problems, Lie group methods, new approaches to regularity problems in linear PDE and certain aspects of mathematical physics. He is also interested in several problems in analytic number theory relating to the Hurwitz zeta function.



Profile: <https://www.homerton.cam.ac.uk/people/anthony-ashton>

Module Structure and Syllabus:

This course will take students through the rudiments of probability theory. We will start with an axiomatic approach; students will be introduced basic notions of counting and combinatorial methods in classical probability theory. After this we will move onto general discrete probability distributions, random variables, expectation, variance. Finally, we will introduce the idea of conditional expectation. This will be a challenging course aimed at late stage high-school students interested in mathematics typically encountered in the first year of an undergraduate degree.

Date	27 th July Monday	28 th July Tuesday	29 th July Wednesday	30 th July Thursday	31 st July Friday
	Axiomatic Framework	Classical Probability I	Classical Probability II	Supervision Day 1	Discrete Probability Distributions I
Date	1 st August Saturday	3 rd August Monday	4 th August Tuesday	5 th August Wednesday	6 th August Thursday
	Discrete Probability Distributions II	Conditional Expectation	Guided Presentation and Essay Writing	Supervision Day 2	Final Presentations

Axiomatic Framework: Foundational principles: sample spaces, outcomes, events, probability.

Classical Probability I: Probability on finite sample spaces, algebra of sets, elementary combinatorics.

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

Classical Probability II: More counting: multinomial coefficients and inclusion-exclusion. Examples of these techniques in classical probability. Independence.

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.

Discrete Probability Distributions I: Examples of well-known discrete distributions: Poisson, Binomial, Geometric. Properties of these distributions, including computation of expectation and variance.

Discrete Probability Distributions II: Random variables, indicator functions, independence.

Conditional Expectation: Definition and examples.

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:

The course will move at a fast pace. Some prior experience with binomial coefficients, real valued functions, geometric sums. No prior knowledge of probability is needed.

