An Introduction to Psychology and Neuroscience

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:

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

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

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:

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

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?

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:

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
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:

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.

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?

<u>Mathematics for the Natural Sciences – Option 2</u>

<u>Mrs Serena Povia</u>

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

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

<u>Module Structure and Syllabus:</u>

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.

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:

Date	28th July Monday	29th July Tuesday	30th July Wednesday	31st July Thursday	1st August Friday
	Mechanical Engineering: Kinematics & Dynamics	Mechanical Engineering: Velocity and Acceleration	Mechanical Engineering: Equations of Motion	Supervision Day 1: Mechanics problems	Electrical Engineering: Physical principles of electronics
Date	4th Aug Monday	5th Aug Tuesday	6th Aug Wednesday	7th Aug Thursday	8th Aug Friday
	Electrical Engineering: Gauss, potential, voltage and capacitance	Electrical Engineering: Alternating current, charge flow, density and magnetic flux	Guided Presentation and Essay Writing	Supervision Day 2: Electronics problems	Final Presentations

Mechanical Engineering, Kinematics & Dynamics: This section of the course is about how things move – the foundation of Mechanical Engineering. On the first day, you will learn how to describe the motion of objects, first without reference to force (kinematics), then predicting the motion of objects with

mass when forces are applied (dynamics). These are the essential foundations from which you can pursue more complex topics in mechanics.

Mechanical Engineering, Velocity and Acceleration: Essential to mechanics is the ability to represent position, magnitude, and direction. To do this, we need to understand how to manipulate vectors. On day two, you will discuss coordinate systems, and the time-derivatives of position – velocity and acceleration. This is 'vector calculus' and is a key topic across the wider engineering disciplines.

Mechanical Engineering Equations of Motion: You should now have the essential principles in place to apply Newton's Second Law to particles under the action of forces, allowing you to obtain equations of motion for systems. On day three, you will derive equations of motions for different systems, understanding the application of D'Alembert Forces, then moving into energy and momentum.

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 during the lectures.

Electrical Engineering, Physical principles of electronics: This section of the course is about electromagnetic fields and their application to the solution of a range of engineering problems, focusing on the physical understanding of the principles involved. It is designed to introduce the physical properties of
electromagnetics leading to the resistor, the capacitor and the inductor. These are the
fundamental building blocks of linear circuits. You will apply fundamental techniques developed earlier in the course in vectors and coordinates. On day 1, you will learn about charge and charge accumulation, Coulomb's Law, simple dielectrics and electric flux density.

Electrical Engineering, Gauss, potential, voltage and capacitance: Building on the previous day's learning, you will learn about Gauss's Law and Gaussian surface, electrostatic potential and voltage and capacitance. You will work through real examples and the applications of capacitance, including plate capacitors and coaxial cables.

Electrical Engineering, Alternating current, charge flow, density and magnetic flux: You will move onto AC properties of capacitance, charge flow (ohms law and current), current density, resistance and resistivity and understand the empirical definition of force between current carrying wires. Finally, you will learn the concept of magnetic flux density, flux linkage, electromagnetic induction and self-induction. This will provide you with basic concepts necessary to expand into studying practical electromagnetic problems and materials.

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 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:
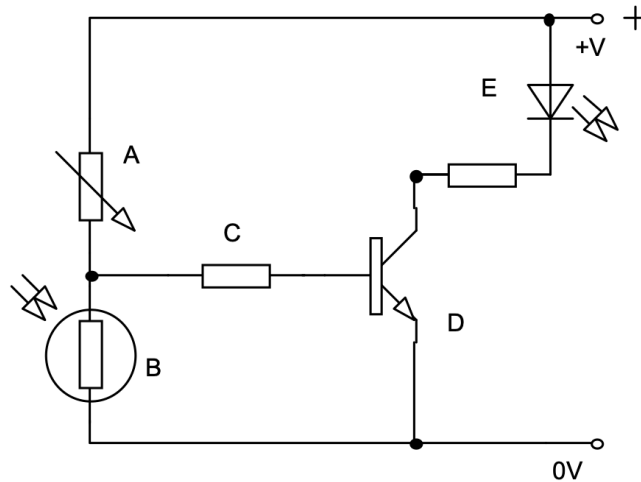
2. A train travels from town A to town B, as shown in the scale diagram below.

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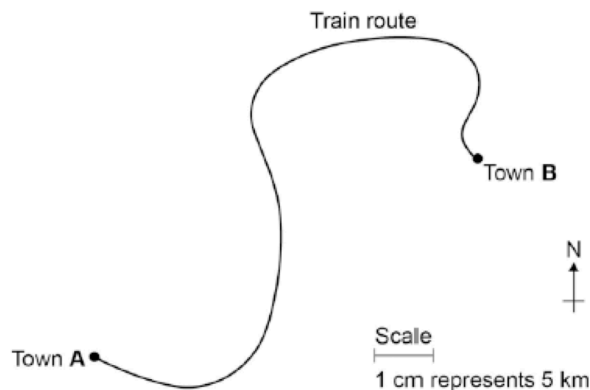
   d) The Figure below shows how the velocity of the train changes with time as the train travels along a straight section of the journey. Estimate the distance travelled by the train along the section of the journey shown.