



FitzEd Middle School Summer Programme 2026

Course brochure

Enjoy browsing the detailed description of all courses that we are going to offer as part of the FitzEd Middle School Summer Programme for 14–15 year olds (12th – 25th July, 2025). For each course you will also find a list of prerequisite knowledge and corresponding problems to test your readiness for our courses.



Dr Peter Bolgar

Director of Summer School Programme

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

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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:

The primary purpose of this course will be to teach students *how to count*. We will build up knowledge and understanding of elementary combinatorics and see how those ideas can be used to solve problems of probability.

Date	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Counting & Permutations	Combinations	Pigeon hole principle	Supervision Day 1	Algebra of sets and Inclusion-Exclusion
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	Probability I	Probability II	Guided Presentation and Essay Writing	Supervision Day 2	Final Presentations

Counting and permutations: Discussion of foundational principles: product rule and permutations.

Combinations. Counting sizes of selections; binomial coefficients and combinatorial identities.

Pigeon hole principle: Exploration of the pigeon hole principle and its generalisations. Applications.

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.

Algebra of sets and Inclusion-Exclusion: Basic set theory; unions and intersections of sets; Moore's laws and applications. Counting the size of a union of sets; introduction to inclusion-exclusion.

Probability I: Axiomatic definitions, probabilities on finite sample spaces. Examples.

Probability II: Independence; conditional probability.

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:

None.



Mechanical and Electrical Engineering

Dr Miles Stopher

Associate Professor, Fellow and Director of Studies in Engineering, Homerton College
Director of Admissions, Department of Engineering, Cambridge
Bye-Fellow in Engineering, Fitzwilliam College

Dr Miles Stopher is an Associate Professor in Engineering and the Director of Admissions in the Department of Engineering. He is a Bye-Fellow of Fitzwilliam College, having previously served as Senior Tutor. He has supervised and directed studies in Engineering for over 10 years, across a number of colleges at the University, including his alma mater, Jesus College. Miles teaches Part IA and Part IB Mechanical engineering, Structural engineering, electrical engineering and materials science to engineering undergraduates at Cambridge. He lectures Nuclear Materials for Part III materials scientists, 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, thermohydraulics and global energy policy. His research covers a broad range of topics but focuses primarily on nuclear reactor design, with particular interest in the design of nanostructured materials for applications in extreme environments. Prior to his arrival at Cambridge, he worked on the design of the Royal Navy's Dreadnought-class nuclear-powered ballistic missile submarines.



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

Module Structure and Syllabus:

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

Date	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Mechanical Engineering: Aircraft design	Mechanical Engineering: Engine design	Mechanical Engineering: Power plant design	Supervision Day 1: Mechanics problems	Electrical Engineering: Electronics
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	Electrical Engineering: Renewable Energy	Electrical and Mechanical Engineering: Robotics	Guided Presentation and Essay Writing	Supervision Day 2: Electronics problems	Final Presentations

Mechanical Engineering, aircraft design: Engineering has many branches, but the oldest and broadest is mechanical engineering. Mechanical engineers look at the design, analysis, and manufacturing of systems that keep our world moving forward. In the mechanical engineering section of this course, you will focus on how mechanical engineers are working towards sustainable solutions within three key industries: aerospace, energy and transport. On your first day, you will be taught the fundamentals necessary to understand aircraft design and the principles that keep them in the air. Towards the end of the day, you will gain a unique insight into the concepts proposed for future aircraft.

Mechanical Engineering, Engines: On the second day, you are introduced to the fundamental concepts of the engine, from steam to internal combustion, focusing on their application to trains, ships, cars and jet planes. Towards the end of the day, you will learn about innovations in sustainable engine design, from hydrogen engines to water engines.

Mechanical Engineering, Nuclear Reactor Design: On your final day of teaching for the mechanical engineering section of the course, you will learn the fundamentals of power plant design. You will study the range of designs in use today, with particular focus on nuclear power, and the advanced concepts proposed for future applications.

Supervision Day 1, Mechanics Problems: Allocated into groups, you will be set a practical challenge to solve, such as assembling a working model engine, and be expected to complete the challenge before your supervision with the course instructor. In the supervision, you will discuss your results and have the chance to ask questions about anything unclear during the lectures.

Electrical Engineering, Electronics: Electrical engineering is the study of electricity, electronics and electromagnetism, and the design of systems based on the respective principles. This section of the course will introduce three exciting industries where electrical engineers play a key role in design, development and testing: integrated circuits, power generation and robotics. On your first day, you will study the fundamentals of analog and digital circuits, understand the key components found in some of the common circuits you might find in your own home and how they are manufactured.

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

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

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

Supervision Day 2, Electronics Problems: Allocated into groups, you will be set a practical challenge to solve, such as assembling and coding a working ultrasonic sensor or radio-controlled car and be expected to complete the challenge before your supervision with the course instructor. In the supervision, you will discuss your results and have the chance to ask questions about anything unclear during the lectures.

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

List of prerequisite knowledge:

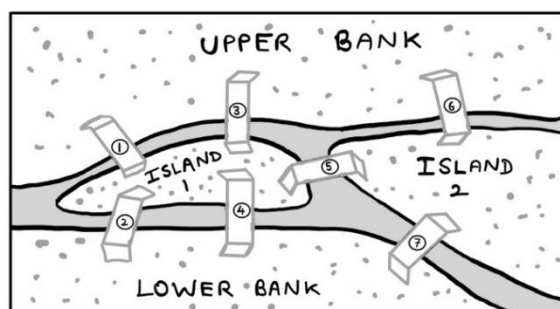
The emphasis during the course will be on the physical understanding of the principles involved. Only elementary mathematical methods will be used. The key is the engineering and not the mathematics behind it. As such, I only ask students have an appetite for learning and an inquisitiveness for engineering. Nonetheless, I've provided a few fun questions below that hopefully you enjoy tackling and can challenge your friends with.

1. Eight of my pets aren't dogs, five aren't rabbits, and seven aren't cats. How many pets do I have?
2. I've forgotten the PIN to my bank card. If I enter six incorrect attempts, I will be locked out of my account: I've already used five! Only two digits are displayed after each unsuccessful attempt: "2, 0" means 2 digits from that guess are in the PIN, but 0 are in the right place. What should my sixth attempt be?



3456		3,0
5890		0,0
1234		2,0
2304		2,1
6241		2,2
????		?,?

3. An infinite number of engineers buy pizza. The first wants half of a pizza. The second wants a quarter of a pizza. The third & fourth want an eighth and a 16th each, and so on. How many pizzas should they order?
4. Fitzwilliam college has installed seven footbridges as shown below. Can you find a route around the college that crosses every bridge exactly once?



Physical Natural Sciences Taster Course (Chemistry and Physics)



Dr Anke Ardern-Arentsen

Research Associate, Institute of Astronomy
Bye Fellow at Fitzwilliam College in the University of Cambridge

Dr Itai Massad

Herchel Smith Postdoctoral Fellow, Yusuf Hamied Department of Chemistry
Research Fellow at Fitzwilliam College in the University of Cambridge

Anke Ardern-Arentsen is a researcher at the Institute of Astronomy, University of Cambridge, where she works on large astronomical datasets to enable studies of millions of stars and galaxies. Her research focuses on using ancient stars to reveal the history of our home galaxy, the Milky Way. At the University of Cambridge, she has taught supervisions for third-year Astronomy students, co-led an astronomy module for the Data Intensive Science MPhil and supervised research projects.



Departmental profile: <https://www.ast.cam.ac.uk/people/anke.ardern-arentsen>

Itai Massad is a researcher in the Department of Chemistry, where his research in the field of supramolecular chemistry explores the design and preparation of supramolecular cages – well-defined three-dimensional assemblies that can trap small molecules within their structures. Itai has extensive experience in teaching organic chemistry from introductory to graduate level.

Departmental profile: <https://www.ch.cam.ac.uk/person/im580>

Module Structure and Syllabus:

In this taster programme, you will get to explore two fields within the physical natural sciences, chemistry and physics. The course will focus on two specific topics within these fields, according to the expertise of the course instructors. In the organic chemistry module, we will learn to understand and predict the structure of organic (and inorganic) molecules and explore modern analytical techniques for determining molecular structure. In the physics/astronomy module, we will revise and study the relevance of various physics topics for the fascinating field of astronomy, explore the history of the Universe, learn about galaxies, stars and exoplanets, and cover different techniques for studying the Universe. The modules will be a mixture of lectures and practical elements.

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

Date	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Molecular structures	Isomerism and resonance	NMR spectroscopy	Supervision Day: Chemistry	Physics for astronomy
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	Galaxies	Stars and exoplanets	Guided Presentation and Essay Writing	Practical Astronomy Day, Institute of Astronomy visit	Final Presentations

Molecular structures: this session will focus on predicting and drawing molecular structures. We will cover the concepts of valence, Lewis structures and VSEPR theory.

Isomerism and resonance: an overview of different types of isomers, their fundamental properties and how these relate to chemical and physical behaviour.

NMR spectroscopy: this session will cover nuclear magnetic resonance spectroscopy and its applications.

Supervision Day, Chemistry 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.

Physics for astronomy: in this session we will cover physics concepts that are important for astronomy, such as motion and gravity, the electromagnetic spectrum, optics and telescopes, nuclear physics and different sizes and scales used in astronomy. We will also cover a brief history of the Universe from the Big Bang to the present day.

Galaxies: this session is all about galaxies: What are they? How did they form and how do they change with time? What do they teach us about dark matter? What is Galactic Archaeology? This day will also include a small group research project and presentation about a topic related to galaxies.

Stars and exoplanets: in this session we will study what stars are made of, how they form and evolve, and why they are so crucial for life. We will also discuss how astronomers have discovered planets around other stars ("exoplanets") and look at the wide variety of planets existing in our galaxy.

Guided Presentation and Essay Writing: This session supports students in preparing their essays and presentations, with guidance from the course instructors.

Practical Astronomy Day: students will apply their astronomy knowledge in practice (computer practical, problem set, demonstration), and we will visit the Institute of Astronomy. Students will also have a chance to ask questions about anything that was unclear to them during the lectures.

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

List of prerequisite knowledge:

Some knowledge of basic physics and chemistry would be useful, as well as a familiarity with using (simple) equations. No computer programming experience is necessary for the astronomy practical.

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

1. Using Newton's second law, determine the force required to accelerate an average adult human being at 2 m/s^2 .
2. What are the three-dimensional shapes of H_2O and CO_2 ? Why do they differ?

Recommended reading list (optional):

Any book on physics and chemistry for high school.



Economic Environment of Business

Mo Tanweer

Academic Associate at Pembroke College, University of Cambridge



Mo Tanweer studied Economics at Cambridge University and, after a career in investment banking, was Head of Economics & Politics at Eton College. He is now an Academic Associate at Pembroke College (University of Cambridge) where his particular areas of focus are The Politics of the International Economy, and Banking & Finance, as well as teaching a course on AI: Friend or Foe? He assists with teaching Macroeconomics and International Business on the MBA, Executive MBA, and Global EMBA at the Judge Business School at the University of Cambridge, as well as contributing to Executive Education courses on global megatrends and their implications. He is also a Teaching Associate for Macroeconomics for the MPhil and Management Studies Tripos. He also lectures Macroeconomics in Business on the MBA programme at the Rotterdam School of Management (Erasmus University). Beyond

academia, he provides consultancy advice to both small and large corporates on how rapidly shifting economic trends and external shocks such as AI may impact their business models. His past research has focussed on the rise of China and its challenges, whilst his current area of research is global technology shocks and how they affect geopolitical relationships and the wider global economy, from labour markets to policy making.

College Profile: <https://www.pem.cam.ac.uk/college/master-and-fellows/list-fellows/mr-mo-tanweer>

Module Structure and Syllabus

The Economic Environment of Business module covers the economic foundations needed to understand firms' decision making. One of the prerequisites of doing well in business is to understand the environment in which you operate. In this context, there are many forces that act on business. Some may be slow and predictable. Others are sudden and very often unexpected. At the same time, while these forces play out, governments are also likely to react with a variety of policy changes. By the end of the module students will understand how decision making in businesses is affected by three core drivers: internal firm factors, external industry factors, and global macro factors. To begin with this module will explore the importance of economics and how it relates to our everyday lives. From there, students will develop familiarity with microeconomic models to better understand concepts such as costs, demand, profit, competition, pricing, 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 strategically. The module will discuss the environment of business from both a micro market perspective whilst complementing it with understanding how firms deal with the complexities of the international economy. Through a mixture of building economic frameworks as well as applied empirical analysis, we will explore how these complexities can be analysed. The individual market and the broader national economy are the environments of business. Hence the dual challenge for people in business is not only to position themselves to either take advantage of favourable economic conditions or take defensive action from negative economic shocks but also to anticipate the likely policy responses of rivals and of governments. This module will offer the tools to offer informed insights on these drivers.

Date	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Introduction to Economics and the Environment of Business	Demand, Supply and Market Equilibrium	The analysis of competitive and imperfect markets	Supervision Day 1	Game theory and competitive strategy
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	Consultancy Case Studies: Firms' strategic decision making	Macroeconomic environment of business	Guided Presentation and Essay Writing	Supervision Day 2	Final Presentations

Introduction to economics and the environment of business: 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.

The analysis of competitive and imperfect markets: understand the models of competition from monopolies to oligopolies, perfect competition to monopolistic competition, and explore dynamics such as collusion to price discrimination, and the consequences for consumers, suppliers, governments.

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.

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

Consultancy Case Studies: Firms' strategic decision making: Using various hypothetical case studies, we will explore strategic thinking frameworks, from PESTLE analysis to SWOT and Unknown-Unknown matrices. Using these case studies, we will put strategic policies into practice.

Macroeconomic environment of business: We will explore how businesses operate within the institutions of both national and global macroeconomies, government policies and rules. Students will grasp why and how firms need to take this into account in their strategic thinking.

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.

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

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

List of prerequisite knowledge:

No prior knowledge of the subject is required.

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

Why diamonds cost more than water, when water is necessary to survive?

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:

Levitt, S.D. and Dubner, S.J., 2005. *Freakonomics: A rogue economist explores the hidden side of everything*. London: Penguin Books.

Frank, R.H., 2007. *The Economic Naturalist: Why economics explains almost everything*. London: Virgin Books.

Harford, T., 2006. *The Undercover Economist: Exposing why the rich are rich, the poor are poor—and why you can never buy a decent used car!* London: Little, Brown.



Medicine and Biological Natural Sciences

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

Dr Laura Frost

Lead Veterinary Surgeon at Woodgreen, The Animal Charity,
Bye-fellow in Veterinary Medicine at Fitzwilliam College
Director of Studies in Veterinary Medicine at Wolfson/Lucy Cavendish Colleges



Robert Abayasekara is a highly experienced medical and veterinary educator who has taught Physiology at the Universities of Oxford, London (Royal Free Hospital School of Medicine, King's College London (KCL), Royal Veterinary College (RVC) and Cambridge. He has been the Director of Studies for Pre-clinical Medicine at Fitzwilliam College, Cambridge since 2004. At Fitzwilliam, Robert conducts small group teaching sessions (supervisions) in homeostasis, human reproduction and veterinary reproductive biology for students reading medicine, veterinary medicine and biological natural sciences. Robert's primary research interest is the biology of the mammalian corpus luteum.

[Dr Robert Abayasekara](#) | [Fitzwilliam College, Cambridge](#) | [College of the University of Cambridge](#)

Laura Frost qualified as a vet from Cambridge vet school in 2009 and initially worked in general practice while studying for a surgical certificate. She now works as a surgeon at Woodgreen, a large rehoming charity dealing with dogs, cats, rabbits, ferrets and other small mammals. She lectures as part of the preclinical vet course teaching surgery to final year students and recent graduate vets. At Fitzwilliam College she conducts small group supervisions in veterinary anatomy & physiology, veterinary reproductive anatomy and comparative vertebrate anatomy. She has a keen interest in education, especially in surgical learning in early career vets. In her spare time, she rehabilitates wild hedgehogs ready for release back into the wild.



College profile: <https://www.wolfson.cam.ac.uk/people/ms-laura-frost>

Module Structure and Syllabus:

This course offers pre-university students an insight into comparative biology with a particular emphasis on medical and veterinary sciences. You will have the opportunity to improve your understanding of important topics in physiology and anatomy in various species including the human. 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	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Intro to Physiology Part 1 (hormones) Introduction to Physiology Part 2 (kidney)	Intro to Physiology Part 3 Aldosterone	Interactive practical involving measuring blood pressure of individuals Topical Discussion	Supervision Day	Comparative anatomy Heart, Respiratory systems, dentition & placenta
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	From hormones to hibernation Hormones in other species, hibernation, adaptation to altitude & other extreme environments	How things heal Blood transfusions, skin healing, bone healing, surgical principles	Guided presentation and essay writing	Practical Day: A surgeon for the day Suture practical & fracture repair practical	Final Presentations

Introduction to Physiology Part 1: In this session, we will investigate how the body communicates through exploring the world of hormones by considering what hormones are, where they are synthesized, how they are transported and how they exert their actions. This material will allow you to better understand some of the topics we will be covering later in the week.

Introduction to Physiology Part 2: In this session we will consider how the kidney functions and how a variety of different hormones influence aspects of kidney function including urine production.

Introduction to Physiology part 3: In this session, we will look at the cardiovascular physiology. We shall be considering in particular the importance and regulation of arterial blood pressure.

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

Interactive Practical to measure Blood Pressure: Arterial Blood Pressure (BP) is an important parameter that can be measured in both humans and animals. This session will involve using an automated blood pressure device on the participants and subsequent analysis of the results.

Topical Discussion: We will discuss a 'topical subject' where all students will be encouraged to contribute.

Supervision Day 1: Discussing your answers to a problem set in small groups (3-4 participants per group) led by the course instructor. You will also have a chance to ask questions about anything that was unclear in 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.

Comparative anatomy: 'Humans, mammals and others'. Looking at the anatomy of teeth, the skeleton, lungs/gills and digestive systems.

Comparative metabolism: 'From hormones to hibernation'. How hormones vary across the animal kingdom including common conditions and metamorphosis. How does hibernation work? How do humans and animals adapt to extreme environments like altitude, the desert and space.

How things heal: Anaemia, Blood types & Bloods transfusions. How do wounds heal (naturally and surgically) and how do bones heal (including how surgeons can fix 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.

Practical day: How to put on surgical gloves and gowns, suturing and knot tying practical (using suture pads), fracture fixing practical (using saw bone models).

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 type of signals does the body use to control the endless array of functions that it needs to carry out in order to maintain life.
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 Matthew Mason's teaching channel. Those on cardiovascular physiology and endocrinology will be most useful.



FitzEd Summer School 2026 - Programme 1

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 1 (12th-25th July, 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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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	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th 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	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	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.

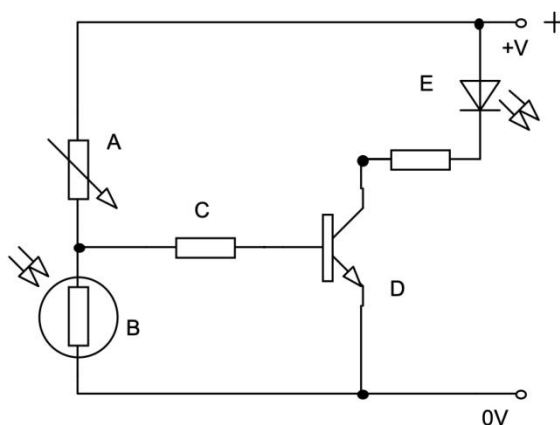
Final presentations: Students will present their research to other participants on the course and the course instructor.

List of prerequisite knowledge:

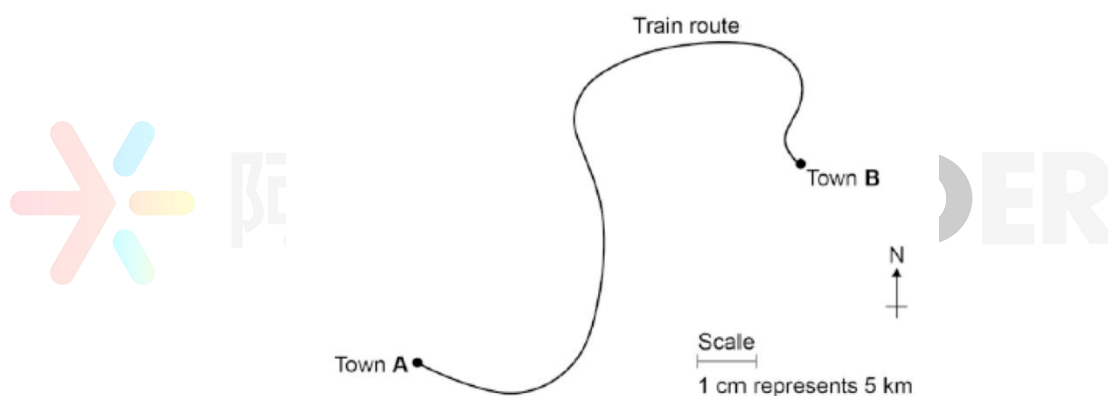
The emphasis during the course will be on the physical understanding of the principles involved. Only elementary mathematical methods will be used. The key is the engineering and not the mathematics behind it. As such, I expect students to have a basic awareness of circuits and their components, alongside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

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

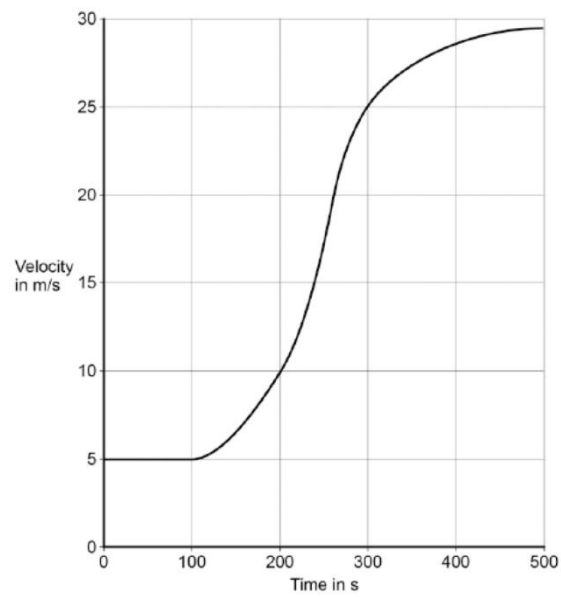
1. Name the components (A, B, C, D and E) in the circuit below:



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.



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Engineering: Sustainable Vehicles

Dr Andrea Giusti

Bye-Fellow, Fitzwilliam College, University of Cambridge
Associate Professor in Thermofluids, Department of Mechanical Engineering,
Imperial College London

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

College Profile: <https://www.fitz.cam.ac.uk/person/dr-andrea-giusti>

Departmental Profile: <https://www.imperial.ac.uk/people/a.giusti>



Module Structure and Syllabus:

The module we propose focuses on the design of new vehicles with sustainability at the centre of all engineering choices. The student will learn the fundamentals of vehicle dynamics, aerodynamic forces, electrification, and new vehicle concepts. Theoretical lectures are paired with practical sessions, which will guide the student towards a conceptual design of the vehicle of the future.

Date	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Engineering and Innovation	Sustainability and life cycle assessment	Vehicle Dynamics	Supervision Day 1	Aerodynamic forces
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	Fuels and Emissions	Electrification of transportation	Guided Presentation and Essay Writing	Supervision Day 2	Final Presentations

Engineering and Innovation: ideal engineering system, S-shaped curve, transition to the super-system, micro-scale interactions, systematic innovation, nature-inspired innovation, examples. In-class problems: definition of an ideal vehicle and identification of barriers to innovation; finding bio-inspired solutions for the improvement of the performance of a vehicle.

Sustainability and Life-Cycle assessment: climate crisis, the concept of sustainability, multi-criteria decision analysis, the lifecycle of a component/system, and the various phases of the life cycle assessment. In-class problems: multi-criteria decision analysis; critical analysis of the life cycle assessment of a car.

Vehicle Dynamics: forces on vehicles, wheels and forces exchanged with the ground, power requirements. In-class problems: identification of engine power requirements to achieve a given performance of the vehicle.

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.

Aerodynamic forces: fundamentals of aerodynamic friction and drag, flow separation, streamlining, wing profiles, lift and downforce. In-class problems: sketch of an aerodynamic vehicle; reduction of drag through the improvement of components (case study).

Fuels and emissions: classification of fuels, emissions from engines, biofuels, and hydrogen. Overview of internal combustion engines, fundamentals of thermodynamics, and efficiency. In-class problems: quantification of carbon dioxide emitted by hydrocarbon combustion.

Electrification of transportation: hybrid cars, fully electric cars, fundamentals of fuel cells and batteries, and electrification of aircrafts. Future vehicle concepts: autonomous vehicles, urban air mobility. In-class problem: evaluate the battery volume and weight for given characteristics of a vehicle (power requirement, range).

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 in the course and the course instructor.

List of prerequisite knowledge:

Fundamental concepts of mechanics (Newton's second law, friction force, velocity, acceleration along a straight line); the concept of energy and power; the concept of work done by a force. Chemical reactions (reading reactants and products; balancing the reaction).

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

1. Consider a block sliding on a table with speed $U=10$ m/s. The kinematic friction coefficient between the block and the table is $\mu = 0.1$. The block is pushed against the table with a normal force equal to 10 N. What is the force parallel to the table that must be applied to the block to keep it moving at constant speed? How much power is needed to move the block?
2. A ball of mass 1 kg is launched vertically from the ground with speed 20 m/s. Assuming that gravity is the only force acting on the ball, what is the maximum height reached by the ball?
3. Methane, CH_4 , reacts with oxygen, O_2 . Find the minimum mass of oxygen per unit mass of methane to completely convert carbon into CO_2 and hydrogen into H_2O .

Recommended reading list (optional):

Any book on physics and chemistry for high school.

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	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Measuring the Universe	Orbital Motion	Powering a Star	Supervision Day	A Star's Life
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	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

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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.

Mathematics for Natural Sciences

Dr Stephen Sawiak

Assistant Research Professor, Department of Physiology, Development and Neuroscience
University of Cambridge
Fellow, Tutor, College Lecturer, Director of Studies in Natural Sciences at Fitzwilliam College,
University of Cambridge

Dr Sawiak is an experienced lecturer, supervisor and director of studies responsible for organising the mathematics supervisions for students taking physical Natural Sciences, Computer Science and Chemical Engineering courses in Fitzwilliam College. He has interviewed Natural Sciences candidates for over 15 years and supervised students in mathematics for 18 years. Day to day he conducts research in magnetic resonance imaging acquisition and analysis methods with applications to neuroscience.

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



Module Structure and Syllabus:

This exciting and challenging mathematics course gives a rapid tour from the fundamentals of calculus (differentiation and integration) up to first-year University level with advanced applications including power series expansion of functions, Fourier series and the extension of integration into multiple dimensions and non-Cartesian coordinate systems. The pace of this course will be fast and most suitable for those with already some familiarity with the basic concepts of calculus who are keen for a preview of University level mathematics made accessible to those of a bright high school level.

Date	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Sums, series convergence	Calculus I Differentiation	Taylor Series	Supervision Day 1	Calculus II Integration
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	Fourier Series	Multiple integration	Guided Presentation and Essay Writing	Supervision Day 2	Final Presentations

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

Calculus I: Differentiation. Definitions, product and chain rules, examples.

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

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.

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Calculus II: Integration. Definitions, relationship to differentiation, integration by parts, harder problems.

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

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

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:

Basic algebra, trigonometry (functions sin, cos, tan; use of radians)

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

1. What does the gradient of a function mean?
2. If $x(a+b/2)=6$, what is b in terms of a and x ?
3. Sketch the graphs of $\sin x$ and $\cos x$, in radians, from $-\pi < x < \pi$

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	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Elements of Mathematics I	Elements of Mathematics II	Elements of Statistics I	Supervision Day 1	Elements of Statistics II
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	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

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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 ?

Critical and Creative Thinking in the Age of AI

Dr Alex Carter

Associate Professor of Philosophy and Interdisciplinary Studies, University of Cambridge
College Lecturer in Interdisciplinary Studies, Fitzwilliam College

Alex Carter teaches Philosophy and Creativity Theory at the University of Cambridge, Professional and Continuing Education. At Fitzwilliam College, Alex supervises philosophy students and provides study skills support to all college members. Alex's research interests are diverse but place an emphasis on skills development; including critical thinking and creative practice. Alex's PhD thesis explored some of the surprising aspects of Wittgenstein's views concerning freedom and fatalism. Alex is currently researching the relationship between humour and creative practice via the concept of 'serious play'.



www.pace.cam.ac.uk/dr-alex-david-carter

www.fitz.cam.ac.uk/person/dr-alexander-carter

Www.ADCPhilosophy.com

Module Structure and Syllabus:

Current debates about our future, and about the future of education in particular, are dominated by questions of how human intelligence can and will be transformed by artificial intelligence (AI). Many express the need for humans to focus on what makes *humans* special, i.e. what we can do that AI cannot. Skills like critical thinking, ideation (idea-creation) and adaptability are emphasised as the essential skills, not just for tomorrow, but *today*. In this course we will develop these skills by examining precisely why they are so important. That is, by considering what it means to be creative we will develop our critical and creative thinking. No prior understanding of the topics covered is required. This course is for anyone, but especially those who feel that they could be more critical or more creative.

Date	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	The skills of the future - how to get ahead	What is creativity?	Why AI cannot create like a human	Supervision Day 1	Introduction to critical thinking: breaking things down
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	Using critical thinking: constructing an argument	Design thinking and other systems for creative practice	Guided Presentation and Essay Writing	Supervision Day 2	Final Presentations

The skills of the future - how to get ahead: We will identify the skills that educators and employers are looking for. As we will see, many (if not most) relate closely to critical thinking and creative practice. Throughout, we will reflect on why, especially in the age of AI, these skills are so important.

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What is Creativity?: Most books on creativity open with a claim similar to the following, “There is no single definition of creativity, but the one I *prefer* is...” I am no different and will introduce you to my own definition of creativity: as ‘serious play’. Even so, we will consider many different definitions so that we can remember that no definition needs to be definitive.

Why AI cannot create like a human: This contentious claim—that humans create in ways that no machine can create—can be defended by appealing to several philosophical theories. The philosophy is, in turn, supported by psychology and computer science. But participants will also be asked to use their own knowledge, be it scientific or artistic, to challenge or defend the claim.

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.

Introduction to critical thinking: breaking things down: “Look before you leap is criticism’s motto. Leap before you look is creativity’s” said E. M. Forster. I tend to agree, but this poses an interesting challenge: Can someone be both critical *and* creative? In this session, we will find out how.

Using critical thinking: constructing an argument: In this session, we will apply critical thinking to solve philosophical, scientific, and technical problems. We will question the methodologies, arguments and assumptions of some prominent figures to show that everyone can and should benefit from thinking critically.

Design Thinking and other systems for creative practice: Having developed our critical thinking skills, we will apply these in existing frameworks. Design Thinking is one example of a systematic approach to devising creative solutions. But how might we *improve* these systems?

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.

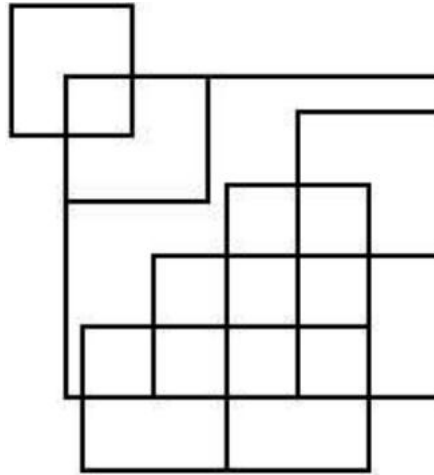
Final presentations: You will present your research to other participants on the course and the course instructor.

List of prerequisite knowledge:

Students will be welcome, even encouraged, to use their existing knowledge in a range of subjects, e.g. physics, mathematics, law, in discussing the above topics. The skills we seek to develop are skills that we all possess and that we can all improve.

If you are unsure about your suitability, you could review the below questions. The more important question is: do you find answering the questions interesting. It is less important that you get the right answer.

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



1. How many squares can you identify in the below diagram?
2. Three people walk into an ice cream shop. The person behind the counter asks “Would **all of you** like an ice cream?” The first customer looks at the other two and says, “I don’t know”. The second looks at the other two and says, “I don’t know”. The third customer looks at the other two and says, “Yes”. Is the third customer correct? Yes or no. (Hint: there *is* a correct answer).
3. Must an artist know *in advance* what they will create in order to create art?

Recommended reading list (optional):

- Butterworth, J. and Thwaites, G., 2013. *Thinking skills: Critical thinking and problem solving*. Cambridge University Press. (Online [here](#))
- Fisher, A., 2011. *Critical thinking: An introduction*. Cambridge University Press.
- Pope, R., 2005. *Creativity: Theory, history, practice*. Routledge

Biology: Microbiology and Pathogen Evolution**Dr Marta Matuszewska**

Research Associate, Department of Medicine, University of Cambridge and Wellcome Sanger Institute, Wellcome Trust Genome Campus

Dr Christopher Ruis

Research Associate, Department of Medicine, University of Cambridge and Consultant, World Health Organization emerging zoonotic diseases

Marta Matuszewska, currently a Research Associate at the University of Cambridge, is an accomplished evolutionary microbiologist specialising in bacterial host adaptation. Holding a PhD in Veterinary Medicine, Marta's research is dedicated to understanding the host range and transmission dynamics of antibiotic-resistant pathogens, with particular focus on *Staphylococcus aureus*. In her current role, she is actively engaged in investigating the biological basis of nasal *S. aureus* and the role of carriage in disease and evolution and spread of antibiotic resistance. Marta is employing a comprehensive approach that integrates microbiology and genetic epidemiology. Beyond her research, Marta actively contributes to education at the University by leading practical classes in mathematical biology and cell biology. Previously she has supervised undergraduate students in mathematical biology, nurturing the next generation of scientists. Marta also enjoys public science outreach, participating in events such as the Cambridge Science Festival, communicating complex scientific concepts to broad audiences.



Google Scholar: <https://scholar.google.com/citations?user=hDJPDIgAAAAJ&hl=en>
Cambridge Infectious Diseases Profile: <https://www.infectiousdisease.cam.ac.uk/directory/marta-matuszewska> LinkedIn Profile: <https://www.linkedin.com/in/marta-matuszewska-b92432131/>

Christopher Ruis, currently a Research Associate at the University of Cambridge, is an evolutionary microbiologist specialising in understanding pathogen transmission. Chris develops and applies methods to generate insights around transmission routes, host species, biology and evolution from pathogen genetic sequences. He has worked on a diversity of viruses and bacteria, with a particular focus on emerging pathogens. Chris' work has a key public health focus and to enable translation of research insights into actionable public health, he works as a consultant with the World Health Organisation. Chris led the identification of SARS-CoV-2 lineages globally during the COVID-19 pandemic, naming Delta, Omicron and their descendant sublineages, and led the genomic response to the mpox virus public health emergency of international concern. Chris has further developed the methodology and software to apply mutational signatures to pathogens, and applied this to identify novel transmission routes for emerging bacteria, highlight virulence of emerging SARS-CoV-2 lineages and demonstrate the dangers of widespread mutagenic antiviral treatment. Chris has extensive experience with supervision and mentoring of students at all education levels.



Google Scholar: <https://scholar.google.com/citations?user=uBrBMBYAAAAJ&hl=en&oi=ao>
GitHub Profile: <https://github.com/chrisruis>

Module Structure and Syllabus:

This course provides an in-depth exploration of the genetic and evolutionary dynamics that drive pathogen adaptation and resistance, focusing on *Staphylococcus aureus* and other significant bacteria. Through lectures on molecular epidemiology, bacterial genomics, and phylogenetic analysis, students will gain foundational knowledge in understanding pathogen evolution. With a blend of theoretical concepts and hands-on activities, including guest lectures and group projects, participants will be equipped to analyse genetic data and explore real-world implications in public health and disease management.

Date	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Molecular Epidemiology	DNA Structure, Causes and consequences of mutations	Micro-organisms Classification	Supervision Day 1	Microbes and Disease
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	Bacterial Genomics	Phylogenetics and Phylogenetic Inference	Guided Presentation and Essay Writing	Supervision Day 2 and Guest Lecture: SARS-CoV-2 Pandemic Response	Final Presentations

Molecular Epidemiology: An in-depth introduction to the methodologies and key definitions essential for studying the evolution of pathogens using genomic data. Students will learn the foundational concepts that underpin molecular epidemiology.

DNA Structure: A comprehensive exploration of cell structure, the intricacies of DNA and RNA molecules, and a deep dive into the Central Dogma of biology. This lecture lays the groundwork for understanding genetic information.

Causes and consequences of mutations: A detailed examination of mutations, including their definition, classification into types, an exploration of their consequences on genetic material, and an analysis of the diverse factors contributing to mutagenesis.

Micro-organisms Classification: A nuanced discussion on the principles governing the classification of microorganisms, emphasising both phenetic and phylogenetic relationships. Students will gain insights into the taxonomic frameworks that categorise these entities.

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

Microbes and Disease: An exploration of infectious diseases, covering the spectrum from foodborne and waterborne to airborne diseases. Students will gain a broad understanding of the diverse microbial agents responsible for various health challenges.

Bacterial Genomics: An introduction to the diverse sequencing techniques employed in bacterial genomics. The lecture will guide students through the process of transforming raw sequencing data into a comprehensible genome, providing essential insights into genomic analyses.

Phylogenetics and Phylogenetic Inference: A deep dive into phylogenetic principles, including real-world examples of phylogenies, discussions on phylogenetic tree rooting and topology, applications in diverse contexts, and a critical examination of potential pitfalls in phylogenetic analyses. Students will also learn the practical aspects of phylogenetic inference. This includes creating alignments, understanding distance matrices, selecting appropriate substitution models, and exploring various approaches to construct phylogenetic trees, such as Neighbour-Joining, Likelihood-based methods, and Bayesian phylogenetic inference.

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.

Guest Lecture - SARS-CoV-2 Pandemic Response: A special guest lecture by Dr Christopher Ruis, offering unique insights into his work during the SARS-CoV-2 pandemic response. Students will gain a first-hand understanding of applying mutational spectra and phylogenetics to decipher pathogen transmission patterns.

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

List of prerequisite knowledge:

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 is DNA, and what is its primary role in living organisms?
2. What is one common disease caused by bacteria?
3. What do we call medicines that help fight bacterial infections?

Recommended reading list (optional):

Brown, T. A. (2002). *Mutation, Repair and Recombination*.

<https://www.ncbi.nlm.nih.gov/books/NBK21114/>

Costa dos Santos, G., Renovato-Martins, M., & de Brito, N. M. (2021). The remodel of the "central dogma": a metabolomics interaction perspective. *Metabolomics: Official Journal of the Metabolomic Society*, 17(5). <https://doi.org/10.1007/S11306-021-01800-8>

Crick, F. (1970). Central Dogma of Molecular Biology. *Nature* 1970 227:5258, 227(5258), 561–563. <https://doi.org/10.1038/227561a0>

Foxman, B., & Riley, L. (2001). Molecular Epidemiology: Focus on Infection. *American Journal of Epidemiology*, 153(12), 1135–1141. <https://doi.org/10.1093/AJE/153.12.1135>

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Hall A. What is molecular epidemiology? (Editorial). *Trop Med Int Health* 1996;1:407–8.

Lakhundi, S., & Zhang, K. (2018). Methicillin-Resistant *Staphylococcus aureus*: Molecular Characterization, Evolution, and Epidemiology. *Clinical Microbiology Reviews*, 31(4). <https://doi.org/10.1128/CMR.00020-18>

MacPhee, D. G., & Ambrose, M. (1996). Spontaneous mutations in bacteria: chance or necessity? *Genetica*, 97(1), 87–101. <https://doi.org/10.1007/BF00132585>

Pitt, T. L., & Barer, M. R. (2012). Classification, identification and typing of micro-organisms. *Medical Microbiology*, 24. <https://doi.org/10.1016/B978-0-7020-4089-4.00018-4>

Tompkins LS. Molecular epidemiology: development and application of molecular methods to solve infectious disease mysteries. In: Miller VL, Kaper JB, Portnoy DA, et al, eds. Molecular genetics of bacterial pathogenesis: a tribute to Stanley Falkow. Part 1. Retrospective look at early advances. Washington, DC: American Society for Microbiology, 1994:63–73



Chemistry

Professor Christopher Hunter FRS

Herchel Smith Professor of Organic Chemistry, Yusuf Hamied Department of Chemistry, University of Cambridge, Fellow at Emmanuel College, University of Cambridge

Dr Peter Bolgar

Bye-Fellow at Fitzwilliam College in the University of Cambridge, Director of Studies and College Lecturer at Magdalene College, University of Cambridge

Dr Andrea Chlebikova

Senior Project Chemist at Isaac Physics, Department of Physics, University of Cambridge
Course Lecturer, Yusuf Hamied Department of Chemistry, University of Cambridge

Prof Chris Hunter did his undergraduate degree in Natural Sciences at Churchill College in the University of Cambridge matriculating in 1983. He completed his PhD at the same place under the supervision of Prof Jeremy Sanders. Later he was appointed to a lectureship in Bioorganic Chemistry at the University of Otago in New Zealand, followed by a lectureship at the University of Sheffield where he was promoted to Professor of Chemistry in 1997. Chris returned to the University of Cambridge as the Herchel Smith Professor of Organic Chemistry in 2014. Chris has received numerous awards for his research over the years, and he has been elected a Fellow of the Royal Society (FRS) in 2008. He is also an Honorary Member of the Royal Irish Academy. Chris is the author of the paper titled 'The Nature of π - π Interactions', which is one of the most cited papers of all times published in the Journal of the American Chemical Society. Departmental profile: <https://www.ch.cam.ac.uk/person/ch664>



internationally.

Dr Peter Bolgar is a teaching Bye-Fellow in organic and bio-organic chemistry at Fitzwilliam College, and he is also the Director of the FitzEd Summer School Programme. 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. Peter is a member of the UK Chemistry Olympiad Working Group, and he mentors students for the International Chemistry Olympiad both nationally and

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

Dr Andrea Chlebikova came to Cambridge for her undergraduate studies in Natural Sciences, specialising in chemistry. She completed her PhD in atmospheric chemistry, focusing on methods of predicting reaction rate constants based on molecular structure. She has been supervising first-year chemistry to students of Natural Sciences as well as more specialised physical chemistry courses since 2015. She lectures third year undergraduates in physical chemistry in the Yusuf Hamied Department of Chemistry. She is 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



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studying STEM subjects at university.

College Profile: [Dr Andrea Cheblikova](#) | [Sidney Sussex College Cambridge](#)

Module Structure and Syllabus:

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

Date	13 th July Monday	14 th July Tuesday	15 th July Wednesday	16 th July Thursday	17 th July Friday
	Physical Chemistry: Thermodynamics	Isomerism in Organic Chemistry	Physical Chemistry: Kinetics	Supervision Day	Introduction to Organic Reactivity and Organic Reaction Mechanisms
Date	18 th July Saturday	20 th July Monday	21 st July Tuesday	22 nd July Wednesday	23 rd July Thursday
	Acids & Bases and Organic Reaction Types	Non-Covalent Chemistry	Guided Presentation and Essay Writing	Laboratory Day	Final Presentations

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.

Isomerism in Organic Chemistry: In this section you will learn about different types of isomerism in organic chemistry. Focus will be on stereoisomerism and chirality, two conceptually difficult topics that are often not explored at depth in secondary school but form an integral part of 1st year undergraduate chemistry curriculum. You will be able to improve on your 3D vision through the use of molecular model sets. We will discuss the relevance of chirality to everyday life, including its significance in biochemistry and the pharmaceutical industry.

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.

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.

Introduction to Organic Reactivity and Organic Reaction Mechanisms: Understanding how and why organic reactions take place is a key skill to have for any undergraduate chemist. We will start by discussing principles that influence electron distribution in molecules. This will be followed by a

quick introduction of simple concepts such as electrophilicity and nucleophilicity. You will then learn the rigorous framework that experienced chemists use to describe and rationalise organic reactions. You will practice drawing reaction mechanisms for progressively more difficult reactions, some of which you would not normally see before your 2nd year of undergraduate studies. By the end of this session you will be able to rationalise reactions unknown to you and have a much deeper understanding of factors that govern reactivity of organic compounds.

Acids & Bases and Organic Reaction Types: You will explore the factors that influence 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. At the end of the session we will expand on organic reactivity that you learnt the day before by discussing in detail a few of the most common types of organic reactions.

Non-Covalent Chemistry: This session will provide an introduction to non-covalent interactions between molecules and their role in determining the relationship between chemical structure and properties. A variety of different types of interaction will be discussed, ion-pairing, H-bonding, aromatic stacking and hydrophobic effects. We will take a look at theoretical models and experimental methods for investigating non-covalent interactions. This session will finish with a discussion of recent examples on the use of these ideas in the design of synthetic supramolecular systems that share some of the important properties of nucleic acids, sequence-selective duplex formation and molecular replication.

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

