FitzEd Online Winter School 2026

Course brochure

The FitzEd Online Winter School is the official winter school of Fitzwilliam College, one of the constituent colleges of the University of Cambridge. The programme will let you experience the type of advanced teaching offered at our institution. The same academics who teach our undergraduate students will help you develop your academic skills. The challenging problem-solving and discussion sessions will reflect the style of Cambridge supervisions, which are the core of the excellent teaching offered at the University.

This brochure contains a list of the various short courses that Fitzwilliam College is going to offer in the winter of 2026. Here you can find a detailed description of the contents of each short course, together with a list of prerequisite knowledge and a recommended reading list for the various courses.

I am delighted that Fitzwilliam College can offer you the opportunity to participate in this Winter School Programme. I hope you will enjoy exploring your chosen topic and that partaking in our course will nourish your passion for the subject. I am looking forward to welcoming you soon to the FitzEd Online Winter School!

Dr Peter Bolgar
Director of FitzEd Educational Programmes

Contents:

Mechanical and Electrical Engineering

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

8th February – 21st February, 2026

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

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

Module Structure and Syllabus:

Engineering has many branches, but the oldest and broadest is mechanical engineering. Mechanical engineers look at the design, analysis, and manufacturing of mechanical systems and machines that keep our world moving forward. Electrical engineering was born in the 18th century, known then as "the youngest of the sciences". Electrical engineers study electricity, electronics and electromagnetism, and their application in the design, development, and testing of systems. This intensive course offers a valuable insight into what it is like to study mechanical or electrical engineering at university, covering the most prominent specialisms within the fields. The course covers a broad range of topics carefully selected to build from one another. Students will follow the historical development of the respective technologies, learn and apply their shared principles, and gain an insight into future developments within these fields. As such, students should graduate from the course with a good understanding of the foundational concepts on which the respective 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	8th February Sunday 17：00-20：00	9th February Monday 17：00-20：00	10th February Tuesday 17：00-20：00	12th February Thursday 17：00-20：00	13th February Friday 17：00-20：00
	Mechanical Engineering: Aerospace - Aircraft Design & Aerodynamics	**Mechanical Engineering:** Aerospace - Aircraft Propulsion & Airframes	**Mechanical Engineering:** Engines – Steam	**Mechanical Engineering:** Engines – Internal Combustion	**Mech/Elec Engineering:** Power Plants – Nuclear
Date	**14th February Saturday 17：00-20：00**	**18th February Wednesday 17：00-20：00**	**19th February Thursday 17：00-20：00**	**20th February Friday 17：00-20：00**	**21st February Saturday 17：00-20：00**
	Mech/Elec Engineering: Power Plants – Renewables	**Electrical Engineering:** Electronics - DC Circuits	**Electrical Engineering:** Electronics - AC Circuits	**Electrical Engineering:** Electronics - Integrated Digital	Final Presentations

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

Mechanical Engineering, Engines: On your third and fourth day, you are introduced to the fundamental concepts of steam and internal combustion engines, from the engine in your car to the turbines found in power plants and passenger jets. You will then learn cutting-edge approaches to apply low-carbon fuels in such engines.

Mechanical and Electrical Engineering, Power Plants: On your fifth and sixth day of teaching, we will begin to transition into Electrical Engineering, looking at power plant design. You will learn the fundamental deisgn characteristics of nuclear reactors, both fusion and fission, and renewables, such as wind and solar. You will study the range of designs in use today and those proposed for the future, focusing on the mechanical, electrical and materials challenges faced.

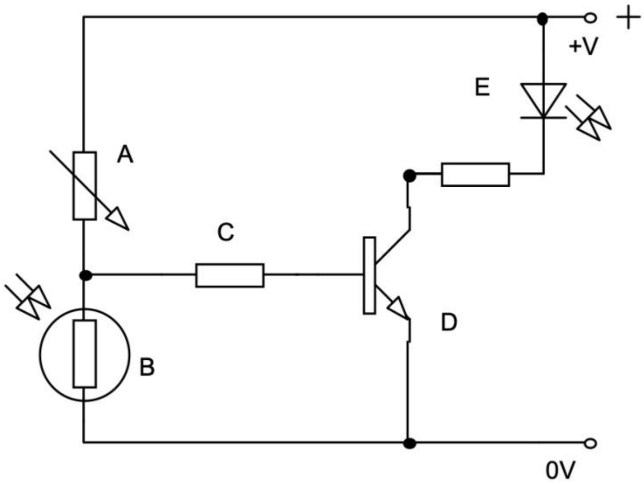
Electrical Engineering, Electronics: Electrical engineering is the study of electricity, electronics and electromagnetism, and the design of systems based on the respective principles. On your seventh day of teaching, you will study the fundamental concepts in direct-current circuits, building a simple circuit for a range of functions. On your eighth and ninth day, you will study the technologies that serve as building blocks to modern digital circuits and their applications. You will learn the fundamentals of design and operation of the major digital integrated circuit technologies, discuss the importance of miniaturising digital circuits and their role in microprocessors, memories and programmable logic devices.

List of prerequisite knowledge:

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

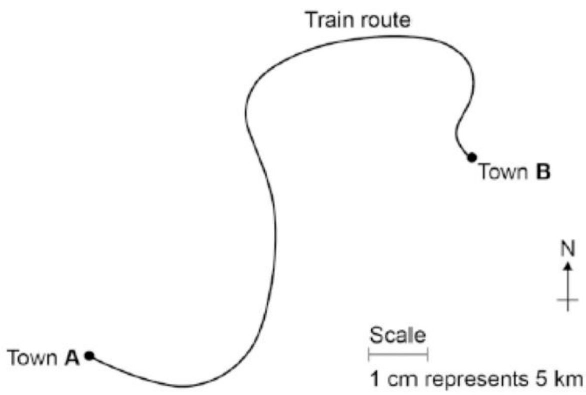
Test your knowledge of the prerequisites! Can you answer the questions below?

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

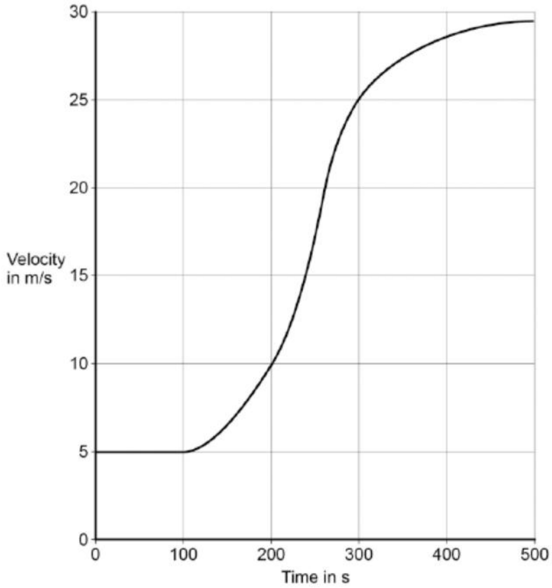


2. A train travels from town A to town B ,as shown in the scale diagram below.

   a) The distance the train travels between A and B is not the same as the displacement of the train. What is the difference between distance and displacement?
   b) Use the figure below to determine the displacement of the train in travelling from A to B.
   c) There are places on the journey where the train accelerates without changing speed. Explain how this can happen.



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



<u>Office hours:</u> to be determined closer to the time.

Special Relativity and Quantum Mechanics
(Physics)

Dr Joao Rodrigues
Bye-Fellow of St Catharine’s College, University of Cambridge

9th February – 21st February, 2026

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

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

Module Structure and Syllabus:

The motion of particles at speeds close to the speed of light is described by equations that are very different from those that we apply to study the motion of the objects in our daily life, such as the planets around the Sun. Special Relativity provides the theoretical framework to study those fast moving particles. We shall study phenomena such as the time dilation, length contraction and the famous twin paradox, which have no counterpart in the classical theory.
And let us explore the Quantum World. The atomic and subatomic particles behave in a way that for us, used to the certainties of Classical Dynamics and Electromagnetism, is unambiguously strange. Quantum Mechanics suggests there is an essential randomness in quantum phenomena and the best theory we have, based on the wave function and Schrodinger equation, can only predict the probabilities of events to occur. Such peculiarities of the theory were not appealing to everyone. We shall look at how Einstein objected to the standard formulation of Quantum Mechanics and how his ideas led to new developments.

Date and time	**9th Feb Monday 17： 00-20： 00**	**10th Feb Tuesday 17： 00-20： 00**	**11th Feb Wednesday 17： 00-20： 00**	**12th Feb Thusday 17： 00-20： 00**	**13 th Feb Friday 17： 00-20： 00**
	The Lorentz Transformation	Relativistic Kinematics	Relativistic Dynamics	Relativistic Optics	Appearance of rapidly moving objects
Date and Time	**14 th Feb Saturday 17： 00-20： 00**	**18 th Feb Wednesday 17： 00-20： 00**	**19 th Feb Thursday 17： 00-20： 00**	**20 th Feb Friday 17： 00-20： 00**	**21st Feb Saturday 17： 00-20： 00**
	The historical development of QM	The postulates of QM and simple applications	Heisenberg’s Uncertainty relations	The EPR paradox and Bell’s inequality	Presentations

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

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

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

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

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

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

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

Heisenberg's Uncertainty Relations: We derive formally the uncertainty relations, give some examples and investigate their implications for the results of real measurements.

The EPR paradox and Bell's inequality: The new ideas were not accepted without reluctance by some, among them Einstein. In 1935, together with Podolsky and Rosen, he wrote an article in which an apparent paradox suggested that the formulation of Quantum Mechanics was incomplete. We shall discuss their reasoning and the more modern version of the paradox due to Bohm. Almost 30 years after the EPR argument was formulated, Bell wrote what has been described as one of the most important scientific works of the 20th century, in which it was shown that Quantum Mechanics could not be completed with the so-called hidden variables. We shall have a good discussion of Bell's theorem and some of its variants, namely due to d'Espagnat.

List of prerequisite knowledge:

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

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

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

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

1. Igor is a cosmonaut in the International Space Station, orbiting the Earth at an altitude of 408 km at speed of 28000 km/h. What is his acceleration and what gravitational force does the Earth exert on him.
2. You apply a 4.9 N force to the free end of a spring, stretching it from its relaxed state by 12 mm. What is the spring constant? What force does the spring exert on you if you stretch it by 17 mm? How much work does the spring force do on your hand?
3. The wavelength of x rays produced in the Stanford Linear Accelerator is 0.067 fm; what is the frequency of these x rays?

Recommended reading list (optional):

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

Office hours: to be determined closer to the time.

Computer Science: Artificial Intelligence and Machine Learning

Dr John Fawcett
Fellow, Tutor, Praelector and Director of Studies in Computer Science at Churchill College
Bye-Fellow in Computer Science at Homerton College, Lucy Cavendish College,
Hughes Hall, and St Catharine's College, University of Cambridge

8th – 20th February 2026

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

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

Module Structure and Syllabus:

Artificial intelligence (AI) and machine learning (ML) have featured in the news regularly in recent years as technology continues to transform our social and work lives. This course explores the problems that we can solve with AI and ML and takes a deep dive into how we create them, including the key maths and algorithms. It moves from narrow-focused classical AI systems to solving open-ended problems that humans cannot necessary solve. Looking beyond today's AI and ML systems, the course looks at the challenges that the technology has still to overcome, posturing you to understand the next wave of developments.

Time and Date	**8 Feb Sunday 14:00-17:00**	**9 Feb Monday 14:00-17:00**	**10 Feb Tuesday 14:00-17:00**	**11 Feb Wednesday 14:00-17:00**	**12 Feb Thursday 14:00-17:00**
	Programming with Prolog	Planning problems	Interactive decision making	Understanding Knowledge	Theorem Provers
Time and Date	**13 Feb Friday 14:00-17:00**	**14 Feb Saturday 14:00-17:00**	**18 Feb Wednesday 14:00-17:00**	**19 Feb Thursday 14:00-17:00**	**20 Feb Friday 14:00-17:00**
	Simultaneous requirements	Scaling to real-world problems	Training a Neural Network	Limits of machine learning	Presentations

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

Programming with Prolog: we will learn a new programming language that can help us to implement our AI algorithms!

Planning: to get us started, we will understand what it takes to build an AI system that can do all of the "intelligence" up-front, solving a problem when everything is known in advance.

Interactive decision making: how can we handle problems that change while we are implementing our solution? Dynamic, or interactive, search problems pose interesting new challenges!

Understanding knowledge: each of us has an intuitive understanding of common sense and knowledge, but how can we represent that in a computer, and what format(s) make it usable?

Theorem provers: as it is often helpful to implement AI algorithms by transforming a difficult and domain-specific problem into a well-known area of computer science, we will look at theorem provers.

Simultaneous requirements: armed with our theorem provers, we will look at ways to solve problems where an acceptable solution requires us to meet several conditions at the same time.

Scaling to real world search problems: some forms of AI are more easily scaled than others. We will look at redesigning our algorithms to better match the limits of modern hardware and to handle different user requirements.

Training a neural network: generalising our approach, can we design systems that can design themselves?

Limits of machine learning: understanding the practicalities of contemporary machine learning solutions and the implications for their reliability, trust worthiness, hallucinations, etc.

List of prerequisite knowledge:
No computer science knowledge is assumed but programming experience is always useful.

Test your knowledge of the prerequisites! Can you answer the questions below?
Suppose you have a function that can tell you which of two items, A and B, should come first in a sorted list.

1. What is the difference between a tree and a graph data structure?
2. Why might breadth first search not perform well on a graph?
3. Why might depth first search not perform well on a graph?

Office hours: 9.30 am – 10.30 am Thursday 12th February
9.30 am – 10.30 am Thursday 19th February