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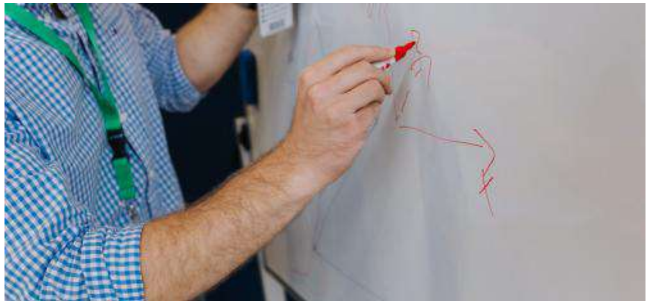

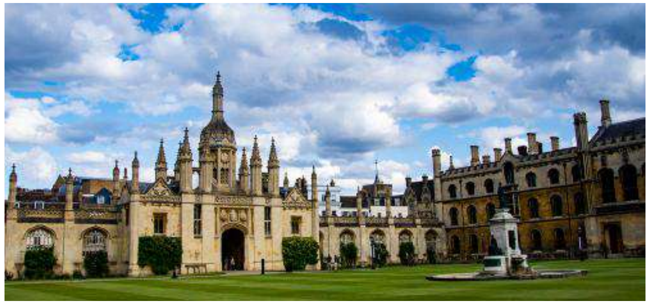



Physics

SYLLABUS OVERVIEW
16-18 YEARS OLDS

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About Immerse

Immerse Education is an award-winning academic summer school provider offering programmes for 16-18 year olds in centres of academic prestige.

The aim of these programmes is to provide participants with academically challenging content that develops their understanding of and passion for their chosen discipline. Through 40 hours of academic sessions, the programmes also offer young students unique and valuable insights into what it would be like to study their chosen subject at university.

This Syllabus Overview provides a summary of the topics and subject areas that participants can encounter during their studies with Immerse. It has been carefully created by our expert tutors who are current members of world-leading universities, and who have experience in teaching undergraduate students.

Academic Sessions

The academic sessions at Immerse are arranged into modules to enable participants to explore a broad range of topics over the course of two weeks. The modules included in this syllabus overview are indicative but not prescriptive.

Tutors are encouraged to include their own specialisms and also focus on any particular areas of interest expressed by participants within the class. They may choose to provide further detail on a specific topic, or they may include new material and information that builds on the knowledge already developed during the programme.

Personal Project

Each programme includes an element of individual work, generally termed the ‘Personal Project’. This can take many forms but is commonly an essay or presentation delivered on the final day of the programme. Participants will receive feedback on this work which may also be mentioned in the participant evaluation which is provided in writing by the tutor once the programmes have ended.

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Preparatory work

Some tutors may ask participants to complete some preparatory work, such as reading or a series of exercises in advance of the programme. Participants are strongly encouraged to complete this work since it will be included in the opening sessions of the programme. Any preparatory tasks will be provided in advance of the programme directly to the participant.

Academic Difficulty

As all of our programmes are designed to provide a unique introduction to advanced material, the syllabus will be academically challenging at times.

This is something to be excited about and all of our tutors will encourage and support participants throughout the programme. Immerse Education aims to develop every participant regardless of ability, and our tutors will adapt their teaching to individual needs.

Aim of the Physics Programme

The Immerse Education Physics programme is designed to build upon the knowledge that participants have already gained in a traditional classroom environment and highlight how this can be used to inspire further study at university. Participants are encouraged to explore new material in-depth and to form independent and considered opinions and ideas based on sound research and practical knowledge. By the end of the programme, participants will have a good understanding, not only of university-level content, but also the variety of degree programmes available in subjects related to physics. Beyond this, participants will also explore the career opportunities available to graduates in this field.

TOPICS LIST

Classical Mechanics

The study of classical mechanics is basically the study of how objects move. In many ways it is physics at its core. This topic is tightly bound to the University of Cambridge via its founding father, Sir Isaac Newton, active at Trinity College. We will extend our knowledge of high school mechanics to include more complex problems relating to kinematics. Interestingly, the skills required for mechanics calculations have a strange tendency to crop up in much more exotic fields of physics, time after time.

Wave Phenomena

Propagation of energy or matter is often described either by the kinematic travel of an object or by the evolution of a wave. Whilst the most popular example of a wave, the water wave, might not seem too thrilling to study, the number of physical processes that include waves are innumerous. Some well-known examples of waves include sound waves, vibrating guitar strings, and microwaves. However, all objects of matter can actually be described by waves via the famous Schrödinger equation. In this topic, we introduce the connection between circular motion and waves, we explore the classical wave equation and we study the behaviour of springs and pendula.

Electronic Engineering

Electronic engineering is a wide branch of engineering which applies the general principles of electromagnetism to digital circuits, sensors, actuators, mobile telecommunications, optic fibres etc. Participants will be introduced to basic electronic components and systems, and we will collaborate to briefly describe their working principle in scientific terms. We will explore digital circuits at the base of modern laptops and smartphones and assess their relative limitations. Successively, we will turn our attention to the practical design of a simple radio receiver and the working principle of the main analog circuits.

Optics

The study of light as a wave initially turned out to be immensely powerful. It lays the foundation for the production of a wide range of things, ranging from reading glasses to far-space telescopes. In this topic, we remind ourselves of how light travels through mirrors, lenses, and pieces of apparatus built with optical elements. We also investigate how different apertures can be used in order to study properties of the light itself and ultimately of the source of the light as well as its utility to us in the everyday world.

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Electricity and Magnetism

Whilst the study of the movements of objects (from planets to apples) occupied physicists for centuries, the Industrial Revolution and the discovery of electricity led to an era of making the impossible possible. It is easy to understand the vast importance of the ability to control electricity. But how do we actually do that? Yet again, the University of Cambridge is the best place to answer this question. James Clerk Maxwell worked here. Maxwell, who managed to confine all of our knowledge of magnetic and electric behaviour in just four comprehensive equations, has influenced the field of modern physicists at a comparable level to Newton. In this topic we will study his equations and apply them to real problems.

Thermodynamics and States of Matter

The matter in our universe can consist in different states. Some common examples include the gaseous state, the liquid state, and the solid state. To the more exotic states we can add plasma and Bose-Einstein condensates. Again, it was during the Industrial Revolution that the study of phases or states of matter started to receive the attention it deserved. In this topic, we will study how the ability to change the state of matter has enabled us to transfer energy from one process to another. We will dive into specific areas ranging from heat engines to the composition of different chemical elements.

Atoms, Nuclei and Elementary Particles

The ancient Greeks realised that many things in our universe seems to be governed by some underlying symmetry. Schools of fish tend to adapt symmetrical formations. Many flowers contain rotation symmetries etc. Over the last century researchers have been occupied with exploring what matter is ultimately made from. It was not very surprising when the results started to indicate that particles exist in some sort of symmetrical arrangement. It became possible to predict the existence of a particle based on the symmetry of the already discovered ones. The overall symmetry model of this is called the Standard Model.v

Quantum Mechanics I

Whilst physicists were happy to work with Newton's laws of motion when describing the movement of macroscopic objects, it eventually became clear that his formalism could not properly describe the movement of small objects. For example, electrons, which had been considered to move as particles, sometimes behaved as waves. To confuse things even more, light, which had been thought of as a wave, seemed to sometimes behave as particles. This famous wave-particle duality forced the community of physics to develop a new theory to resolve the paradox. This theory was called the theory of quantum mechanics.

Quantum Mechanics II

The 20th century saw the development of the two most ground-breaking theories of physics, the theory of relativity and the theory of quantum mechanics. The non-intuitive nature of quantum mechanics naturally resulted in a revolution of the way researchers approach physics. It also gave the physics community some extremely powerful tools to accurately predict the behaviour of the smallest parts of our universe. In this session, we will look at how the theory of quantum mechanics enables non-classical computing (quantum computing), super-safe communication (quantum key distribution), and communication without particles (counterfactual quantum communication).

TOPICS LIST

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Excursion to the Physics Department

The physics department (or the Cavendish laboratory, as we call it here) of the University of Cambridge was founded in 1874. It is one of the most influential institutions of physics research in the world, having collected a total number of 29 Nobel laureates. Today, the research spans a vast spectrum, ranging from the theoretical study of quarks to the experimental realisation of super-efficient solar panels. This session will be a tour of the department. There will the opportunity to meet and interact with researchers, but we will also be visiting various laboratories. Additionally, if time allows, we should be able to see the historical equipment of famous Cavendishers.

Special Relativity

We really do not want to treat the good old Newtonian mechanics too badly. However, this topic is also related to a study of scenarios that are badly described in the classical picture. Around the beginning of the 1900s, it was clear that one ran into problems when trying to apply Newtonian mechanics to objects of very high speed. The underlying reason for this has to do with the fact that the speed of light is constant and that light is a massless form of energy. In this session, we will study the non-intuitive effects of the theory of relativity. These include length contraction, time dilation, and mass changes.

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Personal Project

Throughout the fortnight, participants will be working on their own personal project. Having been provided with a brief, participants should research and prepare a presentation for their peers. This will build upon an aspect of the theory that they have learnt over the course of the programme and is also an opportunity to showcase the practical skills they have developed. The presentation is followed by questions from the audience and wider class discussion of particular points of interest. The tutor may also include feedback about the presentation in the written evaluation which is sent to participants after the programme has ended.

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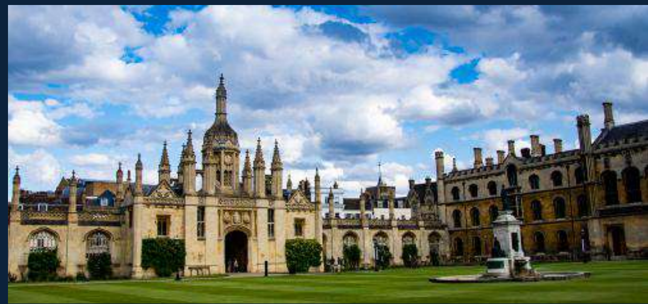

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