Physics & Astronomy at St Andrews

- Students at the University of St Andrews have voted themselves the most satisfied in the UK for the quality of their higher education experience, according to the National Student Survey 2018. This is the tenth time in the past 12 years that St Andrews has been ranked at the top of universities across the UK in this survey.
- Students enjoy a wide range of activities in a student-focused community within a historic coastal town.
- Entrant students applying appropriately are virtually guaranteed a place in University accommodation.
- Our School is large enough to have major research strengths, but small enough that there is good student-staff interaction, and some small class sizes.
- Programmes are flexible, with a choice of entry and exit points and degree intention as a student proceeds.
- Well-qualified entrants may complete an Honours BSc degree in three years, or an MPhys degree in four.
- The University Observatory contains the largest operational optical telescope in the UK.
- The 2018 formal review of our teaching programme commended the School for “its strong sense of community. Students perceive staff as welcoming, approachable and supportive.”
- Internationally recognised research in astrophysics, biophotonics, lasers and optoelectronics, mm-waves, magnetism, semiconductors, solid-state and theoretical physics informs our teaching.
- In the Guardian University Guide 2019, Physics in St Andrews was rated top in the UK.

Physics and Astronomy are key subjects for understanding the universe around us. There is a fascination and a challenge here. Why is the sky blue? What is the difference between metals and semiconductors? How are matter and energy related? What happens near a black hole? How did the universe begin? Answers to these and similar questions can then lead to investigation and understanding of related phenomena, and to the development of new technologies.

We can use physics to understand aspects of systems ranging from the smallest parts of our bodies to the vast collections of galaxies. Physics is relevant in almost every human endeavour. Our teaching emphasises an understanding of these ideas. Our courses are interesting, current, relevant, and thought-provoking.
Along with several other science Schools, Physics & Astronomy lies on a pleasant modern site close to the town centre, as pictured on the back cover of this leaflet. Teaching, research, library and computing facilities are in our building, and the well-equipped University Observatory nearby has the largest operational optical telescope in the British Isles.

Having about 40 members of teaching staff and around 150 research staff and students, the School is large enough to provide a wide coverage of physics and astronomy at undergraduate level and lively enough to produce significant research. However, the School is small enough for staff and students to get to know each other in a way that is not possible at much larger universities. Some 60-100 students per year graduate from the School. The comparatively small size of the University as a whole facilitates the ready mixing of those studying different subjects. There is a cosmopolitan feel to St Andrews, with students from all over the UK, and indeed from around the world.

The Institute of Physics 2013 accreditation report commented on the “strong commitment to high quality teaching”, and also that “students informed the panel that staff are approachable and willing to provide individual feedback and assistance when requested. The students noted that from Junior Honours onwards the lecturers get to know all students which supported the feeling of community within the School.”

### Degree Options for Physics or Astronomy

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<td>Physics and Astronomy (Gateway) BSc (FH31) and MPhys (FH3C)</td>
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The “Elephant Trunk” star forming region, as imaged by the Calar Alto 2.2m telescope. St Andrews astronomers use observatories worldwide and in space, across the electromagnetic spectrum, to study our universe. Targets range from nearby exoplanetary systems to the large-scale structure resulting from the Big Bang.

The Joint European Torus, exploring the science of nuclear fusion, which may be a future ‘clean’ energy source. One of the engineers in charge is a St Andrews Physics graduate. (Photograph supplied courtesy of EFDA JET).
When a fine nickel powder is agitated by electric and magnetic fields, it shows dynamic co-operative effects. Honours students are investigating this ordering phenomenon using a specialised video camera and LabView software.

Investigating the phase structure of laser modes in the senior teaching labs.

**BSc & MPhys Programme Details**

A five-level structure is used in order to provide suitable entry and exit points tailored for students with different backgrounds and desires. These levels, which usually last an academic year each, are shown in the table on pages 6 and 7. There can be a choice of entry level depending on school qualifications and how broad you wish your entry year to be.

First year (1000-level) entry has been designed for those entering straight from Scottish Highers, those wishing to experience the traditional broad-based first year at university, and students on some joint programmes. If you have good Advanced Highers or A-Levels, and you are sure that you wish to study for a degree in physics and/or astronomy, you are invited to enter directly into second year (2000-level). Currently around one third of our entrant students take this accelerated route.

There is an alternative 1000-level entry called the Physics and Astronomy (Gateway) designed for students with high academic potential who have experienced disadvantage. Slightly lower qualifications (e.g. ABBB at Higher) are needed for entry, and although about half the entry year is with the traditional entry students, about half is on strongly tutored modules in academic skills relevant to physics and mathematics. Successful completion of this year allows progression to our second year physics, astrophysics, and mathematics modules.

There is a choice of exit levels with the BSc Honours degree taking three or four years and the more advanced MPhys Honours degree taking four or five years, depending on the point of entry. The MPhys (Integrated Masters) degree is particularly appropriate if you wish to go on to pursue a research or development career in physics or astronomy. Your final decision on the BSc or MPhys degree need not be made until third year.

In third and fourth year you take some or all of the mainstream modules in quantum mechanics, nuclear and particle physics, thermal and statistical physics, electromagnetism, computational physics, and condensed matter physics, as well as choosing additional modules in specialist areas. Depending on the degree programme these might include Extragalactic Astronomy, Computational Astrophysics, Special Relativity and Fields, Fluids, laboratory modules and many others. All final year students undertake a major research project, which is usually carried out within one of the School’s research groups.
The MPhys additional year contains a choice of advanced lecture modules in areas such as Biophotonics, Group Theory, Monte Carlo Radiation Transport Techniques, Applications of Quantum Physics, Magnetofluids and Space Plasmas, and Contemporary Astrophysics, as well as a major research project. All our BSc, MPhys and MSci degrees are accredited by the UK Institute of Physics.

In all modules, lectures are supplemented by tutorials. At second and third year these tutorials may be in groups comprising only four or five students. Tutorials provide the opportunity for in-depth discussions of issues arising from lectures, as well as broader topics in physics and astronomy.

Appropriate laboratory periods introduce you to a wide range of equipment and techniques. Third and fourth year physics lab modules, for example, contain work with scanning tunnelling microscopes, X-ray crystallography, cryogenics, and optical tweezers. Astronomy students have the use of telescopes at the Observatory.

In your final year you can participate in the extensive research activity of the School by undertaking a project which extends over a large part of the academic year. This is a great way to learn and experience the development of physics at first hand. Some projects result in scientific publications, and may include travel to international facilities. Recent projects have included the investigation of extra-solar planets, the use of our cleanroom to explore novel liquid micro-optics, the use of terahertz radiation for drug detection, and the theoretical physics of invisibility cloaks.

For Single Honours students in the School, advanced communication and other skills are developed in the 3000-level Transferable Skills for Physicists module, which includes an informal weekend spent away from St Andrews, giving a talk on a chosen topic in physics or astrophysics.

Depending on the modules you have chosen to take, it is possible to postpone the final choice of degree title at least until you reach 3000-level. Many students make use of this flexibility.
Outline of BSc & MPhys Degree Programmes

Entry point for those with Highers only
Also for those who wish to take a broader first year, and for all on some joint degree programmes

Typical entrance requirements for Highers are AAAA, for A-Level are AAA, and for International Baccalaureate 38 points, in all cases including Physics and Mathematics (HL6 for IB).

Possible entry point for those with good Advanced Highers or A-Levels and planning a Single Honours degree in the School*

University entry as for first year entry, but to be eligible to start at second year Highers-qualified students would also need A grades at Advanced Higher in Physics and Mathematics along with Highers at AA in two other subjects.

First Year

Six 20-credit modules are normally taken in this first year of study. These include Physics 1A and 1B, which cover topics such as Newtonian Mechanics, Quantum Phenomena, Waves and Optics, Properties of Matter, and Lasers.

Intending astronomers must take AS1001; this is an option for others. The astronomy module contains topics on The Solar System, Stars & Elementary Astrophysics, The Galaxy, and Galaxies & Cosmology.

All these modules contain suitably graded practical work and tutorials.

Intending physics or astronomy students must include at least one or two Mathematics modules, depending on school qualifications. A wide choice of other 1000-level modules from across the University is available, subject to timetable constraints.

Second Year Direct Entry

Students take the second year Maths modules MT2501 Linear Mathematics and MT2503 Multivariate Calculus, which build on their Advanced Highers or A-Level knowledge. Astronomers take a short 1000-level Astronomy module in first semester and Astronomy 2 in second semester.

All Physics and Astronomy students take Physics 2A and Physics 2B, which build on 1000-level, Advanced Highers, or A-Level work. Topics include Classical Mechanics, Relativity, Oscillations in Physics, Quantum Physics, Classical Waves, Electricity and Magnetism, and Thermal Physics. Practical work and small-group tutorials also aid learning.

Second Year Continuing Students

A total of 120 credits of 2000-level modules are taken. All our students take at least MT2501 and MT2503 as Mathematics modules. Astronomers take AS2001. This or another 2000-level module is taken by physicists.

*Direct entry to second year of the joint degrees with Mathematics is also possible. Typically required grades in Advanced Highers and IB as for Single Honours, A-Level qualified applicants also need A in Further Mathematics.
Physics and Astronomy (Gateway) entry point
Students who have academic potential, but due to disadvantage are unlikely to quite reach our normal entry requirements, may be eligible for an alternative first year programme that leads on to the existing second year. Please see page 4 and the School web pages for more details.

This information is for guidance only. For Joint Honours degrees the subject with the higher entrance requirements determines the likely minimum grades. Admissions Officers consider all aspects of every application, particularly the Personal Statement. Remember that you must also meet the Faculty Entrance Requirements (see Undergraduate Prospectus: www.st-andrews.ac.uk/study/ug/prospectus).

Third Year and Fourth Year to BSc (Hons)
These two years of study can lead to the BSc Single Honours degree in:

Physics or Astrophysics
Lectures are supplemented by tutorial work. Third and fourth year Physics students take two laboratory modules, and Astrophysics students can take observational and computational physics modules. Theoretical Physics students usually take theory modules instead of labs. Fourth year BSc students undertake a major project.

For students who have taken the appropriate modules in the second subject, the following joint BSc degrees are also available:

Physics and Computer Science
Physics and Philosophy
Physics and Mathematics

Exit point with an Honours BSc Degree
The BSc Honours degree is taken in three or four years, depending on the point of entry.

Exit point with an Honours MPhys or MSci Degree
The MPhys degree is taken in four or five years, depending on the point of entry.

MPhys and MSci Additional Year
This year contains advanced lecture courses, and a substantial project.

The MPhys degree titles are:

- Astrophysics
- Physics
- Theoretical Physics
- Theoretical Physics and Mathematics

The MSci degree:

- Physics and Chemistry
Entrant Scholarships
The School offers a number of scholarships of £1,000 or more to selected students. Details are on the School website: www.st-andrews.ac.uk/physics/pandaweb/admiss/bursaries

The University has a variety of other scholarships on offer: www.st-andrews.ac.uk/study/ug/fees-and-funding

Research and Teaching Quality
In the 2014 Research Excellence Framework (REF) our research in physics and astrophysics was ranked third in the UK for quality. The submission to REF was joint with the physics and astronomy research programme at Edinburgh University, both Schools being part of the Scottish Universities Physics Alliance.

The formal review of our teaching programme in 2018 commented on the “attractive, balanced and modern presentation of Physics and Astronomy” and “a well-functioning School with a healthy student-staff relationship”.

Overseas Links
We are pleased to welcome a number of overseas students to our School for a semester, a year, or the full degree programme. Our University has exchange links with a number of overseas universities. Students may apply to be considered to spend third or fourth year at one of these institutions.

The School’s Student-Staff Council organises summer placements for selected students at international facilities such as the High Magnetic Field Facility in Grenoble.

Research links are maintained with scientists in many countries.
Visits to the University
The University organises Visiting Days for prospective students to visit the University and see for themselves the Schools in which they are interested. These take place on a number of Wednesdays through the year. They include an introduction to the University and town, as well as visits to relevant Schools. The School runs a special Visiting Day on one Saturday in February each year. Please see the School’s web pages or contact us for details. On request, visits may be organised at other times as well. Please see the back cover for contact details for arranging such visits.

Student Organisations
The School’s students run AstroSoc and PhySoc with social and academic events associated with astronomy and physics respectively. The School’s Student-Staff Council also plays an active role in academic and other events, including a dinner-dance for students and staff.

Career Opportunities
Degrees in physics and related subjects are welcomed by employers, and St Andrews graduates do well at finding employment in areas of their choice. A significant number of graduates go into some form of research or development in industry or in Government agencies, either immediately after graduation or following a higher degree. Examples of high technology industries in which physicists work include optoelectronics, computing, telecommunications, aerospace, and semiconductors. In our degree programmes we work with students to develop relevant skills such as problem solving, mathematical modelling, and the ability to communicate complicated ideas. These skills also make for graduates who are well-suited for more general careers in management, banking, and related areas. A good physics training opens the door to many different careers. We have a number of graduate profiles on our website. These include graduates who have entered careers in research (various universities and companies), software consultancy (QAS, London), intellectual property law (Bristows, London), accountancy (Deloitte), and a pair of graduates who started up a small business in scientific displays (FifeX, Tayport).
Research
The School has a successful research programme exploring a range of fundamental and applied areas of physics and astronomy. The 2014 Research Excellence Framework ranked the quality of our research third across UK physics departments. Our submission was joint with the University of Edinburgh, both Schools being part of the Scottish Universities Physics Alliance. With most teaching staff directly involved in research you can expect to find classes that are informed by the latest research in astronomy and physics, and taught in many instances by internationally-recognised experts in their fields. Through their research many staff also have useful links with companies and organisations. The links between teaching and research are probably strongest for students in their final-year project, which they usually undertake within one of the research groups and with access where appropriate to specialised equipment. The main research activities of the School are in the areas of: Astronomy and Astrophysics, Laser Physics and Optoelectronics, Biophotonics, Quantum Optics, Magnetism and Superconductivity, Quantum Materials, Millimetre-wave Techniques, and Theoretical Physics. The School is a member of the Scottish Universities Physics Alliance, which is a major collaborative project enhancing physics research in Scotland.
www.supa.ac.uk

Recent research contributions to science from our School include:

- The discovery of the nearest yet seen rocky planet outside our own solar system.
- The discovery of planets around another star looking like an analogue of our solar system.
- Exploring black hole physics in a special optical fibre.
- The development of light emitting polymers for the treatment of certain skin cancers.
- Using optical forces to create the fastest man-made rotating object.
- Wide-field high-resolution imaging for neuroscience and developmental biology.
- Tracking biological cells through feeding them microlasers.
- Extreme slowing of light in micro-structured semiconductors.
- The generation and study of collective quantum states of matter, where $10^{23}$ electrons behave as a coherent group in exotic conducting oxides.
- Theory of how to build quantum materials that absorb light at a super-fast rate.
- Reproducible and quantitative detection of cancer markers using nanoplasmonic sensors.
Research and Students
Our undergraduate students have various opportunities to interact with the research work of the School. The most obvious is the final year project, which sees most students working with one of the research teams. The five students pictured were all working in the millimetre-wave research group for their projects. Tom is demonstrating his mm-wave motion-sensing radar, which is now being used in outreach events. After graduation these students went on to a career in scientific administration, teacher training, a Jones Fellowship to Georgia Institute of Technology, and research degrees in Imperial College and St Andrews. In 2018 one of our final year students won first prize in the Global Undergraduate Award in Physics and Mathematics for his project work on intracellular microlasers.

The School’s research informs our teaching generally. In some of our first year labs students carry out a research-style investigation, followed by a visit to a relevant research lab. There is a tour of research labs in our second year modules. A visit to the “optical black hole physics” research lab is shown opposite. Third year students can explore topics of local research and present this to the class in the Transferable Skills for Physicists module. Final year lectures can take students to the current research frontiers and final year projects are usually within the School’s research groups. There are opportunities for funded summer internships with our research groups, and astronomers can, after suitable training, have access to some of the Observatory’s telescopes to carry out their own investigations.
Graduate Profiles

Susanna says:

“In the summer of 2014, I completed my Physics degree. With the enthusiasm for Physics built up in St Andrews and, keen to keep learning, I then spent some of my summer characterising materials using a vector network analyser in the School’s mm-wave group before attending a summer school in Holland on the Physics of the Climate System.

In September 2014, I started at KP Technology, working as a Graduate Research Assistant. Our specialism is the measurement of the work function and electrical characterisation of materials, with wide applications including research into (organic) semiconductors, sensors, nano-materials, solar cells and forensics. Since graduation, I have worked and collaborated with Universities, agencies and companies all around the world, accrued thousands of hours of measurement and research time, attended my first scientific conference and co-supervised some student interns! I am now studying for a PhD as part of my job and was awarded a Royal Commission for the Exhibition of 1851 Industrial Fellowship to support this research.

I have been able to build on my practical experience in the labs, theoretical knowledge gained and the thinking and transferable skills developed in St Andrews, to conduct research and assist with future equipment development within the company. An enjoyable and exciting future is just beginning!”

Joe says:

“I graduated from St Andrews in 2010 with a joint degree in Mathematics and Theoretical Physics. I enjoyed my time in St Andrews so much that I continued on to study for a PhD in Astrophysics. During the four years studying for my PhD I had the opportunity to travel to many conferences both in the UK and internationally and to publish multiple scientific papers.

After completion of my PhD in 2014, I accepted a research position as an astronomer at Lowell Observatory in Flagstaff, Arizona. At Lowell I continue to build on the research I began in St Andrews and actively participate in outreach to educate visitors to the observatory about Physics and Astronomy. Lowell is home to the 4.3 metre Discovery Channel Telescope, a world-class research facility which I am extremely fortunate to be able to use to study the properties of extra-solar planets and their parent stars.

I could not have asked for better preparation and training for my position at Lowell than I received at St Andrews. The broad choice of courses available to me during my undergraduate degree, along with access to world-class facilities during my PhD, were an integral part of my current success and have allowed me to continue my research and answer fundamental questions about the universe.”

Susanna (Working in Wick, Caithness)
BSc Physics

Joe (Working in Arizona)
MPhys Theoretical Physics and Maths 2010
“My love of numbers and equations drew me towards studying physics. The highly modern and well-equipped labs make studying experimental physics a great experience at St Andrews.

The staff in the School of Physics & Astronomy make studying at such a world-class university easier. My advisor told me exactly what to expect and gave me guidance throughout the year. There is always someone in the School to speak to, whether for a chat about quantum mechanics or a motivational pick-me-up during a tough week. You can be guaranteed that you’ll get to know your lecturers well and feel supported throughout all your years at St Andrews.

Settling into St Andrews and the School is an enjoyable process, with many events held during Orientation Week, including the Physics Society brunch and Astrophysics Society BBQ. The vast number of societies and sports clubs ensures you can find something that suits your interests and meet some great new friends. I have been in the handball club for almost four years and have made some of my best friends from all around the world.

St Andrews has a very strong community amongst the students, supported by the wider university. It’s a welcoming and supportive place to be.”

Andie (Prestwick, Scotland)
“It was after attending one of the School of Physics & Astronomy’s visiting days during my sixth year at school that I was convinced that St Andrews was the university for me. Everyone in the School was very friendly and had an infectious enthusiasm for their subject. Having now spent three years studying physics, and a whole summer carrying out research in experimental physics within the School, my initial impression has not changed one bit.

The School provides a great all round learning environment. The teaching and laboratory facilities are modern and well appointed. But it is the fantastic community spirit that makes it stand out. Right from the outset I have found that all the staff take an interest in your individual studies. In my eyes it is this close relationship between the lecturers, postgrads and undergraduate students, combined with St Andrews’ outstanding reputation for physics research that makes it the perfect place to study physics. St Andrews is also a great place for a keen golfer.”

Euan (Edinburgh)
“Having lived in Norway my entire life, I was excited to study somewhere abroad where I would have the opportunity to improve my English. I did not really know what to expect when I first accepted my offer to study Physics at the University of St Andrews.

Somewhat to my surprise, I was immediately welcomed to an international and friendly environment. It was easy to get to know students across all Schools and nationalities, and the University was forthcoming in helping with any concerns I had as an international student.

I have also enjoyed how small the gap is between the students and the staff in the School. Rather than just being one of many students, many staff members make an effort to get to know me. As a Physics student at the University of St Andrews, I have been exposed to so many various aspects of physics, and I have become a part of a really supportive and enthusiastic community.”

Nina (Norway)
The online version of the Undergraduate Prospectus can be seen at: www.st-andrews.ac.uk/study/ug/prospectus

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