Department of Physics

Undergraduate Studies

ROYAL HOLLOWAY UNIVERSITY OF LONDON

Royal Holloway is one of the UK's leading research-intensive universities. One of the larger colleges of the University of London, we are strong across the sciences, social sciences, arts and humanities. We were ranked in the top 200 in the world (Times Higher Education World University Rankings 2018), which described us as 'truly world class'.

As an international community, with students from 130 countries, we focus on the support and development of the individual. Our friendly and safe campus, in Surrey, 40 minutes by train from central London, provides a unique environment for university study where students quickly feel at home.

"One of the 16 most beautiful universities in the world" (*Daily Telegraph*).

Visit us

Our College and departmental Open Days offer you a unique opportunity to come and find out more about us and get a taste of what university life is really like. Parents and friends are very welcome to come with you.

To find out dates and register to attend please visit our website: **royalholloway.ac.uk/opendays**

Welcome to Physics

Royal Holloway is a major centre for Physics study and research. We pride ourselves on creating a vibrant, friendly and cultured atmosphere, allowing students to progress from the founding concepts of Physics to working side by side with internationally respected scientists.

The department has an outstanding international reputation for its research and an excellent record of teaching from its origins in the late 1800s.

We provide a very special educational experience: a choice of options worthy of one of the UK's largest teaching departments, smaller class sizes, small group teaching and a beautiful, safe, green campus within easy reach of central London.

I am delighted that you are considering Physics at Royal Holloway and look forward to welcoming you here.

Professor Stewart Boogert
Head of Physics

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YouTube: RHUL Physics

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MORE INFORMATION

This brochure is designed to complement Royal Holloway's Undergraduate Prospectus and information on the department's website at **royalholloway.ac.uk/physics**

It is also available as a PDF at **royalholloway.ac.uk/studyhere**

Why study Physics?

In choosing Physics you may have in mind your interest in the subject, your desire to be challenged or simply your wish to better understand this, the most fundamental of all sciences. Or perhaps you are thinking of your possible contribution to the challenges that our civilisation faces in the 21st century.

World experts in our department are trying to answer some of the most fundamental and important questions in Physics today: what are the consequences flowing from the discovery of the Higgs Boson? Can we detect the so-called 'dark matter' that forms most of our universe? Can we build a quantum computer or discover better energy storing materials? Does Quantum Mechanics really apply to cats? These same experts are our teaching staff and all have international reputations in their field. Our aim is to convey a deep understanding and the excitement we feel for the subject of Physics.

A degree in Physics is a highly regarded qualification. You will graduate after three or four years with first-class skills, lifelong friends and a degree that commands great respect and excellent career prospects.

86% RESEARCH RATED 4* OR 3* WORLD LEADING OR INTERNATIONALLY EXCELLENT

REF 2014

TOP 5 UK PHYSICS DEPARTMENT

(Guardian University Guide 2018)

95% OVERALL SATISFACTION FROM OUR STUDENTS

(National Student Survey, 2017)

Physics at Royal Holloway

The Department of Physics at Royal Holloway is internationally recognised for teaching and research excellence in a wide range of areas including: particle physics at the LHC including the Higgs boson, dark matter searches and neutrino experiments, particle astrophysics, accelerator physics, nanophysics and graphene, quantum matter, superconducting/superfluid physics, quantum computing, as well as theoretical physics. We offer:

- Flexible degrees that are based on a modular system that maximises your choice of options
- A friendly, supportive environment focused on small group teaching and personal development
- State-of-the-art teaching and research facilities including the UK Centre for Superconducting and hybrid Quantum Systems
- £1,000 and £3,000 bursaries available on selected Physics degrees for high achieving applicants (conditions apply)
- A beautiful campus with high quality student accommodation and easy access to London
- Extensive summer research placements in research groups and industry
- High overall student satisfaction according to HEFCE and Ipsos-MORI (NSS 2017)
- Institute of Physics Juno Champion and Silver Athena SWAN awards for best practice in equal opportunities
- Masters and PhD opportunities available to graduates
- An active Physics society, PhysSoc, organising social and scientific interest events and providing a strong support network

Degree programmes

DEGREE PROGRAMME OPTIONS AND COURSE CODES

Single Honours programmes	
4 year degree programmes	**3 year degree programmes**
Physics MSci (F303)	Physics BSc (F300)
Theoretical Physics MSci (F321)	Theoretical Physics BSc (F340)
Physics with Particle Physics MSci (F372)	Physics with Particle Physics BSc (F370)
Astrophysics MSci (F510)	Astrophysics BSc (F511)
Experimental Physics MSci (F313)	Experimental Physics BSc (F310)
Joint Honours programmes	
Mathematics & Physics MSci (GFC3)	Mathematics & Physics BSc (GF13)
Physics as a Major Subject	
Physics with Music BSc (F3W3)	Physics with Philosophy BSc (F3V5)

All degree programmes in Physics are accredited by the Institute of Physics

Royal Holloway offers a range of degree programmes in Physics, including the possibility of studying other subjects in addition to Physics. Physics itself may be studied with an emphasis on pure, experimental or theoretical physics and in three or four year formats.

The most important choices are between:

- the MSci, a four-year programme and the BSc, a three-year programme
- a straight Physics programme or one with an emphasis on a particular theme or topic in Physics
- a full Physics degree, or a programme incorporating another subject.

Your choice of degree programme depends on your interests as well as your career aspirations. We understand that after submitting your application, or after arrival, your interests may change and so we try to ensure that it is possible to switch between degree subject programmes and between BSc and MSci programmes, as late as the end of the second year of study.

Admissions and entry requirements

We look for the most talented and enthusiastic candidates and we encourage applications from students from a diverse range of backgrounds.

All applications, including international applications, must be made through the Universities and Colleges Admissions Service (UCAS) online at **www.ucas.ac.uk**

All suitable applicants are invited to visit the department, usually on an Open Day dedicated to applicants. This also provides an opportunity to talk to members of staff and students, view our teaching and research facilities and find out more about studying at Royal Holloway.

Generally, applications are considered on the basis of predicted grades, previous achievements, references and performance at interview.

Typical entry requirements are listed on our website. We admit students to both MSci and BSc degree programmes on equal terms. Offers of a place for study are usually conditional on the outcome of the A-level examinations; unconditional offers may be made to candidates who are already qualified.

Equivalent qualifications are also welcome. For further information or advice about your own specific qualifications, circumstances or application, or about any other aspect of becoming a student, please contact the Admissions Tutor.

INTERNATIONAL STUDENTS

Applications from overseas students are welcome; Physics is, in essence, universal. Each year a number of non-UK students join our full degree programmes and many other international students study for limited times through Erasmus or other exchange programmes. For entry we seek qualifications that demonstrate skills that are broadly equivalent to the UK A levels, in particular in mathematics.

MATURE STUDENTS

We look favourably at existing qualifications and provide appropriate advice on where and how to gain the knowledge and skills that best prepare you for the study of Physics at degree level as a mature student. Mature applicants are strongly encouraged to explore their options directly with the Admissions Tutor.

SCHOLARSHIPS AND BURSARIES

Royal Holloway offers a generous package of scholarships and bursaries to recognise achievement and offer financial support (eligibility criteria apply). Please see our website for full details.

FEMALE APPLICANTS

Royal Holloway, University of London was formed by a merger of Royal Holloway College and Bedford College, both of these institutions had their origins as pioneering women-only educational establishments in the 19th century. The Department of Physics has received a number of prestigious awards for our efforts to promote both equality and women in science.

IOP Institute of Physics Juno Champion

Athena SWAN Silver Award

Degree structure

Year 1

First year topics generally focus on the foundations of Mathematics and Physics, consolidating and extending your knowledge from A-level.

Mathematics: Transcendental functions, Calculus, Series, Determinants, Vector calculus, Statistical Distributions, Partial differentiation, Multiple integrals, Differential equations, Fourier Series, Matrices, Vector Field Theory.

Laboratory: Practical experiments to develop measurement, data analysis and interpretation skills. Hands on exploration of experiments that changed the course of history. Testing of theoretical models and reliability of experimental results.

Physics: Vector calculus approach to mechanics, Einstein's special theory of relativity, Central forces and orbital motion, resonant harmonic motion, coupled oscillators, linear waves, dispersion, fundamental static and motive electricity and magnetism, Ampere, Biot-Savart, Faraday, Gauss theorem, ideal gases, the laws of thermodynamics, macroscopic and microscopic models of matter, kinetic theory, equations of state, the breakdown of classical physics, quantum foundations, atomic spectra, Schrödinger's equation and solutions, Heisenberg uncertainty, astrophysics, observation, stellar structure, Hertzsprung-Russell stellar evolution, Hubble's law, the cosmic microwave background, the early universe.

Year 2

Second year topics provide an in-depth study of the most important components of modern Physics.

Mathematics: Ordinary Differential Equations and their solutions, Legendre's equation, polynomials, Frobenius method, Bessel's equation and functions, Sturm-Liouville theorem, orthogonality, partial differential equations, the Laplacian, Fourier transforms, the gamma function and the Dirac delta function.

Computing: Python, Mathematica, C++, Labview; visualisation, data analysis, regression, data fitting, numerical integration, Monte Carlo, Fourier transforms, Runge Kutta method, diagonalisation.

Physics: Schrödinger's equation, interpretation of the wave function, operators, eigenvalues, expectation values, commutation, applications, the hydrogen atom, the exclusion principle, the periodic table, perturbation, geometrical, fourier and quantum optics, masers and lasers, Maxwell's equations and their solutions in free space and in media, electromagnetic potentials and gauges, single and multi-electron atoms, atomic and x-ray spectra, hyperfine structure, nuclear models, radioactive decay, nuclear reactions, chain reactions, nuclear detectors, particle accelerators, the Boltzmann, Fermi-Dirac, Bose-Einstein distributions, the partition function, microstates, entropy, electrical and thermal transport properties, the structure and properties of metals, insulators, semi-conductors, structure, symmetry and probes of matter, band theory, electrons, phonons, photons, astronomy, the solar system, observing the universe, instruments and measurement.

Year 3

Year three generally forms an introduction to subjects that are the focus of current research. Final year BSc students undertake a research project. Optional modules may be chosen from the following:

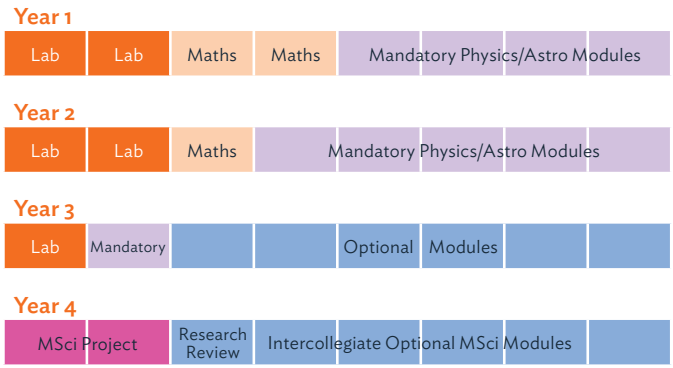
- Laboratory Skills (MSci)
- Energy – Generation, Distribution, Utilisation
- Further Mathematical Methods
- Nonlinear Dynamical Systems – Chaos
- Quantum Theory
- Frontiers of Metrology
- Particle Physics
- Metals and Semiconductors
- Superconductivity and magnetism
- General Relativity and Cosmology
- Stellar Astrophysics
- Particle Astrophysics
- Planetary Geology and Geophysics
- C++ and object oriented programming
- Experimental Design

Year 4

Year four is for the study of advanced material. MSci students complete a major research project and undertake a review of current published research papers in an area of interest, together with options chosen from approximately 35 possible modules. These include:

- Advanced Quantum Theory
- Statistical Mechanics
- Quantum Computation and Communication
- Particle Physics
- Particle Accelerator Physics
- Order and Excitations in Condensed Matter
- Physics at the Nanoscale
- Statistical Data Analysis
- Cosmology
- Solar Physics
- Space Plasma and Magnetospheric Physics
- Lie Groups and Lie Algebras
- Relativistic Waves and Quantum Fields
- Electromagnetic Theory
- Galaxy and Cluster Dynamics
- Atom and Photon Physics
- Molecular Physics
- Theoretical Treatments of Nano-Systems
- Superfluids, Condensates and Superconductors
- Standard Model Physics and Beyond
- Nuclear Magnetic Resonance
- String Theory and Branes
- Supersymmetry
- Stellar Structure and Evolution
- Relativity and Gravitation
- Astrophysical Fluid Dynamics
- Planetary Atmospheres
- The Solar System
- The Galaxy
- Astrophysical Plasmas
- Extrasolar Planets and Astrophysical Discs
- Molecular Biophysics

Typical degree course pathway for MSci Physics



MSCI PHYSICS DEGREE PROGRAMME PATHWAY

Year 1		Year 2		Year 3	
Term 1	Term 2	Term 1	Term 2	Term 1	Term 2
PH1110 Maths for Scientists 1	PH1120 Maths for Scientists 2	PH2130 Mathematical Methods			PH3150 Further Mathematical Methods
				PH3170 C++	
			PH2310 Optics		PH3810 Frontiers of Metrology
				PH3180 Experimental Design	
PH1620 Classical Matter	PH1420 Fields & Waves	PH2420 Electromagnetism	PH2610 Classical & Statistical Thermodynamics		PH3730 Superconductivity and Magnetism
				PH3710 Metals and Superconductors	
			PH2710 Solid State	PH3210 Quantum Theory	PH3040 Energy
PH1320 Classical Mechanics	PH1920 Physics of the Universe	PH2210 Quantum Mechanics	PH2520 Particle Detectors and Accelerators	PH3520 Particle Physics	PH3930 Particle Astro.
					MT3280/PH3160 Non-lin & Chaos
		PH2900 Astronomy		PH3920 Stellar Astrophysics	
			PH2510 Atomic & Nuclear Physics		PH3910 Gen. Rel. & Cosmology
				GL3510 Planetary Geol. & Geophys.	
PH1140/PH1150 Scientific Skills		PH2150 Computing Skills		PH3010 Scientific Skills for MSci	

Key

- Mandatory Courses
- Optional courses

Year 4
PH4100 MSci Project
PH4110 Research Review
Choice of five courses from the year 4 options (see page 20 for the full list of options)

To see the pathways of the other Physics Programmes see **www.royalholloway.ac.uk/physics**

Teaching and assessment

Physics combines experimental work with conceptual thinking and mathematical analysis. Each of these demands its own teaching and assessment techniques.

The teaching of Physics at Royal Holloway assumes that the motivation to study exists within the student. Our task as teachers is to introduce, explain, challenge and excite. A year's worth of study is normally broken down into eight modules, each of a nominal 150 hours of study. This study can take a variety of forms.

LECTURE-BASED COURSES

These usually comprise 50-minute lectures conveying material essential to the study of the subject. Lectures are usually supplemented by question sheets that are worked at in the student's own time. The related answer sheets and solutions classes provide some of the necessary feedback.

PROBLEM CLASSES

Problem classes provide an environment for working through selected problems in the presence of academic or graduate teaching staff. The teaching technique allows gaps in a student's understanding of the topic to come to the fore and to be remedied in an informal, helpful and immediate way.

TUTORIALS

In your first two years, small group teaching is undertaken with three or four students and a member of academic staff, typically providing informal help with academic problems, practice at short presentations or discussions of current scientific discoveries. Often the topics to be discussed are chosen by students. Tutorials are useful in building confidence, filling gaps in understanding and providing a route for discussion of topics not covered elsewhere.

EXPERIMENTAL WORK

Typically, this takes up around 20 percent of study time. Experimental work can vary from exploring classic experiments two afternoons a week in your first-year, in our well equipped and modern teaching laboratories, to working alongside academic staff in six month long research-related projects in your final year.

PC-BASED CLASSES

These develop computer skills. You will work with software packages such as those for mathematics, numerical modelling, presentation, data acquisition and data analysis. You will also have the opportunity to learn programming languages such as C++, Python, LaTeX, Java and LabVIEW.

PRESENTATIONAL MODULES

Typically these comprise reviews of research papers or a specialised topic of Physics. The subject matter is often chosen and researched by a student for presentation to other students. Group study is also used, with tasks being shared and a speaker usually selected by and from the group.

ASSESSMENT

For lecture courses, assessment is usually by two-hour examination at the end of the year in which the module is studied. In many modules, coursework and in-class tests also contribute to the assessment. Experimental work is generally assessed by the production of written reports of the experiment or by oral presentation.

Research areas

We are a major centre for Physics research and teaching in the University of London. Our research portfolio continues to expand through the exploration of exciting new research directions, and our strong involvement in strategic research partnerships such as those at CERN and the National Physical Laboratory (NPL).

As an undergraduate at Royal Holloway, your education will be enriched by the international quality of this research environment within the department and it is an important element of your student experience. As an MSci student, your final year project will be undertaken as a member of one of our research groups. Undergraduates have made state-of-the art nanostructures in our in-house nano-fabrication suite or contributed to the analysis of data from CERN. Such activity provides key exposure to, and training in, all the skills (practical, analytical, theoretical, presentational) that both research and many other jobs require. Final-year BSc students have similar opportunities.

Undergraduate summer studentships (with stipend) are also awarded on a competitive basis for students to work in research groups over the summer vacation, usually at the end of year 2 or year 3. These placements may be either at Royal Holloway, at a SEPnet partner, a national laboratory or in industry.

Research projects at Royal Holloway reflect the activity of our research groups. The majority of these have a strong internationally collaborative dimension, involving other world leading groups. Frequently, these projects involve exploring new research directions, and often students are motivated to continue onto PhD research in a similar area.

Our research ranges from exploring key questions in fundamental science, both experimentally and theoretically, to applied instrumentation development. Topics include: understanding quantum matter in all its forms – from the Higgs boson to dark matter to superfluids; the quest for new materials with new functionality; making, understanding and applying new nano-scale electronic/ optical devices; developing new instrumentation and technology for healthcare and; developing accelerator technology for future particle accelerators.

Research activity locations range from in-house state-of-the-art laboratories, to major national and international facilities, and covers:

- **LHC Physics including the Higgs boson; dark matter searches and neutrino physics; theoretical particle physics**
  Centre for Particle Physics
- **John Adams Institute for Accelerator Science**
  (joint with University of Oxford and Imperial College)
- **Fabricating 'artificial atoms' for quantum computation**
  Quantum Information Processing Group
- **Developing a new electronics based on metals rather than semiconductors**
  Nanophysics and Nanotechnology Group
- **New instrumentation for medical diagnostics**
  Biodiagnostics Group
- **Materials discovery: fundamental understanding and applications**
  Quantum Matter Group
- **Theory of strongly correlated quantum matter**
  Theoretical Condensed Matter Physics Group
- **Helium, at ultralow temperatures, as a simple model system for quantum matter**
  Quantum Matter Group

To find out more visit
royalholloway.ac.uk/physics/research

VIEW

"NPL is the UK's National Physics lab. We keep the most precise clocks and develop many kinds of measurement standards, such as the Volt and the Ampere. We have strong links with Royal Holloway, including teaching the Frontiers of Metrology advanced course. Royal Holloway undergraduate students take part in some of our most advanced research programmes, both as paid summer interns and on final year projects. We have found that the quality of the College's students is exceptionally high."

Professor Alexander Tzalenchuk, National Physical Laboratory

Your future career

96% OF OUR GRADUATES GO ON TO WORK OR POSTGRADUATE EDUCATION WITHIN SIX MONTHS OF GRADUATING.

DLHE 2016

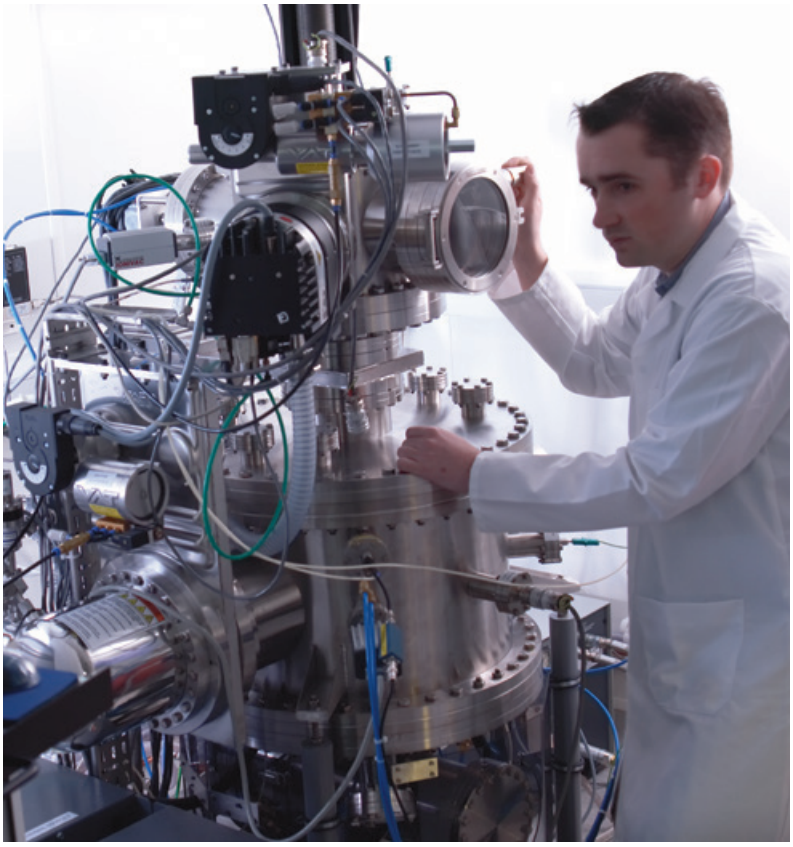
A degree in Physics is one of the most sought after and respected qualifications available. Graduate employment levels for Physicists are amongst the highest of any subject. According to the Institute of Physics, in the UK alone Physics-based industry employs more than 1.79 million people, while UK graduates in Physics earn more than those in most other disciplines.

The fundamental reason for the high employability of physics graduates is their possession of rare and valuable qualities.

Quite apart from the specialist knowledge of, say Einstein's relativity or Schrödinger's quantum mechanics a degree in physics provides graduates with a range of skills that are highly prized by employers and are also directly transferable to problems outside of physics or science, for example in social science, finance, engineering or business.

Chief among these, and far from a complete list, are

- mathematical literacy and modelling skills;
- practical, experimental, mathematical and conceptual problem solving skills
- creativity
- logical thinking
- computer literacy, numerical modelling and data analysis skills
- communication skills.



Because it is a training in fundamental science rather than a vocational qualification, a degree in physics can lead to many different career paths. About one third of physics graduates go on to study for a higher degree or enter research. Our graduates regularly accept offers to study at doctoral level from institutions such as the Universities of Oxford and Cambridge, Imperial College, the University of St Andrews, the Institute of Cancer Research and many others. Many of our students also choose to stay at Royal Holloway to continue their studies at PhD level.

Graduates entering employment are often no longer called physicists, but enter professions with titles such as aeronautical engineer, computer analyst, programmer, software engineer, satellite engineer, meteorologist, finance analyst and investment analyst, to mention just a few examples from our recent graduates, plus many others. Much more information on career paths for physicists can be found at **www.iop.org/careers**

Recent employers of our graduates include:

- National Physical Laboratory
- MSSL (Mullard Space Science Laboratory)
- SSTL (Surrey Satellite Technology Ltd)
- The Meteorological Office
- ECMWF (European Centre for Medium-range Weather Forecasts)
- Qinetiq
- Smith Aerospace
- Lockheed Martin
- Gama Aviation
- St George's Hospital
- ONR (Office for Nuclear Regulation)
- Oxford Instruments
- Ministry of Justice
- Metropolitan Police
- Bank of New York
- Deutsche Bank
- Morgan Stanley
- KPMG
- Societe Generale
- St James Place
- Experian

INTERNSHIPS AND INDUSTRY LINKS

We operate a wide range of summer placements explicitly designed to enable students gain valuable work experience, taste a selection of different career paths, prepare more deeply for a wide range of careers and provide opportunities to develop contacts and networks. These include extensive paid summer research placements within the department, external placements sponsored by international and UK national laboratories such as the National Physical Laboratory, CERN, Diamond and ISIS and various placements at other universities, high technology companies, local schools and other employers. These are usually sponsored either directly from the department or through our partners in the South-East Physics Network (SEPnet) or from a wide variety of other sources. Placements and internships are generally taken in the summer and occasionally dispersed through the teaching terms in order to ensure that the gaining of transferable skills and the development of personal career preferences is as efficient and compact as possible.

The high demand for graduate physicists means that most students prefer to enhance their scientific and technical work experience and build their CVs via a summer internship system rather than spending, for example, a year in industry. Through our internship system our graduates gain permanent paid employment or a place on a higher degree course earlier by graduating sooner.

Royal Holloway is a member of SEPnet, the South East Physics Network, a consortium of nine world-class universities that is changing the face of physics, leading the way with high quality research, teaching and outreach activities. Many of our students have benefited from work placements that develop experience and skills and lead to successful graduate careers.

CAREERS SUPPORT

We help students to recognise their own strengths, skills and abilities so that they can make the strongest possible applications for their chosen job or training course. The acquisition of the transferable skills so valued by employers is embedded within our teaching and it is also possible to have other activity such as science outreach and charitable volunteering formally certificated, verifying to future employers the ways in which you have picked up other valuable skills or contributed to life within the University or more widely. Participating in outreach activities, for example, not only promotes the subject of Physics but also allows you to hone your communications and presentational skills.

The Department's Careers Weekly sessions provide an insight into the wide variety of career routes open to you, with advice from careers specialists from the Institute of Physics and SEPnet and returning Physics alumni sharing their experiences, building connections and networking opportunities and providing invaluable advice to students.

The College Careers Service, which is part of the University of London Careers Advisory Service, provides a wide variety of services including advice on choice of careers and help with CV writing, completing application forms and preparing for an interview. One-to-one advice with a Careers Consultant is available each term.

The Careers Service also brings many important employers onto the campus throughout the year but especially during the 'Careers Fair', an event dedicated to enabling students to talk directly to the employment managers of major companies. The Careers Service can also help with part time jobs, allowing you not only to earn some cash during your studies but also providing another way to develop your career aspirations.

Find out more at
royalholloway.ac.uk/careers

STUDENT VIEW

"During my MSci degree I did a summer placement at NPL in the quantum detection group and that sparked my interest in research in quantum fluids. In my fourth year I chose to work on an exciting project involving Noise Thermometry at low temperatures and this experience really confirmed that I wanted to get a PhD in Physics. I chose to pursue this in the academic environment and be part of the low temperature group at Royal Holloway, pushing the frontiers of cryogenic systems. Both the academic training and skills that I acquired during my degree are fundamental to my current research project and with my experience of the experimental techniques and experience within the laboratory, I was able to be productive in my research right from the start of my PhD." *Harriet van der Vliet MSci and PhD in Physics*

This brochure was published in September 2017 and the information given was correct at that time. It is intended primarily for those considering admission to Royal Holloway, University of London as undergraduate students in 2018-19. Occasionally it may be necessary for the University to vary the content and delivery of programmes so we advise all applicants to refer to the website prior to making any application. Full terms and conditions of admission can be found at royalholloway.ac.uk/studyhere.

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