

PHYSICS

Physics is a basic science which explores the relationship between matter and energy, and pursues its theoretical, practical, and commercial applications. It lies at the very heart of our modern, technological society. Without it we would have no radios, TV, stereos, computers, fax machines, sophisticated telecommunication systems, radar based air traffic control systems, jet aircraft, push-button washing machines, microwave ovens, high-rise buildings, exploration of outer space, or fun with visual reality machines. Most of us use the results of physics research in our everyday lives blithely ignorant of how and why things work. But some of us do have to know about physics if our society is to maintain and enhance these technological marvels, let alone develop new ones, so the study of physics is likely to remain important and relevant into the foreseeable future.

CAREERS

The study of physics can lead into very different fields - food technology, textile research, electronics, instrumentation, computer hardware and software development, scientific measurement, meteorology, astronomy, geophysics, and the development and testing of new materials such as superconductors.

Physics graduates have highly transferable skills and most find good, well-paid jobs. Employers are looking for the best person for the job, and that person may well be a physicist even though a mathematics graduate, say, could also do the job. But it is important for students to realise that pure research jobs with good career structures are limited in number and generally require very good qualifications. Students should follow their dreams and passions, but also know that they may have to be flexible, keep an open mind about employment and change direction if necessary. The same technological changes mentioned above will lead to future jobs that no-one has even thought of.

Many physics graduates go into computer-related occupations because over three or four years they have built up a solid background of working on very sophisticated and complex but highly quantitative problems. They can transfer those modelling skills into many other areas which use computer technology such as finance, economics, traffic and fisheries management and operations research.

WHERE DO PHYSICISTS WORK?

Research Jobs

Most researchers go into applied science areas, taking up positions in government (or quasi-government) research organisations, such as Industrial Research Ltd (IRL), National Institute of Water and Atmospheric Research Ltd (NIWA), Building Research Association of New Zealand (BRANZ), National Radiation Laboratory, Institute of Geological and Nuclear Sciences (IGNS), and Canesis (formerly Wool Research of New Zealand).

Industrial Research Ltd (IRL) has research groups in materials science, measurements standards (time, length, weight and mass volume etc), superconductivity, smart polymers and super hard ceramics.

The Institute of Geological and Nuclear Sciences Ltd (IGNS) employs physicists in development of particle accelerator technologies for radiocarbon-dating, environmental science and geoscience; develops measuring equipment and the instrumentation used to assist industry in quality control and process control; and also employs geophysicists with strong computer and mathematical skills (see under Geophysics).

Topical coverage of career related issues brought to you by Victoria University Career Development and Employment.

Areas covered include how degrees and courses relate to employment opportunities, to life/work planning, graduate destination information and current issues or material relevant to the employment scene. Your comments and suggestions always welcomed.

The National Institute of Water and Atmospheric Research Ltd (NIWA) has jobs in meteorology, biological modelling and physical oceanography.

The MacDiarmid Institute for Advanced Materials and Nanotechnology offers graduates research opportunities, sometimes with scholarship assistance. Major research themes include nanoengineered materials and devices; novel electrical, electro-optic, and superconducting materials; and conducting polymers. A range of Post-doctoral Fellowships are funded by the Institute for specific projects.

Canesis employs physicists in textile research e.g. fibre assembly, yarn structure, fabric construction and wool harvesting on contract for industry, government and Wools of New Zealand. It is also involved in the development of intelligent textiles and wearable electronics, for example, a washable and flexible textile composite fabric that acts as a switch under finger pressure.

Building Research Association of New Zealand (BRANZ) researches energy efficiency in buildings, indoor air quality in buildings (heat and moisture control and ventilation) and weather tightness. Their work is a mixture of research, commercial testing, and work on standards and building codes.

Industry and Commerce

Large industrial and manufacturing enterprises such as *Fisher and Paykel*, *Comalco* and *Tait Electronics* employ physics graduates both in technical areas and in management. Physicists, or people with some knowledge of the physics of liquids (fluid mechanics), are needed in the food technology industries.

Computer and Software Industry

Because of their extensive experience in modelling systems, physics graduates often make good computer programmers. Many are employed by large computer enterprises such as *IBM* and others find jobs in the growing number of small software development companies which are meeting individual companies' needs for specific applications.

Electronics

Electronics can be studied at VUW as part of the Bachelor of Science (BSc), Bachelor of Science and Technology (BScTech) or Bachelor of Information Technology (BIT) degrees. The teaching of electronics

concentrates on the area of electronic instrumentation and most students combine their electronics with studies in computer science and/or physics. Graduates then go into a wide range of career options, from research and development in *Crown Research Institutes (CRIs)*, to industrial development or productions in the manufacturing industry. The New Zealand manufacturing industry ranges from large, well-known companies such as *Fisher and Paykel* or *Tait Electronics*, to specialised companies in the Wellington region such as *Beaglehole Instruments* or *4RF*.

Some graduates continue studies in electronic or telecommunications engineering at Canterbury and Auckland universities (credit of up to two years towards a Bachelor of Engineering (BE) degree may be given for previous study). From 2006 suitably qualified students can also continue with a Master of Science (MSc) in Electronics and Computer System Engineering at VUW. Such further studies will concentrate on specialised areas such as in mechatronics.

Hospitals and Medical Research

Medical physicists are employed in small but growing numbers in hospitals throughout New Zealand, working in aspects of radiotherapy and acoustic imaging (ultrasound scanning). Graduates with a BSc in physics can go on to specialised postgraduate training in medical physics at Otago University or elsewhere e.g. Queensland University of Technology, Australia. (Occasionally PhDs in physics can go straight into medical physics but this is unusual.)

Education

There is a strong demand for well-qualified high school physics teachers, and also for graduates with first and second year level physics who can teach the more junior levels. A limited number of openings exist in polytechnic teaching and university lecturing, for which a PhD is usually required.

Defence Forces

The Air Force gives training in physics to trainee pilots, navigators and air electronics operators, so a degree in physics can assist entry to these fields. It is also a basic subject in avionics and aircraft technician training. A BSc in physics is regarded as a plus for competitive entry into officer training in the Navy. Education officers are employed in the defence forces to teach, for example, the

theory of aeronautical dynamics and meteorology.

Meteorology

The School of Earth Sciences offers a Postgraduate Diploma in Meteorology which is a practical training course for meteorologists taught by staff of Victoria University, the Meteorological Service of NZ Ltd and NIWA. The Meteorological Service takes on a number of trainee meteorologists each year (but this varies according to demand) and they receive a major part of their training through this course. Subsequent employment is likely to be in either the *Meteorological Service* or, for those with research interests, at *NIWA*. Physics graduates can also go on to do a BSc with Honours, MSc and PhD in meteorology; their qualifications may then lead into employment at research institutions (e.g. NIWA) and universities but opportunities are limited.

Geophysics

For solid earth geophysicists, most opportunities lie in applied geophysics; especially oil, gas and mineral exploration. *IGNS* employs geophysicists as scientific researchers and technicians, particularly in the area of earthquake seismology and tectonics. Opportunities are also available for physicists and geophysicists with private consultancy firms such as *Opus International's Central Laboratories in Lower Hutt* (check with your careers office for Graduate Recruitment Programme details) and *Groundsearch E.E.S. Ltd* in Auckland, especially for geophysicists with a strong practical bent and project management skills. The combination of intellectual challenge and the physical outdoor activity of geophysics fieldwork appeals to many students. Physics majors wanting the option of going on to postgraduate study in solid earth geophysics should consider including geology and applied geophysics in their BSc.

Management

In industry as well as large scientific organisations there is a need for employees who are qualified in both management and a scientific or technical area. If you are keen on physics but are also interested in a business career, a conjoint Bachelor of Science and Bachelor of Commerce and Administration (BSc/BCA) degree programme, which can be completed in four years, is an option to consider. Alternatively the Master of Management Studies (MMS) postgraduate course is designed to equip science and engineering graduates for managerial

roles in technological product and service organisations.

Senior scientists in CRIs and in industry often become managers so inclusion of management courses within the BSc of research-oriented students can be helpful. Some subjects to consider are: management, marketing, accountancy and information systems. Statistical abilities are also very useful in business.

Operations Research

Physics graduates have a sound base in mathematical modelling that enables them to move into operations research, the application of mathematical and scientific concepts and techniques to the solution of problems in government and industry. Jobs as operations researchers or business analysts are available in government departments, consultancy firms and large companies. Courses in operations research and statistics can be included in a BSc. Postgraduate study in operations research and statistics leading to a Graduate Diploma in Operations Research and Statistics is recommended for those wishing to pursue a long-term career in this area. (See Mathematics Career View for further information.)

Intellectual Property and Patent Attorneys

The *Intellectual Property Office* grants patents and registers trade marks and designs. It employs patent advisors, including those with physics degrees. Requirements for specific subjects however depend on the mix of specialisations within the office at the time. A science and law combination is ideal, but not necessary. Many patent advisors move on to work for Patent Attorneys. Further on-the-job study is required to become a qualified patent attorney.

SKILLS AND PERSONAL QUALITIES

Mathematical skills are highly important in physics and many students do a double major in the two subjects. It is impossible to do advanced theoretical physics without being completely at ease with mathematical concepts. Mathematical modelling using computers is an important part of physics course work and often leads to work in non-physics areas. Not all areas of physics require such a high level of mathematics, however many aspects of applied physics need only a good grounding in mathematics plus specialised study.

Computer literacy is needed in all advanced areas of physics; this together with familiarity with appropriate

software is developed during course work. Knowledge of computer systems is an advantage to many physicists, particularly in electronic work, so inclusion of computer science courses in a physics degree is worth considering.

Problem solving instincts are as necessary in physicists as they are in mathematicians (see Mathematics Career View). Logical thinking and analytical skills are extremely important. These skills transfer very readily to other job areas, particularly management roles where strategic planning and decision making are significant components of the job.

Practical skills: Employers in some areas of applied physics look as much for practical attitudes and know-how as they do for scientific expertise. In geophysical fieldwork, for instance, common sense and the ability to fix instruments that are not working or make equipment out of what's available may be very important. Many scientists work in groups so teamwork is essential, as is the ability to get on with other people and good communication.

Innovation and Imagination: As in all sciences, the instinct to “build things”, to create, is important in electronic development work and many other aspects of physics. The ability to envisage something that seems almost impossible is the driving force behind many modern technologies.

HOW MUCH PHYSICS DO I NEED?

Jobs that need advanced studies in physics: physicist, medical physicist, astrophysicist, geophysicist, meteorologist, astronomer, seismologist, physics lecturer.

Jobs that need university level physics: civil/electronic/electrical/mechanical engineer, architect, quantity surveyor, aircraft pilot, aircraft engineer, physics teacher, radiologist, physical oceanographer, textile researcher.

Jobs in which knowledge of physics can be useful: computer scientist, manufacturer, industrialist, physical geographer, hydrologist, geomorphologist, operations researcher, medical technician, metrologist.

I'VE DONE NO PHYSICS BEFORE

If you have a desire to be an astrophysicist but have taken little or no physics before, don't give up. Victoria runs a summer bridging course as well as an Introductory Physics course which gives a grounding in the basic concepts you'll need for further studies (this is also available at some of the other universities). You do need reasonable maths so if you've missed out there as well, take the bridging course offered by the mathematics department each February. If you've no physics but are really strong in maths it might be possible (but really hard work) to bypass the introductory course. Discuss it with departmental staff if this is what you want to do.

GRADUATE PROFILES

Swee Kuan Goh

*Research Scientist
Industrial Research Limited*



After completing my high school education in Malaysia, I joined Victoria University in 2001. In my first year I chose physics, mathematics, chemistry and astronomy papers. At the end of my first year I decided to major in both physics and mathematics and I ended up having my first degree, Bachelor of Science, in mathematics and physics.

I joined the Superconductivity Group of Industrial Research Limited (IRL) at the end of 2002 as a Summer Research Scholar. My tasks involved synthesis and characterisation of various superconductors. Superconductors are a class of materials which lose all electrical resistance below a certain temperature, known as the *critical temperature*. I made my own superconductors using furnaces which can go up to 1100°C and I measured the electrical and magnetic properties of these superconductors at temperatures as low as 4.2K (–269°C) using very expensive liquid Helium. I really

enjoyed my time at IRL and therefore I applied and was re-appointed to the same position over the summer vacations of 2003 and 2004.

During my time at Victoria University, I have been awarded the John P. Good Memorial Prize in Mathematics and Noel Ryder Prize in Physics. I have also been awarded a fellowship by Industrial Research Limited to study for a BSc (Honours) in Physics.

After finishing my BSc (Honours) in Physics in 2004, I came back to IRL to take up a post as a research scientist – the position I am holding at the moment. Apart from continuing the project on the synthesis of (new) superconductors, I started examining the critical current of some commercially available superconducting wires. The critical current is an important parameter of a superconductor – it tells you the amount of current a superconductor can carry before superconductivity is destroyed.

Besides the more experimental aspect of physics, I am also interested in modelling the electronic conduction mechanism of various materials – especially the nanoscale, low-dimensional materials such as carbon nanotubes. In collaboration with Alan Kaiser, a Professor of Physics at Victoria University, I have analysed a lot of high quality data from Germany and Korea using conduction models developed at Victoria University. We have shown that the conduction in many materials can be modelled in terms of the metallic pathways interrupted by an insulating barrier, and thermal fluctuation can help the conduction electrons to overcome the barrier.

I have been fortunate to have a lot of brilliant classmates throughout my undergraduate career. I clearly remember the times we spent discussing various physics problems in our Honours office. I think the best way to learn physics is to discuss the problems and try to explain them to your friends. It is pretty dangerous to get a key concept wrong. Through discussions, you could minimise the risk of misunderstanding the concept.

The high quality education provided by Victoria University and the vibrant research environment at both IRL and Victoria University have been extremely helpful for me in deciding to follow the career pathway of being a scientific researcher.

Bridget Ingham

PhD in Physics

*Post-doctoral Researcher,
Imperial College, London*



I completed my PhD research in physics in 2005. I am just starting a post-doctoral research position at Imperial College in London, working on synchrotron studies of nanoclusters and thin films.

Synchrotron radiation experiments have only been possible since the 1960s, when the first synchrotron facility was built at Stanford University. Today there are over fifty such facilities of different sizes. However, virtually all of them are in the northern hemisphere! Synchrotron radiation is much more intense and precise than laboratory sources, allowing experiments to be performed on very small samples, samples with weak responses, or small areas within a sample. These are important benefits with regards to the escalating development of nanotechnology and nano-materials in general.

I had been interested in physics since high school, and this continued into university. I especially enjoyed the laboratory work, the 'hands-on stuff', which has played a big role in directing my current research into experimental physics. To me, that is the best thing about physics – to be able to understand our physical world in a mathematical way. In particular, my current research is concentrating on understanding the properties of various materials. Some projects I have worked on include high-temperature superconductors, x-ray storage phosphor glasses, metal nanoclusters from which one is able to make nanowires, and thin oxide films that form on metals to prevent corrosion.

My PhD research concentrated on a new structure of material, consisting of self-assembling molecular layers of alternating oxide (inorganic) and organic species. By altering the composition of either component, it is possible to change the physical properties (structure,

conductivity, magnetic, etc.) of the material. In testing each material we produced, I learnt how to use a variety of equipment and techniques, which will no doubt be useful in the future. I also learned the value of working alongside experienced researchers from a variety of disciplines. There is seldom a dull moment in scientific research – you are constantly learning new things!

The biggest development towards my career in physics was working as a summer student at Industrial Research Limited. During this time I met my then-future PhD supervisor, who then recommended me for the job I am currently doing. There have also been several other opportunities for me to attend scientific conferences in the US and Europe.

If you are considering studying physics, you will also need a relatively strong mathematics background. For this reason many people who major in physics for their BSc also major in mathematics – myself included. However, don't let the maths overwhelm you: physics is about understanding phenomena and explaining how and why things happen, and using maths to do it; rather than applying maths to a real-life situation per se. I have found physics to be a very rewarding subject, especially at the post-graduate level. So don't give up – be prepared for an exciting time!

Stephen McNeil

Materials Scientist

BRANZ



After starting out studying towards an engineering intermediate in 1998, I switched to a BSc majoring in Physics and Maths in 1999. During 2000 I approached BRANZ for some part time work over summer, which ended up becoming a full time job after I graduated in 2002. After that, I completed Honours in Physics, part time over the next two years. My work at BRANZ has been interesting and varied, drawing on both my physics and mathematical background. A major focus of my work has been 'Leaky Building Syndrome', involving

working with and modifying computer models of the building envelope that deal with heat and mass transfer. This aspect of my work has led to a number of overseas travel opportunities, both working with, and building up, our relations with international counterparts. Another focus of my work is the involvement in varied instrumentation tasks, involving both design and installation of systems to measure all sorts of parameters. My study at Victoria helped me in a secure grounding in Physics and Maths, which along with the ability to teach myself new things has made for the beginnings of a successful career.

Ocean Ripeka Mercier

Lecturer in Maori Studies

Victoria University of Wellington



Kei raro i te maunga e kore e neke, ko Hikurangi, ka tū ahau, he uri nō te whānau Taiapa.

When I was 11 years old, my big school project was on Antarctica. This was the culmination of my curiosity about the icy continent and the beginning of a life-long fascination. I never dreamed that I might actually visit the Antarctic. Physics got me there!

My journey from childhood dream to wish fulfilment seemed a path I was destined to walk, set from the time I started doing well at mathematics and science. In physics I was immediately drawn to its power to explain how things work. It was the combination of pure mathematical simplicity and real-world application. So, even though it wasn't my best subject at school (that was French), it was a natural choice for me to continue on with physics and maths at University.

I'd been drawn to the University since I was 14 years old, so it didn't bother me that on one side of my family I was the first in the whānau to head to University. However, I had a rather auspicious beginning: on my first day at Uni I got hit by a car and missed my geology lecture. When no-one chased me to check why I wasn't

in class, I came to a realisation. At university, my greatest motivating factor would have to be me.

I continued in physics and maths at Victoria University through to the completion of my BSc. I enjoyed a supportive environment there, so remained for an honours year in Physics. For the experimental component of Hons, I was getting friendly with an infrared spectrometer and using it to probe electron behaviour of plastics that conduct electricity. Again, it was the support factor that made up my mind to remain at Victoria University and, in collaboration with Industrial Research Ltd and the support of a Tūapaā Pūtaiao Māori Fellowship, I completed a PhD in physics. Apparently I was the first Māori woman to do so! My research investigated relationships between the magnetic and electronic properties of metal oxides - with a view to using them as high-density storage devices in computers.

While working as a postdoctoral fellow on superconductors, and teaching physics at Victoria University, I was approached by Prof. Paul Callaghan who was in urgent need of someone with a PhD in physics who was willing to travel to Antarctica and work on the sea-ice. I remember that excitement I felt like it was yesterday, and feel deeply blessed to be given the opportunity. Antarctica itself? It was everything I expected and ten times more!

The journey I've taken has given me the experience and skills to do anything I wish. My current position as a lecturer in Māori Studies, miles away from the discipline I trained in, is evidence of that. Physics has been extremely rewarding for me, so for those of you who are into it or just interested, go for it!

Andres (Olly) Pantoja

Research & Development Engineer

Beaglehole Instruments Limited



I took up physics from my very first year at Victoria as a way of learning more about the intricate nature of the way the world is made up – from atoms and nuclei all the way to planets and galaxies. Since then I've completed both an Honours degree and a PhD in physics at Victoria, in conjunction with Industrial Research Limited in Lower Hutt. My doctorate studies (as well as employment as a research assistant at both institutions) have allowed me to work first-hand with professional scientists both here and overseas, and has given me a unique insight into how cutting-edge physics research can lead to high-tech real-world applications.

Electronics has also been a long-term interest of mine that I took up as a hobby when I was about 10. After studying all the electronics courses I could at Victoria, I took the job of lab demonstrator for 2nd & 3rd year electronics labs, which allowed me to pass on my practical knowledge in a very personal manner. Teaching students the intricacies of electronics and encouraging them to join a profession that is seriously lacking in numbers was in itself a highlight of my time there.

It has also led me to a career at Beaglehole Instruments where we mix the science of physics with the engineering aspects of electronics and computing. We design and build very high precision instruments for measuring the thickness of incredibly thin layers on substrates – sometimes down to a single layer of atoms. We are perhaps unique in that our company is not only run by a former lecturer at the School of Chemical and Physical Sciences, Em. Prof. David Beaglehole, but also employs a number of physics graduates (and sometimes students) from Victoria itself.

Our customers require us to find unique solutions to complex research problems, which I work on designing, developing and incorporating into our existing systems.

Currently we are involved with biomedical laboratories that research into DNA and protein screening and semiconductor manufacturers that produce the integrated circuits on silicon wafers in the never-ending demand for faster and smaller electronic devices. The work is both challenging and fulfilling and would not have been possible without the analytical and research skills I learnt at Victoria.

PHYSICS AT VICTORIA

The School of Chemical and Physical Sciences offers a full range of undergraduate and postgraduate physics courses, with special undergraduate programmes in the more applied area of electronics. The University is fortunate to have close ties with large CRI's in the Wellington region whose business lies in these areas, providing us with special support and input for these programmes.

Two Physics related majors are offered for the Bachelor of Science (BSc): A student can either do a major in Physics or in Electronic and Computer Systems. The entry courses for these programmes are the standard 100-level courses PHYS 114 and 115, although students who have very strong backgrounds in physics and (even more importantly) mathematics may gain direct entry to 200-level courses on application to the chairperson. Students with inadequate preparation may wish to enrol in either PHYS 134, which runs over the summer trimester, or PHYS 130 in the first trimester. Courses in such topics as electricity and magnetism, quantum

mechanics, solid state and nuclear physics and the various applications of these are found in the second, third and Honours years.

Major in Electronic and Computer Systems: Victoria University students can do a major in Electronics and Computer Systems, reflecting the fact that these disciplines are of critical importance in most areas of modern science. The courses are taught by both physics and computing departments and concentrate on the hardware side of computing, on designing and building instruments and how to connect computers to measuring equipment (e.g. a seismometer measuring the strength of earthquakes).

Physics research at Victoria University is focused in the area of material science, with strong research programmes in fields such as superconductors, nanomaterials and the physics of liquids. Research is also conducted in specialised areas such as astrophysics and geophysics (including meteorology and Antarctic physics). Another research area is in the field of mechatronics, which is the integration of electronics and mechanics to produce autonomous robotic mechanisms. In many instances the research at Victoria is performed in collaboration with a New Zealand Crown Research Institute or with another local or international university. The University is then well placed to help students develop their special interests in a wide variety of research areas.

Physics is an integral component in the Bachelor of Science and Technology degree (BScTech) and in two of the options for the Bachelor of Information Technology (BIT).

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