PicoQuant small and reliable picosecond and sub-nanosecond pulsed diode lasers deliver wavelengths from 390 to 1550nm at up to 80MHz repetition rate. A large variety of driver electronics for all types of diode lasers is available, including modulation (up to 2GHz) and long pulse generation (nsec to μsec).

Fluorescence Lifetime Systems
PicoQuant offers time-resolved spectrometers for different purposes from compact table-top spectrometer for teaching or daily routine work to modular high-end spectrometer with exact timing down to 30 ps instrument response width. Samples can be liquids in standard cuvettes, membranes or even semi-conductors wafers for in-line quality control.

Photon Counting Instrumentation
PC-card based timing electronics are available from PicoQuant. The versatile instruments for time-correlated single photon counting readily support sophisticated techniques in single molecule detection and 2D scanning applications.
**When Size Matters**

*The Latest in Portable Fibre Optic Spectrometry from StellaNet Inc.*

**EPP2000C**

*Measuring Intensity & Colour of Light*

- EPP2000C UV-VIS or EPP2000 VIS-NIR with Fibre Optic Cosine Receiver
- Optional IC2 Integrating Cube, 2 x 2 x 2" with 5/8" Input Port
- Measure Irradiance in watts/m²/nm or µwatts/cm²
- Also Photon Dose Rate in moles/s/m²/nm – PAR
- Illuminance in lumen/m² - LUX, xy Chromaticity Diagram for LEDs
- NIST Traceable IRRAD-CAL 300-1100nm, UV CAL 200-400nm Available

**EPP2000-HR**

*High Resolution Optical Spectrum Analyser*

- More than Double the Resolution of a Standard EPP2000
- Optical Resolutions to Better than 0.1nm
- Works with All EPP2000 Fibre Optic Accessories, Interfaces & Software
- Rugged Metal Enclosure
- Measures Peak Wavelengths, Centroids, & Signal FWHM Bandwidths
- For Microsensor Applications, Laser Tuning, & Laser Stability Measurements

**EPP2000**

*Portable Spectrometer with High Speed Interface*

- Works on Desktops or Notebooks with Windows 9x/NT/00/XP/Dos
- Miniature sizes from 1.5 x 3.5 x 6 inch in Rugged Metal Enclosures
- IEEE1284 Digital Interface (faster than USB1). Can be Daisy-Chained
- UV-VIS Model has Aberration-Corrected Concave Grating - no Mirrors
- Optional Battery Powers Spectro & Lamps to Extend Portable Lifetime
- Plug & Play Installation for Notebooks, Desktops, & New USB2 Option

---

**WARSASH Scientific**

*Advanced Instruments for Research & Industry*

Sydney
PO Box 1685
Strawberry Hills
NSW 2012
Tel: (02) 9319 0122
Fax: (02) 9318 2192
sales@warsash.com.au
www.warsash.com.au
January/February/March 2003

Contents

Presidents Column

Editorial

Around the Traps

Biophysics & Biochemistry of Photosystem II

Elmars Krausz

Fasts

2002 Bragg Medal

Rebuilding the Enabling Sciences

Eureka Prizes

Physicist Crossword

Conferences & Meetings

Physicists in Australian & New Zealand Universities 1997 - 2002

P J Jennings, J R de Laeter & G O Putt

Product News

Reviews

Oils 'ain't Oils

Phar Lap Resurrected Through Physics

Graeme D Putt

Cover: The cover features a collage of key components in the reaction centre of Photosystem II, generated from recent crystallographic data (Kamiya and Shen (2003)), together with the low temperature absorption spectrum of a fully active ANU Photosystem II preparation, recorded in the G region of the pigment. In the background are crystalline needles of the ANU preparation, grown at St Vincent's Institute for Medical Research in Melbourne.

Contributions should be sent to

Corinna Horrigan, Editor

The Physicist

PO Box 3497

Parramatta NSW 2124

Tel: 0417 775 109

ozphysicist@operamail.com

Design, Artwork & Printing

Scott Williams

Cronulla Printing Co. Pty. Ltd.

16 Cronulla Plaza, Cronulla 2230

NSW Australia

Phone 02 9523 5954

Fax 02 9523 9037

physicist@cronullaprint.com.au

Advertising Enquiries

Mrs Leigh Wallbank

PO Box 70,

Oyster Bay 2225

NSW Australia

Phone: 02 9528 4362

Fax 02 9523 9037

Published 6 times a year, on behalf of the Australian Institute of Physics by Cronulla Printing Co. Pty Ltd.

Copyright 2003 P Sullivan. PP 224960 / 00008 ISSN 1036-3831

The statements made and the opinions expressed in the The Physicist do not necessarily reflect the views of the Australian Institute of Physics or its Councils or Committees.
PRESIDENT’S COLUMN

I enjoy the TV series called Corridors of Power and Yes Minister not only for their humour but also because of the element of ‘truth’ that resides in their content. The best line I recall from any of these episodes is that “the ship of state is the only ship which leaks from the top” - you might think that, but I could not possibly say that!! Oh yes, I also like the House of Cards series!

I mention these because the concept of government being a ship seems very real in that it builds up momentum and it takes much to alter its momentum. Indeed let’s analyse what it does take. To change the momentum it takes impulse that I will express as PRESSURE times AREA times TIME. The pressure is the influence that an individual can bring to bear, the area represents the number of people involved, and time is obvious. For the moment I will assume that all the people are pushing in the same direction but that cannot always be taken for granted!!

To achieve anything means that this product has to be big. So if we look at the 25 year effort of John Prescott in monitoring the job advertisements with a small dedicated band then we see that impressions of what is happening with jobs have been translated into facts. Small area, long time = big impulse! GREAT EFFORT. We are all grateful for this effort, which has strengthened the hands of many advocates for physics around the country. We thank him for this outstanding effort. It is now time to find someone else to take up the challenge. This has been a valuable service that needs to be continued - can you help?

The same issue of impulse applies to the combined efforts of the AIP, the RACI, IE Australia, the Australian Council of Mathematical Societies and FASTS. Much bigger area, a shorter time, but the impulse here has developed into a significant change in parliament awareness of the importance of the enabling sciences. It is now on their lips and in their consciousness. There is more to do but the ‘ship of state’ is changing direction.

On a different scale can I draw attention to the valuable combination of pressure and time that my fellow members of the executive have applied. I thank them for their efforts to redirect the ‘ship of state’ of the AIP. It is a great group of professionals and I consider it a privilege to work with them. There is a larger group I would also like to acknowledge and that is the people involved at the branch level and in the organisation of the topical groups. We have seen some significant changes in the recent period and with the council meeting in February I can predict we will see more. There are great new changes in the pipeline that the next executive will finalise.

In all these processes we only see changes while-ever the impulse is applied.

We need to continue applying pressing to the perceptions about the employability of physicists, to the need for support of the enabling sciences and to the requirement for a dynamic, responsive AIP. It will help if we can reduce the peak pressure by increasing the area (number of participants). I hope you have seen that the gains we have made are in the best interests of individuals by being in the best interest of all and with a little extra assistance we can achieve much more.

This is my last column as President. I must admit that in taking on this role the presidential column is one that I had greatest anxiety about. I hope I have informed and sometimes entertained you. Thank you for your support.

John O’Connor
John.OConnor@Newcastle.edu.au
Ringing the Changes

Whether we like it or not, change is inevitable, and so The Physicist has a new editor. As that new editor, I'd like to thank Chris for all his hard work over the past few years and to congratulate him on a job well done. Just putting this first issue together would have been inordinately difficult if not for the wealth of material that Chris passed on to me.

For most of you, I am currently an unknown quantity so I have included a brief, informal biography below that will tell you a little about me, and this editorial outlines some of my thoughts about The Physicist.

It seems to me that one of the roles of this journal, is to be a forum for the Physics community. This can be a place where you can find out what others are doing, for news and views and where you can discuss ideas or issues – or even politics at times. That, of course, sounds remarkably like a mission statement – but what does it mean in practice?

I would like to see some more social comment or debate in The Physicist. For example – what happens to the women who graduate in physics? The numbers don't seem to flow through to employment in the field. Motherhood and childcare no longer seem to be sufficient to explain this. Is the drop in numbers real or illusory? If it is real, what is causing women to leave? The article in this issue gives us the data to examine at least on side of the issue. Or perhaps we could discuss the issue of ethics in scientific research. While it is a big part of biological research today, does it also have a place in physics?

The physics community is not homogeneous, nor are all its members academics or researchers. These readers possibly want different things from The Physicist and I would be interested in finding out what they might like to see in this publication. I'd also like to include articles that are more general. Most of us are used to preparing articles for scientific journals with all the weight of rigorous detail that entails; writing a more popular style of article that still gives the vital information succinctly and interestingly can be just as much a challenge!

I'm also considering a "Viewpoint" column each issue – there's no reason that the editor should be the only one to have a chance to express their views. Anyone want a soapbox?

Of course, the editorship may change overnight, but a magazine doesn't. This issue has no great changes and may even suffer from 'changeover' problems as I endeavour to remember everything. Finally, I have been working for other magazines for some years now. While they have completely different raisons d'être to this one, they all must try to provide the type of information that their readers want – otherwise we are just wasting trees. Feedback is thus a vital part of the evolution of a journal and I hope to get a lot from you as changes are made.

Corinna Horrigan

A brief biography

I arrived in Australia at the age of two and spent my early life in Newcastle. I have a B.Sc., a B.A. and a Dip.Ed. from Newcastle University – although some of the subjects for the Arts degree were done at Macquarie University. My majors were in Physics (of course) and Classical Civilisation respectively. After teaching for a few years in Newcastle and surrounds, I moved to Sydney to work at the CSIRO National Measurement Laboratory in temperature measurement.

In my 21 years there, I continued to work in temperature measurement, but also expanded my interest into electron microscopy. In 1999, during one of the cutbacks in CSIRO, I took a redundancy. Then followed a brief period of rest and recuperation, followed by the inevitable job search. I have now been working for the Australian Consumers’ Association (Choice Magazine) as a Verifier for over three years. This is a position that allows me to release my inner pedant – the verifier gets to check the test reports and the articles to make sure that everything has been done properly and interpreted correctly: that all the equations are correct and the assumptions are justified. I also get the opportunity to do some software testing for Computer Choice and to write the occasional article – but I don't get to verify those.

My interests include singing, reading, costuming, playing with and on computers and good conversation. I share my house with my partner, two cats and a variable number of computers.
Business and the Australian synchrotron
The Committee for Economic Development of Australia (CEDA) called for business to increase its understanding of the opportunities created by the synchrotron in Australia. The CEO of CEDA, David Edwards, said: 'The synchrotron construction is about more than saving our scientists the cost of using overseas facilities. Industries as diverse as pharmaceuticals, textiles, food, automotive and aeronautics have successfully used synchrotron technology for breakthrough innovations.'

[CEDM Press Release]

Nano heat
New Scientist reports, from the NanoTech Conference in San Francisco, on the development of a 3 mm wide 'micro heat engine' that converts heat into electricity. The Washington based team that developed it hopes that arrays of them may some day be able to be use waste heat to replace batteries in consumer appliances. The heat engine is made by sealing Fluorinert fluid between silicon membranes. On the top membrane a layer piezoelectric PZT is sandwiched between thin gold and platinum electrodes. As the base of the device is heated, the liquid expands and the PZT flexes and generates a voltage.

[Anil Ananthaswamy, 'New Scientist', 22 February]

The rough or the smooth
Theories that try to explain how gravity acts on the very smallest scales say that space and time must be irregular. If they were smooth such phenomena as black holes and the big bang could not exist. However, two astronomers from the University of Alabama have made observations that imply that space is smooth.

When looking at a distant galaxy (PKS1413+135) they saw an Airy ring interference pattern around it. According to them, if space-time were rough, the light from a galaxy that distant should be distorted in so that the rings would be blurred. In a paper to be published in a future issue of Astrophysical Journal Letters, they argue that this means that space-time must be smooth. Not surprisingly, there is some controversy over this.

[Stephen Battersby, 'New Scientist', 22 February]

Switching molecule
A group of scientists from the University of Basle, IBM Zurich and the CEMES-CNRS Lab in Toulouse, have created the lowest energy single-molecule switch to date. Requiring only 47 zeptojoules (~47 x 10^{-21} joules or 0.3 eV) to operate, it uses 10,000 times less than the power needed in the transistor switches currently used in high-speed computers (C. Loppacher et al. 2003 Phys. Rev. Lett. 90 066107).

The switch consists of a 'porphyrin' molecule with four phenyl 'legs'. Using the tip of an atomic force microscope (AFM), they rotated one of the legs from one stable position to another. The switch is "on" when the leg lies perpendicular to the central part of the molecule and is "off" when it lies parallel. On the leg is rotated, the researchers record the force-distance characteristics of the structure. They can then identify the force and energies required to rotate a single carbon to carbon bond in the molecule.

The scientists found that rotating the phenyl leg requires less than 100 zeptojoules, which is four orders of magnitude lower than state-of-the-art field effect transistors. The researchers believe their method approaches the thermodynamic limit of switching.

[IoP Physicsweb & American IP Physics News Update, February]

The speed of gravity
Sergei Kopeikin of the University of Missouri-Columbia and Ed Fomalont of the National Radio Astronomy Observatory in the US used a rare cosmic alignment to check that gravity and light travel at the same speed — as predicted by Einstein. The astronomers presented their findings today at the American Astronomical Society meeting in Seattle.

On September 8 last year Jupiter passed almost directly between the Earth and the quasar 3J983+1835. The Very Long Baseline Array of radio telescopes in the US and a 100-metre radio telescope in Germany, were used to measure how radio waves from the quasar were deflected by Jupiter. Previously they had shown that the size of the deflection depends on the speed at which gravity propagates from Jupiter. From their measurements, they calculated the speed of gravity to be 95% of the speed of light, with an error margin of plus or minus 25%.

Prior to this work, physicists had assumed that the only way to measure the speed of gravity was to detect gravitational waves. Kopeikin believes that this new result is the first of many observations of gravitation that will shed new light on the general theory of relativity.

However, some other scientists disagree with this interpretation of the results and say that the radio leaking data does little more than provide a measurement of the speed of light, not gravity.

[IoP Physicsweb & American IP Physics News Update, January]

Still symmetrical
The principle of Lorentz invariance is fundamental to the special theory of relativity and the Standard Model of particle physics. It states that the result of an experiment is independent of the velocity at which it is performed. However, many extensions of the Standard Model involve violations of Lorentz invariance. Now, Dimitri Avaloff and colleagues at Stanford University in the US have set new limits on these violations (J A Lipa et al. 2003 Phys. Rev. Lett. 90 060403).

In 1998, over a hundred co-authors permitted to possible violations of Lorentz invariance were identified in a "general" extension to the Standard Model. Astrophysical measurements and experiments with accelerators can set a limit on many of these parameters, but nine parameters that involve electromagnetic effects have yet to be constrained.

Avaloff and co-workers have devised a new experiment that is sensitive to these parameters. It involves monitoring microwaves inside a pair of cylindrical cavity resonators. One cavity is oriented in a horizontal direction, while the other points vertically. The researchers believe that any violations of Lorentz invariance will affect the cavities in different ways as the Earth orbits the Sun.

The Stanford team found no difference between the one in 10 for the parameters and no anisotropy to one part in 10 for three other parameters. These bounds now constrain seven of the nine coefficients that were previously unknown in the general standard model extension.

[IoP PhysicsWeb - February]

Shaken not stirred
The progression toward smaller and smaller electrical and mechanical components presents tremendous challenges to engineers and scientists as they strive to create devices on scales measured in microns and nanometers. One solution may be to develop materials that automatically arrange themselves in useful patterns. A collaboration of researchers at Argonne National Laboratory and Institute of Physics for Microstructures of the Russian Academy of Sciences has developed a new method for encouraging microscopic particles to self assemble into desirable complex patterns. The technique is inspired by the patterns formed in shaken mixtures of much larger granular materials.

Numerous experiments involving agitated containers of sand, ball bearings, or other granular materials have shown that the combination of gravity and inter-particle forces from collisions can lead to a rich variety of patterns, ranging from particle-like localized excitations known as oscillons to honeycomb shapes to chaotic swirls. The new research extends such experiments into microscopic regimes.
the method uses electrostatic fields to drive metallic microparticles immersed in liquids. The researchers placed 120-micron bronze spheres in a mixture of toluene and ethanol trapped between glass plates. The plates were coated with thin layers of transparent conducting material, and an electric field of up to 3 kvolts per millimeter was applied between them. Particles that contacted the lower plate acquired a charge and were repelled toward the upper plate. If the upward electrostatic force is sufficient to overcome gravity, the particles fly upward, contact the upper plate where their charge is reversed, and then are forced back down again. In effect, the alternating charge on the particles is analogous to shaking a container of macroscopic grains. As in the classic granular material experiments, varying the conditions causes the particles to form vortices, pulsating rings, honeycomb patterns, or other structures. Ultimate, say the researchers, studies such as this may allow us to design systems that spontaneously self-assembly into complex structures on increasingly tiny scales. (M. V. Sapozhnikov, Physical Review Letters, upcoming article)

[American Institute of Physics - Physics Update, February]

A bigger, brighter, better synchrotron

On January 29, the Bracks Government announced plans to build a synchrotron twice as powerful than originally proposed.

Innovation Minister, John Brumby, said the new design, known as Boomerang 20, would 100% guarantee that Australian researchers had access to world leading synchrotron technology and would be a major boost to Australia’s scientific infrastructure. The Victorian Government will fund the synchrotron building and machine, with the beammLines to be funded from other sources such as universities, industry and other governments.

Mr Brumby said: “The facility will generate over $65 million a year to the Victorian economy and create up to 2500 new direct and indirect jobs.”

“It will ensure our top researchers have the world leading technology they need to make major breakthroughs in everything from cancer research to the design of new computer chips.”

The Government will provide $157.2 million for the synchrotron building and machine, with consortia comprising universities, research institutions, other governments and the private sector to fund the cost of the beammLines. The total cost of the project will be $206.3 million.

“This approach is already paying dividends, with Professor Alan Gilbert, Vice Chancellor of Melbourne University, today announcing that the University will contribute funding towards the construction of one or more beammLines,” Mr Brumby said.

Boomerang 20 will:

- Accommodate up to 95% of Australian research requirements. Scientists currently have to travel overseas to use synchrotron technology;
- Generate light twice as bright as the previous design — brightness that is essential for the analysis of complex compounds such as the structure of proteins in cancerous cells;
- Have a larger circumference (216 metres) to accommodate over 30 beammLines. The previous design was limited to around 24.

[Victor Press Release]

AUSTRALIAN SYNCHROTRON – LIGHTING THE PATH TO INNOVATION

EXCITING OPPORTUNITY TO JOIN THE TEAM TO BUILD A POWERFUL NEW TOOL FOR INDUSTRIAL & SCIENTIFIC RESEARCH.

Major Projects Victoria (MPV) has a mandate for planning, developing and managing the delivery of major development projects for the Victorian Government in a commercially and socially responsible manner.

One of the most significant projects being undertaken by MPV is the Australian Synchrotron Project (ASP). Synchrotrons provide researchers with a powerful new tool for scientific and industrial research, and this will be the first synchrotron to be built in Australia. Located in Clayton adjacent to Monash University, the facility is scheduled to commence full time operations in 2007.

A number of experienced Managers, Engineers and Physicists are now required to work as an integral part of a project delivery team which will also include specialist international experts to design, construct and deliver the project on time, within budget and achieving all of the performance acceptance criteria to meet the facility user expectations.

Technical Manager
- Technical Project Team Leadership
- Critical Coordination and Interface Management Role
- Ensure Time, Cost and Quality Milestones are Achieved

You will be responsible for the development of project scope, technical specifications, and the primary interface for technical coordination on a multi-disciplinary engineering project. This is a four year fixed term position with a salary package negotiable in the vicinity of $100k.

Lead Accelerator Physicist
- Responsibility for all Aspects of Physics Design
- Preparation of Technical Specifications for Accelerator Systems
- Key Member of Technical Director’s Team
- You will be responsible for the development and implementation of the detailed pre-operational testing, commissioning and operating procedures for accelerator components and systems, including development of high level control algorithms. This is a four year fixed term position and a salary package will be negotiated commensurate with capabilities and proven track record.

Accelerator Physicist
- Assist in Physics Design and Participate in QA & Testing Process
- Develop Specifications for Major Accelerator Components & Systems
- You will be capable of performing simulations of injector systems including a 100 MV linear accelerator and a 2 GeV booster synchrotron, and of a 3 GeV storage ring, to validate the beam dynamics. This is a four year fixed term position and a salary package will be negotiated commensurate with capabilities and proven track record.

Commercial Manager
- Management of Project Control Group Functions
- Manage Procurement Services for Entire Project
- Manage Interface between Engineering and Procurement Teams

You will develop and implement procedures required for procurement activities on a large multidisciplinary engineering project. This is a three year fixed term position and a salary package will be negotiated commensurate with capabilities and proven track record.

Lead Engineers
- Positions available - Mechanical, Electrical and Control Systems
- Lead and Coordinate Discipline Design Teams
- As a Key Member of the Technical Director’s Team
- Four year fixed term positions; salary range $60K-$100K

Lead Mechanical Engineer
- You will be responsible for managing the mechanical design, specification, procurement, inspection and testing of the synchrotron and beam line components and systems.
- Lead Electrical Engineer
- You will be responsible for managing the electrical design, specification, procurement and quality assurance of the synchrotron and beam line components and systems.
- Lead Computer Control Systems Engineer
- You will be responsible for managing the development and comprehensive overview of the design, specification, procurement, installation, testing and integration of the computer control and digital feedback system comprising the instrumentation, control and diagnostics for the project.

Department of Infrastructure - Major Projects Victoria
Background

The delicate yet powerful processes of photosynthesis have fascinated biologists, biochemists, chemists and physicists over many generations. A comprehensive understanding of photosynthetic processes is now evolving from a myriad of experiments and experimental techniques. A great deal has been learnt of the overall nature of the many photosynthetic steps. The energetics involved are summarized in the ‘Z-scheme’ shown in Figure 1. Protons are extracted from water and an effective trans-membrane driving potential generated, enabling the myriad of (energy requiring) processes within the organism. The time-scales of the many physical and chemical processes involved vary enormously and range from femtoseconds to seconds or longer.

Photosynthesis has the life-sustaining ability to convert light energy into chemical energy. It does so with enviable efficiency and precision. In photosynthesis, visible photons are first harvested by arrays of strongly absorbing pigment molecules. Many of these pigments are chlorophylls. These have ‘conjugated’ carbon-nitrogen structures, which serve as the visible chromophore. Other pigments such as β-carotene are long chains of ‘conjugated’ carbons. To a first approximation, electronic excitations within the ‘conjugated’ structures of these two classes of pigments are described as that of a particle in a ring and a particle in a wire, respectively. The precise energy at which any pigment absorbs can be ‘fine tuned’ by tweaking the length, shape or local environment of the ‘ring’ or the ‘wire’. The pigment molecules are intercalated within specialised pigment proteins. The pigment proteins have a characteristic helical structure and, in-vivo, span across the thylakoid membranes contained within the photosynthetic assemblies in organelles called chloroplasts. These pigments, when bound to a protein, are located at specific sites and maintain well defined orientations and separations. The pigment molecules are not usually chemically bound to the protein.

There is a great range of pigment-containing proteins. These assemble and organise into fascinating, complex, intertwined structures. The subsequent multi-protein assemblies (complexes) are in turn loosely embedded in lipid bi-layers (the thylakoid membranes) within the organism. Some photosynthetic assemblies are not directly involved with chemical processes but act simply to harvest light. They increase the overall absorption of light by the complex and funnel the subsequent electronic excitation to special pigment assemblies called reaction centres where important chemical transformations occur.

The study of the structure and dynamics of the light-harvesting complexes is a fascinating study, showing some beautiful photophysics. The reader is referred to Graham Fleming’s Website were there is an on-line PowerPoint presentation providing an introduction to some of the physics in these systems as studied by femtosecond spectroscopy: http://www.cchem.berkeley.edu/~grfgrp/research/lightharvesting/sld01.htm

At ANU, we are deeply involved in the study of Photosystem II (PSII), the more strongly oxidising of the two photo-activated reaction centres. When electronic excitation is transferred from one of the light-harvesting systems to the PSII reaction centre, very energetic chemistry ensues, the most energetic of any process in biology. Firstly, an (as yet) undefined assembly of chlorophylls, within the reaction centre, and labeled P680, becomes excited. The identity of the actual chlorophylls involved and their electronic coupling(s) is a subject of continuing discussion.

The label P680 arises from the fact that the PSII reaction centre absorbs light near 680 nm. The excited state of P680 (P680*) is dissociative, and rapidly ejects an electron. The electron is captured by an adjacent pheophytin pigment molecule and then transferred to a quinone electron acceptor molecule. A pheophytin is a chlorophyll minus the usual magnesium in the centre of the ‘conjugated’ ring. The magnesium is replaced with two protons.
The light driven charge separation of P680 provides the potential enabling (along with a parallel process of P700 in Photosystem I), the many physico-chemical processes in photosynthetic organisms. The end result in all of this is that CO₂ is converted into the food we eat and water is converted into the O₂ we breathe.

A description of many aspects of PSII is available on Jim Barber’s Website: http://www.bio.ic.ac.uk/research/barber/photosystemll/greenplants1_intro.html. Nature manages to photo-oxidise water efficiently, using relatively low energy (visible) light and in a delicate protein environment. The determination of the details of how this is achieved remains the greatest challenge in photosynthesis research.

The crystal structure of the bacterial reaction centre was determined in the early 1980’s, leading to the award of the Nobel Prize in chemistry to Deisenhofer, Huber and Michel in 1988 (http://www.nobel.se/chemistry/laureates/1988/). The crystal structure of PSI has now been determined to essentially atomic resolution (2.5 Å). A crystal structure of PSII has recently been published by the same group in Berlin and a group in Japan. Although the PSII structure obtained is a very significant breakthrough, it provides only limited (3.7-3.8 Å) resolution. Nonetheless, detailed spectroscopy of PSII is now benefiting from the knowledge of overall pigment content and location (but not as yet full orientation) within each protein. The collage on our cover has a background showing some of this organisation.

The first PSII crystal structure obtained was of a thermophilic cyanobacterium, Synechococcus Elongatus. Cyanobacteria (often called blue-green algae although they are bacteria and not algae!) were the first photosynthetic organisms on the planet (>3.5x10⁹ years ago) and are still responsible for most (>60%) of atmospheric oxygen (and subsequent bio-mass) currently being generated. The crystal structure of plant based PSII material has remained elusive. To obtain this structure is indeed one of our current projects! Our crystals of plant PSII also adorn our front cover. Electron diffraction data, albeit at lower resolution, is available for plant PSII material.

**Spectroscopy of PSII at ANU**

The literature on PSII is not for the faint hearted. It’s both voluminous and, as early studies required much inspired guesswork spanning a number of disciplines, can be confusing. One gleans from the historical literature that the sample preparation used in experiments is of great importance.

Figure 2 provides an ‘inside out’ cartoon of plant PSII, with the (smaller) inner reaction centre proteins given prominence. Also shown in Figure 2 is the overall electron transfer pathway, from the manganese cluster where water oxidation occurs, to the quinone electron acceptors. The full PSII complex has many protein components. A favorite ‘minimal’ PSII sample consists of stripping out the central reaction centre D1 and D2 proteins together with the cytochrome (cytochrome) unit. This contains just six chlorophylls rather than the >200 in the full complex. It does temporarily ‘charge separate’ upon illumination but the full machinery required for water oxidation is no longer present.

At ANU, we have concentrated on straightforward, but precise, controlled and detailed low temperature measurements on PSII ‘core complex’ samples. While not as reductionist as the D1/D2 preparation mentioned above, our samples are fully enzymatically active (i.e. they evolve oxygen) but have had everything not essential to this activity removed. They retain the inner light-harvesting proteins CP43 and CP47 as well as other proteins that are essential in keeping the manganese water oxidising cluster intact. Our samples do live, but within an inch of death. By controlling the temperature and illumination conditions of the sample, we are able to ‘lock’ it into a number of distinct intermediate states (called Kok S states) in which charge transfer has occurred between one or more of the many charge transfer active (redox) centres in the assembly.
Comparing P680 in PSII systems

We are making systematic and very precise low temperature absorption, circular dichroism (CD) and magnetically induced circular dichroism (MCD) measurements as well as parallel electron paramagnetic resonance (EPR) measurements on a range of PSII materials. There have been some surprises!

The putative spectrum of P680, as determined from studies in the minimal D1/D2 PSII preparations, appears to be quite different in the enzymatically active material. In Figure 3 we present the absorption spectrum of a plant PSII core complex, compared with spectra, taken separately, of isolated D1/D2 and of isolated inner antenna proteins CP47 and CP43. Absorption intensities have been scaled according to the known protein pigment content. The structure associated with P680 (which is associated with pigments in the D1/D2 proteins) appears to have changed upon removal of CP43 and CP47 to form the D1/D2 particles.

Another indication of the susceptibility of P680 to details in protein structure and environment comes from a comparison of spectra of PSII core complex particles prepared from either plants or cyanobacteria (Figure 4). Plants are thought to have evolved from cyanobacteria but have adapted to very different environmental stresses. One could expect from high homology in the genes expressing D1, D2, CP43 and CP47 of PSII in the two systems that the PSII core complexes would be practically identical. A comparison of their absorption spectra (Figure 4) shows that structure on the low energy side, which we feel is dominated by P680, is quite different.

'Exciton' coupling

The inner pigments in the D1/D2 proteins have their closest neighbours at a consistent 1.0–1.3 nm. The oscillator strength in the Q band (650–700 nm) is ~0.1, and this corresponds to a transition dipole of ~57 Debye. The maximal interaction between neighbouring transition dipoles then scales to ~100 cm⁻¹ (or ~10 nm in this region). An electronic (Davydov) splitting of the excited state of a pair of coupled pigments of 200 cm⁻¹ (maximally) would ensure. The final magnitude of the splitting, the relative intensity of the Davydov components and their polarisation depends on the relative geometry of the transition moments. Figure 5 is a schematic of the interaction.

The two transition dipoles can interact in and out of phase, with an interaction energy ε, to give rise, in the simplest case, to the |→⟩ Davydov eigenstates. R is the vector connecting the two (point) transition dipole moments μAA and μBB.

|→⟩ = (|A⟩⟩B ± |A⟩⟨B⟩)|/√2

and

ε = |μAA| · |μBB|//R

In an extended periodic array of chromophores, such interactions give rise to molecular excitons. By analogy, interactions of this type in small clusters, even dimers, are called 'exciton' couplings and the structure 'excitonic', although there is clearly no wave vector that can be constructed.

The transition dipole-transition dipole interactions in P680 are smaller than that between the 'special pair' of chlorophylls in PSI. This interaction, of around 300 cm⁻¹ bridges pigments in two proteins analogous to D1 and D2 and has a major influence in PSI. Even larger interactions (1000 cm⁻¹) are seen in reaction centres containing bacterio-chlorophylls, a chemical variant of 'normal' chlorophyll. These pigments have larger dipole strengths and also maintain closer inter-molecular distances. In PSII, the distances between neighbouring chlorophylls and also plastoquinol to the closest chlorophyll, are all similar. With these distances being comparable, the exciton interactions are thus determined by inter-pigment geometry and particularly the relative orientation of transition dipoles.

However, not all pigments, even of a given type, absorb at precisely the same energy. There is a significant variation, leading to a diagonal disorder of pigment energies, of up to 500 cm⁻¹. With interaction energies being comparable to diagonal disorder and the precise orientation of the pigments within proteins not known, it has proved difficult to provide a unique assignment of P680. We will note later that Stark shifts of pigments, associated with charge movements within PSI can also be ~100 cm⁻¹, which further exacerbates the analysis.

Some workers have proposed a limiting description of P680 in terms of zero coupling and the treated pigments not having any significant interactions. We know this is simply not the case. For example, the prominent feature at 683.5 nm in plant PSI has an intensity corresponding to 2.2 chlorophylls and behaves, in a number of ways, as a single excited state. Thus, we conclude it to be an exciton feature. We have identified one of its partners and consequently a major splitting to be 187 cm⁻¹.

It seems likely that a number of pigments couple to form P680. Coupling leads to energy shifts and also polarisation changes. We have broached these by measuring both CD and MCD spectra of our samples, taken in parallel to absorption measurements.

The rotary strength Rₕ arising from CD in a chromophore has the form

Rₕ = 1/m(ψ|μ|ψ) = <ψ|μ|ψ>/<ψ|ψ>

and thus involves both the electric (μ) and magnetic (m) transition dipoles, which must have a parallel component to allow a non-zero CD. Transition dipole-dipole coupling between pigments leads to a significant source of magnetic dipole intensity. This is associated with transition charge moving helically between coupled chromophores, and at (relatively) large distances. This creates a large magnetic moment that can be generated in the optimal direction for strong CD. This gives rise to exciton CD. The CD of coupled pigments can be far stronger than the intrinsic CD of monomeric pigments and is naturally quite sensitive of the relative geometry of the sub-units.

Magnetically induced CD (MCD) arises from an entirely different origin, from electronic Zeeman interactions. The MCD of chlorophyll in the region of interest (the Qₐ transition) is dominated by magnetic field induced mixing between the Qₐ state and its partner Qₐ state, which is at higher energy. There is an entirely different sensitivity of the MCD spectrum to exciton coupling and this sensitivity provides us with an independent 'look' at P680.
The situation is subtle. Nature often uses variability in a system to fine-tune evolutionary opportunities, and this may have happened in the changes in PSII from cyanobacteria to plants. The phenomenal oxidising potential of P680 may arise from a balance between the unusual environment of pigments when located in the D1/D2 proteins and the relatively modest interactions between them. We look to unravel this complexity by using parallel spectroscopic probes.

Stark shifts

Controlled illumination of our samples leads to the formation of a metastable form of PSII, in which an electron is placed on a plasto-quinone acceptor molecule ≈1.3 nm from the phyto-phytin on the D1 protein. The change in electric field experienced by the phyto-phytin is ≈10⁸ V/cm and, as the change in dipole moment Δμ, between ground and excited states is ≈1 Debye, a Stark shift between approximately −100 cm⁻¹ and +100 cm⁻¹ can be expected, depending on the orientation of Δμ with respect to the quinone charge.

This Stark shift allows us to immediately locate the D1 phyto-phytin chromophore (see Figure 4) as it is the closest pigment to the quinone. A quantification of the differential feature seen by subtracting spectra taken before and after illumination and analysis indicates a Stark shift of about +8 cm⁻¹ upon quinone reduction. One surprise is that the Qₐ phyto-phytin excited state is below what we assign as the lowest energy P680 feature in plants by 30 cm⁻¹, but above the corresponding feature in cyanobacteria by 20 cm⁻¹. A series of similar experiments is helping us both identify pigments and by using pigments as electric field reporters, map out charge movements within PSII during the multi-step synthesis of oxygen.

**CD and MCD in P680**

Figure 6 shows the low temperature absorption, CD and MCD of plant PSII, all measured on the same sample in the same spectrometer at the same time. The CD is far stronger than that predicted for an equivalent assembly of non-interacting chlorophylls. It is also strongly structured having a small overall zeroth moment, both properties clear signatures of exciton CD. An immediate analysis of the CD is precluded by the knowledge that the CD of an isolated pigment can be strongly modified when intercalated in a protein. The dominant feature in absorption and CD is at 683.5 nm. From a number of its spectral characteristics, including Stark shifts, we attribute this feature to P680.²⁻⁸
The MCD has been scaled so that if all the chlorophylls were “normal” (i.e. each had the MCD it would show as an isolated chromophore in solution), the absorption and MCD would follow the same trace. A close correspondence is followed at higher energy, in a region that corresponds mostly to the (weakly interacting) chlorophylls in CP43 and CP47 proteins. For the P680 feature and a region to higher energy, the MCD has been reduced by around 50%. The total effective area that has experienced the reduction corresponds to 3-4 chlorophylls. We feel the reduction is a signature of the P680 spectrum. This conclusion is supported by MCD measurements on isolated D1/D2 preparations.

Finding a theoretical basis for the MCD reduction has proved difficult. We have investigated the consequences of two centre magnetic moments (Gauge terms) in the exciton MCD, similar to those terms giving rise to exciton CD. Although we can achieve the correct phenomenology using one of these terms, the parameters needed to achieve a 50% reduction seem unphysical. This result highlights one of the main directions in which our investigations are leading. The molecular properties of a pigment when part of P680 in D1 and D2 can appear very different to those of the same pigment in a light harvesting protein or in solution.

Perspectives

We feel we are well on the way to identifying the physics and chemistry that make P680 so potent. There is little doubt that this fuller understanding will help enable new ways of harnessing solar energy. This could be via the targeted tuning of aspects occurring in natural photosynthetic processes or by using what we have learnt in the design of artificial (bioanalog) photosynthetic systems.

It is a pleasure to acknowledge the team involved with the many aspects of this project; Ron Pace, Tom Wydrzynski, Garth Hendry, Paul Smith, Sindsa Peterson, Vanessa Masters, Joe Hughes, Corinne Dobson, Barry Prince and Michael Parker. Special thanks are extended to our invaluable technical assistant, Keith Jackman.

References:

15. J. Hughes, BSc (Hons) Thesis ANU (2001).

THE 2003 WALTER BOAS MEDAL

Nominations are invited for the award of the 2003 Walter Boas medal of the Australian Institute of Physics and should reach the Honorary Secretary by normal mail at the address below, or by email, by the end of July at the latest.

The Medal was established in 1984 to promote excellence in research in Physics and to perpetuate the name of Walter Boas. The award is for physics research carried out in the five years prior to the date of the award, as demonstrated by both published papers and unpublished papers prepared for publication, a list of which should accompany the nomination.

Any AIP member may make nominations or may self nominate for the award. Nominees should be members of the AIP and be Australian citizens and should have been residents of Australia for at least five of the seven years preceding the closing date for nominations. The Medal shall not be awarded more than once to any person.

Previous winners of the Walter Boas Medal:
1984 Dr Peter Hannaford, CSIRO Division of Materials Technology
1986 Professor Don Melrose, Sydney University
1987 Professor Tony Thomas, University of Adelaide
1988 Professor Robert Delbourgo, University of Tasmania
1989 Professor Jim Williams, University of Western Australia
1990 Professor Geoff Opat & Professor Tony Klein, University of Melbourne
1991 Dr P Hariharan, CSIRO Division of Applied Physics
1992 Professor B H J McKellar, University of Melbourne
1993 Professor Jim Williams, Australian National University
1994 no medal awarded
1995 A/Professor David Blair, University of Western Australia
1996 Professor Andreas Stelbovics, Murdoch University, and Dr Igor Bray, Flinders University
1997 Professor Keith Nugent, U of Melbourne & Dr Stephen Wilkins, CSIRO
1998 Professor Bob Clark, University of NSW
1999 no medal awarded
2000 Professor Hans Bacher, ANU
2001 A/Professor Tony Williams, University of Adelaide
2002 Professor Peter Robinson, University of Sydney

The award is conditional on the recipient delivering a seminar on the subject of the award at a meeting of the Victorian Branch of the AIP in November 2003. The recipient is also expected to provide a manuscript based on the seminar for publication in The Physicist.

Further details may be obtained from:
The Honorary Secretary
Australian Institute of Physics
PO Box 16, Willetton WA 6955
Phone: 08 9332 1513 email: i.bailey@curtin.edu.au
News from FASTS

Executive changes
The new President-elect of FASTS is Professor Snow Barlow. He will join the Executive immediately and will begin his two-year term as President in November this year. Professor Barlow is a member of a CRC and has been on Boards or Committees for the R&D Corporations, the Academy of Science and the ARC. He has represented Australia at international treaty discussions on such environmental matters as Greenhouse and Climate Change.

The current President of FASTS, Professor Fell, said that Professor Barlow’s experience would stand him in good stead. “Snow Barlow is a working scientist in areas such as water use and climate change. Members of Parliament nominated both these issues as being in the top five in our ‘Science meets Parliament Day’ event.”

FASTS also has a new Secretary in Associate Professor John O’Connor from the University of Newcastle and Immediate Past President of the AIP.

Professor Fell thanked retiring Executive members Jan Thomas and Peter French.

FASTS Top Ten

FASTS’ has determined the ten issues it believes most important for 1003. These issues relate to industry, education and the development of a national strategy for science. Amongst other things, the issues include proposals to increase the number of scientists working in industry, for scientists to have greater interaction with Parliament and for encouraging more science graduates to take up teaching as a career.

The Ten Top Issues for 2003 (from the FASTS Newsletter)

1. AUSTRALIA NEEDS A MAP AND A COMPASS: We have a 10-year plan for defence - why not for science and technology? We should plan for the future, set national goals, and ensure that science serves the national interest.

2. BOOST FUNDING FOR UNIVERSITY SCIENCE: Science and technology are expensive courses to run but vital to Australia’s future. The special funding requirements of these courses need to be recognised by Government and universities.

3. ENHANCE INDUSTRY INNOVATION: Meet halve the cost of employing new PhD graduates in industry for 2 years, to encourage industry make the best use of science in developing new products and improving existing ones.

4. BRING ON “BACKING AUSTRALIA’S ABILITY”: The Innovation Statement was the first step to re-invest in Australian science, but we continue to lag in international terms. It’s time to take the second step and increase our national investment to OECD average by 2012.

5. VIVE LA DIFFERENCE! Encourage universities to pursue individual excellence in teaching and research, rather than being clones of each other. Foster institutional cooperation on expensive equipment and joint projects.

6. ENCOURAGE INDUSTRY TO BE INVENTIVE: Give tax breaks on a sliding scale to companies prepared to invest more in research, because enterprise and inventive companies grow and provide more jobs.

7. SCIENTISTS ADVISING PARLIAMENT: Place scientists in Parliament for one-year secondments, to advise MPs on science-based issues such as water, salinity, energy sources of the future, climate change, health and resources.

8. EQUAL HECs FOR SCIENCE AND MATHEMATICS TEACHERS: Science and maths teachers are in short supply in Australia, but they still are forced to pay higher HECS fees than teachers in other subjects; and so they take home less pay.

9. ATTRACT VENTURE CAPITAL INTO NEW INDUSTRIES: Venture capital is in short supply. Make it more attractive to invest in new ideas and new industries by introducing new measure such as diminishing annual rates for capital gains tax.

10. IMPLEMENTING NATIONAL RESEARCH PRIORITIES: Australia has adopted research priorities. Now we need to implement them, and find effective ways to measure the progress our science makes to meeting the goals.

2002 Bragg Gold Medal Winner

The winner of the 2002 Bragg Gold medal for the best PhD thesis from an Australian University, is Dr Annette Berriman, of the Australian National University, for her thesis entitled “Investigating Entrance Channel Effects in Fusion-Fission Dynamics”.

According to the judging panel, the State finalists for the 2002 Bragg Medal were of exceptionally high quality. In her thesis, Dr Berriman has proposed and carried out a challenging program of research to identify and explain new physical processes involved in the fusion-fission of heavy ions. Her work involved accurate measurements of capture cross sections, modeling these measurements, and physical interpretation. Her thesis is a model of clarity. The novelty of the experimental approach and of the physical insights developed by Dr Berriman to explain her results is indicated by the publication of her results in Nature, with an accompanying article reviewing the paper and acknowledging its significance in the field.

The other state finalists were, in alphabetical order:

- Dr Pradip Deb, University of Melbourne. Thesis: Proton-Nucleus scattering and proton/neutron distribution in nuclei.
- Dr William Detmold, University of Adelaide. Thesis: Non perturbative approaches to quantum chromodynamics
- Dr Simon Drew, Monash. Thesis: Selected topics in modern CW and pulsed EPR.
- Dr Jeremy O’ Brien, UNSW. Thesis: Correlated and confined electrons: towards the fabrication of a solid state quantum computer.
- Dr Saiedeh Saghafi, Macquarie University. Thesis: Characterisation of output beams produced by high power unstable laser resonators through model analysis.
- Dr John Winterflood UWA. Thesis: High performance vibration isolation for gravitational wave detection.

Congratulations from the AIP Executive and members to Dr Berriman and all the State finalists, and we wish you all continued great success in the future.

Moira Welch
Honorary Secretary
Rebuilding the Enabling Sciences

Reclaiming the Key to Unlock the Nation’s Potential

There are serious issues facing Australian Science, Engineering and Technology which, if not addressed, will condemn our country to a never ending fate of ‘catch up’ with more enlightened countries. Backing Australia’s Ability and Knowledge Nation are first steps in addressing aspects of problems with the SET disciplines in general, but there are potentially more devastating problems specific to the mathematical, physical, chemical and engineering sciences which need urgent attention. This joint release by the Royal Australian Chemical Institute, the Australian Institute of Physics, the Australian Mathematical Sciences Council and the Institution of Engineers Australia is aimed at promoting the discussion by the community and the major political parties of how to address the need for crucial ongoing support of the enabling sciences (throughout this document the ‘enabling sciences’ refers to Chemistry, Physics and Mathematics where ‘Mathematics’ is an inclusive term encompassing Statistics). It is imperative that we address the growing problem of the current shortage of supply of top quality training in the ‘enabling sciences’ for industry.

MAIN STATEMENT

Chemistry, Physics and Mathematics are often called the ‘enabling sciences’. The knowledge contained within these sciences represents the foundations upon which all scientific discoveries are built and technology developed. They are fundamental to the success of a research and innovation culture in the ‘emerging technologies’ such as biotechnology, nanotechnology, photonics and information technology. They are an essential platform to engineering which converts scientific discovery into economic growth as well as playing a key role in most other areas of human endeavour and skills.

The successful progress of Australia’s economy and quality of life for its citizens requires policies for Education and Research that foster the creation of an environment in which the enabling sciences are able to operate and grow in a vigorous manner. This growth should contribute to the formation of an enquiring and innovative culture in science, engineering and technology and thus advances in the ‘emerging technologies’ through provision of a well trained, flexible, and motivated workforce.

Progress can be achieved through:

Education

Provision of high quality training and a stimulating and rewarding career environment for teachers at all levels of education, together with allocation of resources to the education sector that ensures education of students in the ‘enabling sciences’ at the highest international standard.

Research

A recognition of the synergies between the quality of teaching in tertiary education, research activity in the ‘enabling sciences’, and the future progress of ‘enabling technologies’, requires an allocation and division of resources that emphasises quality at the highest international levels in educational and research outcomes.

The specific issues that need addressing fall into the following general areas:

PUBLIC

There is a serious disparity between the public reliance on science, mathematics and technology and their perception of the roles of training and employment prospects in these areas. Therefore we advocate the launching of a SCIENCE AND MATHEMATICS INITIATIVE FOR THE NEW MILLENNIUM which uses the strategies below to renew the interest, awareness and excitement factors in the enabling sciences, and demonstrate that there are rewarding, challenging and creative jobs for science, mathematics and engineering graduates.

1) Its primary goal is a national campaign (similar to advertising for the armed forces) showing the many varied and interesting careers available for Science and Mathematics graduates. There is a growing gap between the supply of science and mathematics graduates in essential areas and the demand for them. This will include creating additional material for careers advisers.

2) Financially support national Physics, Chemistry and Mathematics professional societies to promote their image as the enabling sciences nationally. This can be channelled through either the Science and Technology Awareness Program or the Australian Academy of Science but must be seen as new funds to target the misconceptions around the role of the enabling sciences. Include programs to focus on gender and minority group issues in the enabling sciences.

3) Put in place long term mechanisms to provide quality data on the number of staff in different mathematical, chemical and physical science and engineering disciplines at the tertiary level and the number of students majoring in these disciplines. This information should then be used as part of a workforce planning process which will identify the long term deficiencies in areas of science and engineering.

EDUCATION

The teaching of science and mathematics in secondary schools is under excessive strain. There is a diminishing resource base of well trained teachers in the enabling sciences. We need to undertake a comprehensive review of the needs and resources in the education and training of the enabling sciences.

SECONDARY EDUCATION:

4) Promote the BSc plus Dip Ed model as the preferred option for teaching staff in senior levels of secondary education in the enabling sciences.

5) Differentiate science and mathematics teachers into discipline specialties at senior secondary school levels.

6) Provide HECs bursaries to students undertaking teacher education programs in priority areas which involve enabling sciences.
7) Develop national standard entry qualification for entry into science and mathematics teacher training programs.

8) Launch national program to improve teaching resources, support staff and additional scientific equipment to maintain modern laboratories in the enabling sciences. While attention should be paid to the increased demand for computers in secondary mathematics, the need for additional equipment extends well beyond computers in Chemistry and Physics.

9) Provide financial support for extensive in-service training programs in the enabling science disciplines for secondary science and mathematics teachers.

10) Eliminate the differential HECS for science and mathematics based degrees.

11) Provide a salary loading to teachers in the enabling sciences with honours or higher degree qualifications in the enabling science disciplines.

12) Develop national standards for matriculation students which involves compulsory study in English, Mathematics and Science to meet the capabilities and potential of every student through to the end of secondary education.

**PRIMARY/SECONDARY EDUCATION:**

13) Strengthen the enabling science component of teacher training programs and provide financial rewards for successful completion of programs to upgrade skills in the disciplines of the enabling sciences.

14) Increase the awareness amongst primary and junior secondary teachers of the long term importance and effects of the specific and generic skills of the enabling sciences, and of the importance of optimising the development of students and avoiding under-expectation.

15) Establish a national triennial conference on Science and Mathematics curricula and implementation with an aim to bring together the schemes in different states. This has great benefits in the sharing of teaching resources and in the mobility of teaching staff.

**TERTIARY EDUCATION:**

16) Review DETYA relative funding model for costs of university course delivery.

17) Increase core funding to reverse $/EFTSU funding decline

**RESEARCH**

18) Provide targeted research training places and scholarships in the enabling sciences.

19) Provide staff support for large equipment items and the high level computing facilities necessary for mathematical and scientific research - not just equipment costs.

These issues must be addressed to support a fruitful high technology future.

---

### The 2003 Australian Museum Eureka Prizes

The Australian Museum Eureka Prizes are Australia's premier and most comprehensive national science awards. The 2003 series consists of a record-breaking 21 prizes worth $210,000 - a staggering increase of over 100% in just three years in the number and value of prizes.

The Eureka Prizes reward excellence in Australian science and raise the profile of science in the community. They provide a highly visible means of highlighting Australian research, with eight prizes focussed specifically on a range of research activity of the type being undertaken within the University:

- **$10,000 Australian Catholic University Eureka Prize for Research in Ethics** - for serious, intellectual investigation of ethical issues that promote scholarly interest in the field of ethics.

- **$10,000 Australian Skeptics Eureka Prize for Critical Thinking** - for critical investigation of conventional wisdoms and/or beliefs that have no rational basis.

- **$10,000 British Council Eureka Prize for Inspiring Science** - a new prize for outstanding research, inventionness, innovation or creativity by an Australian scientist between the age of 18-35 that has raised the profile of science, engineering or technology.

- **$10,000 GRDC Eureka Prize for Research to Improve the Environmental Sustainability of Grain Growing** - a new prize for innovative research in the sustainability of the use of natural resources.

- **$10,000 Royal Botanic Gardens, Sydney Eureka Prize for Biodiversity Research** - for innovative scientific research that makes an outstanding contribution to the conservation of Australia's biodiversity.

- **$10,000 Royal Societies of Australia Eureka Prize for Interdisciplinary Scientific Research** - a new prize for outstanding research that involves the active collaboration and/or cooperation of scientists in two or more disciplines.

- **$10,000 Sherman Eureka Prize for Environmental Research** - for research leading to the resolution of an environmental problem or improvement in our natural environment.

- **$10,000 University of New South Wales Eureka Prize for Scientific Research** - for outstanding curiosity-driven scientific research, undertaken in Australia by an Australian scientist under the age of 40, judged to be under-appreciated by the Australian public.

Candidates for Eureka prizes can either enter themselves or be nominated by others. Information and entry forms for all prizes are available at www.amonline.net.au/eureka. Entries close on Friday 16 May 2003.

In previous years there has been a reluctance by some researchers to enter their work. Yet the Eureka Prizes can only fulfill their purpose of rewarding and publicising outstanding Australian research if quality entries demonstrating the excellence of Australian research are received. Your assistance in alerting university staff and students to the opportunities provided by the Eureka Prizes and encouraging entries would be very much appreciated.

Roger Muller  
Manager, Strategic Initiatives Unit  
Australian Museum  
Tel: 02 9320 6230 Fax: 02 9320 6074

---

*The Physicist* Volume 40, Number 1, January/February/March 2003
Dan O'Keefe receives AIP award for outstanding service to physics in Australia

At the meeting of the Victorian Branch on Thursday 21st November 2002, Dan O'Keefe was awarded the AIP award for outstanding service to physics in Australia. The Federal President of the AIP, John O'Connor, presented Dan with a certificate and read out a brief citation outlining the enormous contribution that Dan has made to physics in Victoria and Australia-wide, primarily in the area of physics education.

Dan influenced the physics curriculum in Victoria at senior secondary level through his involvement in the Australian Institute of Physics Victorian Branch Education Subcommittee, which through the 1990s until the present provides a valuable forum for communication about physics education between secondary teachers, tertiary lecturers and other interested parties. Dan has been an influential member of this committee and completed three years as Chair in 2001. Dan was also a member of the Board of Studies Victorian Certificate of Education (VCE) Physics accreditation panel in 1998 and was a writer of the revised study design. He contributed to training days and conference sessions where the re-accredited study design was introduced to teachers and the changes in assessment were discussed. Dan has also been a member of Physics Course Committees under the Victorian Universities and Schools Examination Board (VUSEB), the Victorian Institute of Secondary Education (VISE) and the Victorian Curriculum and Assessment Board (VCAB) and was a member of the reference group during the development of the initial VCE Physics Study Design.

The success of the annual AIP/Science Teachers' Association of Victoria (STAV) Physics Teachers' Conference, held in February each year has been very largely due to Dan's organisation each year. This conference, which is run as a joint effort between the AIP and the STAV, has become a feature of Victorian senior secondary physics teachers' year. More than three hundred teachers regularly attend. Dan has led planning for the conference at education subcommittee meetings, liaised with the STAV, contacted speakers, programmed the speaker packages, written the feedback questions and analysed the responses, presented sessions, and collated material for the conference proceedings. Dan's vision and organisation was also central to the establishment of the Vicphysics web site (www.vicphysics.org) which was launched at the AIP/STAV Physics Teachers' Conference in July 2001. Dan was a key sponsor, promoter and organiser of the AIP-supported tutorial program aimed at preparing Victorian students for the Physics Olympiad National Qualifying Exam.

Dan has also been extensively involved in the development of Australia-wide programs to promote physics education. In particular, he has been instrumental in the success of the Switched on to Physics (SOTP) and Switched on Science programs for year 10 students. Dan's involvement in SOTP ranged from putting together the student kits for the activities to obtaining government funding. The initial pilot programs in 1996 and 1997 in Victoria provided a springboard for obtaining funding from the Federal Government's Science and Technology Awareness Program to run a national Switched on Science program in 1998 and 1999. SOTP continued in Victoria in 2000 with funding from the Victorian Government's Science Partnership Scheme. Under Dan's leadership, the Education sub-committee was awarded a substantial grant for the 2002-2003 financial year to support SOTP Australia-wide from the Federal Department of Industry and Science and Resources under its National Innovation Awareness Strategy.

In addition, he has been a long-serving and extremely valuable member of the Victorian Branch Committee of the AIP as well as the Education Coordinator on the AIP's National Council. This commitment to Australian physics education has been in addition to his role as Head of Science and Physics at Camberwell Grammar School where he led staff and students to excellence in teaching and learning until his retirement at the end of 2002.

Dan has been outstanding in his contribution to physics, particularly physics education, and in his commitment to advancing the field of physics. Dan's dedication is inspirational and the sheer amount of work that he contributes to the AIP and its committees is extraordinary. This well-deserved AIP award for outstanding service was presented in recognition of Dan O'Keefe's substantial contribution and achievements.

Biophysics awards

Congratulations to the biophysics department at the University of NSW. Professor Hans Coster has won the inaugural Sir Rutherford Robertson medal for Biophysics at a ceremony last Saturday in Melbourne.

In addition, the Biophysics Department also scooped the pool at the Annual Conference with Dr Louise Brown winning the Young Biophysicist award and

AROUND THE TRAPS

Till Boecking one of the two Student Prizes.
THE PHYSICIST'S CROSSWORD NO. 7

ACROSS
5. On reflection, one joins in the celebration (6)
6. The fifty-one pound phase (6)
9. Point of phase coexistence wantonly let rip (6)
10. Displays no longer greeting binary digits (8)
11. (see 14)
12. Electricity too cheap to meter? Thermodynamics may hold the answer (4, 6)
13. Current technology encrypted in stone circle (11)
18. Opening leading to shattered relics in chambers (10)
21, 20. Law proposed by spineless bigots with average skill (4-6)
22, 23. Wild convent orgy with pit indicating the flux of power (8, 6)
23. (see 22)
24. Strike an aphorism (6)
25. At liberty to take half of zero and to take below zero (6)

DOWN
1. Grant's first step? (8)
2. The identity of one who would stifle change (6)
3. Permutation of the eigenvalue (8)
4. Astronomer lurking at the edges of hungry rabble (6)
5. Outcast song with a measure of acidity about it (6)
7. Period after period of feeble-minded senility (6)
8. Loo geometry taken as a field of study (11)
14, 11. Judgmental service which is potentially explosive (8, 4)
15. Little rooms: I see fifty in boxes (8)
16. Compiler with issue creating particles (6)
17. Cipher in code makes gloomy (6)
19. Ten sorry starters with more indices than 23 (6)
20. (see 21)

SOLUTION TO CROSSWORD No. 6

The Physicist Volume 40, Number 1, January/February/March 2003
CONFERENCES & MEETINGS
2003

July 13-16
COIN '03 and ACOFT '03
Optical Networking: Technologies, Traffic Engineering and Management
Hilton-at-the-Park Hotel, Melbourne
Contact: ACTS Conferencing
coinacoft@ausconservices.com.au
www.ee.mu.oz.au/conferences/coin_acoft_03
Tel: +61 2 6257 3299 Fax: +61 2 6257 3256

August 19-21
Workshop on Recent Advances in Absorbed Dose Standards
ARPANA, Melbourne
Contact: Mr Robert Huntley, ARPANSA,
Lower Plenty Rd., Yallambie, VIC 3085
Robert.Huntley@health.gov.au

August 24-29
World Congress of Medical Physics
Sydney

October 26-29
Australasian Radiation Protection Society Conference 2003
Hobart Function Centre, Hobart, Tasmania
Contact: arps2003@leishman-associates.com.au

29 September
- 2 October
APAC'03
The APAC Conference and Exhibition on Advanced Computing,
Grid Applications and eResearch
Royal Pines Resort
Gold Coast, Queensland, Australia
Website: www.apac.edu.au
Conference Organisers: Martin Lack & Associates Pty Ltd
Phone +61 7 3878 9470 Fax: +61 7 3378 9513
Email: apac03@mlaa.com.au

November 6-12
The 9th ASIA PACIFIC PHYSICS CONFERENCE - 9th AIPCC
Hanoi
Mail: 9th APPC Secretariat
Institute of Material Science
18 Hoang Quoc Viet, Cau Giay, Hanoi
Vietnam
Tel: +84 4 7564129 Fax: +84 4 8360705
Email: appc03@ims.ncst.vn Website: www.ims.ac.vn/appc03
PHYSICS ENROLMENTS IN AUSTRALIAN AND NEW ZEALAND UNIVERSITIES 1997 - 2002

PHILIP JENNINGS, JOHN DE LAETER AND GRAEML PUTT

This is the twelfth of a series of triennial surveys of physics enrolments in Australian and New Zealand Universities. This project began in 1974 with surveys by de Laet and Watson-Munro for physics enrolments at Australian Colleges of Advanced Education and Universities respectively in the period 1963 to 1973. The original aim of the surveys was to collect data for planning purposes and to study the effects of Government policy on the physics profession.

In 1975, de Laet and Watson-Munro produced the first of these combined surveys for all Australian tertiary educational institutions covering the period 1965-1975. They repeated the exercise in 1979. Following the retirement of Professor Watson-Munro in 1979, Philip Jennings and John de Laet combined to continue the surveys at triennial intervals through the eighties. In 1993 the survey was expanded to include New Zealand universities and Graeme Puth joined the team.

We now have a consistent set of data covering the period 1968 to 2002 for Australian universities and from 1991 to 2002 for New Zealand universities.

Introduction

Originally, the surveys focused on numbers of third and fourth year physics students. These were easier to identify than graduates as some of them do double majors and are difficult to keep track of, while others graduate at mid-year. Although it is easier today to collect the data on physics graduates because it is required by the Government, after 1987, the survey was continued to count third and fourth years physics majors for consistency. These also represent a more realistic estimate of the enrolments in physics rather than the output of physics departments.

Beginning with the 1982 survey, we began to collect the total number of postgraduate students in physics. Here again we chose to count the total number of postgraduate students to gain an indication of the size of the postgraduate effort. In earlier surveys we also estimated the number of pass, honours and postgraduate graduates each year.

Beginning in 1991, we also began to address gender issues because of the perceived low level of participation by females in physics. Initially there was some difficulty in obtaining this data but we now have sufficient data to draw conclusions and as time goes by, we are able to study trends in participation rates of males and females.

The 1996 and 1999 surveys were undertaken in the midst of considerable upheaval and unprecedented anxiety about the future of physics in Australia and New Zealand due to the severe budget cuts and declining enrolments in Physics in many tertiary educational institutions. The situation has not improved although this new data shows some early signs of a recovery.

Methods

This survey was conducted in July and August of 2002 at a time when North American and European Universities were reporting renewed student interest in Physics. In addition to collecting data about third year, fourth year (Honours and Diploma) and postgraduate (MSc and PhD) enrolments we asked a set of questions about recent changes in course content and structure and to the administration of the Physics course in the various Universities. We also sought information about changes planned for the near future, changes in the student population and significant problems facing the Departments.

This data was obtained from the Heads of the various physics departments in Australia and New Zealand. We have tried to ensure that the data is consistent and accurate by circulating the tables to Heads for checking. However, there are certain to be minor errors due to the difficulty of uniquely identifying physics majors. We encourage readers to notify us if they detect any errors in the data.

Analysis of Enrolment Data

The third year, fourth year and postgraduate enrolments for the period 1996 - 2002 are presented in Tables 1, 2 and 3. Figures 1, 2 and 3 show the trends in total enrolments at third year, fourth year and postgraduate level over the 35-year period since data collection began in 1968.

The following observations are made:

Third year enrolments

Twenty-six Australian Universities are now offering some sort of Physics degree compared with thirty a decade ago. Six New Zealand Universities offer a degree in Physics, the same as a decade ago.

Australian third year enrolments seem to have stabilised after falling from 711 in 1993 to 468 in 2001. The results for 2002 show early signs of recovery in all States of Australia. This may be partly due to the introduction of new physics-related degrees such as photonics, nanotechnology and medical physics that run alongside the existing physics degrees and utilise their 3rd year units. The New Zealand enrolments have been almost static over the past decade with fluctuations of 15% about a mean of 127 students.

The proportion of female students in third year physics has not
Table 1

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Griffith University</td>
<td>9</td>
<td>10</td>
<td>5</td>
<td>13</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>James Cook University</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Queensland Uni. of Technology</td>
<td>14</td>
<td>6</td>
<td>5</td>
<td>11</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Central Queensland University</td>
<td>18</td>
<td>32</td>
<td>28</td>
<td>10</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>University of Southern Queensland</td>
<td>7</td>
<td>12</td>
<td>4</td>
<td>9</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>University of Queensland</td>
<td>9</td>
<td>12</td>
<td>11</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Griffith University</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>James Cook University</td>
<td>14</td>
<td>6</td>
<td>5</td>
<td>11</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Queensland Uni. of Technology</td>
<td>18</td>
<td>32</td>
<td>28</td>
<td>10</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Central Queensland University</td>
<td>12</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>University of Southern Queensland</td>
<td>7</td>
<td>12</td>
<td>4</td>
<td>9</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

changed significantly over the past decade and is in the range of 20 - 30% of the class in Australia and 10 - 20% in New Zealand.

Fourth year enrolments

Fourth year enrolments in physics in Australian Universities seem to have stabilised and begun to increase again after falling substantially from 264 in 1996 to 134 in 2000. In contrast the fourth year numbers in New Zealand have remained relatively about a mean of 65 over the past decade. The gender balance in 4th year courses in Australia and New Zealand has remained stable and similar to that in the 3rd courses over the past decade.

Postgraduate enrolments

Postgraduate enrolments in Physics in Australia have fallen from a high of 1201 in 1993 to 734 in 2002. In contrast the postgraduate numbers in Physics in New Zealand Universities steadily increased from 105 students in 1991 to a maximum of 174 in 1996 after which they levelled out at 165 till 2001. This year there is a disturbing fall of about 20% prompting concerns about staffing for laboratory demonstrators and assignment markers.

The proportion of female postgraduate students in Australia and New Zealand is about 25% and appears to have risen slowly over the past decade.

Analysis of the Questionnaire Data

In addition to the enrolment data we collected responses to five questions. Responses were received from 30 Australian Universities (26 of which offer an undergraduate major in physics) and 6 New Zealand Universities.

A content analysis was carried out on these responses and the results are summarised below.

Describe any major changes to your educational offerings in Physics over the past five years (eg new directions, new awards, termination of courses, etc)

Australia

16 new, physics-related courses have been introduced by these Australian Universities. These include photonic (5), medical
Table 3
Physics Enrolments in Australian & New Zealand Universities 1997 – 2002
Numbers of Postgraduate Physics Students

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Griffith University</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>James Cook University</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Queensland Solar Technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Queensland University</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Queensland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of South Australia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Australia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macquarie University</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of New South Wales</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Sydney</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of New Zealand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total New South Wales</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avant-Defence-Fin Fac.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anzac National U.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANU / Nat. Sch. of Phys Sciences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Act</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Trobe University</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monash University</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Royal Inst. of Technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science University</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Melbourne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Quebec</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Victoria</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Tasmania</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Adelaide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Quebec</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Western Australia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern Territory University</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Australia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Massey University</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Auckland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Canterbury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Otago</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Waikato</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total New Zealand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

physics (3), computational physics (3), astro/pace physics (3), nanotechnology (2).

- 4 Australian Universities have terminated their physics courses since 1997.
- 8 Australian Universities have undertaken major reviews and subsequent restructuring of their physics courses over the past five years.
- 4 Australian Universities have introduced joint degrees with physics and engineering.
- Only 4 Australian Universities reported no substantial changes to their offerings over the past five years.

New Zealand

Most initiatives undertaken in NZ seem intended to maximise employment opportunities for graduates that might otherwise steer away from standard BSc degrees majoring in Physics that are perceived as limiting unless they are followed by postgraduate degrees.

Otago has launched a series of 4-year Bachelor of Applied Science degrees that link applied science and technology with business skills. Physics hosts two of these in Electronics and Energy Management and contributes to a third in Telecommunications.

At Victoria University of Wellington, Physics has amalgamated with Chemistry to produce courses for science degrees that have a strong technology edge to the Physics and Chemistry involved.

At Waikato, Physics contributes strongly to a newly introduced electronic engineering degree, while Massey has steered its undergraduate electronics teaching program in Physics in a similar direction to accommodate the introduction of engineering on its campus. The viability of these new engineering programs depends heavily on cooperative Physics
input. Regrettably the additional teaching demands all of these new initiatives involve have not been matched by staffing needs. Accordingly smaller departments like Waikato have had to steadily shed some of their interesting but less essential courses at senior level in order to survive.

On a different note Canterbury now offers an undergraduate research project to students at the third year level for credit in place of part of the standard papers requirements. It was introduced on trial for US students on one-year exchange programs but is now included as a fixture in their third year course offerings.

Meanwhile Auckland, intent on improving links between physics and the formal mathematical offerings of the Mathematics Department, has introduced alternative papers - analytical techniques in physical sciences - for its physics students, the teaching of which it shares jointly with Mathematics.

Are there any major changes planned in your educational offerings in the next three years?

Australia

14/30 Australian Universities indicated that no major changes were planned.
- 13 Australian Universities have planned major new initiatives for the next three years, including nanotechnology (4), photonics (4), medical physics (1), biophysics (1), computational physics (1), astrophysics (1), environmental physics (1).
- 5 Australian Universities have plans for major restructuring of their physics major in the next three years.

New Zealand

The answer to this question is a resounding NO. It is clear that Physics Departments across NZ are under great stress staff-wise. Initiatives undertaken in the past five years have not been resourced with staff as expected. Indeed several departments have even lost staff through attrition without replacement. Accordingly most departments are struggling to survive with existing commitments let alone opening themselves to new ones.

Otago mentions the possibility of a new Masters degree in medical physics but only in passing.

Have you observed any substantial changes in the Physics student population at your University over the past five years? (eg change in gender balance, change in quantity or quality of students, changing age profile, etc)

Australia

12/30 Australian Universities have not observed any substantial changes in their student population in Physics over the past five years.
18/30 Australian Universities have observed some substantial changes. The most commonly reported changes are:
- more part-time students (4)
- better quality students attracted by new applied physics offerings (4)
- demand for flexible learning packages (4)
- decline in the standard of mathematics preparation (3)
- more female students (2)
- more overseas students (2)
- declining enrolments (2)
- increasing enrolments (2)

New Zealand

While there is an ongoing concern about the declining student ability at entrance level, departments are reluctant to address it by restricting entry to first year courses for fear of being penalized for falling student enrolments. There is genuine concern in most institutions about the general decline in post graduate numbers and the effect this has on recruiting well prepared graduate assistants to assist with junior laboratory staffing and the heavy marking demands of assigned coursework.

Auckland, the populous centre for most of the recent Asian immigration to NZ, reports a steadily increasing proportion of Asian students in its physics classes that has now reached a level exceeding that of its traditional cultural intake. Language difficulties and different cultural approaches to completing laboratory and coursework tasks with this group's infusion pose new challenges in teaching and assessment strategies for academic staff.

Have there been any significant changes to the administration of your Physics degree over the past five years? (eg mergers, closure, etc.)

Australia

15/30 Australian Universities said that there had been no significant changes in the administration of their physics degree over the past five years. The other 15/30 Australian Universities have experienced substantial changes. The most common were mergers with a related discipline and consequent loss of departmental autonomy. The most common mergers were with engineering (3), chemistry (4) and mathematics (3).

New Zealand

Mergers have occurred at Wellington (VUW) and Palmerston North (Massey) of former Physics and Chemistry departments.
- In Massey’s case, the former department of Mathematics was also merged with Physics and Chemistry to form the Institute of Fundamental Sciences.
- Both Waikato and Massey have been forced to accommodate demands from fresh engineering initiatives on their campuses that have both modified and reduced their departmental offerings.
- Canterbury which has had a long standing 4-year honours program in Astronomy now runs a standard 3-year BSc program in Astronomy.
What do you consider are the most significant problems facing your Department at this time? (eg declining enrolments, lack of junior staff, etc)

Australia
One Australian University said that there were no significant problems facing their Department. The remaining Universities listed a wide variety of issues of concern. These are listed below in descending order of frequency of response.
- Funding cuts/funding crisis (12)
- Loss of staff (11)
- Workload explosion for staff (9)
- Declining undergraduate enrolments (9)
- Shortage of postgraduate students (7)
- Skewed age profile of staff/succession crisis (4)
- Loss of service teaching (3)

New Zealand
The common cry is the lack of junior staff due to a decline in postgraduate numbers and the inability to recruit additional staff to undertake the new teaching programs as well as cope with extra, externally funded research contracts departments now seek to support overall funding. The perceived decline in postgraduate numbers is based on this year’s sudden drop of about 20% rather than actual longstanding information as the statistics reveal. Nevertheless it highlights the stress permanent staff are under.

In NZ the squeezing effect on academic staffing has not produced the dramatic closedown of departments Australia has experienced. Instead the effect has been spread, somewhat unevenly, across the existing institutions. This might help explain any relative optimism of the majority of Australian surviving departments compared with their NZ counterparts.

Auckland, the largest NZ Physics department, had 26 permanent staff five years ago. Now with overall EFTS numbers essentially unchanged it has 22, a drop not offset by the appointment of temporary staff.

At a time when phrases like the “knowledge economy” and the “knowledge wave” abound in national forums, commitment in the country to “science and technology” as its prime mover still slumbers as far as Physics is concerned.

Most of the plum rewards available within NZ are still to be found in management, accounting, law and medical specialisation. Physics therefore continues to harvest only a modest numbers of talented students and this is a matter of critical concern to the discipline.

Conclusions
The past five years has been a time of major changes in Physics education in Australia and New Zealand. Most Departments have undergone changes of structure and many have been merged with other similar departments.

At the end of this survey period the third and fourth year enrolments in Australian Universities seem to have stabilised and may even have begun to recover, although they are still as well below the levels reached a decade ago. In contrast the corresponding enrolments in New Zealand Universities have remained almost static over this period.

Australian postgraduate numbers in Physics continued to decline from their high point in 1993 and are now down by more than 25% from that peak. In contrast, NZ postgraduate numbers increased through the nineties and have turned down only in the last year.

Many Physics Departments have introduced new allied courses in applied areas such as photonics, medical physics and computational physics in an attempt to make their courses more attractive. Many others are planning to make similar changes in the near future. There is some evidence that these changes have been successful in attracting more high-quality students into physics, at least in the short term.

Many Physics Departments are facing funding crises and workload explosions as a result of the departure of staff who are not being replaced. Many Heads of Department expressed concerns about continuity and succession planning as older staff retire and are not replaced. Most Departments now have highly skewed age profiles with most staff over 50 and in senior positions.

Overall it appears that the funding and enrolments crises that appeared in the mid nineties may have almost run their course and that Physics Departments have successfully restructured in many cases to cope with the new funding arrangements. Considerable staff losses have occurred and further losses seem inevitable but the enrolments picture is encouraging and there are early signs of a recovery. Over the next five years most Physics Departments will have to cope with an increasing workload and declining staff and financial resources but the future does look more promising than it did three years ago.

Acknowledgments
The authors are indebted to our colleagues in the various universities of Australia and New Zealand who have supplied us with the data and checked the tables for us.

References
**PRODUCT NEWS**

**Thermoelectrically Cooled InGaAs Photodiode Array Detection System**

Released late last year, Roper Scientific now offer the Princeton Instruments OMA-V high performance detection system for spectroscopy applications in a thermoelectrically (TE) cooled version, to complement the liquid nitrogen (LN) version already available.

This new system offers high precision cooling of a 512 x 1 InGaAs photodiode array (PDA) detector between +20°C and -50°C, while delivering excellent sensitivity over the 0.3mm to 1.7mm.

The OMA-V system has many superior features:

- 1MHz scan rate allows 1800 spectra/second to be acquired.
- The controller for the detector has dual amplifiers (software selectable) for either high-speed or high-sensitivity applications.
- With either mode the system offers the lowest read noise of any commercially available system.
- The quantum efficiency of the detector exceeds 80% in the region 1.05mm - 1.55mm.

The system is ideally suited for high performance spectroscopy techniques such as Raman, photoluminescence and absorbance.

For further information please contact Jen Weeks (jen.weeks@coherent.com.au)

**Coherent Scientific Pty Ltd**

116 Sir Donald Bradman Dr, Hilton SA 5033
Phone: 61 8 8150 5200 Fax: 61 8 8352 2020
Web: www.coherent.com.au

**New Series of TE Cooled Diode Lasers**

Micro Laser Systems of the US has developed the SRT Series of TE Cooled Diode Lasers, an OEM module specifically designed to stabilize single mode diode laser frequency from temperature variations.

The SRT Series consists of rugged, compact package containing the collimating lens, thermoelectric cooler, thermostat and heat sink.

Mounting holes are provided as are a series of driver boards and thermoelectric controllers for obtaining a highly stable diode laser source.

The module minimizes mode hops and frequency can be tuned to a few nanometres from the central wavelength.

Output is precisely aligned and highly collimated so the most consistent performance can be achieved for the user’s instrument.

The SRT Series has been utilized in many applications such as spectroscopy, DNA analysis, metrology, interferometry and research.

Further information on these and other specialist scientific systems is available from WARSASH Scientific Pty Ltd at (02) 9319 0122 or sales@warsash.com.au

**New Single-Photon Counting Array**

The SPCM-AQ4C Single-Photon has been released by PerkinElmer Optoelectronics and is available from WARSASH Scientific Pty Ltd.

The 4-channel photon-counting card is capable of detecting single photons of light over a wavelength range from 400 nm to 1160 nm. Each channel is independent from the others.

The SPCM-AQ4C utilizes a unique silicon avalanche photodiode (SiAPD) with a circular active area whose peak photon-detection efficiency exceeds 60% at 650 nm.

Each photodiode is both thermoelectrically cooled and temperature controlled, ensuring stabilized performance despite changes in the ambient temperature.

Further information on these and other PerkinElmer Optoelectronic products is available from WARSASH Scientific Pty Ltd at (02) 9319 0122 or sales@warsash.com.au.

**Brilliant Nanosecond Laser System Solutions from Quantel**

The Quantel Brilliant series laser systems are designed for reliability and flexibility in the laboratory, as well as harsh outdoor and industrial environments.

The unique features of these laser systems are:

- Ease of use, including flashlamp change and installation
- Fully sealed cavity mounted on a single monolithic block for maximum stability and minimum time spent on alignment
- Excellent beam quality and pointing stability
- Active temperature stabilisation
- Full features remote control unit
- Second, third, fourth and fifth harmonic generator modules
- Full one year guarantee on all parts, including optics

The Brilliant concept includes a complete range of associated products including single and dual oscillator double-pulsed systems for PIV and holographic PIV, as well as fully integrated tunable solid-state OPO systems.

For further information please contact Jen Weeks (jen.weeks@coherent.com.au)

**Coherent Scientific Pty Ltd**

116 Sir Donald Bradman Dr, Hilton SA 5033
Phone: 61 8 8150 5200 Fax: 61 8 8352 2020
Web: www.coherent.com.au

**New Series of TE Cooled Diode Lasers**

Micro Laser Systems of the US has developed the SRT Series of TE Cooled Diode Lasers, an OEM module specifically designed to stabilize single mode diode laser frequency from temperature variations.

The SRT Series consists of a rugged, compact package containing the collimating lens, thermoelectric cooler, thermostat and heat sink.

Mounting holes are provided as are a series of driver boards and thermoelectric controllers for obtaining a highly stable diode laser source.

The module minimizes mode hops and frequency can be tuned to a few nanometres from the central wavelength.

Output is precisely aligned and highly collimated so the most consistent performance can be achieved for the user’s instrument.

The SRT Series has been utilized in many applications such as spectroscopy, DNA analysis, metrology, interferometry and research.

Further information on these and other specialist scientific systems is available from WARSASH Scientific Pty Ltd at (02) 9319 0122 or sales@warsash.com.au

**Spectra-Physics Wide Tuning Ultrastable Mai Tai Laser**

Spectra-Physics has expanded their ultrastable product line with a new Mai Tai laser offering an extended tuning range from a “one-box” ultrastable laser. This new Mai Tai delivers a peak output power of more than 1.5 watts and a continuous tuning range covering 710-920 nm, with a typical output pulsewidth of 100 femtoseconds. Because of the use of field-proven regenerative mode locking, the tuning is achieved with no dropouts and no need for re-optimisation. The laser can be tuned over its entire wavelength range in only seconds, while maintaining mode-locked operation.

The laser head is completely self-contained, integrating a solid-state Millennia pump laser and a Titanium: Sapphire laser oscillator. (The laser head measures only 23.4" x 13.8" x 5.8" - 59.5cm x 35cm x 14.7cm).

The combination of high power and a wider tuning range has been achieved by utilising several design innovations in the proven Mai Tai laser head. This includes use of a higher power pump laser, and next generation broadband cavity mirrors. Wavelength tuning is completely hands-free and all laser functions are controlled via a user-friendly RS-232 interface. The recently introduced StabiLok™ system ensures there is virtually no change in beam pointing direction during wavelength tuning – eliminating the need to re-align optics in demanding applications such as multiphoton microscopy.

Since 1999, the Mai Tai product line has been the only one-box femtosecond laser offering tunable output for the multiphoton imaging market. With the ability to reach 710 nm, this new laser will enable efficient two-photon excitation for short wavelength fluorophores, further expanding the use of one-box lasers in this important application.

In addition, the wide tuning range coupled with higher output power makes this latest Mai Tai an ideal source for applications in time-resolved spectroscopy and photochemistry.

For further information please contact:

Laseik Pty Ltd, 10 Reid St., Thebarton SA 5031
Tel: 08 8443 8668, Fax: 08 8443 8427
Toll Free: 1 800 88 2215
Email: sales@laseik.com.au
Worldwide: www.laseik.com.au
Reviews

Tides, A Scientific History
David Cartwright
Cambridge University Press, Cambridge 1999
xii + 292 pp, A$ 59.95 (paperback)

For many the word “tides” means only the rise and fall of the sea at the beach. But there is much, much more! Tidal phenomena, and the physics behind them, have fascinated your reviewer for over forty years. A few examples will illustrate why.

When sailing in the English Channel in the 1960s, I asked the question: “Why are the tides on the French side of “La Manche” much higher than those on the English side?” I soon found the answer - it’s due to the Coriolis force. Then, teaching Classical Mechanics at Melbourne, I puzzled as to “Why is the same face of the Moon always seen on Earth?” It’s because tidal forces in the “solid” Moon rock can transfer its rotational angular momentum into orbital angular momentum. Finally, a few years ago I was amazed to learn that the tidal distortion of the rock in which CERN’s LEP accelerator is built changes the energy by significant amounts so that the experimenters have to take account of the phases of the Moon when analysing their data!

This book is a delight, I learned about tides in the atmosphere, and tides in the Earth’s Electromagnetic field - which induce voltage fluctuations in telephone cables. And, before the advent of modern computers, there is the “India Office Machine” of 1878, which summed 24 harmonic constituents to predict tidal levels in the Ocean. Here is a serious, scientific book that is reasonably mathematical. I can highly recommend it to fellow “tide addicts” - and I predict that many who read it will become one.

Stuart Tovey
CRC for High Energy Physics
University of Melbourne

An Introduction to Geophysical Exploration (3rd ed.)
P Kearey, M Brooks and I Hill
Blackwell Science, Oxford UK 2002
ix + 262 pp., UK £29.95 (paperback)
ISBN 0-632-04929-4

This book covers the usual variety of exploration techniques expected in an introductory text. This new edition was updated by extending the seismic method to three-component and 4D reflection seismology and the application of seismic refraction techniques in engineering site investigation.

Despite these additional sections, this is a dated textbook. A count of the suggestions for further reading reveals that more than 90% of the references are more than 10 years old and many are out of print.

The scale of geophysics should be approached in a more rigorous way, as the influence of fracture planes in rock is often the most relevant property measured by geophysicists. There is little mention of environmental geophysics and borehole geophysics is dismissed briefly.

The chapter on electromagnetic methods is not well structured, the discussion on tilt angle methods is very dated and there are some significant misunderstandings in places. For example, the statement on page 210 that “Conductors striking at right angles to the direction of propagation are not cut effectively by the magnetic vector” might be true, but the effect on the RF field is quite dramatic. The statement that the VLF EM field is vertical precludes any reference to the surface impedance methods that are common in VLF EM.

I found the very odd use of hyphenation quite annoying. While the explanations are relatively clear, the book is not friendly if the university course is to have a significant practical component.

David V Thiel
Radio Science Laboratory
Griffith University

Classical Theory of Gauge Fields
V Rubakov (Translated by S S Wilson)
Princeton University Press, Princeton NJ 2002
x + 444 pp., US$65 (hardcover)
ISBN 0-691-05927-6

Gauge theories have a central role in modern quantum field theory and particle physics. They are also providing fascinating challenges for our mathematical colleagues. This volume, based on third and fourth year lectures at Moscow State University, provides a thorough and comprehensive overview of classical gauge theories. In the Australian context, it is best suited for postgraduate students and professional theorists. It certainly requires an excellent knowledge of classical mechanics and relativistic quantum mechanics.

Topics covered in the first section of the book include a thorough introduction to Lie groups and algebras, followed by spontaneous symmetry breaking, Nambu-Goldstone bosons and the Higgs mechanism. The author then turns to solitons, beginning with simple kinks and vortices. An entire chapter is devoted to homotopy theory and this should be extremely use-
The core of the middle section of the book deals with vacuum structure, tunneling, false vacua and instantons. These are important concepts and the treatment is at a good level for a postgraduate student.

The last third of the book deals with fermions in various background fields. This includes such fascinating topics as fractional fermion number (of interest in condensed matter physics too) and violation of baryon and lepton number.

Throughout, the origins of the book as a lecture course are clear. There are numerous well-chosen problems for the student to check progress, although hints as to relative difficulty and solutions for some fraction of them would have made this aspect even more valuable. In summary, postgraduates and professionals working in modern quantum field theory will find this a valuable reference.

Anthony Thomas
Physics CSSM
University of Adelaide

Nuclear Electricity Gigawatts
Colin Keay
The Enlightenment Press*, Waratah 2002
36pp., $7 (posted within Australia)
ISBN 0-9578946-2-7
(* P O Box 166, Waratah, NSW 2298)

In modern physics, experimentation, practicality and scepticism are going out of fashion. Enthusiasm for untestable theories and for ‘alternative’ energy schemes, more the impractical and ‘imaginative’ the better; that is the trend. It takes a brave man to go against it, but Colin Keay, lone, self-published author, keeps trying; a solo voice amid the chorus of ‘environmentally aware’ physicists promoting ‘pollution-free’ electricity.

Keay discusses the various ways of generating gigawatts of electricity. First considered are the reliable old fossil fuels, with a few comments on biomass and co-generation. Hydrogen fuel cells are discussed (but he says little about where hydrogen might come from). Then the host of ‘alternatives’: wind turbines, solar thermal, solar photovoltaics, wave power, tidal power, geothermal, ocean thermal gradients. Not one of them makes much sense economically or technologically. Maybe in some Bass Strait Islands, or outback stations, where they are desperate for electricity and prepared to pay over 30 cents/kWh, you might install 10, or even 100 MW or such plant, but when it is a matter of replacing a fair fraction of the 30GW of conventional generating plant now installed in Australia - forget it. Why is it, one wonders, that it falls to a retired physicist to point out the impracticality of ‘alternatives’ like wind and solar power as major energy sources, while the engineers of Energy Australia trumpet their virtues and try to sell deceived consumers ‘green’ electricity at a premium.

The only proven alternative for generating many GW of electricity is the nuclear reactor. Keay, in his earlier book "Nuclear Energy Fallacies", has already put the case that there is no good reason to reject them.

Arthur Pryor
Physics Department
Macquarie University

Quantum Mechanics and its Emergent Macrophysics
Geoffrey Sewell
Princeton University Press, Princeton 2002
xi + 292pp., US$65.00 (hardcover)
ISBN 0-691-05832-6

In principle the quantum statistical mechanics of many body systems provides an acceptable theoretical framework to deal with macroscopic properties of matter. In this book, Geoffrey Sewell provides a novel approach on macrostatistical mechanics that contrasts sharply with the well-known microscopic descriptions. In a post-modern perspective, Sewell believes emergent macroscopic properties are independent of microscopic details. He has made two debatable assumptions: (i) macrostatistical description relies only on the laws of macrophysics and (ii) macroscopic properties of complex systems are dominated by the molecular chaos, which is ignored in a macro-description.

The main thrust of the book lies on three formal aspects, namely: operator algebraic quantum theory, stochastic processes and classical dynamical systems. The first two parts of the book dwell on equilibrium and non-equilibrium thermodynamics, whereas the last two parts deal with some physical problems related to order and chaos in condensed systems. Being a mathematical physicist, Sewell admits the choice of topics is inevitably dependent on his personal interests. Perhaps this constraint has affected him while dealing with physical phenomena in later parts. He avoids many-fold complexity of microscopic details in the electron-dynamical and thermodynamical aspects of superconductivity. Features like off-diagonal long-range order, gauge invariance and thermodynamical stability are either assumed or imposed to bring simplifications. One would expect more content in chapter 8: Theoretical survey of superconductivity; and chapter 10: Schematic approach to a theory of non-equilibrium phase transitions. But undoubtedly this book will be liked by mathematical physicists interested in learning the physics of quantum macroscopic systems.

Makunda Das
RSP/Physics
Australian National University.

Dayside and Polar Cap Aurora
P Sandholt, H Carlson and A Egegland
xiv + 287 pp., EUR 112 (hardcover)
ISBN 1-4020-9407-8

Aurora result from the capture of energetic particles from the solar wind and are very dynamic, moving rapidly over thousands of kilometres in response to solar wind changes. Although primarily a high latitude phenomenon, auroral displays appear over southern Australia around sunset maxima.

Dayside and polar cap aurora are largely subvisual and so were little studied until the deployment of sensitive photometric imagers in the 1980s. Weak aurora do occur frequently throughout the dark polar night and on the Earth’s dayside. Sun-aligned arcs, first described scientifically by Mawson, occur 50% of the time. These discoveries helped revolutionise our knowledge of solar-terrestrial coupling because the polar cap region, with its dayside boundary in the so-called cusp ionosphere, is a focal point for such coupling. However understanding this coupling requires knowledge of more than just auroral emissions and so the authors include discussions of charged particle populations, magnetic and electric fields, and plasma motions observed by a wide range of satellite and ground based measurements.

Experts in the field will appreciate the authors’ approach since the phenomena are so complex. Concluding chapters discuss polar-cap sun-aligned arcs, describing observations in detail and provided theoretical explanations. Theory is still evolving and the authors point out where the theories they present are tentative.

Overall, an important book for researchers in the field and one from which non-experts can gain an understanding of the complexities of aurora and the solar wind interaction with the Earth.

P L Dyson
Department of Physics
La Trobe University

The Evolution of Galaxies II
- Basic Building Blocks
M Stave, G Stasinska and D Schaerer (eds)
xiv + 562 pp., US$183.00 (hardcover)
ISBN 1-4020-0622-5

In October 2001, the second of the Three Euroconferences on The Evolution of Galaxies was held on Île de la Réunion. More than 130 astronomers took part in the meeting, the thrust of which concerned a thorough examination of the so-called "building blocks" of galaxies, including star formation, nucleosynthesis and stellar evolution, energy flows in the interstellar medium, environmental effects on galaxy evolution, and primeval stars and galaxies.
The sheen breadth of the subject material covered is in one sense its strength, but in another, its weakness. With an extraordinary 134 articles distributed over 500 pages of effective text, there are fewer than four pages per article, with only a few identifiable ten-page reviews. While it can be a thankless task accommodating the contributions of all participants in a conference proceeding of this magnitude, a strong case could have been made for including a significantly greater number of targeted reviews and summaries in order to lend a sense of coherence and direction to the volume. One is not likely to pick up this text and simply start reading, as the short, shotgun nature of the presentations does not lend them to casual inspection.

Its price may limit the impact of this book, which is a shame as there is a wealth of information to be found in it - unfortunately, the lack of supporting background material conspire to make this a difficult volume to enthuse about unequivocally, despite the gems lurking within!

Brad K Gibson
Centre for Astrophysics and Supercomputing
Swinburne University

An Introduction to Polymer Physics
David J Bower
Cambridge University Press, Cambridge 2002
xx + 444 pp., A$95 (paperback)

This textbook is aimed at undergraduates. The approach is suitable for students of physics, materials science and chemistry, though some will find parts of it quite demanding mathematically and conceptually. No previous knowledge of polymers is assumed, but a familiarity with basic thermodynamic concepts is taken for granted.

A wide range of topics is included, and the material is well chosen, with a good blend of fundamentals and more recent developments. Approximately ten problems appear at the end of every chapter, except the first two, and the solutions to each problem is set out clearly and comprehensively at the rear of the book.

I paid particular attention to the chapter on electrical and optical properties, having fairly recently taught a course in this area (though not limited to polymeric materials) to third year materials science and engineering students. I was very favourably impressed. The introductory material (e.g. relative permittivity, refractive index, dipole moment and dielectric relaxation) is presented clearly and concisely, and is followed by an account of ionic conduction due to ionization of impurities, and electronic conduction in conjugated molecules such as polyaniline and polypyrrole. The short section on optical properties begins with an informative qualitative discussion of transparency, moves on to the processes underlying absorption at visible wavelengths, and finishes with a fairly demanding outline of the calculation of the refractive indices of polymer crystals with orthorhombic symmetry.

Very few textbooks on polymer physics as a whole are available. Dr Bower has made a valuable contribution to the field.

R J Fleming
School of Physics and Materials Engineering
Monash University

Mathematics and Music
G Assayag, H G Feichtinger and J F Rodrigues (eds)
Springer-Verlag, Berlin 2002
xiv + 288 pp., EUR64.95 (hardcover)
ISBN 3-540-43727-4

In 1999, a Diderot Mathematical Forum on this topic was held simultaneously in Lisbon, Paris and Vienna, with exchange of views by teleconferencing. The Lisbon forum concentrated on historical aspects, Paris on logic and music in the twentieth century, and Vienna on analysis and synthesis of musical sounds. This book is a selection of the papers presented.

The final four chapters range from Pythagoras to Lagrange. The mathematics is mostly arithmetic, but Lagrange went close to discovering Fourier analysis. There is then a short but informative chapter on musical patterns in canons before we plunge into philosophy. For those who can extract meaning from sentences such as "musical autonomy is neither autarky [sic] nor, strictly speaking a homology" or "expressing musical coherence in a formal logic can be based on the representational entities of an underlying coherence system of spatio-representational entities", these three chapters may be illuminating - but not to the average physicist.

The final nine chapters, constituting about half the book, discuss the analysis of musical structures, several computational models for musical sound synthesis, a Mathematica program illustrating scales and chords in various tunings, and a chapter discussing some examples of ethnomusicology and ethnomathematics. These are an illuminating survey of some aspects of the subject.

Given the eclectic nature of the total subject matter, I cannot see this book appealing to many people, but it would be useful to have it in the library for the few chapters you might want to read.

Neville Fletcher
R S Phys S E.
Australian National University

Explaining the Universe: The New Age of Physics
John M Charap
Princeton University Press 2002
xiv + 226pp., US$29.95 (hardcover)
ISBN 0-691-00663-6

This wonderful book has been written for the general reader and I recommend it highly. Charap enjoys his physics and this comes through in the manner and style with which he recounts the transition from classical to quantum physics and along to string theory in the search for the Grand Unified Theory. In this journey the emergence and importance of
chaos is mentioned as is the technology and engineering necessary to unravel the structures of sub-atomic particles in which he specialises. The contributions of the great minds of science have been skillfully incorporated, with quotes as to what the individuals thought of their own, and others, contributions to the hot topics of physics in the last 150 years. While these are probably highly selectively edited, that Boltzmann reputedly said “You should live that long” in response to advice that the Poincaré recurrence time undermined his macroscopic time asymmetry argument, is a gem worthy of promulgation.

Charap takes the general reader through Feynman diagrams, quantum electrodynamics and quantum decoherence as well as the standard model of particle physics without a single equation other than E=mc². He has bravely included a chapter on predictions that makes interesting reading. In this, and in general, he has written a book that will be enjoyed by any with an interest in physics and the publishers have established a price barrier that should allow significant tunnelling.

John Holdsworth
School of Physics
University of Newcastle.

The Extravagant Universe
Robert P Kirschner
Princeton University Press, Princeton NJ 2002
xxii + 328pp., US$29.95 (hardcover)
ISBN 0-691-05862-8

This book is subtitled ‘Exploding Stars, Dark Energy, and the Accelerating Cosmos’. It tells the story of the author’s involvement in pushing Hubble’s velocity/redshift relation to the greatest redshifts using supernovae as standard candles. Like a number of books in recent times, it is a personal chronicle of a current and exciting scientific topic. The personal touch gives it some characteristics of a novel. In the end, it describes a race to be the first to claim the observational return of Einstein’s Cosmological Constant. At times it seems almost like good versus evil and, in the end, the tale becomes a breathless gripping read.

The cover of the book identifies the existing topics to be covered, but not the intended audience. This takes us to the downside. I enjoyed the contents of the book. But I teach this material. I found it hard to see how someone with ‘merely a general curiosity about science’ would cope with the subject matter. It is not easy material, even when covered essentially without equations and with excellent chapter notes. A first year physics major would probably manage, and would certainly sense the excitement, but the book needs some systematic introductory material to get a more general audience into the topic. Also, the book rambles (sometimes in the nicest way) and I found it frustrating at times wondering where we were supposed to be heading.

The author teaches introductory astronomy topics to a large class at Harvard. It shows. Anyone who teaches at first year will get lots of good ideas on metaphors, to be used in difficult topics, from this rather randomised walk through observational cosmology.

Roger Clay
Department of Physics
and Mathematical Physics
University of Adelaide

Paul S. Addison
xxii + 353 pp., UK£45.00 (hardcover)
ISBN 0-7503-0692-1

One of the most widely used data analysis tools in science and engineering has been the Fourier Transform, which readily identifies the principal component frequencies in a periodic signal. The Fourier Transform is of little use for aperiodic or noisy signals or for non-stationary signals in which the principal frequency components change with time. Enter the Wavelet Transform, whose application in science and engineering commenced in earnest in the early 1990s. The Wavelet Transform is a two-parameter function obtained by convolving the signal with a localized wave (wavelet) scaled by one parameter representing the magnification and the other representing the position. It is not an overstatement to say that the Wavelet Transform has revolutionised the analysis of aperiodic, noisy or non-stationary signals.

Addison’s book has much to recommend it. Foremost it is obvious that its purpose is to provide the reader with the necessary know-how to apply Wavelet Analysis for themselves. The author guides the reader, with absolute clarity, through the introductory theory and the application of Wavelet Transform methods, using an abundance of illustrative examples from medicine, finance, atmosphere-oceanic dynamics and engineering. Any reader with a reasonable knowledge of undergraduate calculus and Fourier Transforms would be able to master the material in this book to the point where they can apply it. The clear typeface, visually appealing layout and rich use of figures also helps to make the material readily accessible. This is a superb reference for anyone wishing to explore the possibility of using wavelet analysis in their own research area.

B I Henry
Department of Applied Mathematics
University of New South Wales

Understanding Physics
D Cassidy, G Holton and J Rutherford.
Springer-Verlag, New York, 2002
xxiii + 851 pp., US$69.95 (hardcover)
ISBN 0-387-98756-8
Student Guide US$24.95 (paperback)

This is certainly not a text for students of science and engineering. Rather, it is an attempt to convey the ideas of physics to liberal arts, business, law and architecture students and others who would have only the simplest mathematics upon which to draw. Even the student guide, which addresses some of the more quantitative aspects, still only uses the simplest arithmetic. Basic laboratory experiments are also included in this guide that would be a valuable aid for anyone presenting this course.

The approach however is for the mature student, emphasising historical contexts and the essence of the scientific method. The writing is clear and (apart from a few typographical errors) precise. The presentation is generally good with many interesting photos and clear drawings. Apart from two central colour plates, all the figures are in black and white. The treatment covers all areas of general physics except for the omission of high-energy physics (quarks rate only a fleeting mention).

In all cases the field is developed slowly and carefully which would be appreciated by students new to the concepts of physics.

Unfortunately, in the attempt to stay simple, some errors have crept into the text. No doubt these will be corrected in later editions. For example, it is claimed (on page 370) “that sound waves travel faster in cold air” and again (on page 400) that ordinary walls of a vessel would be “vaporized instantly” should contact be made with a hot plasma! There is also the unfortunate definition of the Lorentz factor, gamma, which is the exact inverse of the normally accepted definition. Finally, some answers to the quantitative questions at the end of each chapter should have been included.

In spite of these shortcomings it would be possible to assemble a very interesting and exciting course using this text. The general university undergraduate needs to be acquainted with these basic ideas - and this might be just the place to start!

I. Peak
School of Physics
University of Sydney.
Oils ain’t oils: lubrication in the assault on Moscow

It is salutary to remember the significance of technology and science in the history of man. There are instances where technology or the failure of technology contributed to a turning point in history. Such an instance involves lubrication and the battle for Moscow during World War 2.

In November 1941, the German attack towards Moscow was halted in the outer suburbs of Moscow when the already-freezing temperature dropped further to -20°C and then -32°C (-38°C was recorded in some areas). The problems encountered with these temperatures were many: frostbite in soldiers, leading to injury and death in a proportion of cases, and failure of radios, machine guns and engines in tanks. The principal problem with tanks was that they stopped working - the low temperatures caused solidification of the lubricating oils (among other problems) and hence engines could not be started or suffered seizure. Machine guns jammed from the effects of cold. At this time, the Russian troops were still mobile and their tanks were still operating and moving - they had better oils. The Germans abandoned much equipment which was then taken by the Russian army.

A series of processes occur in oil at low temperatures. The first of these is the separation and precipitation of waxes leading to an increase in turbidity at the Cloud Point, although the oil will still flow at this temperature. As the temperature is lowered past the pour point, the oil forms a network structure from these waxes, and the oil solidifies. The pour (or setting) point of oil is the lowest temperature at which the oil flows. Crystallization of benzenes and hydrocarbons is involved in this process.

The Soviet Army of course had access to a number of grades of oil which had pour points as low as -60°C hence ensuring their tanks and other machinery would operate in the field under the harshest conditions. It is clear from the history that the German Army at this time was poorly supplied and had not come prepared for the low temperatures. Typical ‘winter’ oils have pour points around -18°C and such an oil would not operate at lower temperatures. Forward planning had assumed that Moscow would be taken before harsh winter conditions set in.

In a very real sense, the lack of oil with a suitably low pour point caused the failure of the Panzers and machine guns outside Moscow at a time when their enemy was still mobile. This failure was a major factor in the ultimate loss of the German Army in the war with the Soviet Union.

References:
(2) V.P.Shukanov, Petroleum Processing, Mir, Moscow, 1982.

Apologies to the author whose name disappeared due to computer idiosyncrasies. Proper acknowledgment will be forthcoming after contact.
PHAR LAP RESURRECTED THROUGH PHYSICS

GRAE D PUTT
Department of Physics, The University of Auckland, Auckland, New Zealand; g.putt@auckland.ac.nz

Introduction

In an earlier article on horseracing the author analysed the 1973 Kentucky Derby, won by champion racehorse Secretariat, to extract estimates of the forces involved during the rapid start-up phase of the race. While the dynamics of balance when cornering turns was also treated, the more interesting aspect of the forces associated with the intermediate stage of the horse race, usually run under uniform pace conditions, was ignored because the available data did not lend itself to such investigation.

The purpose of this article is to address this shortcoming by exploiting data that does. Appropriately the data comes from a freak galloping performance by Australia's most famous racehorse, the incomparable Phar Lap. All it requires is some garnishing with plausible assumptions and estimates of the effective forces operative on a champion racehorse galloping at full speed can be extracted.

The specific event we focus on in is the 1930 AJC (Australian Jockey Club) Plate raced at Sydney's Randwick racetrack over 21⁄2 miles. Why this particular race? Well primarily because it lends itself to a most interesting Physics analysis. But it also had drama akin to the famous 1938 Pimlico Special match race between Seabiscuit and War Admiral in the USA in so much as it was seen as a match race between the two outstanding Australasian horses of the day, the 3-year-old Australian (but NZ born and bred) freak Phar Lap and the 4-year-old New Zealand champion Nightmarch. There was a difference - a third well performed horse named Donald started, no doubt expecting to set the pace for the other two. However, the major contrast was that Phar Lap dominated the race from start to finish, knocking over intermediate track records with impunity and literally cantered past the winning post with daylight to spare to the other two in a new Australasian record time for the distance. Of all the 37 victories this Australian legend notched up during his short life, most of which were notable in one way or another, the 1930 AJC Plate is the one that turf experts still rave about. So we have the drama and sensation of this event to enliven our interest if we are teachers, as well as the data to analyse to satisfy our curiosity as physicists.

The AJC Plate was run five months after Nightmarch's dubious victory over a highly fancied but appallingly ridden Phar Lap in the 1929 Melbourne Cup raced over 2 miles. It was eagerly awaited by the Australian racing public and clockers, specialists trained in hand-held stopwatch timing, were set up at various vantage points around the track to measure sectional as well as special course distance times. Phar Lap, under the trainer's instructions to be given free rein and race from the front, smashed record after record as he galloped out front with awesome majesty. Table 1, shown below, chronicles the times recorded for various distances. The asterisks highlight the times run that either equalled or broke Australasian (rather than mere track) records of the time. When taken in hand with the available reports of the racing journalists of the day, these data form a useful basis for analysis.

<table>
<thead>
<tr>
<th>Distance Traveled (in furlongs)</th>
<th>Existing Australasian Record</th>
<th>Phar Lap's Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>(START) 0f</td>
<td>00.0s</td>
<td>00.0s</td>
</tr>
<tr>
<td>4f</td>
<td>45.0s</td>
<td>49.0s</td>
</tr>
<tr>
<td>7f</td>
<td>1m 24.0s</td>
<td>1m 24.0s *</td>
</tr>
<tr>
<td>9f</td>
<td>1m 49.8s</td>
<td>1m 51.0s</td>
</tr>
<tr>
<td>10f</td>
<td>2m 03.2s</td>
<td>2m 04.5s</td>
</tr>
<tr>
<td>12f</td>
<td>2m 28.5s</td>
<td>2m 28.5s *</td>
</tr>
<tr>
<td>13f</td>
<td>2m 43.5s</td>
<td>2m 40.5s *</td>
</tr>
<tr>
<td>16f</td>
<td>3m 22.7s</td>
<td>3m 20.5s *</td>
</tr>
<tr>
<td>18f</td>
<td>3m 50.5s</td>
<td>3m 49.5s *</td>
</tr>
</tbody>
</table>

Table 1. Comparative Times for Distances Traveled in the 1930 AJC Plate

A synopsis of the race goes as follows. Phar Lap was ridden hard from the start in the manner of a sprint rather than endurance event at the trainer's instruction "to run the legs off of Nightmarch". After 4f, covered at a suicidal starting pace for such an endurance event, he was out in front by 11 lengths (approx 36 metres) at which point the jockey stopped urging him. Nevertheless he continued to increase his lead as he sped towards the winning post (WP) for the first time covering the initial 7f it involved in a time that equalled the Australasian record time for that distance. After passing the WP Phar Lap eased off as the times in Table 1 indicate, in the apparent belief the race was over and cruised accordingly over the next 3f as if on a training exercise. However, the jockey then reminded him that another circuit was required and he immediately went back on task after that for the next 6f as Table 1 illustrates. During this period he extended his lead over the other two out to an estimated furlong (about 200 m) at the home turn (second time around) by which time he had covered 2 miles and smashed the Australasian record for that distance. As he came down the final 2f of the finishing straight before an astonished crowd his rider, aware of the enormous break he had on his rivals, 'reined him in' allowing him to literally coast from the vicinity of the
final furlong pole to the finish line. He passed the winning post in a canter and came to a halt just 25 metres after passing it. Even so his time of 3m 491/2 s for the journey broke the Randwick track record for the 21/4 miles by an amazing 61/2 s and the Australasian record by 1 s. Track racing stewards, unhappy at the distance that separated the two ‘matched’ champions throughout the race, summoned Nightmarch’s rider into the enquiry room and began grilling him until it was revealed that, notwithstanding the almost comical end to the race, Nightmarch, in finishing second, had himself broken the existing track record!

Formulating the Analysis

So how do we exploit this solo, record-breaking extravaganza in a plausible fashion to obtain insight into the effective forces at work on a racehorse during the lengthy intermediate stage of a race? Well for starters the champ raced in front without cover and therefore experienced the full impact of the drag force at all times. Accordingly we may express the air resistive force acting on him as kv^2, where v is the horse’s speed and k is the horse-jockey drag constant we can sensibly estimate, if we so wish, by calculation. Furthermore he raced without needing to cover any extra ground or without interference - being held up, or challenged to accelerate by trailing horses intent on ‘taking him on’. So can we take the distances travelled as actual and the motion smooth, free of any jerky ‘braking’ effects. Next the Randwick racecourse has rises and falls in its elevation. This is illustrated in its topological features laid out for the full 18f of the race in Fig. 1.

![Fig. 1: Randwick Racetrack Elevation for 1930 AJC Plate](image)

The track has a circumference of 11f (approx) with the lowest point of its elevation located about 2f past the winning post (WP), as Fig. 1 shows. It then peaks 6.3 metres above this trough some 6f further on, 3f before the second and final negotiation of the WP. A racehorse at full gallop has a typical kinetic energy of about 80 kJ. The potential energy change due to this variation in elevation is about 35 kJ. An energy related comparison of the kinematical data for selected sections of the uphill/downhill intermediate stages of the race would therefore be instructive.

Finally we know from clocked times that Phar Lap covered the last 2f in 29.0 s as he dawdled through the last furlong coating to a virtual stop 25 m past the WP. We can include this fact in our analysis - first to allow the constant k to be treated as an unknown quantity and second to determine an empirical value for the distance over which he coasted (when he essentially switched off his internal ‘thrust engine’ that actually powered his gallop) to the finish line. The values so obtained will be used to examine the credibility of the assumptions that we will need to make to complete our analysis.

Apart from the brief heavy acceleration phase during start-up, a horse usually races at uniform pace for the majority of the race (appropriately modified by any topological features) summoning a special effort in the finishing straight in a focused attempt on victory. When racing on level ground, the horse experiences two external retarding forces. One is the drag force already described. The other is the impedance caused primarily by the speeding foreleg hooves that make initial (sliding) contact with the stationary track, providing a pivot that permits the majority of the momentum of the horse to carry forward as the hind legs scoop underneath its girth in readiness to unleash the drive that recovers the lost momentum and propels it onward at racing speed. The nature of both the driving and impeding forces involved in the gallop is impulsive rather than continuous like that for a car driving at constant speed along the road under the action of friction. However, we can smooth their staccato effect, modelling them analogously to the driving force of static friction and the dissipative retardation forces of rolling friction (from the flexing of the tyres, etc) a car experiences as it travels on a journey. The combined effect of both drag and the dissipative forces acting on racehorses are immediately apparent when they cross the finish line, shut down the drive from their hind legs and ‘coast’ to a halt a few hundred metres past the post. Horses can of course ‘apply the brakes’ (as they sometimes have to do in running to avoid serious interference) and stop in a much shorter distance rather than coast to rest. Phar Lap galloped relentlessly but smoothly throughout his epic journey and virtually coasted to rest over the last furlong or thereabouts of the Randwick final straight being, as he was at that stage, about a furlong clear of his rubber-legged rivals.

Because of the relative absence of acceleration once the field has settled into a steady racing pattern we turn to the force related concept of power to shed light on the forces that are at work sustaining the ‘uniform’ speed. Using uphill and downhill sections of the track as comparators for power expenditure clearly maximises our opportunity to exploit the impact of the (known) gravity force on the change in speed and kinetic energy that is sustained by the horse in its galloping motion as it negotiates different sections of the track. Phar Lap’s performance over this extended race is highlighted by a deliberate explosive initial phase during the first uphill phase (UP1) and then a somewhat mixed final downhill phase (DP2, the 15f - 18f section) that includes sustained aggression into the finishing straight followed by a final demeaning canter to the finish line, stopping 25 m past the winning post. On the other hand we know the first downhill phase (DP1, the 4f - 7f split) following the initial explosive phase continued aggressively inso-much as a 7f sprint record tumbles in an 18f race, while the second uphill phase (UP2, the 12f - 15f split) was also attacked energetically as the 12f, 13f and (subsequently) 16f Australasian records tumbled. We note that the 12f to 16f split
not only includes all of UP2 but also the beginning of DP2, that continues energetically into the finishing straight before the final coast to the finish line.

Summarising we can say that DP1, UP2 and the first two-thirds of DP2 are galloped aggressively by Phar Lap (and also the other two horses galloping hard to maintain the relatively vast and constant distance deficit behind him) up until the last furlong of DP2 when the big chestnut’s jockey coaxes him “into neutral gear” and he coasts to the finish line. In order to progress the analysis our assumption is that Phar Lap galloped these segments at the same average power expenditure (APE) level and we will look to validate its plausibility by the efficacy of the results it produces. A necessary consequence of this common APE assumption is that the first part of the motion for DP2 replicates that of DP1.

**Theory & Dynamics**

Our general equation of motion for the driving force $F$ the horse of composite (horse, rider, saddle, etc) mass $M$ must apply to balance the dissipative, retardation forces and maintain constant speed $v$ along a section of track of grade $\Phi$ is then:

$$ F = kv^2 + f + Mg \sin \Phi \quad (1) $$

where $f$ is the effective impeding force the horse experiences as part of its galloping dynamic.

The power, $P$, a racehorse or any machine expends while operating under a constant speed, $v$, condition is:

$$ P = Fv $$

where $F$ is the effective overall force it exerts to balance the dissipative forces acting on it. While we do not know $F$ directly we have access to timing information on how the difference in racetrack grade affected Phar Lap’s galloping speed. Applying the common APE assumption that he galloped the DP1 downhill section with the same power expenditure as the UP2 uphill section of the 18f race then we may write:

$$ F_u v_u = F_d v_d $$

where the $u$ and $d$ subscripts refer to the respective uphill and downhill driving forces and speeds. Eliding this condition with Eqn (1) we obtain after substitution:

$$ [kv_u^2 + f + Mg \sin \Phi_d] v_u = [kv_d^2 + f + Mg \sin \Phi_u] v_d $$

Following algebra this simplifies to:

$$ k[v_u^2 + v_u v_d + v_d^2] + f = Mg v_d - v_u [v_u \sin \Phi_u - v_d \sin \Phi_d] \quad (2) $$

Now we consider the coasting situation. The equation of motion during this deceleration phase on a part of the track with grade $\Phi$ is:

$$ - kv^2 + Mg \sin \Phi = Ma \quad (3) $$

Eqn (3) is a differential equation that can be easily solved after substituting the well known identity for the acceleration $a$ namely:

$$ a = \frac{dv}{dt} = \frac{d(\frac{1}{2}v^2)}{dx} \quad (4) $$

arrive at

$$ \frac{d^2}{dx} \left( \frac{1}{2}v^2 \right) = - \frac{k}{M} \left( v^2 + \frac{f + Mg \sin \Phi}{k} \right) $$

where $x$ is the distance travelled in the coast that commences ($x = 0$) the instant thrust is extinguished. The solution to this differential equation is relatively straightforward having the exponential form,

$$ v^2 = \frac{(f+Mg \sin \Phi)}{k} \{ \exp[2k(L-x)/M] - 1 \} \quad (5) $$

Here $L$ is the total coast distance travelled when $v$ has correspondingly decreased to zero. If $v_c$ is the speed of the horse at the beginning of the coast ($x = 0$) then upon substitution we obtain:

$$ v_c^2 = \frac{(f+Mg \sin \Phi)}{k} \{ \exp[2kL/M] - 1 \} \quad (6) $$

We can eliminate $f$ from Eqns (2) & (5) further simplifying matters by noting that in this particular case $v_c = v_d$ and $\Phi_u = \Phi_d$ because of the commonality of DP1 and DP2 to obtain:

$$ Mg(v_u - v_d) - k(v_u^2 - v_d^2) = \left( Mg(v_u - v_d) - \frac{k}{v_u^2 - v_d^2} \right) \exp[2kL/M] $$

This is a transcendental equation with $k$ the only unknown, assuming $L$ is known. It can be solved by numerical or graphical methods as described elsewhere.

**Analysis & Results**

From Table 1 we note that Phar Lap covered the $4f - 7f$ section of DP1 in $35.0 \,\text{s} = (84.0 \,\text{s} - 49.0 \,\text{s})$ at an average speed of $17.24 \,\text{m/s} = (603.4 \,\text{m} + 35.0 \,\text{s})$. Accordingly $v_d = 17.24 \,\text{m/s}$. Moreover we have already argued that he was travelling at the same speed when he began the coast to the finish line as he was for DP1. So $v_c = 17.24 \,\text{m/s}$ also. To obtain $v_c$ we likewise average over the $3f$ section of UP2 ($12.5f - 15f$ section). While we do not have a clocked time for the $15f$ distance we can nevertheless rigorously infer it within our assumption of the common APE he exerted during his gallop from the $12f$ to the $17f$ mark (the vicinity of the last furlong pole). His APE here is also assumed to be the same as his APE for DP1 where he galloped furlongs on average in $11.8 \,\text{s} = (35.0 \,\text{s} - 3.0 \,\text{s})$. This then dictates a predicted time for the $15f$ distance of $3m 8.8s = (3m 20.5s - 11.67s)$. Thus we arrive at $40.33 \,\text{s} = (3m 8.33s - 2m 28.5s)$ for the $3f$ split of UP2. Accordingly $v_u = 14.96 \,\text{m/s} = (603.4 \,\text{m} + 40.33 \,\text{s})$. 

The Physicist Volume 40, Number 1, January/February/March 2003 31
Surveying information upon which Fig. 1 is based, kindly supplied by the AJC for the Randwick track, reveals that \( \Phi \), and \( \Phi \), have average values of +0.0072 and -0.0072 radians over their respective 3 f segments. Phar Lap had a composite mass \( M = 576 \) kg when racing the AJC Plate. If we take the distance coated as commencing nominally at the last furlong post and ending 25 m past the WP, i.e. \( L = 226 \) m, we arrive at values of \( k = 0.0277 \) km/m and \( f = 379.3 \) N following substitution in Eqn's (6) and then (2). We can use these initial values of \( k \) and \( f \) to calculate a time taken, \( \Delta t \), for the last 2 f covered. We do this in terms of a standard if tedious numerical procedure that uses average speeds over incremental distance steps to obtain the incremental time intervals that are then summed. We obtain \( \Delta t = 29.7 \) s which is close but can be whittled down to the actual 29.0 s by iterating the procedure, varying \( L \) about its nominal 226 m value. The result of this exercise hones the values of \( k \), \( f \) and \( L \) to 0.237 km/m, 410 N and 212 metres, respectively, for the required \( \Delta t = 29.0 \) s. A plot of the speed-distance profile based on these values appears below in Fig. 2.

![Graph showing speed-distance profile](image)

**Fig. 2.** Phar Lap's Simulated Speed-Distance Profile for the Final 2-furlongs.

**Discussion of Results**

The plausibility of the common APE assumption we have made to arrive at our final results rests with the sense we can make of their predicted values. The 212 metres of coast we obtain places its beginning at 187 m (= 212 m - 25 m) prior to the winning post. This is consistent with its commencement being in the vicinity of the last furlong pole that is 201 m from the finish. The drag constant \( k = 0.237 \) kg/m corresponds to an effective silhouette area of 0.74 m² for Phar Lap and rider. This is in keeping with the dimensions of the big chestnut as adjudged from available photographs. Moreover, textbook information on skydivers' presenting gauged silhouette areas of 0.70 m² yield effective drag constants of 0.20 kg/s. The empirically determined value for the horse is consistent with expectations we might infer from this as well. Finally the effective dissipative force of 410 N Phar Lap's weight was 5645 N. In the context of rolling friction in cars this corresponds to 0.07 (= 410 ÷ 5645) for Phar Lap's effective coefficient of (dissipative, flexure) friction. This seems reasonable insomuch as car wheels which we expect to be more efficient in this regard than galloping horse hooves, have values around 0.02. So all three values for distance, drag and 'dissipative flexure' are reasonable, supporting

the plausibility of our constant APE assumption. Cautiously if not confidently then we estimate the effective power expenditure appropriate to Phar Lap during these two common exertion phases. Given \( F_v = 507.2 \) N (= (0.237 x 14.962) + 410 + (576 x 9.8 x 0.00783)) and \( v_e = 14.96 \) m/s we obtain \( P = 7588 \) watts = 10.2 horse power for the common APE sections. Values at other times like the start-up phase and during what was considered by experts to be the suicidal pace of the first four furlongs of the race will exceed this, while during the break he obviously took between the 7f to 10f section there will be a shortfall. But overall we are looking at an energy expenditure of several megajoules - roughly equivalent in explosive energy to a kilogram of dynamite but mercifully released for the 1930 Sydney racegoing public over four minutes!

**Concluding Comments**

This article together with the other earlier one cited on start-up and cornering provides a reasonably simple and comprehensive picture of the effective forces involved in horseracing. While the races chosen are atypical and the creatures studied extraordinary, the results obtained act as useful guides for the magnitudes of the forces at play in horseracing. Teachers interested in constructing assignment questions and test problems in Mechanics in the context of a noble creature rather than an anonymous machine could therefore use them with confidence. The emphasis in both articles is really on pedagogy rather than biomechanical research. Accordingly the usefulness of both these investigations rests more in their ability to enhance teaching and learning rather than provide the final word on the Physics involved.

**Acknowledgements**

It is a pleasure to acknowledge the unstinting cooperation the author received from John Digby, Keeper of the Australian Stud Book, in gathering the data on which this analysis is based. And our posthumous thanks to Phar Lap whose extraordinary abilities provided the data for this interesting analysis. Long may his imposing taxidermal presence in the Melbourne State Museum interest and excite new generations of Australians and other visitors as it has done for those past and present.

**References and Sources**


32 The Physicist Volume 40, Number 1, January/February/March 2003
Phar Lap the ANZAC icon in full flight.

Born in NZ and raced in Australia, he started 51 times for 37 wins and 5 placings, winning 36 of his last 41 races! The ANZAC tag is appropriate - he was shot at, succeeded against all forms of handicap and died an agonising death on foreign soil while representing his country.
Brilliant Nanosecond Laser System Solutions from Quantel

Flow Visualisation

Holography

Holographic PIV

LIDAR

Laser Induced Fluorescence

See inside product news for details

Coherent SCIENTIFIC

116 Sir Donald Bradman Drive, Hilton SA 5033
Ph: (08) 8150 5200  Fax: (08) 8352 2020
Email: scientific@coherent.com.au  Web: www.coherent.com.au

Coherent Scientific Pty. Ltd., Inc. in South Australia. ABN 20 008 265 969