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PRESIDENT'S COLUMN

Given the recent release of the report by the Chief Scientist, Dr Robin Batterham, and that from the National Innovation Summit Implementation Committee, the timing of the FASTS 'Science Meets Parliament Day' scheduled for November 1st could not be better. These two reports are necessary reading for all of us engaged in science at any level and November 1st will provide a great opportunity for about 100 scientists to encourage all Federal politicians to take the recommendations of the reports seriously.

The Chief Scientist's report should be welcomed for it picks up a good many of the issues that have been at the heart of FASTS Policy documents in recent years, matters that I have sought to emphasise in this column. The recommended increases in funding, if implemented by the Federal Government, will go a long way to restoring the balance to the enabling sciences given that funding for medical research is already being increased towards the doubling of the 1999 NHMRC budget level by 2004.

The report from the National Innovation Summit addresses broader issues about innovation, business R & D and how to improve it, but it does complement the recommendations regarding the basic science that underpins innovation and should be read in concert with the Chief Scientist's report. Since the National Innovation Summit was an initiative of Minister Minchin when he realised it was in the 1996 Coalition Election Policy, it is to be hoped the Government will be ready to take the recommendations on board as a matter of great urgency.

The Science Policy Committee is at present preparing a response to the Chief Scientist's Report using the ground-work carried out earlier this year towards the preparation of a pre-election paper for the major political parties. Work on that has stalled in the light of the two major reports now before us and it makes sense to concentrate our present effort on making submissions on the key recommendations of both reports. If the basic or enabling sciences end up better-off as a result, then physics will, of course, also benefit.

Recent pressure on the Australian dollar has prompted some financial analysts to suggest that international investors perceive that Australia is not seriously involved in the new technologies, other than being a voracious user. The Innovation Summit Report adds weight to the idea that Australia is at a crossroads in terms of technology and innovation. It is to be hoped the Federal Government will take action to remedy the situation. The alternative will be second rate status in the world and costly dependence on technologies developed elsewhere.

John Prescott has again done a great job in the last Physicist [Vol 37, No 4, 140-144] providing hard data about jobs in physics. We should all read John's report thoroughly and be able to put the message out there in the community that physics is not dead! There is no cause for complacency, however. In a recent New Scientist Ian Lowe refers to the Photonics Industry which at present in Australia employs about 200 R & D scientists and engineers. Those inside that industry predict a need in Australia for up to about 5000 R & D scientists and engineers over the next few years! Many of those will have to be physicists. This is mind-boggling and definitely food for thought. We should be training not just a few but many more than at present in our universities. How can we move forward to that sort of goal?

At the Congress there is to be an AIP Forum with the following agenda items:

- What kind of Institute do we want or perceive we need?
- Therefore, what kind of publication do we want, need and/or can afford?
- What level of administration do we need, want and/or can afford?
- What level of subscriptions will enable us to build up the membership?
- What should our relationship be to cognate societies and what do members think about the desirability of a Council of Physical Societies, albeit a fairly informal arrangement?

Members may suggest other items but these should be submitted to the Secretary by 1 December. As there will be only 45 minutes available for the Forum, discussion will need to be well focussed.

In my final President's Column in the next issue of the Physicist, I will report on my visit to the Korean Physical Society meeting in Pohang at the end of October and, of course, my impressions of the 'Science Meets Parliament Day'.

John Pilbrow
EDITORIAL

The Olympic Spirit

As I write, the Olympics are underway in Sydney. The earlier gripes and grumbles are gone, and a carnival atmosphere has the city in its grip. In our neighbourhood, we had our own torch relay with a tin can on a stick fuelled by kerosene, and then settled in to enjoy the spectacular opening ceremony on TV. So far, the Games have been a triumph.

The Olympic Games are a celebration of the spirit of humanity. Every four years people from all over the world can come together to share triumphs such as the Dutch swimmers in the pool, or disasters such as the Russian girls in the team gymnastics. We can put aside wars and conflicts, and remember that we all belong to a world community. Who can forget how the Berlin games in 1936 punched a great hole in Hitler's myth of Aryan racial superiority? The Olympics should be a festival time for us all.

Science Reviews

Two major reports recommending increased support for scientific research and development in Australia have appeared recently. One is the final report of the Innovation Summit Implementation Group (ISIG), entitled "Innovation: Unlocking the Future" (www.isr.gov.au/industry/ISIGReport.pdf), and the other is the Chief Scientist's review of Australia's science capability, "A Chance to Change" (www.isr.gov.au/science/review). They include some heartening proposals, such as:

- Increase the business R & D tax concession rate to 130%;
- Double spending on ARC competitive grants over 5 years;
- Increased funding for infrastructure;
- Double funding for commercializing emerging technologies;
- Review remuneration and incentives for research activities;
- 200 new HECS scholarships for combined science/education students.

All of these proposals will be applauded by the science community. The need for them has been highlighted by recent news that the level of business R & D in Australia has slumped to 7th lowest among developed nations. The value of information and communications technology produced in Australia amounts to less than 1% of GDP, lower than any other advanced economy except Norway. Australia's reputation as an 'old economy' is even being quoted as a reason for the recent collapse in the value of the dollar.

Robin Battersham, the Chief Scientist, has reckoned that he needs about 10,000 letters of support to get his recommendations accepted. We urge all our readers to express their support - for details, see the FASTS section in this issue.

Unfortunately, these proposals will have little impact on the most serious problems facing science in Australia: namely, the declining interest in science among school students, and the withering away of science faculties in our universities. DETYA and the universities must find some way to address the latter problem. They could insulate science faculties against the whims of student fashion in the same way that the Americans or Europeans do, by allotting some base funding independent of student numbers; or else by allotting an increased share of funds in proportion to research students enrolled, or competitive research grants won. As to the first, more deep-seated problem, it is hard to know what to do. Perhaps, like the Americans, we will be forced to look overseas to countries like India, to fill our need for graduates skilled in IT or other scientific disciplines.

Chris Hamer
C.Hamer@uaw.edu.au

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Response to the Government’s White Paper “Knowledge and Innovation”

Physicists interested in discussions about the Government’s White Paper on research at universities may be interested to refer to the following URL where a submission I prepared has been posted. It was too long to get into the printed pages of the Physicist but was aimed at raising the amount of debate on this important topic and to present, perhaps, some new ideas.


Physicists who are interested may contact me at the Department of Exploration Geophysics at Curtin University to discuss some of the matters which I present in my paper.

Dr BM Hartley, FAP
Department of Exploration Geophysics
Curtin University
hartley@geophy.curtin.edu.au

Very Many Thanks

In the May/June 2000 issue of the Physicist is a letter entitled “A Tribute” by Peter J Seebacher.

It is with great emotion, humility and gratitude that I would like to thank Peter for the sentiments he expressed so eloquently.

I have now been retired for 16 years and I often think of my academic life and how very fortunate I was to spend so much of my life as an academic.

I enjoyed my work immensely and I have always thought that to be an academic, steeped in the old, beautiful beliefs of what a University represents, was the greatest treasure for one to find in life.

I tried to impart what little knowledge I had to my students.

But I learned, with great appreciation, so very much more from the students. And to receive such an accolade as Peter has written must surely be the greatest reward an academic could ever receive.

Any words I could say to thank you, Peter, for your beautifully expressed sentiments would be quite inadequate in trying to express the depth and the humility of my feelings on reading, and re-reading, your ‘tribute’ to me.

So, Peter, I would like to say just: Thank you very, very much, Peter J Seebacher.

I will always remember and appreciate so much your incredibly kind thoughts.

Your ‘tribute’ alone, has made me realize that I have achieved an aim of an academic: to incalculable the love of learning in a fellow student.

Ed Sullivan
29 Howard Street, Randwick

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The University of Sydney

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AROUND THE TRAPS

Synchrotron Proposal in the Spotlight

A proposal to establish a national synchrotron facility will go to the Australian Cabinet in the next few weeks. If approved, construction of the $100 million machine, to be known as 'Boomerang', could begin in the second half of next year. Several nations in Asia have already shown interest in joining the proposal, including Singapore, Malaysia and Indonesia.

At present, Australians needing synchrotron facilities are forced to go overseas, to Tsukuba, Brookhaven or elsewhere. An Australian team led by Stephen Wilkins of CSIRO have established their own beamline at the Photon Factory in Tsukuba, which is used by about 50 Australian scientists every year, from a wide range of disciplines. The synchrotron is useful for many applications, including protein crystallography, powder diffraction, surface analysis and micromachining.

[Bob Johnstone, 'New Scientist', 30 September 2000]

Schmidt Wins McIntosh Prize

Dr Brian Schmidt of the Mount Stromlo and Siding Spring Observatories has been awarded the inaugural Malcolm McIntosh Prize for Achievement in Physical Sciences, worth $35,000. The prize is named after the former chief executive of CSIRO who died earlier this year.

Schmidt was leader of an international team which discovered in 1987 that the Universe is expanding at an ever-increasing rate, as outlined in his article 'Measuring the Universe' in the Physicist, March/April 1999. This was nominated discovery of the year by the journal Science.

Debate on the 'New Economy' Hots Up

The release of the Innovation Summit report, and the Chief Scientist's review of Australia's Science Capability, have touched off a political debate on measures to improve Australia's R & D performance. The Labour party has taken up the "Knowledge Nation" as one of its major campaign themes for the next election, and its agenda is being pushed by the new spokeswoman for industry, innovation and technology, Dr Carmen Lawrence. The Business Council of Australia, the Australian Chamber of Commerce and Industry, the Institute of Chartered Accountants, FASTS and other organisations have signed an open letter to the Government calling for increased investment in new technology. They argue that some of the increased Budget surplus of $3.3 billion for 1999-2000 ought to be spent on R & D. Prime Minister John Howard has indicated that Cabinet will consider some decisions in this area over the next month or two.

Square Kilometre Array Inches Closer

Consortia from Europe, North America, Asia and Australia have signed an agreement to plan what will be the world's largest telescope, the Square Kilometre Array (SKA).

The array will consist of up to 1000 stations spread over an enormous area, each with a collecting area between 30 and 300 square metres. Plans will be finalised in 2005, and construction will not start until 2010. Australia is hoping to be chosen to host the project.

www.rsc.ucalgary.ca/SKA/index.html
['Physics World', September 2000]

Scientists claim Quantum Computer Breakthrough

Lawyers have filed patent applications for a development that could give Australia the lead in the worldwide race to build a stable, working, scalable quantum computer. The breakthrough was made at the Semiconductor Nanofabrication Facility at UNSW, part of the Special Research Centre for Quantum Computing Technology. Those involved include Prof. Bob Clark, and Dr. Nancy Lumpkin, Alex Hamilton, Michelle Simmons and Andrew Dzurak.

The researchers have evolved a 'top-down' strategy, involving the precise implantation of phosphorus atoms into a chip, whose spins will act as qubits. The proposed quantum chip would be physically and chemically stable and would be constructed with a silicon base, making it compatible with existing computer chip-making technologies.

www.snf.unsw.edu.au
['The Australian', 22 August 2000]

ANU Solar technology for WA power grid

A 20-kW solar power station using ANU technology has begun operation at the Rockingham campus of Murdoch University in Perth, and is feeding power into the WA grid. The trial station is the result of a program led by Professor Andrew Blakers of the Centre for Sustainable Energy Systems, ANU. The system has 8 moveable mirrors which track the sun, and concentrate light onto solar cells of a novel low-cost, high-efficiency design developed at the ANU. Recent developments in satellite dish tracking technology have enabled the slow tracking required for the mirrors to follow the Sun.

Funding for the station came from the Australian CRC for Renewable Energy, the Australian Greenhouse Office, the NSW State Energy Research and Development Fund and the Alternative Energy Development Board of WA. A new company is being established to manufacture the high-performance solar cells on a commercial basis.

[Julia Visch, 'ANU Reporter', 15 Sept. 2000]

The Hunt for the Higgs

Physicists at CERN claim to have found possible evidence for the mysterious Higgs boson. Theorists have predicted that it should have a mass somewhere between 100 and 150 GeV, and decay mostly into bottom (b) quarks. Now experimenters at the ALEPH and DELPHI teams at the LEP accelerator have seen five b-quark events above background at a mass around 115 GeV. Unfortunately LEP is due to shut down, in order to allow construction of the Large Hadron Collider (LHC) to begin. Fermilab may be able to confirm the existence of the Higgs at 115 GeV, even before the LHC comes on line.


France bids for fusion project

The French Atomic Energy Commission has proposed to host the International Thermonuclear Experimental Reactor (ITER) at its Cadarache site. This will be a boost to the program, after the US recently decided not to continue its participation.

ITER is a joint effort by the EU, Japan and Russia to develop a fusion reactor using magnetic confinement for a plasma of deuterium and tritium. The fusion power generated will be 10 times the "breakeven" level. ITER is seen as a crucial step towards a working fusion power plant. Canada and Japan are also interested in bidding for the project. It is expected to cost about A$6 billion.

['Physics World', September 2000]

SYNROC Alliance

The French nuclear agency Cogema has joined with the Australian Nuclear Science and Technology Organization (ANSTO) to bid for the right to immobilize weapons-grade plutonium in the United States. The US engineering firm Burns and Roe is also involved, and they have formed a new company known as Roe CA. They have
Virtual Reality for the Olympics

The development of multi-screen virtual environments is becoming big business for graphics programmers at the ANU Supercomputer Facility (ANUSF) Visualisation Laboratory (Vizlab). Their third public display has been opened at the Powerhouse Museum in Sydney, focussing on archaeology. It recreates the Greek village of Olympia, and includes an image of the Greek god, Zeus.

Vizlab have developed their own software program, pSpace, for driving interactive virtual environments. Stereo images are displayed across a number of screens and viewed through special glasses, creating the experience of a 3D, interactive, virtual movie. “We haven’t even officially advertised our services - all of our clients have approached us”, says Drew Whitehouse, Vizlab founder and lead programmer. Other displays are at the CSIRO Discovery Centre in Canberra, and a second display at the Powerhouse in the “Universal Machine” exhibition.

First Duffield Chair to Ken Freeman

The Walter Geoffrey Duffield Chair of Astronomy and Astrophysics was inaugurated at Mount Stromlo Observatory recently. The Chair is named after the first Director of the Observatory, and was awarded to Professor Ken Freeman, who has made significant contributions in astrophysics and fundamental physics, specifically in the study of dark matter in galaxies, and the formation, dynamics and chemical properties of galaxies and globular clusters. A special guest at the inauguration was Prof. Duffield’s daughter, Miss Joan Duffield.

Australian Shares Dirac Medal

The 2000 Dirac Medal has been awarded to Howard Georgi of Harvard University, Jogesh Pati of the University of Maryland and Helen Quinn of the Stanford Linear Accelerator Center. Helen was brought up in Australia. The prize is awarded by the Abdus Salam International Centre for Theoretical Physics in Trieste. Georgi, Pati and Quinn were honoured for their pioneering contributions to the quest for a unified theory of quarks and leptons and the strong, weak and electromagnetic interactions.

www.ictp.trieste.ij/sci_info/awards/Dirac.html

["Physics World", September 2000]
NOMINEES FOR POSITIONS
ON THE AIP EXECUTIVE 2001

Only one nomination has been received, by the closing date, for each position on the new National Executive. There will therefore be no necessity for voting, and the nominees will take office at the Council meeting in February 2001. However, present Executive is persevering with the formalities and publishing the following profiles for the information of members, in the hope and expectation that eventually we will really have an election for office bearers. Members, it is up to you!

Moira Welch
Hon Secretary

D.J. O’Connor, BSc(Hons), PhD, DSc(ANU), FAIP
presently Vice President, Nominee for President
Currently an Associate Professor in the Mathematical and Physical Sciences at the University of Newcastle. Completed BSc(Hons) and PhD at ANU (1971-1978) and then worked as a postdoctoral fellow at the University of Sussex in UK for two years. Then took up a post at Newcastle in 1981 where I was Head of Department from 1991-1998.

I have had a long link with the NSW branch of the AIP serving on the branch executive from 1983-1994. This period included a year as Deputy Chair (1992) and Chair (1993). During that time I also served on the editorial board of the Australian Physicist from 1988-1992. In 1994 I established the physics list servers allowing effective communication through the electronic mail system.

In other activities I have served as the Secretary of the Vacuum Society of Australia continuously since 1990. Through my links with that society I have held the positions of Australian Councillor to the International Union of Vacuum Science, Techniques and Applications (1996-2002), Australian representative for Surface Science (1996-2002) Secretary of the Surface Science Division Executive of IUVSTA (1996-2002) and trustee of the Welch Foundation (1997-2000).

Clearly I have a research interest in Surface Science with over 140 papers published in refereed journals. I have been the recipient of an Alexander von Humboldt Fellowship and a Bede Morris Fellowship. I was awarded a D.Sc by ANU in 1999.

I have a strong interest in Science Communication and effective teaching and learning of Physics. I have a weekly radio show on the local ABC 2NC and a fortnightly show on 2NURFM. I founded the Hunter chapter of The Australian Science Communicators which brought together 18 science bodies in the Hunter Region.

Robert G. Elliman PhD, FAIP
Nominee for Vice President
Dr. Elliman is a Senior Fellow in the Electronic Materials Engineering Department, Research School of Physical Sciences and Engineering, Institute of Advanced Studies, Australian National University, where he leads a group working on ion beam modification and analysis of materials. He is a Fellow of the Australian Institute of Physics (AIP) and has previously served as Secretary, Deputy-Chair and Chair of the ACT Branch of the AIP. He is also a Member of the American Institute of Physics and the Materials Research Society (MRS), and serves on the international advisory board of the journal Nuclear Instruments and Methods B, and on the international conference committees for the “Ion Beam Modification of Materials” and “Ion Beam Analysis” conference series. Dr Elliman has published over 200 papers in peer-reviewed journals and conference proceedings, was awarded the 1996 Pawsley medal by the Australian Academy of Science for his contribution to physics research and received a DSc based on peer review of his published work in 1997.

Peter Johnston PhD FAIP
Nominee for Honorary Registrar
Peter Johnston is Associate Professor of Applied Nuclear Physics in the Department of Applied Physics, RMIT. He graduated PhD from La Trobe University in 1986 after undergraduate studies at the University of Melbourne. Before joining RMIT in 1989, he was a Research Scientist at the Australian Radiation Laboratory where he worked for 9 years in environmental radioactivity, health physics and radionuclide metrology. His research and teaching activities are concentrated in the areas of radiation physics and application of nuclear physics including Ion Beam Analysis techniques for analysis of optoelectronic semiconductor materials; Atomic Inner-Shell Physics; Directional Correlation of Nuclear and Atomic Radiations; Health Physics; Environmental Radioactivity. He is technical consultant to the Maralinga Tjarutja, who are the traditional owners of the former nuclear test sites at Maralinga and Emu. Peter Johnston has been a member of the AIP Membership committee and numerous AIP Accreditation Committees since 1994. He represented RMIT on the Council of Deans and Directors of Graduate Education in Australian Universities from 1996-1999.

Moira Welch MA(Cantab), MAIP
Nominee for Honorary Secretary
Although officially retired from full time work at the University of Western Sydney, Nepean, since the end of 1996, I am still involved continuously with physics teaching at UWS Hawkesbury, soon to be part of the new restructured University of Western Sydney. Throughout my long teaching career I have found my previous experience in industry in both the UK and USA to be invaluable.
I am still studying - this time for a degree in Theology (which is not as far from Physics as some might suppose!).

I have now been Honorary Secretary of the AIP for seven years. Over that time the most dramatic change has been in our methods of communication, which has shifted almost entirely from paper to electronic. Meetings can now be held, if appropriate, by teleconferencing, saving both time and money. The Executive is also investigating videoconferencing.

There is great variety in the Honorary Secretary position: organising Executive meetings and Council meetings, assisting with Heads of Physics meetings, overseeing procedures for the Bragg, Boas and (in conjunction with IOP) Massey medals and the Pawsey lecture, providing information and assistance to Branches, members, Congress Organisers, Government Departments and publishers when requested, maintaining the Articles and Bylaws of the AIP, and often being the first point of contact, to both members and those in the general community, for an astonishing range of queries.

With such a variety of tasks, knowledge of procedure is vital, and I am continuing the development of an AIP Procedures Manual, for the benefit of the Institute in general and future Honorary Secretaries in particular. I look forward to the AIP fulfilling its role in serving an ever increasing proportion of the physics community in Australia.

Dr Cathy Foley
Nominee for Honorary Treasurer

Dr. Cathy Foley is a Senior Principal Research Scientist with CSIRO Telecommunications and Industrial Physics. She is the project leader of the Superconducting Devices and Applications Project which is developing High Temperature Superconducting systems for Mineral Exploration, Detection of metal for quality assurance in manufacturing, heart monitors and remote detection of contraband at airports. This multiple million dollar project assisted with the discovery and delineation of the BHP Cannington Silver mine and her team is currently commercialising their systems. Her group are the only team to successfully fly superconducting systems for mineral exploration and Cathy has a world class reputation in her field being a Fellow of the Institute of Physics in the UK.

Dr. Foley is well known for her interests in physics, science education, women in science, science in the media (she was a regular weekly guest on ABC radio 2BL radio for 5 years) and nuclear disarmament.

Dr Pal (Paul) Fekete, BSc (Hons), PhD, DipEd, MAIP
Nominee for Communications Officer

Dr Fekete has a PhD in plasma physics where he used a microwave source called a gyrotron to study perturbations in a plasma due to RF heating. Since his PhD he has worked in the fields of optic fibres, audio acoustics, confocal microscopy and adaptive optics, and physics education research. Pal (Paul) is currently Science Coordinator for the University of Sydney Foundation Program preparing international students for university entry.

Pal has a wealth of teaching experience in both high school and university environments and stays abreast of current developments in the pedagogy of teaching physics at both levels of education. As part of his research he is currently developing a diagnostic test to evaluate conceptual understanding in Thermal Physics. He is a member of the Sydney University Physics Education Research (SUPER) Group in the School of Physics at the University of Sydney and the NSW AIP Education Sub-committee. He is also a member of the Australian Optical Society.

Pal has maintained the web site for the NSW branch of the AIP since 1995 and in 1996 established the National AIP web site. Since these early days he has done (and continues to do) much to enhance the functionality of these web sites. Pal also maintains the web sites for the Department of Physical Optics and the SUPER Group in the School of Physics at the University of Sydney.

Pal has been an active member of the executive of the NSW AIP since 1995 and is currently Deputy Chair. In October 2000 he will take over the role of Chair of the NSW branch, an exciting position as the National AIP conference will be held in NSW during his tenure. In 1999 he was appointed as Publicity Officer on the national executive of the AIP in recognition of his work promoting physics in Australia.

Pal is committed to promoting physics in Australia and believes that the best future is through our youth. He is committed to excellence in teaching and hopes to establish a national web site for high school teachers in the near future. He also plans to add a number of other enhancements to the National web site over the next twelve months.
Rheo-NMR. How nuclear magnetic resonance is providing new insight regarding complex fluid rheology

PAUL T CALLAGHAN
Institute of Fundamental Sciences—Physics
Massey University, Palmerston North, New Zealand

Introduction

Nuclear Magnetic Resonance was independently discovered in 1945 by Edward Purcell, Felix Bloch and their co-workers at Harvard and Stanford universities\(^{1,2}\). Soon after that discovery, it was realised that NMR was exquisitely sensitive to the nuclear environment in condensed matter. This sensitivity arises through terms in the spin Hamiltonian related to the detailed chemistry of the molecular host (the chemical shift and the scalar spin-spin coupling), to the orientational order of the host molecules (the nuclear quadrupole interaction with the local electric field gradient), to the spatial and orientational distribution of these molecules (the inter-nuclear dipolar coupling), and to the molecular dynamics (nuclear spin relaxation processes). In 1973, the discovery that NMR performed in the presence of magnetic field gradients\(^{3,4}\) enabled imaging of the nuclear magnetization density, leading to the development of MRI as an important tool in modern radiology.

Over the past five decades, NMR has revolutionised chemistry, and has found widespread application in condensed matter physics, in molecular biology, in medicine and in food technology. Most recently NMR has made a significant impact in chemical engineering, where it is being extensively used for the non-invasive study of dispersion and flow in porous media. One of the most recent applications of NMR in materials science concerns its use in the study of the mechanical properties of complex fluids. This particular aspect of NMR has been extensively developed in research carried out at Massey University in New Zealand and in this short article, some of the ideas behind this work and the applications which have resulted, will be described.

We tend to think of condensed matter as sub-dividing into the two basic phases of solid and liquid. When subjected to a stress a solid will deform by a fixed amount and store energy elastically whereas a liquid flows and dissipates energy continuously in viscous losses. But many interesting materials in their condensed phase possess both solid and liquid-like properties. These include polymer melts and solutions, lyotropic and thermotropic liquid crystals, micellar surfactant phases, colloidal suspensions and emulsions. Most biological fluids, most food materials and many fluids important in industrial processing or engineering applications exhibit such complexity. Complex fluids manifest both an elastic and a viscous response, and they generally possess "memory", which means that the stress which they exhibit at any moment will depend on their history of prior deformation. They tend to exhibit non-linear mechanical behaviour, which means that their mechanical properties may change as the deformation increases, an effect which is generally attributed to molecular reorganisation. And they invariably possess a wide range of characteristic time scales, from the rapid (ps to ns) local Brownian motion of small molecules or molecular segments, to the very slow (ms to s) motions associated with the reorganisation or reorientation of large molecular assemblies or macromolecules. The study of the mechanical properties of complex fluids is known as "rheology"\(^{5}\), a name which derives from the Greek word "rhein" which means "to flow".

Traditionally, rheology was a subject concerned principally with mechanical properties. Recently however attention has focussed on trying to determine the molecular basis of complex mechanical properties. If we can better understand this basis then we can better design desirable fluidic properties, we can better process modern materials based on polymers and organised molecular states, we can better produce foods of the right texture, and we can better understand how nature works, for example, in the way synovial fluid protects our joints, or in the way a spider can extrude a protein silk whose strength surpasses that of steel.

The interest in the molecular-mechanical link has led to the amalgamation of a number of spectroscopic and rheological techniques in which a flow or deformation cell is incorporated within the spectrometer detection system. Examples include the use of neutron scattering, light scattering, birefringence and dichroism techniques. The most recent addition, NMR, has provided a number of new and valuable features. For example,
it can be used to study materials which are optically opaque. The imaging capability of NMR means that it can be used to directly measure local velocity profiles and molecular densities. And the wide-ranging spectroscopic tools available to NMR makes it possible to measure molecular order and dynamics. A detailed review of the science of Rheo-NMR can be found in a recent chapter in Reports on Progress in Physics. Here we will outline the basic principles, and give a few examples from our work at Massey University. At the heart of our method is a dual focus on NMR microscopy and NMR spectroscopy, the former giving insight at the mechanical length scale and the latter at the molecular length scale.

**Micro-imaging and NMR velocimetry**

A proton (spin = 1/2) immersed in a magnetic field, $B_0$, occupies one of two quantum states with respect to the field direction and the quantum phases of those states rotate at the frequency $\omega = \gamma B_0$ (for example $\omega/2\pi = 300$ MHz for a proton immersed in a 7 T field), where $\gamma$ is the gyromagnetic ratio, the factor which determines the ratio of its magnetic properties to its spin properties. This phase rotation arises from the combined magnetic and spin properties of the nucleus and is known as precession. The proton has a very high value of $\gamma$ (and hence radiofrequency photon energy) relative to other nuclei and it is highly abundant in many materials, as the nucleus of atomic hydrogen. It is thus the prime candidate for NMR. Also relevant, although less often used, are the spin-1/2 $^{13}$C (=1% abundant in carbon) and $^{31}$P (=100% abundant in phosphorous), and the spin-1 $^1$H (generally requiring deliberate isotopic labelling at prescribed hydrogen sites).

Detection of the underlying precession frequency requires the intervention of a resonant radiofrequency field, generated by a coil surrounding the sample. This field is applied as a pulse for a finite duration $t$, at the same frequency as the underlying precessional circulation. As a result, the spins gradually re-align themselves so as to leave a component of the magnetisation precessing in the plane transverse to $B_0$ and consequently providing an induced voltage in the same sample coil used to excite the spin system from equilibrium. Thus the NMR spectrometer consists of a magnetic field, a coil as antenna, and a radio transceiver. In the case of a micro-imaging system, an additional requirement is a set of magnetic field gradient coils.

A schematic representation of the NMR magnet system is shown in figure 1a.

A spin at position $r$, in the presence of a magnetic field gradient, $G$, will experience an additional local spin precession frequency, $\gamma G r$, thus acquiring a phase $\exp(ikr)$, $k$ being the reciprocal space dimension conjugate to $r$ and given by $\gamma G t$, where $t$ is the evolution time. The nuclear spin density can be reconstructed by acquiring the complete signal over some appropriate volume of $k$ space and performing an inverse Fourier transformation, generally, in two dimensions using a plane of spins prepared by a frequency-selective excitation. The high spatial resolution needed for NMR microscopy depends on the use of large polarising field ($\geq 5$ T), small receiver coils of high sensitivity and gradient coils capable of delivering in excess of 20 G cm$^{-1}$.

**Figure 1**

a) Schematic diagram shown arrangement of magnetic fields used for NMR spectroscopy and micro-imaging.
b) b) NMR proton density image from a 1.9 mm 1D capillary in which a surfactant solution is flowing. Also shown is a velocity map from the same capillary displayed as a stacked profile plot.
In order to image velocity we further encode the signal with a Pulsed Gradient Spin Echo (PGSE) pair. These pulses define a second wave vector domain, \( q \), and impart a phase shift to the spins which depends directly on the motion of their parent molecules. In particular a spin moving by \( R = r' - r \) over the time \( \Delta \) between the PGSE pulse pair acquires a phase factor \( \exp[iq.R] \). This contrast factor means that the signal acquired is effectively modulated both in k- and q-space. Double inverse Fourier transformation of the signal with respect to both k and q returns the local spin density \( \rho(r) \) as well as the function, \( P_q (R,\Delta) \), which describes the ensemble distribution of molecular displacements for that location. Image analysis software can be used to automatically process these distributions, using the width to estimate the rms Brownian motion \( (2D_0 \Delta)^{1/2} \) and the mean displacement estimate the flow. In this manner maps of \( D_0 (r) \) and \( \nu (r) \) may be constructed. While the method depends on steady state flow conditions in the sample (a typical image will take several minutes to acquire), it does have the advantage of returning accurate and precise velocity maps. The sensitivity of the method is very high, enabling velocity resolution on the order of \( 10 \mu m \ s^{-1} \). Figure 1b shows an image of the Poiseuille velocity field for fluid in laminar flow in a capillary.

In our laboratory we use a number of shearing and extensional flow cells which can be used to deform complex fluids within the rf coils of the NMR system. These include cone-and-plate cells, cylindrical Couette cells, four roll mills and bi-axial extension cells, these latter devices being used to produce purely extensional flow. All these deformational flow devices are driven by a drive shaft which sits in the bore of the magnet and which is turned by a stepper-motor gearbox assembly mounted above the magnet bore.

### Rheology and the flow curve

In rheological measurements a material is subject to deformation and the stress, \( \sigma(t) \), is monitored as a function of the time dependent strain, \( \gamma(t) \). One important class of measurement concerns the large strain response known as the “flow curve” for which the stress is measured as a function of the rate of strain, \( \gamma = \partial \nu / \partial t \), in a steady state shearing flow. Figure 2a shows examples of flow curves for different classes of materials, including Newtonian, shear thinning, shear thickening, and fluids exhibiting a yield stress. The principal rheometric device for such measurement, the small angle cone-and-plate, is shown in figure 2b. In this device the stress is almost uniform, varying weakly as \( \cos \theta \) between the bottom plate (\( \theta = 90^\circ \)) and the cone (\( \theta = 90^\circ - \alpha \)) where \( \alpha \) is the cone angle, typically less than \( 10^\circ \). The strain rate \( \dot{\gamma} = \partial \nu / \partial \gamma \) and is assumed to be highly uniform since both the cone tangential velocity, \( \nu_\gamma \), and the gap are proportion to the local radius.

One of the first significant contributions of Rheo-NMR has been to show that the uniform shear-rate assumption may be violated in the case of certain classes of fluids in which pathological flow properties are exhibited. Figure 3 shows velocity maps and associated shear-rate maps obtained at Massey University by post-doctoral fellow, Melanie Britton.
for the wormlike surfactant system, cetylpyridinium chloride/sodium salicylate in water. While the velocity gradients show no deviation from uniformity at very low shear rates, above a certain critical value $\gamma_c$ we observe a dramatic variation in the rate-of-strain across the $6^\circ$ cone gap in which a very high shear rate band exists at mid-gap (i.e. fixed angle $\theta=90^\circ-\alpha/2$) and independent of radius.

![Graph showing shear rate distribution](image)

**Figure 3**
Shear rate distribution for cetylpyridinium chloride/NaSal wormlike micelle solution at an apparent shear rate, $\gamma_{app}$, of 16 s$^{-1}$, well beyond the critical shear rate and in an unstable region of the flow curve (horizontal field of view 25 mm with vertical field of view smaller by a factor of 6). Also shown are experimental shear rate profiles along a line of approximately fixed radius.

This shear banding phenomena explains the plateau in the flow curve seen in figure 4. In the reptation reaction model of M.E. Cates$^{10}$, the wormlike micelle system is predicted to exhibit a constitutive behaviour as shown schematically in figure 4 where the region of decreasing stress as the shear rate increases finds its origin in the reduction in entanglements as the worm chains align in the flow. This section of the flow curve is associated with unstable flow. Cates et al.$^{11}$ have suggested that because of the instability beyond the shear rate corresponding to the stress maximum, $\sigma_{max}$ in the schematic flow curve, separation of distinct shear bands may occur, in the manner of a first order phase separation. These bands will be associated with the intersections of a coexistence stress tie line with the upper and lower branches of the underlying flow curve and the proportions of each band will be as required to satisfy the average shear rate. That the NMR results are consistent with this picture is clear in figure 3 where a series of profiles show that as the gap apparent shear rate, is increased the high shear rate band expands in width at approximately constant maximum shear rate.

![Graph showing flow curve](image)

**Figure 4**
Flow curve for cetylpyridinium chloride/NaSal wormlike micelle solution along with schematic constitutive model exhibiting doublevalued stress vs rate-of-strain behaviour. In the phase separation model for shear banding, $\gamma_1$ and $\gamma_2$ correspond to coexisting shear rates at a single stress value.

Shear banding effects have apparently been seen in these materials via optical birefringence. Birefringence effects are associated with anisotropic molecular alignment and, as a consequence, the flow instability of the wormlike micelles have been associated with the onset of molecular ordering. NMR is also capable of investigating order and alignment through utilising inter-nuclear dipole interactions or nuclear quadrupole interactions. It is through the use of such spectroscopic approaches that Rheo-NMR holds the promise of further linking mechanical and molecular properties.

By the use of deuteron labelling, it is possible to employ the deuteron quadrupole interaction to measure local order, since this interaction results in a two line NMR spectrum in which the splitting is proportional to the local order parameter, and to the alignment with respect to the magnetic field via the second rank Legendre Polynomial, $P_2(\cos\theta) = (3\cos^2\theta-1)/2$. Elmar Fischer, a German postdoctoral fellow working at Massey University, has used quadrupole interaction spectroscopy to investigate shear banding in a wormlike micelle system in
which birefringence banding had been observed (20% CTAB/D$_2$O at 41 C). Figure 5 shows the D$_2$O $^3$H NMR spectrum plotted as a function of radial position across the gap of a cylindrical Couette cell where the magnetic field is aligned with the vorticity axis. At the inner wall, where the stress is highest, a splitting is observed, indicative of a finite quadrupole interaction, while at the outer wall a single peak is observed. This data suggest the formation of a nematic phase at high stress and the transition to an isotropic phase, through a mixed phase region, at the region of low stress. What is particularly interesting about this experiment is that the associated velocity profile shows a banding in the shear rate which does not correlate simply with the local order parameters seen in the $^3$H NMR spectra, indicating that the molecular ordering is associated with the monotonically varying stress, rather than the discontinuously varying rate of strain. The example provides valuable new insight regarding the origin of shear banding in systems close to an isotropic/nematic phase transition.

Another intriguing correlation between shear and molecular conformation has been investigated in our laboratory.

Figure 5
$^3$H NMR spectra obtained from 20% w/w CTAB/D$_2$O (41 C) at different positions across the annular gap of a cylindrical Couette cell and at an apparent shear rate of 20 s$^{-1}$. Near the inner wall, where the stress is highest, a quadrupole splitting is observed, consistent with an ordered phase, while near the outer wall the single peak of an isotropic phase is seen. In between a mixed phase region exists.

in figure 6. As a result of the deformation, the chain entropy is reduced leading to an increase in the Free Energy, the basis of the elastic response of the polymer melt.

Figure 6
Schematic diagram of "horizontal Couette cell" in which the vorticity axis is aligned transverse to the magnetic field. The angle between the local velocity direction and the magnetic field is given by $\Phi$. The angle between the principal axis of the molecular (1,2,3) frame and the velocity axis, $X$, is the so-called extinction angle, $\chi$. The inset shows elements of the alignment tensor, $S_{\alpha\beta}$.

The deformation may be usefully described by means of the averaged segmental alignment tensor

$$S_{\alpha\beta}(t) = \left( \int_0^L ds\, u_\alpha(s,t)u_\beta(s,t) - \frac{1}{3}\delta_{\alpha\beta} \right)$$

where $\langle...\rangle$ represents the ensemble average and the integral is taken over the curvilinear path of s chain segments along the chain length L. In the Doi-Edwards formulation of entangled polymer dynamics, the stress tensor $\sigma_{\alpha\beta}$ is shown to be directly proportional to the average alignment tensor $S_{\alpha\beta}$. Where polymer segments are aligned so that $S_{\alpha\beta}$ is non-zero, other physical properties will be anisotropic as well. In particular the dielectric properties which determine the material refractive index will be affected, leading to the optical anisotropy known as birefringence. The correspondence of the stress tensor and the anisotropic part of the refractive index tensor is known as the "Stress-Optical Law".

PhD student, Maria Kilfoil, has used deuterium nuclear magnetic resonance to measured the alignment tensor in a high molecular weight polyethyleneoxide melt. We employed a small horizontal Couette cell (gap 0.5 mm) in which both the velocity axis element $S_{xx}$ and the gradient element, $S_{xy}$ of the
alignment tensor can be projected along the magnetic field. In this work we use a small benzene probe molecule which is placed as a dilute species near a polymer segment whose orientation defines the local director. The tumbling probe molecule will undergo steric interactions with that segment and experience an anisotropic mean orientation. The probe will thus exhibit a scaled down quadrupole splitting associated with that local site via a "pseudo-nematic" interaction and samples an ensemble average value for $P_2(\cos\theta)$ as it diffuses over the molecular dimensions.

Standard NMR micro imaging is used to view the PDMS both to image the velocity distribution across the gap and to excite a desired region of the sample for spectroscopy experiments during steady-state shear. Figure 7 shows the measured alignment tensor elements along with fits using the Doi-Edwards model, in which the hierarchy of molecular relaxation times is terminated by the tube disengagement process associated with reptation. Also shown are the selected regions in which either the velocity direction or the velocity gradient (shear axis) is parallel to $B_0$. The selective excitation pulse sequence which we used has been specially devised to minimise exposure of selected nuclear spins to any relaxation. The best overall fit yields a tube disengagement time of 310 ms, a value which is consistent with the terminal relaxation rate obtained from mechanical measurements. We have also carried out this experiment at fixed shear rate ($\gamma_0 = 3.9$), varying the angle $\Phi$ between the velocity direction $X$ and the magnetic field direction through a number of prescribed angles. This was achieved by changing the orientation of the magnetic field gradient used in the precursor selective storage pulse. The angular dependence of the splitting is shown in figure 8, along with the Doi-Edwards curve calculated using equation 7. Again the agreement is excellent, and consistent with the molecular principal axis being aligned at 14.6 degrees to the velocity axis.

![Figure 7](image)

**Figure 7**

Quadrupole splittings, $\Delta v$ versus Deborah number, obtained from deuterated benzene in 350 kDaotn PDMS, using a selected region of the horizontal Couette cell in which the velocity direction (solid circles) and gradient direction (open circles) are respectively parallel to the magnetic field. The lines are fits using the Doi-Edwards model in which the horizontal axis is scaled to yield the tube disengagement time, $\tau_0$.

![Figure 8](image)

**Figure 8**

Quadrupole splittings, $\Delta v$ versus orientation angle, $\Phi$, at a fixed Deborah number of $\gamma_0 = 3.9$. The solid line shows the predictions of the Doi-Edwards model. The images show the selected regions used to obtain $\Phi = 0^\circ$, $45^\circ$, and $90^\circ$.

These examples provide a glimpse of possible applications of Nuclear Magnetic Resonance to the study of complex fluid rheology. While this is a very new field of research in which only a handful of groups presently participate, the potential exists for a substantial increase in Rheo-NMR research activity. Systems studied to date include polymer melts and semi-dilute solutions, thermotropic and lyotropic liquid crystals and liquid crystalline polymers, micellar solutions, food materials and colloidal suspensions. Rheo-NMR suffers in a number of respects by comparison with optical methods. It is expensive, it is difficult to use, it suffers from poor signal-to-noise ratios and the effective interpretation of spectra often depends on familiarity with the nuclear spin Hamiltonian and the associated effects of spin dynamics. Nonetheless NMR offers some unique advantages, including the ability to work with opaque materials, the ability to combine velocimetry with localised spectroscopy, and the ability to access a wide range of molecular properties relating to organisation, orientation and dynamics. Rheo-NMR has been able to provide a direct window on a variety of behaviours, including slip, shear-thinning, shear banding, yield stress behaviour, nematic director alignment and shear-induced mesophase reorganisation. The unique information available with this method suggests that it is likely to become an important tool in elucidating the intriguing rheological behaviour of a wide range of complex fluids.

**Acknowledgement**

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References

The testing of aircraft models in wind tunnels gives valuable insight into aerodynamic behaviour. Although much of aircraft design is now accomplished using computational fluid dynamics, wind tunnel testing is still necessary to validate these models. Pressure measurement has previously been limited to a few key locations on the model where mechanical pressure transducers could be placed.

The recent advent of pressure sensitive paint means that optical measurement of the pressure over the surface area of the object is now achievable. The front cover shows a wind tunnel model of an F-16 fighter jet covered with a paint formulation that fluoresces under short wavelength excitation. As the pressure is increased, collisions between oxygen and the painted surface cause fluorescence quenching. The change in fluorescence intensity can then be used to generate a pressure map of the aircraft's surface.

Roper Scientific digital CCD cameras were used to record the fluorescence image. A critical requirement for the cameras was large format pixels with corresponding large full-well capacity. The large full-well capacity allows the maximum signal-to-noise to be achieved, which is necessary in order to measure the small changes in fluorescence intensity.

Roper Scientific cameras are used in all of the world's premier wind tunnel testing facilities. Multiple camera control from a single host computer, accurate and calibrated response, and a reputation for reliability in demanding environments are just a few of the reasons why these cameras are used.

Roper Scientific is represented in Australia by Coherent Scientific Pty. Ltd. For contact details, please refer to the Roper Scientific advertisement on the rear cover of this edition.

NEW HIGH-POWER DPSS MICROLASERS

CARLISBAD, California — The Melles Griot Laser and Electro-Optics Group has developed a new family of cw diode-pumped solid-state (DPSS) micro lasers that produce up to 400 mW output at 457 nm. These new lasers, designated the 58 BLD series, are designed specifically for critical OEM applications where small size, low power consumption, hands-off operation, and rock-solid reliability are critical. The compact, air-cooled laser heads are less than ten inches long, including cooling fan and heat sink, and total power dissipation is only 100 W.

The 58 BLD series micro lasers are available with specified output of 100 mW, 200 mW, and 400 mW. The output is linearly polarized. Beam quality is excellent, with an M2 factor of less than 1.2, amplitude noise of less than 3 percent, and pointing stability as low as 7 mrad/hr.

The wavelength of the 58 BLD series micro lasers is virtually identical to the important 457.9 line of the argon-ion laser. Dean Hodges, director of business development at the Laser and Electro-Optics Group, has been closely associated with the development of these lasers. According to Dr. Hodges, "For the first time, there is an extremely attractive alternative to a mid-size water-cooled argon-ion laser for deep-blue and violet applications."

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Two major reports on science in Australia have recently been released.

A CHANCE TO CHANGE

The Chief Scientist's Science Capability Review has been greeted with enthusiasm by Australia's scientists and technologists. Professor Sue Serjeantson, President of FASTS, said Chief Scientist Robin Batterham has identified many of the outstanding science issues where Australian investment lags behind other countries.

"Basically, it's a terrific report," she said. "Robin Batterham is spot-on in his analysis of where we need to invest so Australia can build itself a future. The Report is a clever balance, calling for greater national investment in people, in ideas, and commercialisation. We do need to find new ways to do things. Robin Batterham has set a clear direction for Australia's Modern Economy."

Professor Serjeantson said the Review picked up almost all the issues FASTS has been urging the Government and industry to act on over the past five years. "We are pleased to see calls for:
- increased investment in basic research
- measures to stop the brain drain
- boosting science education for our kids
- investment in national innovation infrastructure"

"The Reports as it stands is literate, but it’s not yet numerate," she said. "It needs dollar figures added." She urged the Government to move swiftly to implement the recommendations of this Review when it resumes in late August.

"The next decade belongs to Science and Technology. The world is undergoing a revolution bigger than the industrial revolution," she said. "That is what the Chief Scientist recognises. The Review is a blueprint for exciting jobs for our young people."

The discussion paper, The Chance to Change, and further information about the Review can be found at:
www.isr.gov.au/science/review
Responses should be addressed to:
The Manager
Australian Science Capability Review
Department of Industry Science and Resources
GPO Box 9839
Canberra ACT 2601
or
S.Clough@isr.gov.au

A copy of the Executive Summary and its 11 major recommendations is below.

Executive Summary (near-final draft)

Innovation - The Only Way Forward

"OUR LIVES WOULD BE UNIMAGINABLE WITHOUT SCIENCE"

Science, engineering and technology underpins our future as a thriving, cultured and responsible community.

The return to community from investing in Australia's SET base will be:
- An economically strong and prosperous nation
- Acceptance at the highest scientific levels internationally
- A responsible, informed and responsive society

Innovation - the only path forward

Innovation is the driver of every modern economy; it is the key to competitiveness, employment growth and social well-being. The cycle of innovation must be fed by new ideas and basic knowledge, and be capable of being transferred and accepted by end-users.

Our international partners and competitors are investing heavily in their SET bases. Clearly the pace of development is quickening. For Australia to participate and thrive, we must, first, be part of this international process, and, second, be committed to developing an innovation process for pursuing scientific advances and implementing them successfully.

What Must Change

Without additional strategically driven investment, it is likely that the SET capability will lack the critical mass needed for the future. Simply increasing funding based on the status quo, however, will not ensure a more seamless and active innovation process.

We need a SET capability that is an integral part of the national innovation capability and can adequately support economic and social goals in the 21st Century.

Our competitors in other countries are also showing the way. Their governments are viewing the systems which generate and translate knowledge into wealth as the primary focus of sustainable economic development. The themes of investment which are emerging are:
* Culture
* Ideas
* Commercialisation

CULTURE

People matter. Without people, Australia has no vision, no ideas and no SET base to create and anchor ideas and turn them into products and processes which enhance the quality of our lives. The SET base is reliant upon people who have progressed through a supportive educational system, from primary school through to tertiary, and beyond. As well, people in SET need to have the skills to communicate with the business world and with the rest of the community.

The culture needs to change. We need more support for those who inspire our children to study science and maths. We need to encourage more of our young people to consider studying science in tertiary institutions and we need those students to have a broader range of skills than they currently have, to prepare them for exciting projects in the business world.

Science and innovation need a transparent framework of public support within which they can flourish. Public awareness and involvement in SET are important.

IDEAS

Ideas have the potential to dramatically change the way we live. Ideas, when translated, can improve our health, sustain our environment, help us communicate better and quicker. Australia needs to create environments in which the best ideas are identified quickly and easily, to promote our contribution to the global knowledge pool and to respond to business and community needs. A much larger commitment to the ideas generation process needs to be made, both in terms of financial support for the SET base in universities and CRCs and the broad research infrastructure.

Excellence must be combined with relevance in a successful modern public sector research environment.

We need to create:
* new and innovative mechanisms by which ideas are translated into achieving societal goals and economic growth;
* new ways of linking infrastructure strengths and pooling scarce resources; and
* new ways of ensuring that excellent research raises the profile of Australia internationally.

COMMERCIALISATION

The ultimate measure of success in innovation is the value placed on it by consumers and the community. Integrating the innovation system across all points can increase the chance of
Commercialisation
- Expand the CRC program to encourage greater SME access and to facilitate stronger networks between the SET base and industry, nationally and internationally;
- Establish a small number of Innovation Centres to provide universities and Government funded agencies with support in commercialising research;
- Establish a pre-seed capital fund for universities, Innovation Centres and government funded research agencies, such as CSIRO, RDCs and CRCs; and
- Universities and government research agencies review opportunities for researchers to better share in the benefits of commercialisation with particular encouragement for formation of start-up and spin-off companies.

Implementation
Investment is, by nature, a risky business. To justify the investment proposed in this discussion paper, close scrutiny and sound measures of accountability are required to maintain public confidence in the SET system. As well, monitoring the SET system will enable government to respond more quickly to priority needs. The community needs to know that the return on its investment will lead to improvements in quality of life. To implement the plan for increasing Australia’s return on investment in the SET base, an implementation committee should be formed, chaired by the Chief Scientist, to ensure that the recommendations of the Review accord with government and community objectives. The Science Capability Implementation Group would, therefore, report to the Prime Minister’s Science, Engineering and Innovation Council on progress with implementation.

INNOVATION SUMMIT IMPLEMENTATION GROUP
BLUEPRINT FOR JOBS
The report of the Innovation Summit Implementation Group (ISIG) has been greeted warmly by Australia’s scientists and technologists. Professor Sue Serjeantson, President of FASTS, said all attention will now be on the Government to see how it responds.

“The Government has two important reports on the table, those of ISIG and Chief Scientist Robin Batterham. Together they provide an integrated package for an innovative modern economy,” she said. “And taken together, they set out a blueprint for Australia’s future in what will be the most competitive century in modern history. David Miles (Chair of ISIG) and Robin Batterham have pointed Australia in a bold new direction. It is up to Australia to take advantage of their wisdom.”

Professor Serjeantson said that many of ISIG’s 24 recommendations have long-term national implications. “To be fully effective, these recommendations need the broad support of all parties,” she said. “There is room for healthy debate over which road we take, but we need national agreement on the destination. That destination has to be an Australia whose employment future rests on the bedrock of science and technology.

“It’s hard to think of worthwhile, high-pay, sustainable jobs in the coming century that do not depend on science and technology. Unless we embrace the general thrust of these reports, we are putting in jeopardy the job prospects of the next generation and the one after that. Australia will become a curiosity, a cute place for tourists to admire the wildlife.”

Professor Serjeantson said that earlier this year, FASTS urged the Government to introduce a mini-Budget to address this most urgent of national problems. “We repeat that call. Australia’s competitive position in the world pecking order has sagged in the last few years, and we can’t afford to let it slip further,” she said.

She said FASTS particularly applauded ISIG proposals to
• double the funding of the Australian Research Council
• provide tax breaks for small innovative companies
• give a massive boost to research infrastructure

“But this is a package,” she said. “It’s not a matter of picking and choosing among the recommendations - they fit together as a plan for future jobs.”

“SCIENCE MEETS PARLIAMENT”
DAY 2000

Australian scientists will be arriving in numbers at Parliament House, to meet with the Members and Senators who represent them in Canberra. “Science meets Parliament” Day will be held on Wednesday November. The event enables Parliamentarians and scientists to exchange views on how to make the best use of science and technology in the national interest.

It comes at a time when important political decisions are being made about science and technology, with the Government considering its response to the Batterham Review and the Innovation Summit Implementation Group.

“Science meets Parliament” Day is organised by the Federation of Australian Scientific and Technological Societies (FASTS). Professor Sue Serjeantson, President of FASTS, said both scientists and Parliamentarians enjoyed the first such event held last year. “We need
more political savvy among scientists," she said. "Scientists and technologists know they have to operate in a political world. At the same time, we need more scientific savvy in our politicians. They need a clear view on the potential and limitations of science and technology."

Professor Serjeantson said FASTS is working with senior MPs from Government and Opposition parties to make the event a success. The Minister for Industry, Science and Resources Senator Nick Minchin, the Opposition Science and Resources spokesperson Mr Martyn Evans, and the Democrat spokesperson for Science & IT Senator Natasha Stott Despoja all support the event.

The Day itself is preceded by a day of briefings, where participating scientists will talk strategy and tactics at the National Press Club. Briefing Day on Tuesday October 31 features a lunchtime address by Dr Neal Lane, Assistant to the President for Science and Technology and Director of the White House Office of Science and Technology Policy.

Professor Serjeantson said FASTS expected that 200 scientists and technologists, and most members of the Senate and the House of Representatives will participate. "Our scientists really enjoyed the Day last year. They learned a lot about Parliamentarians and the pressures and constraints that operate in their lives," she said. "And I think Parliamentarians have a new respect for scientists and technologists, and their determination to make Australia a better place."

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Georgina Statham, Jonathon Burdach, Simon Roberts and James Welch
Third place was tied between teams from Elizabeth College and a second team from the Hutchins School. These teams comprised:
Andrew Swan, Daniel Hugo and Craig Steer (Elizabeth College) Arthur Pitman, David Bell, Oscar Potter and Sutha Manoharan (Hutchins)
A special prize, newly founded by the CSIRO Marine Laboratories in Hobart, went to Nicole Morse of Marist Regional College for correctly identifying Lise Meitner in a "Who am I" style question. The quiz is made possible by sponsorship from Comalco Aluminium (Bell Bay) Ltd., Australian Antarctic Division, CSIRO Marine Laboratories, Bureau of Meteorology (Hobart), Queen Victoria Museum and Art Gallery Planetarium and ComputerLand.
Details of the quiz with all the questions and some photos can be found on the branch web page at http://www.phys.utas.edu.au/physics/AIP_TasBranch/default.htm.
Marc Duldig

TASMANIA
The Tasmanian Branch held two public lectures with the AIP Women in Physics lecturer, Michelle Simmons. The first talk was at the Queen Victoria Museum in Launceston on Friday 1st September and the second was on Monday 4th September at the Physics Department of the University of Tasmania. Attendance in Launceston was disappointing but the Hobart lecture was well attended. Media coverage on ABC radio was excellent state wide and a report appeared in the Hobart Mercury newspaper several days after the event. Michelle's talk was very well presented. It was informative and explained difficult concepts in a clear and understandable manner that was appropriate for the general public. During her visit to Tasmania Michelle also delivered a lecture to the University's first year physics class.

On Saturday 9th September the Branch held its annual physics quiz for year eleven and twelve students. The quiz takes the form of six rounds of 10 questions. At the end of rounds 1, 2, 4 and 5 there are "Who" or "What am I" style questions with clues read out until a correct answer is given. This allows the markers time to mark and tally up scores before the next round. These questions were all related to the centenary of the foundation of quantum physics (Planck's constant, neutrino, laser light, Louis de Broglie). After round 3 there is a break for refreshments. The quiz is held alternately in the north-west, north and south of the state and this year it was held in Launceston at the Launceston Church Grammar School. First place went to a combined team from the Hutchins School and Collegiate and comprised:
Eric Daniel, Michael Shaw and Toby Ekins from Hutchins and Sarah Hewer from Collegiate.
Second prize was a team from Launceston Church Grammar School comprising:
INHARMONICITY, NONLINEARITY, AND MUSIC

N.H. FLETCHER
Research School of Physical Sciences and Engineering
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Western music is based upon the sounds of instruments with repeating waveforms and harmonic frequency spectra. While strings and pipes come close to this ideal, they achieve it only because of the influence of great levels of nonlinearity in the sound generating mechanism. Bells and gongs, on the other hand, generally have very inharmonic spectra, and when significant nonlinearity is present it leads to phenomena such as pitch glide, frequency-multiplication cascades, and transition to chaos.

The music with which we are all familiar is based upon simple principles. Musical instruments produce sounds in which the overtones are exact integer multiples (harmonics) of the fundamental, and two notes sound pleasantly together if their fundamental frequencies are in the ratio of two small integers — 2:1 for an octave, 3:2 for a perfect fifth, and so on. And the reason why this works, we have all been told, is that the vibrational modes of taut strings, and of the air in cylindrical or conical tubes, have frequencies that form a simple integer progression, albeit a progression of odd integers in the case of a cylindrical tube stopped at one end.

If you have examined the subject a little further, you will know that even this simple prescription has its difficulties, for it is not possible to step out a sequence of fifths and get back to an octave of the note you started from, simply from the prime number theorem, which says there are no integers n and m such that 2^n = 3^m. We return to discuss scales, harmony and music in the final section of this piece, but for the moment we concentrate upon physical phenomena.

Let us return to strings and tubes for a moment. Are the overtones of a real string really exact harmonics of the fundamental? The answer is “no”, and the reason is that a real string is not infinitely flexible. For an ideal string, indeed, the frequency f_n of the n'th mode is nf_1, while for a simple stiff rod f_n = (n + ε)^2 f_0 where ε depends upon the way in which the ends of the rod are fixed and has a value in the range ~0.5 to +0.5. Putting these effects together in a fourth-order differential equation, we find that the modes of a real string have frequencies like

\[ f_n = nf_1(1 + \beta n)^{2/3} \]  

(1)

where β depends on the elastic modulus, radius and tension of the string. A skilled piano tuner adjusts the string tensions so that there is no beat between the string being tuned and the second mode of the string an octave below it, with the result that all the octaves are slightly stretched above a 2:1 ratio, the total stretch being nearly half a semitone over the compass of the piano.

Much the same thing occurs in the resonance of air columns in tubes, though for a different reason. The acoustic length of a tube, as is well known, is greater than the geometric length by a small additive quantity called the end-correction. For an open end, this correction is about 0.6 times the tube radius. The complication is that the end-correction depends on frequency and decreases towards zero as the frequency is raised, effectively vanishing when the sound wavelength is equal to half the circumference of the tube. The upper modes of an open pipe are therefore higher in frequency than true harmonics of the fundamental, the behaviour being very like that given by equation (1) above. This effect is even more exaggerated for a partly-open pipe termination such as the mouth of an organ pipe or the blowing end of a flute.

Sustained-Tone Instruments

All this would cause us no concern except for the experimental fact that the sounds made by sustained-tone instruments such as violins, flutes and clarinets have exactly repeating waveforms. This can be demonstrated only over half a minute of so by an actual player, but for an indefinitely long period using a belt-bowung machine or a compressed air source and, as we all know, a repetitive waveform consists of precise harmonics of the fundamental. How can these be generated from modes that are quite significantly inharmonic? The surprising answer is “by nonlinearity”!

Figure 1 shows a system diagram for a sustained-tone instrument. A power source (the player) provides a steady flow of mechanical or pneumatic energy to a sound-generating mechanism (the bow in contact with the string, or the reed-valve on a clarinet) that is closely coupled to a slightly inharmonic resonator. The player controls this resonator by moving fingers along a fingerboard or by opening holes or valves in the resonator, and can also control the bowing speed and force or the air pressure delivered from the power source. There is feedback from each part of this system to its neighbours and to the player. Rather surprisingly, it turns out that the sound power actually generated by the instrument is typically less than 1 percent of the input power, most of which is wasted in viscous and thermal losses along the way.
With one exception that we come to later, the resonator is driven at a level sufficiently low that its response is linear, but this is not true of the sound-generating mechanism. Indeed it is the nonlinear behaviour of the sound generator that makes the whole instrument function properly - we might term it “essentially nonlinear.”

Consider first the reed generator in a clarinet, as shown in Figure 2. The air pressure in the player’s mouth causes a flow of air through the reed opening that is proportional to the square root of the pressure drop and directly proportional to the area of the opening between the reed and the mouthpiece. At the same time, this applied pressure tends to close the reed opening, so that the actual volume flow \( U \) has the form

\[
U = A \Delta p^{1/2}(1 - B \Delta p)
\]

where \( A \) and \( B \) are constants and \( \Delta p \) is the difference between the blowing pressure and the pressure in the instrument mouthpiece. The form of this curve is shown in the figure. In acoustic terms, the pressure can be considered the analog of electric potential and the volume flow the analog of current, so the slope of the curve gives the acoustic conductance of the reed valve. The first important thing is that this conductance is negative when the blowing pressure exceeds one-third of the pressure required to completely close the reed, so that for pressures above this threshold and below the closing value the reed valve can act as an acoustic sound generator. The second thing of note is that the slope of the curve varies with pressure, so that this negative driving resistance has a nonlinear behaviour.

Much the same thing happens for the lip-valve of a trumpet player, except that here the mouth pressure tends to force the lips apart instead of closed. It turns out that what is required to make the lips act as a generator is a change in the phase of their motion relative to the acoustic pressure, and this is brought about by having them driven a little above their resonance frequency, while the reed of a clarinet is driven well below its resonance. The details need not concern us here, except to note that, once again, the flow is a nonlinear function of pressure.

Flute-like instruments are rather different and more complex in behaviour, and depend upon wave propagation on an air jet. The important thing from our present viewpoint is that, when this air jet reaches the sharp edge of the mouth-hole in the instrument, it can do not more than blow completely into or completely outside of the lip. Thus, while flow into the instrument is a linear function of acoustic disturbance at small amplitudes, it saturates for large jet displacements in either direction.

**Nonlinear Mode-Locking**

Let us briefly examine the behaviour of a linear resonator driven by a nonlinear negative-resistance generator. Suppose the angular frequencies of the resonator modes are \( \omega_n \) and that they are not in harmonic relationship. Then the behaviour of the \( n \)th mode is governed by an equation of the form

\[
x_n'' + k_n x_n' + \omega_n^2 x_n = g(x_m, x_m')
\]

where \( k \) is a damping coefficient, \( g \) is a prime indicates differentiation with respect to time, and \( g \) is a nonlinear function of all the mode amplitudes and velocities. There are potentially contributions to \( g \) from all modes \( m \), and there is an equation of this form for each of the modes. Notice that the right-hand side of (3) depends solely upon the values of the mode amplitudes \( x_m \) and their time derivatives, and that if \( g \) is positive it contributes a positive damping that can balance out the term \( k_n x_n' \) on the left-hand side. If this happens, the system breaks into self-excited oscillation.

While this looks complicated, it turns out that it is quite easy to find a solution by writing \( x_n = a_n e^{i(\omega_n t + \phi_n)} \) and assuming that both \( a_n \) and \( \phi_n \) are slowly varying functions of time. We can then find explicit expressions for both \( da_n/dt \) and \( d\phi_n/dt \) as time-integrals of \( g \) multiplied by \( \cos(\omega_n t + \phi_n) \) or \( \sin(\omega_n t + \phi_n) \) respectively, and from these we deduce a shift in the actual frequency of mode \( n \) to a new value \( \omega_n + d\phi_n/dt \). The extent of this frequency shift is proportional to the magnitude of the terms in \( g \) that are in-phase with \( x_n \) and that have frequency...
close to $\omega_n$. Similarly, the rate of change of amplitude is proportional to the terms in $g$ that are in-phase with $x_n'$. In systems with nearly harmonic modes, the simplest and most important of these terms arise from quadratic combinations of the form $x_n x_m$ with $\omega_n + \omega_m = \omega_n$. It turns out that, provided the nonlinearity is large enough, the system will settle down after an initial transient to a state in which the modified frequencies are in simple integral relationship, giving a repetitive waveform and a harmonic frequency spectrum.

Since the pipes of an organ are included among the instruments just discussed, we conclude that their sound spectrum is precisely harmonic and that the octaves on an organ should be in exactly 2:1 ratio. This is confirmed by examination of the tuning of these instruments. An organ does not go well with a piano!

All this may not sound like a big deal for a simple pipe with nearly harmonic modes, but for most notes on a woodwind instrument there are several finger holes open along the length of the pipe, and measurements show that there are several modes that are in nothing like harmonic frequency relationship. If the nonlinearity is not large enough, then two or more of these modes may be excited independently, and the nonlinearity will then produce multiple sum and difference frequencies. The result is a non-harmonic chord-like sound termed a multiphonic. These sounds are much loved by those modern composers who are unable to write melody or harmony, but otherwise have only a very limited place in music.

Brief mention should also be made of a completely different nonlinear effect that occurs in instruments such as trumpets and trombones when played very loudly. Measurements and calculations show that in this case the internal sound pressure level can be as high as 175dB, which is equivalent to about 10kPa or one-tenth of normal atmospheric pressure! Under these conditions, sound waves propagating along the narrow cylindrical bore of the instrument develop into shock waves with steepened wavefronts. This effect transfers energy from low to high frequencies and gives the incisive tone quality that we associate with these instruments.

**Bowed-String Instruments**

Consider now the bowed string of a violin. The frictional force between the bow and the string is a function of relative velocity, as well as of the normal force which we take to be constant. Static friction is higher than dynamic friction, and there is a smooth decrease in the coefficient of friction with increasing relative velocity. This situation is illustrated in Figure 3. Since the slope of the friction vs velocity curve is uniformly positive, more energy is supplied to the string when moving in the same direction as the bow than is lost when its motion is reversed, so that the frictional contact acts as a negative mechanical resistance. The slope of the curve is, however, not constant, and indeed the force has a catastrophic reversal of sign when the string velocity equals the bow velocity. Mild nonlinearity on the gently sloping part of the curve becomes pathological when the string catches up with the bow!

While we can employ the same mathematical analysis set out above to this case, it is actually easy to see how the extreme nonlinearity leads to mode-locking and a repetitive waveform. The string simply sticks to the bow for a large part of each oscillation cycle and then slips rapidly to the further extreme of its motion, giving a repetitive waveform.

Both Helmholtz and Raman are among those who investigated bowed strings in detail, and there has been much recent progress using computer analysis of the motion. There is a well-defined range of possible bowing speeds, for a given bowing position along the string and a given normal force, within which the stick-slip mechanism works well. Outside this range, despite the extreme nonlinearity, mode-locking fails to occur, and we experience the excruciating sounds made by some beginning violinists!

From this discussion and that in the previous section, we conclude that the sustained-tone instruments upon which Western music is based have repetitive waveforms and harmonic frequency spectra. In a later section we return to consider the influence that this has had upon the development of music.

**Impulsively Excited Strings**

Musical instruments such as the guitar, the harp and the piano are based upon the impulsive excitation of taut strings by a plucking or hammering action. The energy supply is thus disconnected from the string after the initial excitation, and the only nonlinearity that remains is that inherent in the oscillating string itself. If the string tension is low and its elastic modulus high, then the tension can be significantly increased by the stretching involved in an oscillation of large amplitude. This extra tension raises the vibration frequency of all modes and causes the string to “twang” unpleasantly as its frequency drops during the decay of the oscillation. For this reason, among others, guitars usually use nylon strings with rather low Young’s modulus, while the steel strings of pianos are tensioned to almost their breaking point.

Apart from this minor nonlinear effect, impulsively excited strings oscillate with a combination of modes that have fre-
quencies given by equation (2) above and amplitudes that are determined by details of the pluck or hammer impact. The nylon strings of a guitar are not appreciably inharmonic, but the steel strings of a piano have stretched octave modes so that the scale of the whole instrument must be slightly stretched, as discussed above. The scale of a harpsichord is very little stretched because the strings have very small diameter.

**Bells, Gongs and Cymbals**

Percussion instruments of the drum family need not concern us here, interesting though they are, but we concentrate on those instruments made from metal. Bells are perhaps the most familiar, and produce a more-or-less harmonious sound, depending upon their design. Tradition plays a large part here, and the shapes of Western bells have evolved over many centuries. The vibration amplitude of the bell is so small, and the stiffness of its thick cast metal so great, that nonlinearity is insignificant and the bell sounds its characteristic mode frequencies. As many as six modes frequencies are adjusted during manufacture by turning metal off the inside of the bell on a vertical lathe, and the result is a sequence like 1/2, 1, 6/5, 3/2, 2... the nominal pitch being 1 and the octave below that being the “hum” note. The presence of a minor third interval, 6/5, is what gives to a bell its characteristic sound.

The thick-walled metal gongs of the Indonesian gamelan are similarly uninfluenced by nonlinearity, but their mode frequencies are very far from being in harmonic ratio. As we discuss later, this leads to a characteristic gamelan scale that is different from the familiar Western scale but, since the decay time of these gongs is quite short, harmonics are not very much in evidence in their music.

The two small gongs of the Chinese Opera have quite a different sound. They consist of a nearly flat central portion, surrounded by a shallow conical section and terminated by a turned-down rim. They are struck centrally with a padded stick to excite just the fundamental mode. The larger of the pair has an exactly flat vibrating section, and large oscillation causes appreciable radial tension which raises the vibration frequency just as in a string. When the gong is struck vigorously, the frequency therefore starts high and falls back towards its small-amplitude value as the sound decays, the pitch glide being as much as a major third (5/4). The smaller gong, on the other hand, has a central portion that is very slightly domed - only about 1mm over its 100mm diameter - and this is just enough to reverse the behaviour, so that the pitch glides up instead of down. Analysis of the radial stress shows why this occurs.

More interesting from our present perspective is the large Chinese gong or tam-tam, which makes occasional appearance in Western symphony orchestras. It is typically about a metre in diameter and nearly flat, though closer examination shows a raised central hump, a turned-down edge, and several circles of hammered bumps. When struck in the centre with a large padded stick, it gives out an impressive sound that starts as a low-pitched simple tone and develops over several seconds into a high-pitched shimmering gloss. Examination of the development of the spectrum over time, as shown in Figure 4, shows that energy is indeed transferred from a low-pitched centro-

![Figure 4. Sound spectrum of a Chinese tam-tam immediately after being struck, and after the lapse of 3 seconds. Note that the initial low-frequency peak has disappeared, and energy has been transferred from it to high-frequency modes.](image)

symmetric fundamental mode into a multitude of high-frequency modes distributed towards the edge of the gong.

Again we see nonlinearity at work. Excitation begins with a simple central mode at frequency $f$. Because the gong is made from thin metal and vigorously excited, it develops significant radial tension forces that oscillate at twice the frequency of the mode concerned, and thus at $2f$. When this tension stress encounters a sharp change in slope, as at the rings of hammered bumps, some of its energy is transferred to the next part of the surface as a transverse vibration at this doubled frequency. In addition, it can interact in the same place with the original mode, giving an excitation at $3f$, and can similarly interact with all other modes present. The result is a cascade of energy to progressively higher frequencies, just as our ears inform us.

The behaviour of cymbals is rather similar, except that they are normally supported in the centre and struck near the edge with a hard stick, thus exciting the higher modes immediately. Perhaps surprisingly, both the tam-tam and the cymbal appear to exhibit chaotic behaviour in their final vibration. Interesting examination of this can be made by exciting the gong in its centre using a sinusoidal shaker with variable amplitude and frequency. Experiments of this kind show regions of period-doubling, behaviour, period multiplication by other factors such as 3 or 5, and ultimately a transition to chaos.

**Implications for Music**

Since this is a discussion of physics rather than of music, there is space for only a brief note on the implications of what we have seen. The aim of music is to produce pleasant sounds, and what is pleasant depends on human auditory perception. For two simple sinusoidal sounds played together, frequency differences of a few hertz are not unpleasant, but simply produce a rhythmic fluctuation in loudness. When the frequency difference approaches 20Hz, however, our ears cannot follow
the time variation and we hear an unpleasant rough sound. For still greater frequency differences, we hear the two tones individually, and it makes little difference what their relative pitch- 
ess are. Perhaps surprisingly, musical intervals such as octaves of fifths do not show any greater degree of concord.

When we come to complex sounds, the degree of concordance can be evaluated by summing the effects of all pairs of partial tones interacting with each other. If the initial sounds are harmonic, as for sustained-tone instruments, then the pair will sound well together when their fundamental frequencies are in the ratio of two small number, like 2:1 (octave), 3:2 (fifth), 5:4 (major third), and so on, for then there are no beats between their harmonics and so no roughnesses. Very slightly out-of-tune intervals are tolerated because slow beats do not worry us too much, but differences of only a few hertz in the fundamental frequency translate to differences of 15-30Hz in some of the higher partials and give unpleasant discords. For this reason, the Western musical scale is based on small-integer frequency ratios, and “playing in tune” is critical. As mentioned at the beginning, we run into trouble when we try to devise a fixed scale that will work in more than a single musical key - but that is another story.

If we begin with sounds that are not harmonic, but do have a regular structure, like the sounds of bells or of gamelan gongs, then the same principles of concordance can be used to construct scales in which notes played together on these instruments sound pleasant. Musicians in the societies concerned have evolved these scales over the centuries, but it is now possible to construct them as a scientific exercise for any arbitrary sound spectrum, simply by minimising the dissonances between upper partials.

Further Reading

There are many places where more information about the matters discussed here can be found. In particular, a recent survey by the present author [1] covers the whole subject in some detail, and a book [2] gives extensive information about the physics of musical instruments. Both these sources give extensive references to the literature. Finally, a recent book by Sethares [3] gives an excellent account of harmonic and inharmonic musical scales, and even goes so far as to construct a scale based on the diffraction spectrum of morphine!

References


AUSTRALIAN SCIENTIST RECEIVES RECOGNITION FOR SURVEY MEASUREMENT ADVANCES

The International Association of Geodesy (IAG), which governs large-scale geographical measurement, has adopted a significant advance in the accuracy of surveying which was made by an Australian scientist.

Philip Ciddor, an honorary fellow at CSIRO's National Measurement Laboratory, developed new equations while on the Association's working party. His research was carried out in consultation with colleagues from several countries, including Dr RJ Hill of the National Oceanic and Atmospheric Administration in the United States and Professor JM Rueger, Associate Professor of Surveying at the University of NSW.

Modern surveying is carried out by measuring the time taken by light to travel over the distance being measured, a kind of “optical radar”. While the speed of light is constant in a vacuum, it varies with the composition and conditions of the atmosphere.

The equations commonly used to correct for this variation were based on outdated data. Errors of one part in ten million were occurring which caused problems in measurement of large distances, for example from the earth to man-made satellites.

The new equations are being applied to geodesy where distances are measured through the atmosphere between terrestrial stations or to satellites. Last year the International Association of Geodesy (IAG) adopted the new equations by recommending them to the surveying community for use in the most accurate measurements, such as measuring distances to the moon and artificial satellites and in synchronising atomic clocks around the world.

Accuracy in distance measurement is vital for many aspects of geodesy and is being applied to satellite communication, meteorology and mining. The work’s importance lies in it being an international collaboration which can be applied to a range of applications, including the study of slight variations in the orbits of the earth's satellites.

The IAG working party is making further studies, including the effect of varying amounts of carbon dioxide in the atmosphere, the influence of molecular resonance lines of water vapour, and a revision of the analogous equations used for radio-frequency waves.

Dr John Luck, Director of SLR Network Management in AUSLIG (Australian Surveying and Land Information Group) last year instituted the working group of the International Laser Ranging Service to study formulae for atmospheric corrections applied to Satellite Laser Ranging. Luck says Ciddor's work is of fundamental importance in all aspects of distance measurement using electro-magnetic radiation at radio, optical or laser wavelengths.

An incidental outcome of Ciddor's research was that the uncertainty of the measured speed of light in standard atmospheric conditions set a limit to the measurement of the diameter of silicon spheres used at CSIRO's National Measurement Laboratory in developing an 'atomic kilogram'. This resulted in the apparatus used to measure the spheres being set to operate at a pressure of a few percent of normal conditions, scaling the underlying uncertainty to an acceptable level.

Most recently Ciddor's research has involved a consideration of the validity of some of the basic equations that describe the optical properties of gases, including a classical experiment performed in the National Physical Laboratory in Britain in the 1930s.

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PROFESSOR SIR MARK OLIPHANT

Sir Mark Oliphant, who died on 14 July, founded the Research School of Physical Sciences of the ANU and was one of those who pioneered the creation in Canberra of a national university dedicated to the conduct of research at the highest international level. A tall, handsome man, with a shock of white hair, and a distinctive voice and laugh, he was well informed on a wide range of scientific matters and expressed firm views on their social consequences. He enjoyed wide respect throughout the nation as a great Australian scientist.

Mark Oliphant was born in Adelaide on 8 October 1901. Always good with his hands, he supported his studies at Adelaide University by working as a cadet in the Physics Department. After completing his Honours degree, he commenced his research career by working on surface tension with Dr Roy Burdon. Oliphant’s interest in modern physics was greatly stimulated by the visit to Adelaide of Ernest Rutherford, the New Zealand-born physicist who was, at that time, head of the famous Cavendish Laboratory in Cambridge. Following Rutherford’s visit Oliphant obtained an 1851 Exhibition Scholarship that took him to Cambridge.

When Oliphant joined the Cavendish, the laboratory contained a number of brilliant young physicists, most of them FRS’s in the sight of God, and several actual or potential Nobel Prize winners, including John Cockcroft, who became Oliphant’s closest friend and a future Chancellor of the ANU. Oliphant worked directly with Rutherford, building a new accelerator and carrying out fundamental work on nuclear transmutations, for which he was made a Fellow of the Royal Society in 1937. His work on nuclear reactions with the isotopes of hydrogen was particularly important and forms the basis for the production of nuclear fusion energy, still one of the Holy Grails of energy research.

Oliphant had done excellent work with Rutherford in Cambridge but wanted to run his own show and in 1937, despite Rutherford’s strong objections, he accepted the Chair of Physics at Birmingham University, and began the construction of the largest cyclotron in Europe. But, as Britain prepared for war, Oliphant was one of a small number of mainly ex-Cavendish men who were informed of Britain’s secret radar work. He and his group in Birmingham made an outstanding contribution to British radar research by developing the cavity magnetron, which provided a source of centimetre wavelength radiation for airborne radar.

Otto Frisch and Rudolf Peierls were physicists of German origin, working in Birmingham. Because of their status, Oliphant could not arrange for them to join in the secret radar program. But they could work on nuclear fission and the practicality of constructing an atomic bomb. Frisch and Peierls wrote a famous letter, in which they calculated that the critical mass of a fission bomb could be as little as a few pounds of separated fissile material. Oliphant recognised the importance of this conclusion and was able to introduce the Frisch-Peierls letter to senior defence science officials in Whitehall, and then in the United States. The British atomic energy group, including Oliphant’s team, eventually transferred to the United States and Canada. Oliphant’s skill and determination, and his friendship with the American cyclotron physicist Ernest Lawrence, were important factors in the establishment of the Manhattan Project and the development of the atomic bomb.

At the end of the war, Oliphant returned to the task of completing the Birmingham accelerators. There were also exciting opportunities offering in Canberra, where a new, national, research university was being planned. Oliphant accepted an invitation to join the group of senior academics in the UK that was providing academic advice on the new university. The advisers were eventually offered appointments as directors of planned research schools in the university. Only Oliphant accepted. He frequently repeated Howard Florey’s comment at the time that all he could expect to find would be a “hole in the ground” and a mountain full of promises. Oliphant was enthusiastic about developing a new accelerator in Canberra. He was always interested in the possibility of new designs and wanted to build machines that stretched technology to the limits. His ambition was to construct a novel machine that would operate at a higher energy than any other machine in the world but which, at the same time, could be built at a fraction of the cost. He did not like large teams and looked back nostalgically to the machines that he and research students had built in Cambridge. The Canberra machine went through a number of design changes and name changes, including the cyclo-synchrotron, the synchro-cyclotron and the proton synchrotron, but was not completed as an accelerator. An unfortunate accident, in which one person was blinded, occurred with the NaK (sodium/potassium) system of the homopolar generator, the power source for the accelerator. The generator was rebuilt using carbon brushes in place of NaK and completed as a stand-alone machine, which was used as a high-power source for a range of plasma and laser experiments. In addition to leading the work of his own group in high-energy accelerator physics, Oliphant, as Director, expanded the work of the research school in astronomy, mathematics, geophysics, theoretical physics, atomic and molecular physics, nuclear physics and particle physics. The research school became a major centre for Australian research and postgraduate training in the physical sciences. After he retired as Director, Oliphant returned to some of his earliest work on the interactions between positive ions and solids.

In 1971, Sir Mark Oliphant began a new career when he was appointed Governor of South Australia, a post he filled with dignity and distinction. He spoke very strongly in favour of environmental issues, especially in defence of the Adelaide Hills, and of the perils of nuclear armaments. Sir Mark’s personal life was touched with sadness but he always had the loving support of his family, especially that of his gentle wife, Rosa, and his daughter, Vivian.

John Curver
I have counted it a real privilege to have collaborated this tribute to a former colleague who served as President of the Institute [1979-80]. Bert was Professor of Theoretical Physics at Monash University from 1962-86 having previously been a Senior Lecturer in Physics, University of Newcastle, UK [1951-62] and Lecturer in Physics at Nottingham University [1946-51].

It was originally my intention to weave all of the contributions below into a single story but once I had read them all, it became clear that they should be reproduced as they stood. I have not attempted to remove duplication because it reinforces the traits that stood out for all to see. Together they form a wonderful portrait of a distinguished scientist, a loyal colleague and a great friend to many of us.

Excerpt from Bert's Funeral - John M Swan

"Many have asked me to speak at this service, at which we honour and farewell our friend and colleague Professor Bert Bolton. I do so with both pride and sorrow. We feel a deep loss at his passing; we can all be proud to have known him and to have shared his companionship.

Bert was much loved by his immediate family, cherished by his grandchildren, admired and respected by his many friends and colleagues and praised for his many contributions to his physics, his mathematics, and the history and philosophy of science. Bert was always willing to help others - many colleagues brought their problems to his door and Bert's mathematical insights would often lead to novel solutions.

He was a truly gentle man, a man of worth and integrity - an English gentleman. He was my friend and colleague for more than thirty years. I never heard him make an unkind or uncharitable remark or criticism of any other person. Quiet?, yes. Modest and self-effacing?, yes. Kind, thoughtful and caring?, yes. A true scholar and outstanding teacher?, yes. In every way, a man to be admired and respected. He taught himself to read and speak German. He was an outstanding calligraphist, a gifted musician, a very fine pianist and accompanist. I once practised the Handel recorder sonatas with him and he somehow took all my errors of timing in his stride. He found great joy in assisting his granddaughter Sarah with her music.

Bert came to Australia from England in 1962 as the Foundation Professor of Theoretical Physics at Monash University. He served the University splendidly and in countless ways, always with the full support of Mary, Mary made one of her interests an active involvement with Lady Matheson's group of wives who worked hard to welcome new staff and assist them to settle into the rapidly growing Monash campus. Bert contributed not only to his university but also to his science and the wider community - he was at one time President of the Australian Institute of Physics.

During my nine years as Dean of the Faculty of Science I developed a strong and enduring friendship with Bert, and relied on him greatly for wise advice and counsel. His constant help to me was always characterised by what was best for the University, its students and graduates, never tainted by a sectional concern for his own discipline. Bert truly understood and epitomised the ideal of the University as a self-governing community of scholars with one central aim - high academic excellence.

I am glad to record that Bert was never happy with the concept of a university as a successful business enterprise, where the students most cherished are those who can pay the maximum fees.

When the Faculty of Science introduced a scheme to give special attention to our most gifted scholars, Bert was in the forefront of acting as a personal tutor and mentor to the first-year students invited to join this scheme, a task he undertook with enthusiasm. I can remember him telling me, on one of our lunch-time walks around the campus, how much pleasure he was getting from this involvement. He was truly an inspiring teacher.

If any of his former students are with us today, I am sure that when we gather together later, after this service, they will testify to his warmth and humanity. The atmosphere will be rich with our shared memories, his spirit and example will be with us not only today but in the years to come. If heaven is a space of eleven dimensions, not the mere four we know here on Earth, Bert will be rejoicing at now truly comprehending the ultimate mysteries of quantum electrodynamics, quantum chemistry and string theory.

I often thought of Bert as a successor to Alfred North Whitehead, the great British mathematician and philosopher. In 1917, just four years before Bert was born, Whitehead published his collection of essays entitled "The Aims of Education". I quote just one sentence from these essays, one that Bert would have applauded: "The justification of a university is that it preserves the connection between knowledge and the zest for life by uniting the young and the old in the imaginative consideration of learning". Bert Bolton’s learning was always highly imaginative.

In the latter part of his career, Bert became more and more interested in historical studies - some family and social history, but mainly the history of scientific enterprises and scientific instruments, and especially the making of scientific instruments in his adopted State of Victoria. He was a member of, and chaired for some years, the Advisory Board of the Australian Science Archives Project within the University of Melbourne, an enterprise which has now grown to become the Australian Science and Technology Heritage Centre.

After his retirement from Monash in 1986 he was welcomed as a Principal Research Associate within the Department of History and Philosophy of Science at the University of Melbourne. The day following the first indication of his final illness, the paralysis of his right hand, he made a special trip to Melbourne to undertake formal farewells to his many friends in DFIPS, some of whom he had known earlier as colleagues at Monash.

Bert and I had found much in common - an interest in nature, bird watching and bush walking, music, the love of family and friends, and especially the excitement and stimulation of new discoveries in science. In recent years we often walked in Wattie Park - the pleasures ranged from seeing Tawny Frogmouths at their nest, to unusual fungi, the theory of elastics and the evolution of species.

I could say so much more, and I am sure that all of us here have individual memories, stories and anecdotes to warm our hearts and preserve Bert's spirit amongst us. I believe we must learn in Australia to honour all our great achievers, in addition to the AEL footballers, tennis players and Olympic athletes. We need to remember what true academics like Bert Bolton have achieved, to use their lives as..."
examples for those who will come after us, to take pride in what they have contributed to our society.

I thought Ian McWilliam and his family expressed it perfectly in their notice in Wednesday's newspaper -

"When we saw the eagle soaring we will think of you, The finest, kindest, wisest man we knew."

I hope I have provided you with a portrait of a man who has been a quiet achiever, a man of worth, a man deserving to be honoured in memory, not just by his family, close friends, and former students and colleagues, but by the much wider community.

Tribute from a long-standing friend and colleague - Bob Street

"Bert was a distinguished student and member of the teaching staff in Physics at King's College, London during and for a period after WWII. He had lively recollections of stirring times there when Maurice Wilkins and Rosalind Franklin were involved with the Double Helix/DNA saga. He was there when the sad and idealistic Alan Nunn May (does anyone remember him now?) was arrested on atomic bomb secrets charges, as legend has it, when giving a Physics lecture. During his time in London Bert became a member of the prestigious Thames Rowing Club. He was proud of the fact that he was Coach of the King's College Women's Eight and of Nottingham University Boat Club.

Bert and I were Assistant Lecturers together in the Department of Physics at Nottingham. LF Bates who had worked with Rutherford in Cambridge was Head of the Department. Bates was proud of the fact one of his appointees - Bert - achieved the highest mark ever awarded by the University of London in the Honours Physics examination. Our starting salaries were £350 per annum for which we were required to give six lectures a week (including Saturday mornings) and undertake 12 hours undergraduate laboratory demonstrating. We had all the time in the world, some of which Bert and I spent in attending classes in the University in Russian and Italian languages. Bert was far more successful and determined than I was as subsequent events were to prove. Bert was a rock climber and we amused ourselves sometimes by clambering up a usually muddy and minuscule rocky fissure in the grounds we called Lunch Time crack.

Bert and another Assistant Lecturer who was born in Austria spent many evening hours in the Department reading page by page the standard German language text 'Ferromagnetismus' by Becker and Doring. Their work could well have been the basis of a definitive translation but this was not to be. Bert moved back to his birthplace when he joined the Department of Physics at Kings College, Newcastle on Tyne, later Newcastle University where W.E. Curtis and later Keith Runcorn was head of Department. Runcorn made a significant contribution to Rock Magnetism. At Newcastle Bert met Stanley Rushbrooke who provided a great stimulus for his later interests in Statistical Mechanics and who became a good friend sharing his interests in walking, climbing and ornithology.

Bert was appointed to the Chair of Theoretical Physics at Monash University when I was Chairman of the Department and thus began a life of distinguished service to Science at Monash and more widely throughout Australia. In my view Bert during his lifetime did not receive the recognition he really deserved no doubt due in part to his innate self-effacing modesty. He came to Melbourne for interview in January 1962 at a time of high temperatures generally in Victoria accompanied by serious bushfires in The Basin in the Dandenongs. He brought Russian texts to read on the plane. In those times it may have been fortunate that his nearest neighbour travelling companions did not include members of ASIO. He stayed with us and we did our best to compensate for the large temperature gradient between Newcastle and Melbourne by providing him with day and night cooling fans. The irony of the situation emerged when he discovered, on his return at Heathrow on his return journey to England, that he had misplaced his overcoat somewhere along the way and spent some cold and miserable hours in an unheated compartment in a train back to Newcastle. During his interview visit he was received with the hospitality which was the hallmark of the early Monash days. He visited the Matheson's beach house at Mt Eliza and much to the astonishment and admiration of Louis Matheson, the visionary first Vice Chancellor of Monash, spent what seemed to be an eternity swimming slowly and deliberately up and down parallel to the shore. Bert impressed our then young children by performing cartwheels and other gymnastic feats for them.

Bert was always interested in ideas and the problems they posed. I think it is this quality which led to the achievements for which he will long be remembered and honoured. His analytical skills provided experimentalists from the University, CSIRO and other organisations with theoretical contributions that added to the clarity and significance of joint publications. He was a great connoisseur of words and took great delight in solving fancy crossword puzzles, savouring long after the event many particularly choice clues. He loved books and I was a fortunate beneficiary of this. He found in a Melbourne bookshop a book published in 1834 on 'Fly Fishing' that he had bound and then most generously gave to me. On another occasion he gave me a copy of "The Mechanical Production of Cold" by

JA Ewing of magnetic hysteresis fame. Bert had a delightful and subtle sense of humour and I have wondered if this gift was inspired by his hot first visit to Melbourne.

Bert was all his life a great seeker and recorder of information. His later publications on the lives and works of some who have made important contributions to Australian Science and Technology are testimonies to his interests and skills. In the tradition of his historical heroes he kept commonplace books throughout his life. A worthy editing task awaits some fortunate author."

Tribute from a more recent colleague - Rod Home

"Bert had a well-developed historical curiosity that led him first into genealogical research and then to the history of science. In 1981 his good friend John Swan persuaded him to join the Bicentenary History Committee being set up by the Australian Academy of Science (and chaired by John) to oversee the Academy's contribution to the nation's bicentenary. Bert played an active role in the committee's work, above all in organizing the first of two very successful conferences on the history of science in Australia that were held at the Academy during the 1980s, that helped generate a wider interest in the field and that eventually led to the publication in 1988 of the book Australian Science in the Making (CUP).

Bert was a founding member and later for ten years Chairman of the National Advisory Board of the Australian Science Archives Project (now the Australian Science and Technology Heritage Centre) set up at the University of Melbourne in 1985. Following his retirement from Monash, he threw himself enthusiastically into the Project's work, getting his hands dirty as a member of various expeditions to rescue important but sadly neglected collections of records documenting Australia's scientific past. He also became a registered valuer of archival materials relating to the history of science and technology, and in this way, too, helped secure the preservation of historically important sets of records.

In 1989, Bert's commitment to the history of science led to his being appointed a Senior Associate (later re-styled Principal Fellow) in the Department of History and Philosophy of Science at the University of Melbourne. He became a familiar figure in the Baillieu Library and around the HPS Department, especially at the Department's regular Tuesday seminars, and at Friday departamental lunches at University House at which he was a constant source of fascinating topics for discussion. The Friday lunch ten days before he died was probably his last social outing: he clearly had an inkling of what was happening inside him, and he came to say goodbye.
Bert published a large number of papers on historical topics in the years after he joined Melbourne HPS, many of them in The Australian Scientist. The majority dealt with Australian topics. As time went on, his research focused more and more on the history of scientific instruments and instrument-making in Australia, on which subject he established a long-running and very fruitful collaboration with Nicola Williams (Chemistry, Monash). Bert was a technically adept, hands-on historian who studied the instruments themselves and their operation, as well as the documents surrounding their manufacture and distribution. His particular passion was optical instrumentation, including the diffraction grating ruling engines built by Henry Grayson in the first years of the 20th century, by William Stone in the 1930s, and at CSIRO Chemical Physics in the 1960s—on all of which he had publications to his credit—and the superb instruments built more recently by his friend Bill James. He worked hard to see to the preservation and display of historically significant items at both Melbourne and Monash Universities.

Tribute to a long-standing Monash colleague - Denis Coates

"Bert never retired. He simply continued his intense curiosity about the everyday world, constantly setting himself problems and tackling them with physical insight and elegant mathematical methods. He studied the distribution of birds in the coastal habitats of Balnarring on Westernport Bay, and worked with Alan Roberts to make sense of his data. He wrote about the night-time propagation of sound from breaking waves on the Balnarring shore. When asked by one of his grandchildren, "How far is it to the horizon?" he was able to produce a paper which he had written on the subject.

He wrote about Wright ("The Painter of Light") in the context of the English Enlightenment and became curious about the arrangements of the planets in Wright's The Orrery.

Bert was a student of the history of Australian Science and Technology, particularly of the history of instruments and their makers. He felt strongly that skilled craftsmen, such as Bill James, who made the first corrector plates for the prime focus of the Anglo-Australian Telescope, should get their due. I collaborated with Bert on a biographical paper about James which puts him into context with optical craftsmen elsewhere in the world and which provides a complete list of James' many major projects.

Bert was a true scholar and gentleman. He was a kind and wise man, not given to enmity. However he was deeply troubled by the damage he saw being done to Universities by attacks on the spirit of free enquiry and open publication. He will be greatly missed."

Re Bert's interest in the history of instrumentation - Nicola Williams

"Doctoral work on dielectric constants at microwave frequencies had led to the quantum mechanical analysis of electrical polarisability of many-electron atoms and molecules and then to theoretical solid state problems. This was needed at Monash where the early direction of research in physics was in experimental and theoretical work on solid state physics. Many theoretical problems were based on statistical mechanics with special emphasis on phenomena at critical temperatures. The Flame Ionisation Detector [FID] used widely in Gas Chromatography was developed in Australia by I G McWilliam and R A Dewar at ICINZ. With McWilliam, general problems of the design of detectors and possible distortions were examined in several papers culminating in a Proc. Roy. Soc. article in 1971. The theory of the FID was established leading to experiments on the mass spectrometry of flame ions.

A long-standing interest in the history of science gradually grew and, because of the sympathetic academic atmosphere, a series of articles on historical topics was written, especially on the scientific instruments made in Australia in the 1939-45 war. Bert noted the contribution of Henry K. Grayson to the construction of ruling engines from 1890 to 1918, and this led to tracing the history of optical research in Australia. As the scientific links between Britain and Australia were weakened during WWII, the physics community in Australia worked independently on optical munitions. Regrettably the optical industry established during the war did not survive the competition from Japan in the post war era.

Bert’s interest in the history of scientific instrumentation in Australia also included astronomical, optics, electrical instruments and many types of measuring apparatus, particularly slide rules, 'pre-chip' calculators, scales and balances.

My collaboration with Bert led to a more comprehensive approach to Australian-made instruments, focussing on analytical balances, for which the early impetus was due to the gold rushes of the 1850's. Early work in numerical computing was also identified. I will always recall the morning coffee conversation Bert and another colleague had in May 1965 when the ARGC had just been announced and we had two days to prepare applications! The search for magnons using the Raman effect in crystals was dreamed up that day. Magnons were not found but Raman scattering as a research topic outlived Bert's time as Professor of Theoretical Physics, for about 30 years in fruit!"
Towards a Happy Ending

Good technical writing is not an easy task. And editing the product, whether it be a report, paper or thesis, can also be a painful process. For such sufferers a powerful anodyne is now to hand in the form of "The Craft of Editing", by Michael Alley. It is described on its cover as a guide for managers, scientists and engineers, which means that technical writers as well as editors will profit from reading this book.

The approach Alley takes is almost conversational, with pearls of editing wisdom presented very understandably, laced with pertinent anecdotes from his own experience, primed by amusing quotations from great writers, and spiced with cautionary tales of those who, despite warnings, failed to thoroughly proof-check their final word.

I know I’ve been there, done that. And when the result appears in unalterable print, felt the pain.

The 150-odd pages of "The Craft of Editing" may be read in less than a day. It is a hard book to put down. From then on it is good to have around to be dipped into for advice. It quickly becomes a desk-side companion to anyone who does much writing and editing. In this regard the excellent 50-page appendix "One Hundred Problems of Style" will be well thumbed, until eventually its advice becomes second nature. Which reminds me that Alley does not make a big deal about split infinitives. There are far more important problems to pay attention to.

"The Craft of Editing" is not encyclopedic like Fowler’s "Modern English Usage", but far friendlier. In fact I have found it so enjoyable I must try to find Alley’s earlier work, "The Craft of Scientific Writing", if only for the pleasure of reading it.

"The Craft of Editing" is published by Springer-Verlag, New York, priced at US$19.75 in soft covers, and bears the ISBN 0-387-98964-1. Department heads should buy at least two copies: one to loan to each writer and one chained to the office for reference.

Colin Keny
Reviews Editor

An Introduction to the Standard Model of Particle Physics

W N Cottingham and D A Greenwood
xviii + 235 pp., AUS29.95 (hardback)
ISBN 0-521-58832-4

Cottingham and Greenwood find a very clear way to present the Standard Model. Their book starts from discussion of quantum fields that, in the following consideration, describe leptons, quarks and their interactions. This discussion includes the classical equations of motion and the corresponding Lagrangians for the scalar, spinor and electromagnetic fields. Quantum properties of these fields are addressed mostly in the simplest, tree-level approximation which is sufficient for the following consideration. Quantum fluctuations, which have strong manifestations (some of them are mentioned in the book) are addressed only briefly. This fact may prompt a dedicated reader to pursue studies in this direction.

The book introduces the non-Abelian gauge symmetry for the SU(2) and SU(3) gauge groups, which are necessary for formulation of the Weinberg-Salam theory and quantum chromodynamics, the two theories which, comprising the Standard Model, describe electroweak and strong interactions. The book addresses also relevant fundamental theoretical ideas: the Higgs mechanism, asymptotic freedom, confinement, and quantum anomalies.

Reading it demands an undergraduate level of quantum mechanics and mathematics, although necessary mathematical details are introduced in appendices.

Numerous problems supplementing the text should help to follow its presentation more closely. Predictions of the Standard Model are compared with experimental results, which so far comply with the theory and make the subject attractive for everybody interested in modern particle physics. This book gives a clear and concise introduction into this interesting area.

Michael Kuchiev
School of Physics
University of New South Wales

Fully Chaotic Maps and Broken Time Symmetry

Dean J Driebe
x + 164 pp., US$37.00 (hardcover)
ISBN 0-7923-5564-4

This rather nice little book is really about chaos and irreversibility, but as its title suggests it is a mathematical introduction to the most recent developments in that area. It leads the reader through the spectral decomposition of the Frobenius-Perron operator for the tent map, logistics map and finally the baker map.

The key point is that the forward time dynamics tends to smooth probability densities along the unstable directions but produce singular distributions along the stable directions. This is the broken time symmetry and the key to the resolution of the irreversibility paradox. Essentially one must consider ensembles rather than individual trajectories, an idea that goes back to Boltzmann.

The importance of these results has yet to filter down to the physics community in general but this book is an important step in that direction, as is another more physical book by Dorfman. The most important book in this area is the recent comprehensive treatment by Gaspard. Gaspard is the leader in this field and it is his work that forms the bulk of chapter 5 of the present book. Considering that Gaspard’s own book is only an extra US$13 it is hard to imagine why a student would buy the present volume.

Unfortunately Driebe’s presentation has a foreword by the leader of one of the great personality cults of our time. This does little to enhance the book and may well deter many people from reading it. The sooner science returns to ideas, rather than personalities, the better!

G. P. Morris
School of Physics
University of New South Wales

Principles of Fluorescence Spectroscopy (2nd Ed)

J R Lakowicz
Kluwer / Plenum, New York 1999
xxiii + 698 pp., US$85.00 (hardcover)

This is a physically impressive book comprising nearly 700, almost A4 sized, pages printed in double column and weighing 2kg. It contains a detailed description of
fluorescence spectroscopic techniques applicable to biochemical research. The author is well published in the field and is the editor of the Journal of Fluorescence. The first edition of the book (1983) was based on a graduate-level course in fluorescence spectroscopy. The second edition maintains the "basic concepts from their fundamental origins" approach while updating the examples to include more recent results.

The first two chapters "Introduction" and "Instrumentation" provide an excellent, informative, summary of the field, which uses fluorescent probes to detect specific components of biomolecular substances. The remaining chapters expand on the techniques in considerable detail.

The field is extensive and the methods employed interesting, e.g., the quenching of fluorescence due to the binding of caffeine to human serum albumin, "an experiment most of us start each morning".

The book is full of information and each chapter has extensive reference lists.

From the perspective of a text book, I found that while the general narrative tone of the author is instructive, very little of his own enthusiasm is transferred to the reader. In general, there is too much hand holding and re-emphasising the obvious, including sections of text that are simply repeated. I would have preferred a more compact format and perhaps, the development of a theme of instruction.

Overall the book is a useful reference resource for those interested in biological fluorescence.

As an aside, my research on this topic uncovered the URL http://www.probes.com/handbook/sections/0069.html which provides an excellent introductory description of fluorescent probing techniques.

Steve Gibson
UV Physics Unit, RSPSE
Australian National University

Count Rumford
G I Brown
Sutton Publishing, Stroud UK 1999
ix + 182 pp., AS$44.95 (hardcover)
ISBN 0-7509-2184-6

"Scientist, Soldier, Statesman and Spy" proclaims the cover of this slim volume. It outlines a full and fascinating life lived at a time of war and violent social change. It also reveals an unusual character, at once quixotic and persistent, caring yet self-centered, someone who disliked (and was disliked by) many people, but loved humanity.

Throughout a turbulent and colourful career Rumford had conducted scientific experiments, mainly connected with the transfer of heat and often in a military context. It was one of his scientific observations of the heat generated during the boring out of military cannons that he was able to show there was a relationship between heat and work. His knowledge of heat transfer led him to design more efficient fireplaces and cooking arrangements as well as warmer army uniforms. He was also knowledgeable about lighting, inventing a photometer "...to determine...the most economical method of lighting up a very large workhouse...".

Count Rumford was born in rural Massachusetts in 1753 as plain Benjamin Thompson and grew up and married in the shadow of the War of Independence, where he spied for the British. In 1776 he fled to London but after a brief return to New York to lead the King's American Dragons, he found himself again in Europe, head of the Bavarian War Department and, still in his 30s, a Count of the Holy Roman Empire, Knight of the White Eagle. In Bavaria he initiated a remarkably successful series of social, military and economic reforms whose effects are still evident. With Sir Joseph Banks, Rumford founded the Royal Institution for the Advancement of Science, an effort motivated by his conviction that science had a part to play in everyday life.

While weaving an enjoyable tale of intrigue, adventure and romance, this book is more a chronicle of events than the more lively narrative tale that the subject deserves.

David Malin
Anglo-Australian Observatory
Epping

The Wandering Astronomer
Patrick Moore
IOP Publishing Ltd, Bristol 1999
208 pp., UK£19.95 (hardcover)
ISBN 0-7503-0693-9

Did you know that on 9 June 1933 an unsuccessful attempt was made to launch a rocket towards Australia from Germany? This was, however, not an early trial of an intercontinental ballistic missile, for this rocket was meant to reach its destination by travelling vertically in a straight line. It was in fact an attempt to prove a theory that we live in the interior of a hollow Earth, the outer shell of which constitutes the rest of the Universe.

The Madgeburg Experiment is but one of many remarkable stories Patrick Moore tells in this book. Brief essays, written with the author's customary clarity, cover a wide spectrum of astronomical topics. Some essays relate to modern research like the discovery of an isolated brown dwarf while others recount fascinating historical tales. One such tale discusses what Moore calls "ghost moons", the many false reports in the search for satellites in the solar system.

There are a few errors that detract from the book. For example, on page 30 the moon's motion away from the Earth is explained as
due to the conservation of energy, not that of angular momentum. And on page 97 nine
times the mass of Jupiter is stated as equalling eight percent of the mass of the Sun, which is an
error of a factor of ten. I would have hoped that such a prestigious publisher as the
Institute of Physics would have taken a little more care in proofreading. Still, in spite of
these minor concerns I can thoroughly recommend this entertaining and informative
book to professionals and non-professionals alike.

Nick Lomb
Sydney Observatory
Powerhouse Museum

The Quantum Mechanics Solver
J-L Basdevant and J Dalibard
Springer-Verlag, Berlin 2000
xi + 241 pp., DMT79 (hardcover)
ISBN 3-540-63409-6

The authors have collected here exam problems in quantum mechanics given at the
Ecole Polytechnique and the Ecole Normale Superieure over the last 15 years or so. They
were given after one semester of quantum mechanics, each as a four hour exam. Most
candidates covered 75% of the problem, and 5% to 10% gave a correct and
correct answer. In the Australian context I would say the problems would be relevant to third
and honours year classes.

Each of the 27 chapters provides background for a problem, presents it in a stated way, and
joy of jokes, gives a complete solution. Many of the problems are topical (Ch.3, “Neutrino
oscillations”, Ch.14 “Quantum cryptography”; Ch.24 “Properties of a Bose-Einstein
condensate”), and together they range widely over quantum physics. I’ll have it next to me
while writing my next quantum exam. I will also consult it when looking for applications to
help student’s comprehension.

However I found the introduction to Ch.9, “ Exact Results for the Three-Body Problem”
strange. The first two sentences read: “The three-body problem is a famous question of
mechanics. Newton actually quit physics because he found it too difficult”. Newton
quit physics? Although his productivity plummeted in his later years, even in his
seventies he produced revised editions of “Opticks” and the “Principia”, despite
running the Mint and the Royal Society.

I recommend this book for the library of any
institution teaching quantum mechanics.

Craig Savage
Physics Department
Australian National University

Scientifically Speaking -
A Dictionary of Quotations
C C Gaither and A E Cavazos-Gaither
Institute of Physics Publishing, Bristol 2000
xiv + 482 pp., UK£19.95 (Paperback)

This dictionary of quotations is a fairly scholarly tome that devotes a fair slice of
space to discussions of the nature of science, in a philosophical sense. As a result, the
quotations are actually fairly meaty paragraphs that, while interesting in their own
right, are not particularly quotable. There are also a number of extracts from poems, such as
Gray (“Elegy”), Edgar Alan Poe and Pope.

The book is split into over 80 sections, with
headings such as Axioms, Beauty, Chaos etc.
Obviously a result of much research, this book
will likely to be of great use to those studying
the philosophy of science (though see below).

The Bibliography alone is over 30 pages, and
the book would be a good jumping off point
for the literature surveyed.

For the casual reader, a downside of the
collator’s approach is that there is a distinct
shortage of snappy quotes that a reader could
use to advantage at dinner parties or in
speeches. I confess, though, that I did like “The
philosophy of science is as much use to
scientists as ornithology is to birds.” (Author
unfortunately unknown.)

There are some famous quotes you won’t find
in this volume. Perhaps the most notable is
Einstein’s oft-misquoted “The theory
produces a good deal but hardly brings us
closer to the secret of the Old One. I am at all
events convinced that He does not play dice.”

Nor will you find Weinberg on the
countlessness of the cosmos, Crick and
Watson’s famous understatement at the end of
their seminal paper, or even Clarke’s Law.

There is a companion volume to this work
listed “Physically Speaking: A Dictionary of
Quotations on Physics and Astronomy” that I
suspect would be of more interest to readers of
this journal.

Andrew Davies
Department of Defence, Canberra

Mathematics of Wave
Propagation
Julian I. Davis
xv + 395 pp., US$49.50 (hardcover)

Authors of books about waves must decide
what level of mathematical background to
assume and which waves to use as examples
and for motivation. Davis assumes
mathematically sophisticated readers and
chapter two, “Partial Differential Equations
of Wave Motion” gives a good treatment of
characteristics theory, perhaps suitable for
Australian honour’s or graduate students.
Chapter three, specifically on “The Wave
Equation”, is less demanding and treats
standard topics such as superposition
principles and D’Alembert’s Solution.
Chapter one, “Physics of Propagating Waves”
follows a clear and concise introduction to
wavelengths. However, given the emphasis
there in later chapters, a more accurate title
would include the words “in Continuum
Dynamics”.

The book’s strength is its mathematical
derivations from fundamental principles of
formalisms for wave motion in continuous
systems, essentially stress waves and fluid
waves. The treatments of Viscoelastic Solids
and Thermoelastic Media are major,
important topics (and suggest that this book
may be of most interest to certain specialist
applied mathematicians and engineers).
Exploration of wave phenomena per se is
limited with virtually no reference to
experimental results.

The final chapter, “Variational Methods in
Wave Propagation”, seems disconnected from
the rest of the book and is mostly about
particle dynamics rather than waves. It very
briefly discusses quantum mechanics and the
analogy between geometrical optics and
mechanics.

In summary, there is some unusual and
interesting material in this book and it could
be a useful reference text.

Colin Pask
Department of Mathematics
Australian Defence Force Academy
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- CMP    Condensed Matter Physics
- AINSE/NUPP  18th AINSE Nuclear and Particle Physics Conference
- SASTA  Australian Conference for Teachers of Physics
- AOS    AOS2000 – 13th Conference of the Australian Optical Society
- ASGRG  Australian General Relativity Workshop – Australasian Society for General Relativity and Gravitation
- PLASMA Plasma2000 – 23rd AINSE Plasma Science and Technology Conference
- WIP    Women in Physics
- MP     Medical Physics

- Public Lecture by Paul Davies – Tue 12 December, 7:30 pm
- Harry Massey Medal Lecture by Professor Tony Thomas – Mon 11 December, 5:45 pm
- Bragg Gold Medal Lecture by Dr Ping Koy Lam – Wed 13 December 10:15 am
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CONFERENCES & MEETINGS

2000

Nov 15-17  ACOUSTICS 2000
Joondalup Resort, WA
Contact: Tien Saw, Ph: (08) 9458 0028 or 0418 915 464
tiens@barclayeng.com.au
www.curtin.edu.au/cmst/aasconference/

Nov 24  ASB 2000
24th Annual Scientific Meeting
University of Melbourne
Contact: Dr Frances Separovic Ph: (03) 8344 6464 Fax: (03) 9347 5180
Email: f.separovic@chemistry.unimelb.edu.au

Nov 26-28  Australian Institute of Nuclear Science and Engineering (AINSE)
Radiation 2000, incorporating 20th AINSE Radiation Chemistry
Conference and 17th Radiation Biology Conference
AINSE, Lucas Heights
Contact: Irene Parker, Conference Manager, Ph: (02) 9717 3436
Email: ainse@anso.gov.au

Dec 3-8  CCP2000 Conference on Computational Physics 2000
Gold Coast, Queensland
Contact: CCP2000 Secretariat, c/o Prof. Peter Drummond, Dept. of Physics,
University of Queensland. Ph: (07) 3365 3405 Fax: (07) 3365 1242
Email: CCP2000@physics.uq.edu.au

Dec 6-8  Conference on Optoelectronic and Microelectronic Devices,
COMMA 2000, Melbourne
Contact: Dr. Brian Usher, Electronic Engineering, La Trobe Uni
Ph: (03) 9479 3745 Fax: (03) 9479 3025 Email:
busher@ee.latrobe.edu.au
A/Prof. John Riley, Physics, La Trobe, Ph: (03) 9479 2629
Fax: (03) 9479 1552 Email: j.riley@latrobe.edu.au

Dec 10-15  AIP 2000 CONGRESS
(Incorporating OzCuPE, STISP, VSA, AMPOC, CMP, AINSE/NUPP,
SASTA, AOS, ASGRG, PLASMA, and ASA)
University of Adelaide
Contact: Stafford Conference Management
128 Fullarton Road, Norwood SA 5067
Tel: (08) 8364 1005 Fax: (08) 8332 8810
email: enquiries@staffords.on.net

2001

Jan 15-26  14th Canberra International Physics Summer School
Biophysics: From Proteins to Cells
ANU
Contact: Dr Serdar Kuyucak, RSPhysSE, ANU, Canberra ACT 0200
Ph: (02) 6249 2969 Fax: (02) 6249 4676
Email: sek105@rsphysse.anu.edu.au

Jan 30 - Feb 2  25th Condensed Matter Meeting ("Wagga")
Marlborough Sounds, New Zealand
Contact: www.vuw.ac.nz/content/ww01/

July 15-20  15th International Conference on Ion Beam Analysis (IBA-15)
(Incorporating 12th AINSE Conference on Nuclear Techniques of Analysis)
Cairns
Contact: Rob Elliman, ANU
Fax: (02) 6251 0672; Email: iba2001@anu.edu.au
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