1989 WARK LECTURE
WHAT AILS PHYSICS
OBITUARY: A. J. TAVENDALE
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Cover: Sample display from Vaisala's lower tropospheric wind profiler DORA 400L. Main uses are local weather forecasting, aviation, pollution monitoring and boundary layer research.
This is the season for annual dinners, so allow me to tell you about one at which the guest speaker decided to expound on the subject of what is wrong with the world. He did so very eloquently for the allotted 15 minutes and received enthusiastic applause at the forcefully argued conclusion that the cause of all our ills is ignorance and apathy.

"What do you think of that?", one of the guests was asked by the lady at his side. Slightly flushed, with wine glass in hand, he was succinct and to the point. "Frankly, my dear", he said, "I don't know and I don't care!".

Well, what's wrong with physics in the world? Do we know and do we care? Of course we know what's wrong with physics in Australia, and of course we care. I said in last month's column that we are overworked, underpaid, starved of resources and persecuted by the likes of Rambo Dawkins and, in the Government sector, by equally destructive but slightly better camouflaged people. In the private sector it is the get-rich-quickly, short-term, bottom-line, cost-accountant's mentality that is the enemy. But is that all that's wrong? No. Here are a few more ills that beset the profession, not just here but worldwide.

First and foremost, the profession is getting fragmented, 'Balkanised', as one observer put it. Now the Vacuum Society is having off, before that it was the Optical Society, the Medical Physicists, the Astronomers... pretty soon there won't be any physicists left! Unless we stick together and realise that there is a lot of specialisation in physics (to which we all welcome a few interlopers such as engineers and technicians), and that the AIP can play an important role as the umbrella-organisation serving the various specialisation groups. At least, that is how I see the resolution of this particular problem.

Another problem, closely related to the first one, is the threat that we will be taken over, piecemeal. Consider what happened to philosophy, once the queen of sciences. The secular movement led to its losing theology, and good riddance they said! Natural philosophy was also hived off early, leaving only temporary vestiges. Philosophy of the mind became psychology and flew the coop. Logic became usurped by mathematicians and ended up in computer science.

Finally the poor philosophers were left with only a few remnants such as ethics and aesthetics... subjects in which opinion threatens to overtake knowledge. Even here, there are claims by theologians and medics in the one can land art and architects in the other. Schools of philosophy have been decimated worldwide whereas only yesterday they used to lay the foundation for courses in the liberal arts.

In the case of physics, engineers may have some prior claims in mechanics and applied thermodynamics, but consider what happened to electromagnetism, then electronics, then chunks of solid state physics, even aspects of nuclear physics. The corresponding professionals would now call themselves engineers of one sort or another and enjoy the protection of strong 'trade unions'. Nowadays it seems fashionable to fill chairs in electrical and/or communications engineering with physicists specialising in optics. Is optics the next piece to fall off the back?

The response may be: Good! Let it! Glad to be of service! From the point of view of the profession, however, it may be healthier if we retained our claims over these specialised areas of our subject but strengthened the professional identity of physicists. The creation of professional grades such as Chartered Physicist or Professional Physicist in the AIP has been suggested here (based, obviously, on overseas models). We hope to discuss this issue at the next Council Meeting, to be held in Perth just before the Congress, and would welcome any comments from individual members as well as State Branches.

Whatever we do, we must recognise that, from the beginning, the AIP has had the dual function of a 'learned society', on the one hand, with the aim of promoting the development of the subject of physics, and of a 'profes-

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**WANTED**

Interesting transparencies or good colour photographs to be used for the *Physicist* front cover.

Please send submissions together with a descriptive caption to:

**Executive Editor**

*Australian Physicist*, PO Box 189, Jemond NSW 2299
SO ENDETH THE DECADE.....

We come to the end of another year, and invariably we reflect on what the past year has delivered and what the new year is likely to offer. Sometimes that can be a depressing activity. Consider 1989 and what it has offered for physicists in Australia.

If you work for CSIRO you are likely to have been restructured yet again and may have even had a name change (or two). You are likely to have been told that your work is in need of an industry input and this must be achieved. Unfortunately industry will not have been told of the contributions physicists can provide since those contributions are usually of longer term benefit. Your position in industry has probably been filled by yet another money-mover.

If you work in education, particularly the tertiary sector, you have probably been amalgamated with another institution or two. You are uncertain of what the future holds for your part of the new all-encompassing Dawkinsian model Institution. Your students in 1989 were at best no worse than those in 1988 but so few of them came with the zeal to be physicists (or even chemists or mathematicians). Your contact load has probably increased, you are still searching for good graduate students but finding it terribly difficult to contend with the almost daily changes in the working rules associated with recruiting such students. And you are under pressure to expand the universities' intake of full fee paying overseas students.

In physics?

If you are in industry you are probably wondering yet again whether to do accountancy or economics at night. Personal management is also an alternative.

On the grant front, the ARC reports a record year in terms of money available but can fund only the best 20% of applications. Your university has had its funds reduced to provide this money for the ARC but where is your share? There are murmurings of 'priorities' and 'concentration of effort' forcing you into shotgun marriages with colleagues with vaguely related interests.

On the salary front, what is there to be happy about? Remember the days when the benchmark for your salary was the Commonwealth Second Division Public Service or the salary of a backbench member of Parliament? Your counterparts overseas, even in England, earn more than you do—'banana republic' is not a joke any more. Your colleagues in other Departments enjoy salary loadings and accelerated promotion, even if they are not active in research.

What else? The National Board of Employment, Education and Training has determined that we spent too long on our Masters and PhDs. In the future, graduate students can have 1.5 years to get a Masters and 3.5 years to get a PhD. Our students' employability is also under threat.

ASTEC decrees that Australian Physics has had it. We no longer produce enough papers and our overseas colleagues do not pay enough attention to our work. We have almost given up hope to access to major facilities such as a synchrotron. The former Department of Science (did it really disappear so long ago?) has had its view that our equipment is antiquated and we need a massive injection of capital equipment grants vindicated by ASTEC's comments (and by the Green Paper and the White Paper).

We remain a net importer of PhD graduates while the few we produce leave Australia because of the lack of a career structure.

At this time of the year, in true Christmas spirit, we ask ourselves, "Why in the hell do we continue?" I guess we love physics. I guess we expect things to get better. I guess we expect Santa Clause to come to physics. I guess we expect next year to be better - it could hardly be worse - unless someone gives Aitken or Dawkins a copy of the Edwards' Report from England for Christmas. Then 1989 might look like a good year for physics and physicists in Australia.

Merry Christmas!

Ron MacDonald
Honorary Editor

With great regret, the WA Branch of the AIP has been forced to cancel the Ninth National Congress due to be held in Perth.

The uncertainty over flights to and from Perth and the absence of discount fares have reduced the number of registrations from outside WA to below a viable number.

However, please note that the Sixth Atomic and Molecular Physics and Quantum Chemistry Meeting will still be held on Thursday, Friday and Saturday, February 2-4, as will the specialist Workshop on Interfaces of Molecular, Electron and Surface Physics from February 5-7.

For further details please phone (09) 380 2738 or fax (09) 381 6427.
VICTORIAN BRANCH LECTURE, OCTOBER 1989
THE 1989 NOBEL PRIZES IN PHYSICS

It has become a Victorian Branch tradition that its October meeting be devoted to a semi-popular, semi-technical account of the life and work of the recent Nobel Laureate(s). An evening for the Nobel lectures is set aside in advance, even before the recipient(s) and their field is known. The day the prizes are announced a scramble for an appropriate speaker takes place, who unfortunately has less than one week to prepare a suitable talk. The process is best described as Nobel Roulette followed by an Impromptu. Nevertheless these meetings are always enjoyable to speaker and audience alike and a good turn-up is usually assured.

This year Norman Ramsey (Harvard), Hans Dehmelt (University of Washington, Seattle) and Wolfgang Paul (University of Bonn) shared the prize for a connected set of inventions and techniques, rather than for discoveries or theories. The game of Nobel Roulette was jointly won by Professors Tony Klein and Geoffrey Opat of the University of Melbourne, School of Physics, for the simple reason that, between them, they were personally acquainted with all three prize-winners. Klein dealt with Ramsey, and Opat with Paul and Dehmelt.

Klein explained how Ramsey’s major invention, the separated fields resonance method, worked. In the hyperfine spectroscopy of beams of atoms and molecules, the precision with which transition frequencies (energies) may be determined is improved by extending the observation time. Ramsey woke up to the fact that the determination of frequency by means of two radiofrequency pulses separated in space along an atomic beam, or in time in the case of ‘stored’ particles, would markedly increase the precision. Such is the precision of these frequency determinations that the clock which depends on a particular transition in caesium has become our standard of time. The caesium clock has 1 in 10¹² stability. Furthermore, the atomic hydrogen maser, based on the 21 cm line of astronomical fame, is likely to supplant the caesium clock, again as a result of the work on Ramsey. It could in principle reach a stability of 1 in 10¹⁸. Of course Ramsey has done much else apart from his Nobel Prize winning work. His Oxford book on ‘Molecular Beams’ is a classic. His ongoing work on the electric dipole moment of the neutron is especially noteworthy, the upper limit being currently around 10⁻³⁵ cm.

Opat described the work of Paul and Dehmelt. Paul has at least three notable inventions to his credit. One is the remarkable magnetic hexapole field, which, by adiabatically transporting atoms and molecules with magnetic moments, provides the molecular beam experimenters with a focusing system and if needed, a spin polariser. Paul also invented a dynamic electrostatic dipole trap for ions, now known by his name. The interaction of tuned laser beams with atomic ions held in his trap has led to atomic beam cooling, and the detection of light scattered by single atoms. Finally, the quadrupole mass spectrometer, which is also his invention, is based on the motion of molecules in the combined static and dynamic electric quadrupole field. This device is now a standard component used in vacuum physics and residual gas analysis.

Dehmelt exploited the properties of both the Paul and Penning traps to carry out extremely high precision measurements on charged particles. The most remarkable measurement of Dehmelt relates to his work with one single electron or one single positron held in a Penning trap. He showed that they had the same magnetic moment to an accuracy of 1 in 10¹⁰, and that the magnetic moment of the electron μe = μB(1+4S) agrees especially well with the experiment. In particular,

\[ a = 1159652188(4) \times 10^{-12} \]

Dehmelt (experiment)\[ = 1159652266(106) \times 10^{-12} \]

Kinoshita (theory)

where the error in the theoretical prediction reflects our ignorance of the fine structure constant. This extraordinary agreement between theory and experiment reinforces yet again our belief in the validity of quantum electrodynamics.

Ramsey, Paul and Dehmelt are pioneering masters of experimental physics; their Nobel Prize was well earned.

Geoffrey Opat

Victorian Branch News
Surface Physics in Aircraft Materials Problems

It has been said that the modern attack aircraft can be likened to a formula 1 racing car. It is a complex, highly tuned, high performance machine that must endure many hours at the extreme limits of its design capability. But unlike the racing car, and most family cars for that matter, Australia’s attack aircraft are expected to provide useful service for over 40 years. A part of the longevity of Australia’s aircraft can be attributed to the Australian Aircraft Laboratory (ARL), which is celebrating its 50th anniversary this year. ARL, established to serve the needs of the local aircraft industry, began as the CSIR Division of Aeronautics and later became the Defence Science and Technology Organisation’s Aeronautical Research Laboratory. It is the work of this laboratory that helps to maintain attack aircraft, transport and training aircraft and helicopters.

Dr David Arnott, who heads the Structure of Materials group in the Aircraft Materials Division at ARL in Melbourne, kindly agreed to cover for the Boas Medal presentation and lecture which was postponed owing to the pilots dispute. Dr Arnott’s group, consisting of 9 physicists, a chemist and laboratory staff, tackles some of the surface structural problems facing many of the aircraft in Australia. Two of the areas in which the group works is the nature of adhesively bonded surfaces and surface corrosion.

The problems with the choice of a brittle steel for the swing wing on the F-111 was well publicised in Australia at the time of the order for the aircraft. The purchase of the aircraft was delayed following ARL advice until the wing carry through box was redesigned. The aircraft wings are tested very 2000 hours of flying time in a special facility at Sacramento, USA to check for defects in the wing pivot fitting. Each aircraft is cooled to -50°C and the wings are loaded to 100% of their design limit. To reduce the likelihood of failure, the wing load needs to be transferred from the steel stiffener rib in the region which is susceptible to failure. One scheme was to bond a boron fibre reinforcement over the wing. This requires treating the surface of the alloy, applying an adhesive and a boron mat and heating and pressing the region to cure the adhesive.

An understanding of the failure of some of these bonds requires an understanding of the nature of the—
surfaces bonded together. On the metal surface is an oxide layer to which the primer is applied. Bond failures often occur in the oxide and primer regions. The surfaces have complex fractures. Work in Dr Arnott’s group has focussed on the fracture surfaces of failed adhesives, with particular attention to the oxide film, surface preparation and surface morphology, and also at non-destructive methods to evaluate the strength of the bonds, providing background support for the F-111 bonding program. One useful test uses an impedance analyser to monitor the impedance (which is mainly capacitive) between the bonded layers. Changes in the leakage currents and fluctuations in the impedance yield information about the state of the bond.

Structural degradation of aircraft by corrosion is a major problem. The corrosion changes the composition of the aluminium alloys used in the wing structure of aircraft and can lead to catastrophic failures. Corrosion particularly affects those aircraft which operate near the ocean and close to sea level. An example of the effects of corrosion on aircraft was reported recently in which the Aloha passenger jet, which carries passengers between the Hawaiian Islands, lost a large portion of its ‘skin’ while in flight.

Corrosion occurs on metal surfaces as a result of the microstructure and variations in the chemical composition of the surface. Essentially a small electric battery is created on the alloy. For example, FeAl precipitates form a local cathode and the aluminium substructure forms the anode. Many reactions occur as a result of this chemical battery, usually producing H+ ions at the anode (i.e., acid) and some alkali at the cathode. These solutions then attack the metal surface.

With NaCl, most of the attention had previously been focussed on the effects of the chloride anion which was known to be chemically active but little attention was directed to the sodium cation. However, investigations at ARL into the effects of different cations led to the discovery that small quantities of CeCl3 in the NaCl modifies the cathodic activity on alloy surfaces. Using a number of surface analysis techniques, such as Auger spectrometry, Scanning Auger Microscopy (SAM), X-ray Photoelectron Spectroscopy (XPS), and Secondary Ion Mass Spectroscopy (SIMS), it was established that the surface becomes coated with a hydrated cerium oxide film. However, it is not a simple film but consists of nodules with a dimension typically 10 microns, on a background film some 200 nanometres thick. As the cerium is deposited on the surface from solution, it forms these nodular islands that grows out from these centres until it covers the surface. It was believed that cerium oxide and hydroxide precipitate out of solution at alkaline cathodic sites while the aluminium is dissolving.

After about 20 days of deposition a corrosion protective film exists on the aluminium surface. Work has been done to accelerate the deposition process and to enable the corrosion protective solution to be applied to aircraft out in the field.

Not only is cerium beneficial for corrosion protection, but other cations such as Pr, Nd, Ni, Co, La, Y, also have similar properties. These cations inhibit corrosion in steel and zinc as well as aluminium alloys to an extent approaching that of the chromate compounds currently being used. The important point is that, unlike the chromates, which are poisonous and carcinogenic, the rare earth compounds are environmentally safe, as far as we know. The work at ARL has sparked international activity into the use of rare earth materials for corrosion protection. Australia has a large proportion of the world market in rare earths, and since tens of millions of dollars will be spent on each aircraft during its lifetime in preventing corrosion and unknown millions will be spent annually in other industries on corrosion related problems, there is a good market potential for the production of these minerals.

T.J. Davis

ACT Branch News
The ANU Microelectronics Centre

In August this year the ACT Branch participated in a joint meeting with the Electrical Branch of the Institution of Engineers (Aust) to hear an address by Prof Jim S. Williams, Head of the new Department of Electronic Materials in the ANU’s Research School of Physical Sciences. This Department arose from a significant restructuring of the research school following the recommendations of the 1987 School Review and forms part of the ANU’s major new development plan.

Prof Williams outlined the objectives and research programs of his new department. It is intended to concentrate on near-surface processing, modification and characterisation of materials, with emphasis on silicon, gallium arsenide and III-V compound semiconductors. Polymers, metallic alloys, superconductors and advanced ceramics are also of interest. The department attaches particular importance to collaborative activities with other organisations such as the Royal Melbourne Institute of Technology (RMIT) and CSIRO. The objective is to link fundamental research at ANU with applied programs and industrial interaction through the collaborating institutes. He also emphasised, however, that the physics research community in Australia with specific interest in this field is very small by world standards. It is imperative that the tertiary institutes should communicate, cooperate and coordinate research programs to ensure that the maximum return is achieved on their combined investment in research effort.

Professor Williams spoke briefly of a number of particular current research programs in his department. The study of the interaction of energetic ions with amorphous-crystalline multilayer structures shows the development of intriguing structural changes. In particular, low-temperature epitaxial crystallisation has been controlled by ion dose in both silicon and gallium arsenide, and amorphous silicon layers have been grown in a layer by layer manner. This has importance in the detailed study of annealing processes.

Another study concerns phase transformations in silicon by the implantation of low melting point elements such as indium, gallium, etc leading to very fine grained structure of great importance in the field of semiconductor devices.

Other studies include:

- the recrystallisation behaviour of ion implanted silicon by various techniques of rapid thermal annealing;
- helium, krypton and xenon ion implantation of gallium arsenide, achieving particular dynamic defect annealing structures of importance to the degree of resistivity;
- gallium arsenide devices; synthesis and study of new microcrystalline and amorphous metal alloys; crystallisation and magnetic properties of metallic glasses; mechanical alloying; and rapid solidification of amorphous and microcrystalline materials yielding some interesting practical magnetic and other properties.

Professor Williams closed by emphasising again his conviction that in this field, as in so many others, the success of Australian endeavours depends on the intense collaboration between theoretical and applied scientists, engineers and the entrepreneurial world.
Obituary

Dr Alistair Tavendale, a Chief Research Scientist employed by the Australian Nuclear Science and Technology Organisation (ANSTO) at Lucas Heights Research Laboratories died on September 19. He was in the middle of a course of radiotherapy following the removal of a brain tumour. Alistair was Project Manager for Radiation Detectors and Standards in the Applications of Nuclear Physics Program and had an international reputation in the field of semiconductor nuclear radiation detectors.

Alistair Tavendale was a New Zealander, born in 1931, and went to secondary school in Auckland. He studied physics at the Auckland University College of the University of New Zealand and obtained a B.Sc in 1953 and an M.Sc in 1956. He was awarded a Sir George Grey Scholarship in 1953. His M.Sc thesis work using ionisation chambers to detect alpha particles was a starting point for his life-long interest in radiation detectors.

In 1956 Alistair went to Weapons Research Establishment at Salisbury in South Australia for 2 years and then moved to Hobart with a fellowship at the University of Tasmania which awarded him a Ph.D in 1963.

Alistair was developing a reputation as an innovative scientist by this time and the Canadians awarded him a National Research Council Post Doctoral Fellowship to work at the Chalk River Nuclear Laboratories. It was in this period 1962-64 that he developed the large volume high resolution lithium drifted germanium detectors which are now associated with his name and which have become so important in nuclear physics and other fields requiring the detection of gamma rays. This was a very significant development and Alistair’s achievement was duly and appropriately recognised. He was a co-recipient of the First Radiation Industry Award of the American Nuclear Society in 1967.

In 1965 Alistair decided to return to the southern hemisphere and joined the Australian Atomic Energy Commission (AAEC) now known as ANSTO, as leader of the Semiconductor Radiation Detectors Group. Highlights of Alistair’s 24 years with AAEC/ANSTO include the first application of intrinsic germanium to gamma ray detection, the demonstration that gallium arsenide could be used to make high resolution detectors operating at ordinary temperatures, the development of the first deep level transient spectrometer in Australia, the neutralisation of deep level defects in semiconductors by atomic hydrogen, and hydrogen ion drift in silicon.

To those working with Alistair his knowledge, reasoning and ability were always obvious and impressive. He was a source of much scientific creativity and understanding, and was a source of inspiration and encouragement to all around him. His scientific standards were at the highest possible level. He had many colleagues at ANSTO, in Australian universities and institutions, and overseas. He will be missed by us all.

Alistair is survived by his wife Olwyn whom he married in 1956 and two children. We extend our deepest sympathies to them.

John Boldeman et al

The University of Auckland
New Zealand

A Lectureship in Physics
(Signal Processing and Image Analysis)
Department of Physics

The Department of Physics seeks to appoint a Lecturer with research interests in Signal Processing and Image Analysis. Other research interests in the Department include Astrophysics, Electronics, Laser Physics, Quantum Physics and several areas of Geophysics.

The present staff of the Department consists of two Professors (with interests in Quantum Optics and Experimental Nuclear Physics), 8 Associate-Professors and 13 Lecturers/Senior Lecturers. A Chair in Geophysics is currently being advertised. The technical and secretarial staff number 29.

Applicants must have an advanced qualification in Physics and preferably have had some teaching experience. Preference will be given to those with a record of successful research involvement in signal processing and image analysis.

The Lecturer will be expected to contribute to both the undergraduate and graduate teaching programmes, supervise laboratories at all levels, undertake research in some area of signal processing or image analysis and to interact with and strengthen the existing research interests of the Department.

Commencing salary will be established within the range $NZ26,000 to $NZ247,200 per annum. Conditions of Appointment and Method of Application are available from the Assistant Registrar, Academic Appointments, University of Auckland, Private Bag, Auckland. Applications should be forwarded as soon as possible but not later than the closing date 12 March 1990.

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WB Nicoll, Registrar

290 Australian Physicist Volume 26, Number 12, December 1989
Policies May Drive Science Profits Overseas

On 20th June 1989 the former chief of the CSIRO Division of Chemicals and Polymers, Dr David Solomon, delivered the 1989 Ian William Wark Lecture at the University of New South Wales.

The Australian Academy of Science awards the Ian William Wark Medal and Lecture to commemorate the work of Sir Ian Wark, who successfully applied chemical research to the separation of minerals. Sir Ian was chief of the CSIRO Division of Industrial Chemistry from 1939 to 1958. The biennial award is made for eminent contributions to the prosperity of Australia made through the advance or application of science.

Dr Solomon is an internationally recognised applied chemist who has done pioneering research in polymer processes and synthesis. He has worked in the paint industry and a number of CSIRO divisions, devising a new manufacturing arrangement with multinational companies that maintains Australian control of products and profits.

A major achievement of Dr Solomon and his group has been the conception, (in 1967) and development of plastic bank notes which are secure and more durable than paper notes. This research led to the bicentennial $10 note. These notes are now being manufactured by the Reserve Bank.

In his lecture, entitled 'Dollar-driven Science', Dr Solomon spoke about his friend Sir Ian Wark, told the story of the plastic banknotes and, referring to that experience, commented on science policy in Australia.

Here are some excerpts from the 1989 Wark Lecture.

Let me go back to 1966 when Australia converted to decimal currency. This occasion was marked by the issue of a series of new banknotes which were state-of-the-art and which the Reserve Bank of Australia were duly proud of. Let me remind you of the security features of our conventional currency. We have the water-mark, metal thread, quality paper and quality printing, particularly the raised (intaglio) print.

From a forger's point of view the situation was tempting—a series of new notes which the public were not yet familiar with, and the confusion of coping with the change to the decimal system. It took less than a year for the forgeries to appear. The 1967 forgery was a sobering experience for the legitimate printers. The forgers chose the $10 note and the two significant points to note about that forgery were:

1. the very good quality (as forgeries go), and
2. even more importantly, the forgeries were produced on very simple, readily accessible equipment ...

The Reserve Bank of Australia was justifiably quite concerned that their latest technology had been simulated so quickly and easily. The Governor of the Reserve Bank at that time was Dr. H.C. 'Nugget' Coombs, who decided to enlist the aid of the scientific community to develop technology that would be more difficult to simulate. After a preliminary meeting in Melbourne in April 1968, a weekend think tank was organised and held at Thredbo in June 1968. Those attending were mainly physicists and only two chemists: Sefton (Dr Sefton Hamann) and myself ...

Following Thredbo, Sefton and I explored many avenues over a period of approximately five years and eventually defined our ideal banknote ... The major break with tradition was that we had decided it was imperative to beat the photographic camera—to develop a note which could not be copied photographically. More specifically we aimed to prevent the forger from making printing plates by the well-developed and easily attainable methods used in conventional printing. We decided to do this by incorporating into the banknote optically variable devices (OVDs); that is, devices that look different if you change some external factor, such as the angle of viewing, the temperature, the pressure, or the type of light. We developed a whole range of devices which could not be copied photographically. Our 1974 patents covered these inventions ...

Let us now discuss the plastic substrate. My original suggestion, pre-Thredbo, was to use a fibre-type paper made from polystyrene alcohol. Whilst this gave unique banknotes they were not recognised as such by the average person in the street. A basic point to note is that the first line of defence against forgeries is the person in the street.

As we developed our OVDs it became obvious that the transparent substrate—one that could be used with transmitted light—would be a tremendous advantage, and so we looked for plastic films. To cut a very long story short we set ourselves the challenge of matching the mechanical properties of paper with a clear plastic—a major scientific challenge. No such plastic film was available commercially and we set about making our own by laminating together thin films which were being used in packaging. The final laminate was unique, readily identified as such, and economically acceptable. The clear plastic laminate was then rendered opaque except for the clear areas and thus we had our 'plastic paper'.

Now we faced the challenge of convincing our partners, the Reserve Bank of Australia, that banknotes of the type we had patented could be produced commercially ...

Now to the problem of technology transfer and a difficult time for all. The difficulties we experienced are more understandable in retrospect than they were at the time. Let us compare the proposed new production line with the one in use at the Reserve Bank for paper notes. The two lines have little if anything in common. What we were experiencing was not new, as Machiavelli had stated centuries earlier:

'Nothing is more difficult than the introduction of a new order because all who have done well under the old are enemies and those who may do well under the new are lukewarm.'

We confirmed this quotation!

Eventually a compromise was reached and the production line modified. The result is the bicentennial $10 note. The project produced:

* the first banknote in the world to use plastic films and OVDs.
* a high-security note which cannot be reproduced by the normal photographic process.
* a more durable substrate than paper.

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1989 WARK LECTURE

* a potential export.
* a note that replaces imported paper.

The project required 20 years of research and development and continuous support from the product champions, through five chairmen of CSIRO and four governors of the Reserve Bank. In 1988 CSIRO sold its share in the technology to the Reserve Bank which has the responsibility to commercialise the technology to the best advantage of Australia. The major financial return only came to CSIRO at the successful completion of the project.

Let us finally consider how we would respond in the present day environment to a request similar to that put forward by the Reserve Bank of Australia in 1967, and ask ourselves the question: Could this be achieved with present-day political policies?

The banknote project was clearly market driven and with one client. Present policies require that we receive full cost, that is 3.2 times salaries. The intellectual property would then belong to the industrial partner. CSIRO divisions are 'judged' by their ability to earn contract research dollars. Each division has a target amount of dollars, in my case approximately 40 percent of the budget, to be derived from industry for contract research. The pressure to achieve these target figures is felt so strongly at the research scientist level that in my opinion they are entering into agreements which could lose technology offshore. If this were to happen the longer term aims of the division would not be achieved.

We in Australia need much more debate on ways of achieving greater CSIRO-university-industry interaction without the risk of the loss offshore of vital technology.

In the specific case of the Reserve Bank of Australia project I doubt that we would have even begun this work if full cost recovery was required from day one. Certainly would not have been prepared to ask for funding when the research pathway forward was unclear.

Even more importantly, the fact that CSIRO owned a share of the technology, as a partner, enabled us to influence the overseas negotiations: there was a stage when the technology was considered as a trade for what we in CSIRO considered to be far less valuable overseas information.

And finally, the return to CSIRO received last year was considerably in excess of what we would have received for straight contract work.

In summary, we worked with industry, not for them.

The answer to the question I posed is, I am sorry to say, NO.


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292 Australian Physics Volume 26, Number 12, December 1989
100 Years Since Michelson & Morley— the Quest for the Ultimate Interferometer

H. A. Bachel & D. E. McClelland

*Department of Physics & Theoretical Physics, Australian National University, Canberra*

In the second half of the 19th century the first high precision measurements with optical interferometers were carried out (1). In particular A. A. Michelson built his first interferometer and in 1889 his now famous experiments with E.W. Morley, establishing the absence of an ether drift, were published (2). The fundamental idea behind the interferometer used in these experiments, now known as a Michelson interferometer, is strikingly simple and elegant: use a partially reflecting mirror M1 to split a beam of light into two beams of equal amplitude propagating along different directions (Fig.1). Then reflect these two beams off separate mirrors M2, M3, back on themselves to recombine at the beamsplitter. An interference pattern will appear at the output of the interferometer. Any difference in the position of the mirrors M1, M2, or any change in the refractive index (or the speed of the light) along the path to M1 or M2, will lead to a change in the interference pattern. This can be measured directly with photodetectors. In such a two-beam interferometer the intensity distribution of the light entering a detector has the form \( I = I_0 \cos^2(\phi/2) \) where \( \phi \) is the phase difference at M2 between the two reflected beams.

Such an arrangement is extremely sensitive—the phases of the two interfering beams only having to vary by a fraction of \( \pi \), or in other words, the optical path length variation \( dL \) need only be a fraction of a wavelength, and the change can be detected. Due to the short optical wavelengths (~0.5 \( \mu \text{m} \)), precision measurement in length down to \( 5 \times 10^{-9} \) \( \mu \text{m} \) are straightforward.

In his first published work Michelson (1) achieved an accuracy of 1/12 of a fringe, corresponding to 0.02 \( \mu \text{m} \), or about 700 atomic diameters (3). This corresponds to a sensitivity, defined here as the relative change in path length \( dL/L \), of \( 2 \times 10^{-5} \), a tremendous achievement at that time. Over the decades, developments in optics, lasers, electronics and quantum mechanics have led to dramatic improvements in the sensitivity, with the most recent developments aiming at a \( dL/L \) of \( 10^{-12} \). Such has been the progress in interferometry that now, in the centenary year since the great Michelson-Morley experiment, it is possible to design and build "ultimate" interferometers—machines which are only limited by fundamental processes, not by technical imperfections. This raises interesting questions on the nature of such limitations and on ways to avoid even these limits. Before looking at these fundamental issues it is worth summarising some of the achievements of optical interferometry in its 100 years of existence (4).

Probably the best known application of a two-wave interferometer is the test of Einstein's assumption that the speed of light \( c \) is constant. This experiment was the initial motivation for Michelson; it led to his collaboration with E.W. Morley (2), and has since been repeated with higher and higher accuracy (5), confirming the initial results. This test, which showed that the movement of the earth has no detectable influence on \( c \) is one of the cornerstones of our present understanding of physics.

An important role has been played by the interferometer in the definition and realisation of the length standard. Between 1960 and 1983, the metre was defined by a number of wavelengths of a specific line in the spectrum of krypton (6). With the fixing of the speed of light, the metre was redefined in 1983 to be the distance light travels in \( (1/299,792,458) \) seconds. The second is defined in terms of an atomic oscillation frequency. Advanced interferometry allows these standards to be reproduced with comparable accuracy in many laboratories. In the course of this work stabilisation of the laser wavelength or frequency and the locking of this frequency to atomic or molecular transitions was achieved. Some lasers can now be stabilised to less than 10 Hz, an accuracy \( \delta v/v \) of \( 10^{-12} \) (7).

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**Figure 1a** Standard Michelson Interferometer Layout

**Figure 1b** An Interferometer as Used at the Time of Michelson & Morley

*Australian Physicist Volume 26, Number 12, December 1989*
Manufacture of high quality optical components for imaging systems requires techniques for testing the curvature and the flatness of the surface. Here interferometry is used extensively — by placing the component in one arm and evaluating the interference pattern, distortions of less than a wavelength can be detected. Some very impressive applications have been demonstrated at the CSIRO National Measurement Laboratory in Sydney. Digital image processing and laser stabilisation techniques were combined to analyse optical surfaces with a resolution of 1/500 of a fringe (8).

Other spectacular applications of interferometry can be found in astronomy, where interference is used in radio astronomy and more recently in visible astronomy. Here an image can be reconstructed from the interference of two or more signals detected at widely separated places, by controlling the phase shift between the signals (9). In this way the angular resolution of the instrument, or telescope, can be increased beyond the limit set by the size of the individual receivers. Such interferometers have recently been built in this country: the Australia Telescope and the Stellar Interferometer at Sydney University are prime examples (10).

Another type of interferometer which has also had a major impact on modern technology is the rotation sensing Sagnac instrument (4). Originally used for measuring the earth’s rotation (11) it now forms the basis of the laser gyroscope. Such instruments when flown on board aircraft can reconstruct the path taken from a continuous series of measurements of the fringe shift, or the frequency shift of the laser light (12).

In addition, interferometers are widely used for measurement purposes such as the testing of optical components, the visualisation of flows and the diagnosis of laboratory plasmas (4). The above list of applications is by no means exhaustive but serves to indicate the impact interferometry has had.

Let us now return to the question of sensitivity. What is the ultimate limit in sensitivity? And if feasible, what could this ultimate interferometer be used for?

There are clearly a number of technical difficulties that need to be overcome. One obvious limitation stems from the mechanical suspension of the interferometer. Any external vibrations of the mirrors with respect to each other have to be suppressed. A rigid connection is a possible solution — and is useful in many applications. However superior results have been achieved by hanging the mirrors as pendula, or even better as a series of pendula with mismatched resonance frequencies. The mirrors in this case behave, above the pendulum frequencies, essentially like free masses unperturbed from vibrations (13). To avoid refractive index variations the space between the mirrors, which is usually filled with gas, has to be evacuated. Scattered light generated inside the interferometer produces a background intensity which may mask the small changes in intensity which we want to observe. Thus it is important that the optical surfaces and coatings do not scatter the light back into the main beam, that walls are kept sufficiently far away from the light beams and that the pressure of the gas inside the interferometer is kept very low. Finally, a change in the interference pattern could well be generated by a change in intensity or wavelength of the light source — this calls for a high degree of stabilisation of these parameters.

Given enough patience and effort, it is now possible to eliminate all these technical limitations one by one. This has recently been demonstrated in several laboratories around the world. For example a sensitivity S/L of about $7 \times 10^{-18}$ measured at 1 kHz has been achieved in a 30 m long interferometer (14). This corresponds to a length change of only $2 \times 10^{-16}$ m — smaller than the classical radius of an electron and less than $4 \times 10^{-19}$ of an optical wavelength — a tremendous achievement!

What might be surprising is that the mirrors can actually be located with such a precision. Is a surface defined at this length scale? Should not there be some fundamental uncertainty? Since the position is averaged over an enormous ($>10^{26}$) number of atoms the quantum-mechanical uncertainty of the mirror as a whole has to be evaluated — and at a mass of 1 kilogram and a measurement period of 1 ms this uncertainty is still much less than the observable S/L. Thus even at this length scale the motion of the mirror can be described using classical physics. A description of the motion in terms of the eigen-modes is valid — all the energy of thermal excitation is contained in these modes. Provided the internal damping of the mirror materials is low, these modes can be spectrally very narrow and at frequencies less than the lowest eigen-mode (5 kHz in the 30 m instrument) the thermal motion is insignificant (15).

**Figure 2. The limits for the 'ultimate' interferometer. This figure shows the limiting noise levels for a 4km interferometer with a 1000 kg mass and a detection bandwidth of 1 Hz, designed for the detection of gravitational waves (13). At frequencies of 1 Hz this 'ultimate' interferometer will be limited by the photon noise of the laser.**

However, there is another fundamental limit which has been reached in these experiments. It is not concerned with the interferometer itself but with the nature of the light used to illuminate it. Light, like any other physical system, has to obey Heisenberg's uncertainty principle. In practical terms this means that the properties of a laser beam, such as the magnitude and the phase of the electromagnetic wave, cannot be measured with infinite accuracy. A certain amount of fluctuation in both these quantities is unavoidable. The best stabilised laser beam will therefore have a remaining uncertainty arising from the product of the fluctuations in magnitude and phase in the
uncertainty principle. This in turn limits the accuracy of the measurement of phase by the interferometer. It is now well established that there are two limits set by these quantum fluctuations of the light. The first is concerned with the uncertainty of the intensity measurement, frequently known as the photon counting error. The relative error in the measurement of the photo signal reduces with an increase in power of the laser beam. Thus large laser powers are required for accurate measurements. The second limit is concerned with the light pressure the laser beam exerts on the mirrors. This light pressure also fluctuates — contributing to the noise in the measurement. This problem increases with the power of the laser beam. The optimum power is the one which balances the photon counting error against the light pressure error to minimise the total error. It is usually much larger than the power output of presently available lasers.

These quantum mechanical properties set the limit of accuracy for the interferometer — the ultimate interferometer is limited by the properties of the light used to measure the position of a mirror rather than the interferometer itself.

What could such an interferometer be used for? The most prominent application at present is for the detection of gravitational waves. According to the general theory of relativity, the distribution of mass and the coordinates of space are coupled. Large masses will distort the coordinates — as has been observed by the very slight bending of light rays passing close to the sun. The periodic oscillation of large masses, like the spinning of two binary stars, will send out a perturbation of the coordinates which will propagate away from the oscillating masses with the velocity of light. These gravitational waves travel, almost unattenuated, through the universe. They should cause minute changes in local coordinates — and it should therefore be possible to detect this effect with an interferometer which measures the changes in length in two orthogonal directions. The expected relative change of the coordinates is of the order of 10⁻²². An interferometer for this purpose, such as the joint proposal by the University of Western Australia and the Australian National University, will have exceedingly strict requirements (see fig.2). These include: very long effective armlengths (~150 km) achieved by reflecting the laser beam many times between mirrors separated by a few kilometres; evacuation of the interferometer down to at the most 10⁻¹⁰ torr; mirrors suspended on a series of pendula so that they move with amplitudes less than 10⁻⁶ m for detection frequencies between 100 Hz and 10 kHz; lasers stabilised to a frequency bandwidth of < 100 Hz with powers of more than 10 W (17). Such an instrument is a challenge both in engineering and manufacturing and in fundamental optical physics.

The story does not stop here! Wouldn’t it be a challenge to improve even on this ‘ultimate’ instrument. Theoreticians have proposed tricks to avoid the fundamental limits and experimentalists have caught up with these theories (18). The fundamental idea is that the uncertainty principle limits only the product of the uncertainties in magnitude and phase. If a type of light could be generated which had more noise in one property than the other and if the measurement could be carried out in such a way that only the property with the smaller uncertainty is of importance the accuracy could be improved beyond the quantum limit. Such a type of light does not exist in classical physics — it is only describable in terms of quantum mechanics. It cannot be created by a laser — but it can be generated in nonlinear materials. It has been demonstrated that these types of light exist, coined ‘squeezed states’ of light because the noise is squeezed into one of the properties only.

Furthermore, it has been demonstrated that an interferometer can operate with a greater accuracy, for the same power input, using these squeezed states.

The search for improvement is continuing — the quest for the ultimate interferometer is an ongoing challenge for both theoreticians and experimentalists alike.

References


(2) A.A. Michelson, E.W. Morley Am.J.Sci, 38, (1889)

(3) A typical atom diameter for nitrogen of 0.3 nm is used.


(6) Definition of the metre up to 1983: 1 m = 1650763.736 wavelength of the 546.1 nm krypton transition at 605.6 nm made in an international agreement on 14.10.1960.


(11) The first observation was by G.M.M. Sagnac Compt.Rendu, 157, (1913). Michelson measured the earth's rotation with a large interferometer of 300 m by 600 m described in A.A. Michelson, H.G. Care Astrophys. J., 61, 137 - 45 (1925).


PhysFest shows Physics in Action

The third annual PhysFest was held at the ANU recently. Some 88 senior secondary students from nine of Canberra’s senior secondary colleges and independent secondary schools attended the event.

According to the Head of the Department of Physics in the Faculty of Science, Professor John Sanderman, the aim of the PhysFest was to show physics in action and present it as an option to students considering continuing their education.

Professor Sanderman said that next year a new physics course would be offered in addition to the existing, traditional course, which provided the rigorous and difficult training required by future physicists.

The new course, The Physical Universe, will be offered to first year students, who do not intend to continue a major in physics. The course has been designed to give students from other sciences and the humanities, who are not interested in a career in physics, background information on issues of public interest, such as future energy sources.

“Knowledge of the physical structure of our environment will help students make informed political decisions on increasingly complex and important scientific issues”, Professor Sanderman said.

While the course focused on relevant and interesting physics, and consequently covered some traditional subjects, the approach was conceptual rather than technical, and sophisticated mathematics were avoided, he said.


Electrode Technology Workshop

A revolution in electrode technologies is taking place worldwide, with Australian research and development at the forefront—but is Australian industry aware of the prospects?

A workshop organised by the Department of Industry, Technology and Commerce, to be held at the University of Wollongong in February next year, is aiming to resolve this.

For almost a century electrode technologies, including batteries, electropolating, metal recovery and refining, and chemicals manufacture, have provided many products which cannot be made by any other economical method.

Electrodes are the conductors whereby electric currents are led into or out of solid, liquid, gas or vacuum devices.

The ability now exists, through electrode technology, to create precisely characterised materials and sensors with previously unattainable levels of sensitivity.

Both new and traditional industries will be affected by these developments, particularly those dealing with:

- batteries and fuel cells
- biomedical science and health care
- chemicals manufacturing
- waste processing
- metal recovery and refinement
- microelectronics
- sensors in processing control, medical and environmental monitoring
- surface modification - coatings, films and corrosion.

Philip Ryan (centre), an ANU PhD student, shows year 11 & 12 school students an experiment in aerodynamics

International competition appears to be keenest in the areas of advanced energy-conversion devices, microelectronics and sensors.

Australia, with its strong R&D base, is well placed to gain a sizeable share of the world market in electrode technologies, currently estimated at between $30 and $80 billion a year.

The workshop, to be held from 5-6 February, will address a wide range of topics related to electrode technologies.

‘A Call for Papers’ for presentation at the workshop has been issued with the themes:

- fabrication of new electrodes - review of world trends
- surface characterisation and properties of new electrode materials
- selected applications and opportunities for Australia
- technology development

The Program Committee, comprising representatives from industry, academia, the CSIRO and Government, will select papers for oral presentation and organise a significant Poster Session, at which researchers and industry can exhibit their capabilities.

All papers accepted for presentation will be included in a review book, 'New Developments in Electrodes and Their Applications', aimed at a wide audience and due to be published after the workshop.

For further information contact:

Leo Wood

DITAC

51 Allara Street

Canberra ACT 2601

Tel: (062) 76 1233

The Beauty of Physics

Announcing the second Institute of Physics photographic competition and exhibition. Once again they are looking for the eye-catching, the artistic, the weird and the wonderful—pictures from the world of physics to attract and interest the non-specialist.

As before, every entry must be accompanied by a caption of 100-300 words. Pictures will be chosen for exhibition by considering both picture and caption. There will be six classes for entries. Colour prints and black and white prints will be judged in each of the following categories:

(i) industrial companies, government establishments, commercially funded research programs;
OF INTEREST

(ii) universities, polytechnics, charity-funded research programs;
(iii) schools, colleges of further education, private individuals.

Prizewinners will be announced in May 1990.

Closing date for entries is 1 March 1990.

For further details see Physics World, Nov 1989, p S8.

Macquarie Laser Expertise to Improve Print Quality

Professor Brian Orr is one of the new generation of physical chemists using laser technology to investigate molecular behaviour. Macquarie’s School of Chemistry has what is probably Australia’s most versatile range of laser devices housed in a single laboratory, enabling him to pursue a variety of fundamental and applied research projects. The laboratory forms part of the university’s Special Research Centre for Lasers and Applications.

Professor Orr and his team are working with Gestetner Lasers, the only Australian manufacturer of laser printers. Their brief is to characterise the laser optics and find ways to improve print quality.

They are also working to develop a small mobile laser unit—rather like a golf buggy—to help industrial companies detect leaks of potentially hazardous substances from waste storage tanks.

Another industrial application is a project to enhance the production of diamond-like surface coatings by a technique known as microwave plasma-assisted chemical vapour deposition (MWPACVD). Used in making microelectronic circuits, lens coatings, machine parts and tool bits, the technology is not yet perfected. By training his lasers on the short-lived chemical species responsible for creating the diamond-like film during the MWPACVD process, Professor Orr and colleagues at Macquarie and the CSIRO are diagnosing ideal conditions under which it will occur.

Inquiries: Professor Brian Orr,
Tel (02) 805 8289.

CSIRO Develops Optical Filters with Space Research Potential

The optical workshop of the CSIRO Division of Applied Physics, through its long support for the Division’s solar physics research and, before that, munitions-related work during the Second World War, has developed formidable skills in polishing glass and crystal substrates to a flatness and smoothness unequalled anywhere in the world.

The Division has now begun to realise some of the commercial benefits of this expertise. In 1986 Professor David Rust, an American solar astronomer from Johns Hopkins University, approached CSIRO with an idea. He knew of the expertise of the optical workshop staff and wanted to enlist their help in developing a totally new optical filter for imaging the oscillations in the sun. He planned to use the device in the solar observatory at Sac Peak (New Mexico) but could also see the potential of such an instrument being fully utilised in a satellite-based solar oscillations imager, and spoke enthusiastically about remote sensing opportunities.

Although the filter was elegantly simple in design, it was extraordinarily difficult to make.

The central component was a piece of lithium niobate, typically 75 mm diameter by around 0.2 mm thick.

Applied to this were optical coatings for high reflectivity and electrical connections to tune the passband of the filter by applying a DC voltage across the lithium niobate. The fabrication tolerances were, however, fearsome: each polished face needed to be flatter than one two-hundredth of the wave-length over light of the full 75 mm aperture. Very few optical workshops can polish surfaces to this tolerance.

Three years later, filters are being produced which are truly state of the art and quite literally unattainable anywhere else in the world. Two filters have been delivered to observatories in the US and Australia for solar observations and a third will be delivered next month to a European research group which will be using it for research on comets.

Space authorities have yet to take the plunge on such new technology and install it in a satellite package, but CSIRO is hopeful that this will come as reports from ground-based users spread through the scientific community.

Because the technology does not exist outside CSIRO, the Division of Applied Physics is manufacturing the filters for direct sale to the end users. The very high value added component to the price tag on the filter and the position CSIRO occupies as the sole international supplier means that the filters are an ideal export product.

The Division is keenly interested in discussing this with companies that may be looking towards high quality optical components or devices as an export business.

Further details can be obtained from Dr Chris Walsh, Manager, Optical Technology Program, CSIRO Division of Applied Physics on tel (02) 413 7211, fax (02) 416 7902.
Computer Generated Assignments in Physics Teaching

E. W. Dearden & L. M. Hastie *(University of Queensland)*

First-time imposition of fortnightly computer-generated-and-marked assignments in a first-year subject (electricity, magnetism and optics) has resulted in an apparent appreciable improvement in student performance, as measured by a conventional final examination.

For some years it has been our perception that our first-year class in electricity, magnetism and optics (PH101), has always contained a core of do-nothing, ask-nothing students, who were impervious to exhortation, and who obtained results consistent with their efforts. The evident solution, regular marked assignments, is very costly in terms of people power. Thus our attention was directed to computer-based systems, and eventually to the Learning Management System (LMS) of Computer Based Training Systems Ltd. We were fascinated to find this system, suitable to our perceived needs, up and running on a large scale, in the Faculty of Commerce and Economics on this campus. Working from a large 'testbank' of various types of problems, the LMS randomly selects questions, and prints individual assignment tests for each student. On returning the answers to the LMS, an individual result slip is provided by the system. Thus the total time spent at a terminal by a student is relatively small, and up to 100 students can be served by a single terminal. A single dedicated printer, of simple multi-pin design, will serve many hundreds of students.

The questions may be multiple choice, true/false, completion/spelling, or numerical. For numerical questions the LMS not only randomly selects questions from a group, but further individualises the questions by randomly selecting, from a specified range, the variables to be inserted into the questions. For our purposes this is the most powerful and useful feature of the LMS. A further advantage is that the individualised paper inhibits direct copying of answers between students.

On the other hand the LMS does not provide a number of features considered appropriate and proper for marked assignments in physical science. For example, the numerical problems function only in fixed-point notation. Coding the solutions is, as a consequence, time consuming. Despite the deficiencies, the LMS will carry out the necessary basic functions, and is a very considerable improvement on no system at all.

A suitable testbank of five-hundred mostly-numerical questions was constructed, and in the second semester of 1988 the LMS was used to provide a compulsory assignment test of four to six questions every two weeks to the PH101 class of 150 students. Answers were to be returned within two working days for the last three tests, somewhat longer for the earlier tests. Students who failed a test (at a pass level of 50%) were required to make a second attempt. Those who failed the second attempt were excluded from the LMS and required to obtain tuition before continuing. The assignments together were to count for 30% of the final assessment for the subject, and students were required to pass both the assignments and the final examination in order to obtain a passing grade in the subject.

This imposition caused a substantial alteration in student behaviour in this class. In tutorials the students all worked at Physics, instead of a variety of other tasks, as in the past. They also sought immediate help when they failed to grasp some principle. Thus staff-student interaction became both more frequent and more to the point. Students having difficulty were identified much earlier than in the past.

Most of the operational difficulties encountered were due to residual coding errors in the solutions, and inadequate clarity in the wording of problems. Such errors are readily corrected, and students marks amended, so that the system develops with continuing use.

The final examination was set and conducted in the usual fashion, and, as usual, marked by a committee which included the writers. The principal result was that the median raw-score final-examination mark rose by 17%, in comparison with the 1987 result. Superposition of the 1987 and 1988 histograms (Figure 1) appears to show that the performance of students has improved according to their ability, becoming quite dramatic for the very-able students. The improvement in performance of less-able students, our target group, is much less impressive. Hence in 1989 the number and variety of elementary questions in the testbank will be increased, with the intention of leading the less-able students in graduated steps towards a better understanding.

A limited effort was made to determine the extent to which the improved result might be due to student self-selection. Accordingly, all students who changed their enrolment and left the class after teaching commenced, when they would have first become aware of the LMS imposition, were identified. The average ability of those who left, as measured by their average first-semester grade-point-average, was found to be lower than the average ability of those who completed the subject. The first-semester grade-point-average was found to be clearly related to the final (second-semester) PH101 examination mark. Consequently it was deduced that if the departing students had remained, the increase in the median examination mark would have been 15% instead of the 17% actually observed. Distinctly more students left the class than arrived. The corresponding potential effect of students who transferred into the class was not tested. A detailed evaluation of the contribution of the scheme will require data from several years of operation.

In this particular operation, and at this stage, the question of any saving does not arise. An additional education function has been provided, and this has a cost. Because of the increased student interaction, and LMS management requirements, the work load on the teaching staff goes up; the costs in computer hardware, software, and running time are significant. In return for this increased cost, the LMS performs the routine tasks of setting and marking assignments, together with the associated bookkeeping. Students have an enhanced educational environment, with plenty of incentive to keep their work up-to-date.

The questions that students ask repeatedly, together with LMS records of the efficacy of questions set in test papers, should
permit improvements in the way that course-work is presented. Further, in the light of user experience, one trusts that the software proprietors will introduce changes to simplify LMS management. Thus, in time, and with proper organisation, a reduction in teaching effort and management overhead can be expected.

It is our thesis that, at the present time, the principal benefit to be obtained from the use of computers in education is for the computer to provide incentive, guidance, supervision, and administration. While screen-based interactive systems are certainly valuable, we believe that young people are configured to be taught, rather than people, and that computers are best used to support, rather than replace, this natural function.

At present, in first-year physics, the availability of text books and other textual materials is extensive, and many are of high quality. Looking towards the future we foresee that with the LMS functioning as 'mother', students may be induced to work from this existing material, in an independent manner, so that the present formal class-contact periods may be converted to less-formal tutorials, inspirational lectures, and demonstrations. The LMS is presently capable of setting and marking final examinations, and, coupled to the central records system, could be extended to take over much mechanical administrative work. In short, we are looking towards a substantial change in the present style of teaching in this field.

More detailed information will be available in Departmental Reports. This project was promoted and supported by the Computer Assisted Learning Unit, the Prentice Computer Centre, and the Department of Physics, and assisted by the Faculty of Commerce and Economics, within the University of Queensland. We are indebted to many colleagues, and clerical and technical supporting persons in these organisations. It was John Baker who opened our eyes, Howard Cook who taught us how to drive the system, and Helen Bergen who kept it on the rails.

Footnote
The Australian distributor is CBTS (Australia) Pty Ltd, 62 Elgin Street, Carlton VIC 3053. The LMS runs on a Digital Equipment Corporation VAX system. The Computer Managed Learning (CML) System is very closely related to the LMS.

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Figure 1 Comparing the final examination histograms for PH101 in 1987 and 1988. The histograms are normalised to equal class sizes.

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Dear Editor,

I am writing in response to a comment by J.E. Cleary in a book review in the September issue of the *Australian Physicist*. Dr Cleary questioned the choice of FORTRAN as a programming language for new generations of physicists. While agreeing with Dr Cleary that more modern languages are often the preferred choice of teaching institutions, I should like to point out that FORTRAN still remains a dominant language in at least one important field of physics and that the field needs support from the universities.

I refer to the field of large-scale computational physics which is a major application of supercomputers. An area of this field in which Australia has significant expertise is computational fluid dynamics, particularly numerical modelling of weather and climate. There has been a strong link between computing and numerical weather prediction (NWP) since von Neumann and Charney chose NWP as an application of the first general purpose computer (ENIAC) in the early 1950s. Australia has been a major contributor to and beneficiary of NWP developments since the formation of the Commonwealth Meteorological Research Centre in the late 1960s by the Bureau of Meteorology and CSIRO.

In April this year the Federal Government initiated a research program to respond to the global threat posed by the greenhouse effect, and one component of that program involves collaboration between CSIRO and the Bureau of Meteorology Research Centre (BMRC) to develop and apply the BMRC global climate model to the problem. Like all the dozen or so global climate models in the world, the BMRC model and the extensive software for analysing the model output are written in FORTRAN. It is therefore necessary for this type of work, which is being carried out at several Australian institutes, to be supported by a pool of scientists (including the new generations) with relevant expertise.

The continuation of FORTRAN to be applied to such problems is not unreasonable. As explained above, the work has roots going back forty years so that the algorithms and language have grown together. Although the incorporation of new ideas into FORTRAN has been slow, well structured programs can be produced in the language. The relevance of FORTRAN has long been recognised by scientific computer vendors, who have invested much effort into the development of optimised FORTRAN compilers.

Moreover the recently agreed FORTRAN-8X standard now accommodates the vector structures necessary to optimise code on supercomputers. Efficient vectorising compilers for other languages are only now being developed for supercomputers.

Thus FORTRAN is the most common language for large-scale numerical modelling, particularly for weather and climate. With the expected increasing demand for scientists with expertise in global climate modelling and related areas, it would be unfortunate if the universities completely neglected the old but evolving language of FORTRAN.

M.J. Manton
Bureau of Meteorology Research Centre

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WAGGA 1990

Contrary to the conclusion of J.F. Doobon (*Aust Phys* 26, 186) the next annual Condensed Matter Physics Meeting will be held as usual at Wagga, 7-9 February 1990, in the week following the National Congress in Perth. The meeting is being organised by Tim J. Bastow, CSIRO Materials Science and Technology, Clayton, Victoria.

S.N. Stuart

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**Australian Journal of Physics**

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*Australian Physicist* Volume 26, Number 12, December 1989
Vaisala Donates $400,000
Meteorological System to
Monash University

Vaisala Pty Ltd, the Australian subsidiary of the Finnish Vaisala Oy, has donated to Monash University a high-tech Marwin meteorological system worth nearly $400,000 to support a continuing program of research into fronts and storms.

The Marwin system includes weather balloon launching equipment, sensors to measure and transmit upper air temperature, pressure, humidity and wind data, as well as portable storage and processing equipment. A personal computer and analysis software were also included in the donation.

Vaisala has also provided operator training and consumables and equipment maintenance for the next three years.

Vaisala, which recently won a substantial contract to update and supply equipment for the Bureau of Meteorology’s radiosonde network, is donating the equipment in part to fulfill offset obligations and continue a long tradition of support for meteorological research.

Professor Bruce Morton of Mathematics (Monash) said: “Vaisala’s generous gift greatly increases our capacity for field investigation of fundamental processes which drive the world’s weather.”

In addition to the latest meteorological measuring technology for weather bureaux, airports and defence, Vaisala is highly regarded in the industrial market as a leader in the manufacture of sensors for measuring humidity and temperature. In Australia, Vaisala has solved difficult humidity monitoring applications in process control industries such as timber drying, food and building products.

To highlight Vaisala’s commitment to research and development in Australia, the company is currently involved with the Road Construction Authority (now Roads Corporation) to test the feasibility of using ice detectors embedded in road surfaces to warn drivers of hazardous conditions. Such sensors have now been installed in the Black Forest stretch of the Calder Highway.

Such development work can be used further by forecasting hazardous conditions well before they occur. Using Vaisala environmental sensors in association with thermal images of road surfaces, road authorities will be able to tell, at a glance, the condition of the road surface at any time of the day or night.

Managing Director of Vaisala Pty Ltd, Mr Hannu Kokko, said: “The Vaisala company was founded 50 years ago on the basis of the research work of Professor Vilho Vaisala. Since then, the company has emphasized the importance of continued research and development, spending 20% of its annual turn over”.

Saueressen Inorganic
High-Temp Cements

Saueressen Cements Company (USA) produces more than 15 inorganic adhesives for high-temperature service to 1425°C, electrical and general assembly, embedding, insulating, selenium, coating and potting. Included among these products are both one- and two-part adhesives. Nearly all exhibit resistance to most acids, electricity and oils. Proven cost and time savers in thousands of applications, the safe, odourless Saueressen inorganic cements see a full gamut of uses, from automobile headlight dimmer switches to movie projector lamps and induction heating furnaces.

A folder with technical data sheets and price list is available from the Australian Agent:
Flash Electronics
PO Box 97
Kalista VIC 3791
Tel: (03) 755 2601

Laserex Scientific Staff
Form New Company

A new company, Coherent Scientific Pty Ltd has taken over part of the distribution business of Laserex Scientific, a division of Laserex (Operations) which was recently placed into receivership.

Boris Balin, formally General Manager of Laserex Scientific is now the Managing Director and major shareholder of Coherent Scientific. Norman Jones and Paul Wardill are also Directors and shareholders of the new company.

Coherent Scientific secured exclusive distributor agreements with all major manufacturers of lasers and optics previously represented by Laserex Scientific.

The Head Office of Coherent Scientific is located in Adelaide, South Australia at 138 Greenhill Road, Unley, 5061, tel (08) 271 4755, fax (08) 271 1202.

ETP-Oxford Ownership Changes

ETP-Oxford’s importing and distributing activities have undergone some changes. ETP-Oxford will continue to function on a business-as-usual basis under new ownership.

A partial management buy-out would be the most apt description. The business will now be owned and operated by Larry Nowland and Rod Harris.

The company will continue to support equipment to the physical sciences areas, as well as medical equipment and science teaching equipment.

ETP Pty Ltd will continue to manufacture and export electron multipliers while other sections of ETP continue to be involved in project business in South East Asia.

ETP Oxford will continue to offer full technical support for all products sold including service contracts.

For further information contact Larry Nowland or Rod Harris on Sydney (02) 858 5122 or (008) 25 1739 if outside Sydney metropolitan area.
Scrupulous Brainfood for the Festive Season

If it is a Christmas treat you want, search no more. Last month a new book was released which is guaranteed to keep the grey matter in a state of healthy ferment well into the new year. That is to say, if you enjoy pondering upon conundrums such as:

- Can the laws of physics explain consciousness?
- Is the brain merely a computer made of meat?
- Will a correct theory of quantum gravity reveal the reason for our existence?

There is really no end to the number of deep questions we might ask about life, the universe, and everything. As somebody once remarked: discovery is the art of asking the right question. So which of the deep questions are the right ones to ask?

The latest contribution to the art of asking questions comes from a man who has made an indelible mark on mathematical physics and our understanding of the universe: Roger Penrose, Rouse Ball Professor of Mathematics at Oxford. His new book *The Emperor's New Mind* presents a highly original perspective on the relationship between science and man, somewhat, but far from slavishly, in the tradition of Douglas Hofstadter's *Godel, Esher, Bach: an eternal golden braid.* Of course, the deep questions are not answered - yet. But one gets an unmistakable feeling of convergence; that somewhere just beyond the marvellous theoretical structures that Penrose classes as SUPERB Physical theories, together with startling new developments like chaos theory, there lies a promised land.

In his book, Penrose not only shines a light towards the darkness of knowledge presently hidden from us, but he brilliantly illuminates the current state of learning. His chapters on 'Quantum magic and quantum mystery' and 'In search of quantum gravity' should be set reading for physics students following their first year of exposure to formal quantum mechanics. These are chapters that most physicists will re-read many times. And it holds so much other intellectual treasure that I will be returning to dip again and again with increasing understanding and enjoyment.

Although Penrose advises that the lines of mathematics may be skipped, there will be few without mathematical training who will master the ideas he presents. Because of this, his volume will not become a best-seller, like Stephen Hawking's *A Brief History of Time,* but it will, I'm sure, become a classic. No other semi-popular treatment addresses the relationship between mind and matter as cogently as does the Emperor's *New Mind,* which runs to 466 substantial pages, with many line drawings by the author. It is well bound in the traditional Oxford University Press style and sells for the reasonable sum of $44.95.

This will be a good year to give a physicist a book token. A newly available companion volume is *The New Physics* edited by Paul Davies, which is reviewed below by Paul George, and for a splendid overview of the development of quantum mechanics and nuclear physics try Richard Rhodes' award-winning *The Making of the Atomic Bomb,* reviewed by Stephen Colliocott.

Colin Keay
Book Reviews Editor

Reviews

**The New Physics**
Paul Davies, Editor
Cambridge University Press,
Cambridge, 1989
xi + 516 pp., A$ 65, (hardcover)

Some professions, like engineering and medicine, organise refresher courses designed to bring their members up to date with the latest developments. Physics doesn’t and this book provides the next best thing. Its eighteen chapters are written by well-known expositors like Frank Close, Paul Davies and John Taylor, to name a few: the authors are eminent scientists in their own right and have made significant contributions to their own subjects. There is a sprinkling of Nobel Laureates. According the Editor, the book is aimed at scientist and layman alike, but I would have said that for the latter the aim is a bit shaky!

About four decades ago, Schrodinger remarked to me (about a paper sent for him to referee) that working on the unification of gravity was like digging over a well-trod graveyard. This is apparently still so. Einstein’s general relativity has recently been subjected to many highly accurate experimental tests using modern technology, and has passed them all with flying colours. There is even now evidence for the radiation of gravity waves from the binary pulsar PSR 1913+16, which accounts quantitatively for the rate of decrease of the orbital period of 75 µs per year. But while electromagnetism, the weak force and the strong force have been melded into a single edifice, general relativity still stands aloof from this ecumenical trend.

It was fascinating to find that cosmology, critical phenomena and particle physics are closely related, and that Ken Wilson, a particle physicist, has applied field-renormalization techniques to condensed matter and made important advances in our understanding of critical phenomena. Similarly, it was good to see the Higgs particle — now being hunted at CERN and Stanford — playing a dominant role in the early universe.

Having read the book, I can now understand why one of my more brilliant students abandoned a promising career in order to work on chaos!

This is a book that ought to be read by all physics teachers at high school and university, and any others interested in the subject outside their own narrow fields. It would make an ideal Christmas present, and though good value for money, would probably need to be from the whole family!

Paul George
Dungog, NSW

**The Making of the Atomic Bomb**
Richard Rhodes

Shortly after August 6, 1945, a press release was issued from the White House which described "the greatest achievement of organized science in history". The event it was referring to was the dropping of the atomic bomb on Hiroshima. This book is the account of the development of the atomic bomb and much, much more, as it is also the history of scientists and physicists in the first half of the twentieth century told against the backdrop of momentous world events. Rhodes tells all with a wonderfully rich style and the craft of a master novelist. It would be simplistic to characterize this book as just a description of the making of the atomic bomb as Rhodes traces the developments in physics and chemistry that produced the atomic bomb. It is a history of the development of quantum mechanics, nuclear physics and the chemistry and...
metallurgy of the actinide elements. Scientific discoveries in these new disciplines caused the men and women who made them to realize that they had unlocked nature's secrets which would allow the production of the ultimate weapons of mass destruction. It is Rhodes exploration of the personalities of these men and women and how world events affected their actions that is truly fascinating. The rise of fascism combined with its antisemitism and ultimately in Europe forced the likes of Einstein, Teller, Fermi, Bohr, Szilard, von Neumann and Wigner to flee. These were the men motivated by the turmoil of Europe and consequently by the quest to return it to peace, by defeating the Nazis, that were pivotal to the successful development of the atomic bomb. The detail with which Rhodes examines people and how events affected them is best demonstrated by the following example. During the Great War Otto Hahn (who did much pioneering work on the transmutation of natural elements by neutron bombardment) was working with Fritz Haber in Germany on the development of poison gases, which were viewed as weapons of mass destruction that would win the war. Haber's wife told her husband that such research was a perversion of science and demanded he cease poison gas research, Haber told her as he had told Hahn that he was a patriot and in times of war a scientist belonged to his country, and then set off to supervise a gas attack on the Eastern Front. That same night his wife committed suicide.

The making of the atomic bomb was not just a series of discoveries by individual or small groups of scientists but an example of organized science on a mass scale serving government. The atomic bomb may not have even come to fruition had it not been for the immense industrial capacity of the United States and the ability to integrate it with the scientific effort through the Manhattan Project. The theme of the relationship between science and government is explored by Rhodes as the US government began to grapple with the ethical and moral problems of using the atomic bomb. In particular, the efforts by Bohr to alert Roosevelt that the world would never be the same post the atomic bomb are discussed. Bohr saw ahead to the present and predicted how the atomic bomb would effect all our lives.

The book is magnificent and I would argue that no person's education is complete until they have read it. It will give you an appreciation for the past events which now guide our future. As a follow up I suggest reading Men Who Play God by Norman Moss (Penguin, paperback) which is the story of the hydrogen bomb.

Stephen Collocott
CSIRO Division of Applied Physics
Lindfield

Quantization, Gravitation and Group Methods in Physics
A.A. Komar (Ed)
Nova Science Publishers
Commack, NY, 1988
viii + 327 pp, US $118.00 (hard cover)

This book contains translations from the Russian of nine papers from the Proceedings of the Lebedev Physics Institute, Academy of Sciences of the USSR (vol. 176, supplemental volume). Although their original Russian versions appeared in 1983, these articles should still be of great interest to any reader concerned with the foundations and the interpretation of quantum mechanics.

Despite the title of the book, neither gravitational nor group theory is of prime concern. The unifying feature of the articles is that they all involve the basic postulates and concepts of quantum mechanics. Thus the various ways in which a classical system may be quantized are discussed, together with their ambiguities and weaknesses. Problems of measurement and of the meaning of uncertainty relations are also treated. Of particular interest is a comprehensive review by V.V. Dodonov, V.I. Man'ko and V.D. Skarzhinsky on the nonuniqueness of the Lagrangian - Hamiltonian approach to quantization. The difficulty arises because, in general, a classical system has associated with it an infinite number of different Lagrangians (not differing merely by a total derivative). All these Lagrangians yield the same classical equations of motion via the variational principle, but nevertheless the corresponding quantum theories are inequivalent and experimentally distinguishable. How then, from the theoretical point of view, are we to choose the 'correct' Lagrangian?

The text is easy to read, the translation being fairly idiomatic and the mathematics mostly standard calculus of second year undergraduate level. I recommend this book to anyone who is interested in the foundations of quantum theory.

G.H. Derrick
School of Physics
University of Sydney

An Introduction to Millikelvin Technology
David S. Betts
Cambridge University Press,
Cambridge, 1989,
vii + 102pp. A $76.50 (hard cover)

This short book is an introduction to the experimental techniques of low and ultra low temperature physics. Its genesis is a series of four lectures given by the author at an international summer school on hyperfine interactions and physics with oriented nuclei held at Bechyné in Czechoslovakia during the summer of 1985. These lectures have been transformed into an excellent introductory text on low temperature physics, suitable for postgraduate students beginning research in this field or for mature researchers moving in from another field.

The simple aim of low temperature physics is to cool a material to low temperatures, which requires some form of refrigeration. The first chapter presents the basic thermodynamics of refrigeration using a monatomic van der Waals fluid and an idealized paramagnet. This theme is continued with a chapter on the properties of $^3$He/$^4$He mixtures, which provides the necessary background for the understanding of dilution refrigeration. The chapter on dilution refrigeration is excellent in both understanding and the practical workings of a dilution refrigerator; attention is given to the startup, the still, heat exchanges and heat leaks. Following chapters deal with the Pommeranchuk refrigerator (not often used), adiabatic nuclear demagnetisation and thermometry. The strength of this book is the numerous figures and diagrams concerning practical working cryostats. For example, details are included on

In summary, this is an excellent introduction to low temperature physics. Anyone doing or interested in low temperature research should have a copy of this book. It is clearly written, logically arranged and contains a comprehensive bibliography.

Charles Winterton
School of Physics
University of Sydney

1991 Churchill Fellowships for overseas study

The Churchill Trust invites applications from Australians, of 18 years and over from all walks of life who wish to be considered for a Churchill Fellowship to undertake, during 1991, an overseas study project that will enhance their usefulness to the Australian community.

No prescribed qualifications are required, merit being the primary test, whether based on past achievements or demonstrated ability for future achievement.

Fellowships are awarded annually to those who have already established themselves in their calling. They are not awarded for the purpose of obtaining higher academic or formal qualifications.

Details may be obtained by sending a self-addressed stamped envelope 12 x 24 cms to:
The Winston Churchill Memorial Trust
218 Northbourne Ave, Braddon,
ACT 2601.
Completed application forms and reports from three referees must be submitted by Wednesday 28 February 1990.
BOOK REVIEWS

the construction of heat exchangers and apparatus for single-stage nuclear demagnetization of PrNi (the diagram is so good that it makes one want to whip one up in the workshop). The one area where I feel the author could have provided more detail is in the chapter on thermometry: carbon and germanium resistance thermometry receive scant attention and nuclear orientation thermometry just one paragraph. There is no discussion of measurement techniques, for example AC bridge methods which are necessary to keep power dissipation in the sensor to a minimum, or of electronic temperature controllers.

It should be noted that this book covers much of the same ground as Betts' earlier monograph, "Refrigeration and Thermometry below One Kelvin", published in 1976. The advantages of this later work are in the much improved figures and diagrams, the discussion of dilution refrigeration, up-to-date references and its greater emphasis on experimental know-how. The 1976 monograph contains much more discussion on thermometry (six chapters as compared to one), enjoys a price advantage of some A$50, and is available in paperback for around A$23.

This book is an excellent introduction to contemporary low temperature techniques and it contains the best discussion of dilution refrigeration I have seen. It provides a good starting point for researchers moving into this field, combined with its up-to-date list of references. For a book that is aimed at postgraduate students and is only 102 pages, the price is A $76.50, which unfortunately will discourage many readers who would benefit from it.

Stephen Collcott
CSIRO Division of Applied Physics
Lindfield

Classical and Quantum Effects in Electro dynamics
A A Komar (Ed.)
Proc Lebedev, Physics Inst. -
Academy of Science USSR No.176
Nova Science Publishers 1988
286 pp, US$106.00 (hardcover)
The Proceedings of the Lebedev Institute are characterized in general by a set of theoretical articles in which not a single mathematical detail is omitted. This book is no exception. The surprise of the book is that many of the 11 articles are unrelated to the title, making access and retrieval problematic.
The articles relating to the title include an excellent review of Cerenkov radiation by V.L. Ginzburg, and several on aspects of nuclear radiation and its interaction with matter. An exception to this is a detailed analysis of the Aharonov-Bohm effect in a 'coherent state' magnetic field. The non-electrodynamic articles include a review of high energy neutrino detection, and an article on Soft X-ray Optics.

For a multitude of reasons, this "browser" found the present volume interesting. Librarians would probably do better to disregard the titles of the various Lebedev Proceedings, and simply regard them as the successive preambles of a review journal in mathematical and theoretical physics. It is difficult but interesting to review the successive volumes of a journal.

Geoffrey I Opat
School of Physics
University of Melbourne

FROM THE BOOK REVIEWS EDITOR

Seasons Greetings to all Reviews readers and special thanks to our Reviewers who have given their valuable time to ensure that potential book-buyers will be happy with their investments. The task has been well done. In the coming year I have been granted six months study leave and will depart overseas at the start of February. It would be very helpful if overdue reviews could be in my hands before January 20. While I am absent, the Book Reviews Section will be kept afloat by Jim Cleary and Jack Ramsay, who will intercept and deal with all mail addressed to me as Book Reviews Editor.

Colin Keay

New Books

Conformal Invariance and String Theory
P Dita & V Georgescu (Eds)
Academic Press, San Diego 1989
xiii + 557 pp US$59.95 (hardcover)

Absolute Radiometry
H Hentsberger (Ed)
Academic Press, San Diego, 1989
xvi + 266 pp, US$69.50 (hardcover)

Introduction to the Mathematics of Quasi-crystals
M V Jaric (Ed)
Academic Press, San Diego, 1989
x + 226 pp, US$59.50 (hardcover)

Origin and Evolution of Planetary and Satellite Atmospheres
S Atreya, J Pollack & M Matthews (Eds)
University of Arizona Press, Tucson, 1989
xi + 881 pp, US $45 (hardcover)

Positron Studies of Condensed Matter
A Alam, G Kogel, H Schaefer & P Sper (Eds)
Adam Hilger, Bristol, 1989
x + 148 pp, UK $20 (hardcover)

Optical Processing and Computing
H H Arsenault, T Szoplik & B Macukov (Eds)
Academic Press, San Diego, 1989
xiii + 493 pp, US$59.50 (hardcover)

Measurement in Australia, 1938-1988
J F H Wright
CSIRO Publications, Sydney, 1988
vii + 134 pp, A$24.95, (hardcover)
   Secretariat, Department of Physics and Mathematical Physics,
   University of Adelaide, 5001.

Jan 15-Feb 2  3rd Physics Summer School on Nuclear and Particle Physics, Canberra.
   B. Robson, ANU (062) 49 2971.

Jan 29-Feb 2  9th AIP National Congress, Perth.
   Dr R.A. Anderson, Dept. of Physics, UWA, (09) 380 2738.

Feb 4-9  Chaos in Australia Conference, University of New South Wales
   Gavin Brown, University of NSW, PO Box 1, Kensington, NSW, 2033

Feb 5-7  6th Gaseous Electronics Meeting, Armidale NSW.
   M.P. Fewell, Physics Dept., University of New England, Armidale,
   NSW, 2351 (067) 73 2388

Feb 5-9  Conference on Solar, Terrestrial and Space Physics. Workshop on Ionospheric
   Modelling and Radio Wave Propagation, Melbourne.
   Dr Essex, Physics Department, LaTrobe University, (03) 479 2644.

Feb 5-9  2nd International Conference on Nuclear Microprobe Technology & Applications,
   Uni of Melbourne.
   Mrs M. Take, Conference Secretary, tel (03) 344 5433.

Feb 6-9  5th International Symposium on Acoustic Remote Sensing of the Atmosphere
   and Oceans, New Delhi, India.
   Dr S. Singal, C/ NPL, New Delhi, 110012.

Feb 6-9  Fourteenth Australian Institute of Physics Condensed Matter Physics Meeting.
   T.J. Bastow, CSIRO, tel (03) 542 2777, fax (03) 544 1128.

Feb 12  Workshop on Millimetre Waves, Sydney
   Dr Bruce Thomas, Kieran Greene, or Lynette Loew, tel (02) 868 0222

April 1-6  Government, Engineering and the Nation, Canberra.
   Conference Manager, IE (Aust) 11 National Circuit, Barton ACT.

April 23-27  International Conference on Physics Education Through Experiments.
   Prof. Zhao Jin Yuan, Nankai University, Tianjin, China, tel (086) 02 318264

   IRE (02) 327 4822.

July 9-12  3rd International Conference on the Structure of Surfaces, Milwaukee, USA.
   Dr M. van Howe, Fax 0031 1 415 486 4995.

July 9-13  5th World Conference on Computers in Education, Sydney.
   WCCE'90 PO Box 319, Darlinghurst 2010. Tel (02) 211 5855

July 16-20  Nonlinear Optics Conference.
   LEOS, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331, tel (201) 562 3895

Aug 5-10  15th Congress of the International Commission for Optics, Bavaria.
   Paul Hewitt (049) 62 0999.

Aug 12-16  International Conference on Optics for the Life Sciences, Munster.
   Paul Hewitt (049) 62 0999.

Sept 24-28  Joint Conference of Australian Radiation Protection Society and Australian College
   of Physical Scientists and Engineers in Medicine, Adelaide.
   David Paix, GPO Box 498, Adelaide, 5001.
This is the first announcement of the fourteenth annual Condensed Matter Physics Meeting which is to be held at the Riverina campus of Charles Sturt University, previously the Riverina-Murray Institute of Higher Education. Wagga is easily reached by road, rail or air. The campus is about 8 km from the town and most of the local taxi drivers know how to find it.

The Meeting will consist mainly of poster sessions, with a few invited review-type lectures and some shorter contributed lectures to be allocated by the organising committee. Accommodation will be in student halls of residence, which are near the Union building, the dining hall and the swimming pool.

At present, the following invited speakers are slated:

- Dr Earl Callen (metastable metallic phases),
- Professor Tony Guenault (low temperatures),
- Professor Geoff Opat (Aharonov-Casher effect),
- Dr Chris Rossouw (electron beam analysis of semi-conductors),
- Dr Brett Sexton (scanning tunelling microscopy),
- Dr Ian Snook (liquids).

The registration fee will be of order $40.00. The cost of full board (three meals a day) and lodging in the halls of residence will be $40.00 per day. Students who are AIP members and wish to attend should ask their local AIP branch secretary about financial assistance.

A second circular with fuller details and a call for papers will be distributed in mid-November. If you wish to be kept informed, please fill in the reply slip and send it to the organisers:

**Tim Bastow or Steve Stuart**  
CSIRO Division of Materials Science and Technology,  
Locked Bag 33, Clayton, Victoria 3168.  
Phone: (03) 542 2777  Fax: (03) 544 1128

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I wish to receive further information.

Name ___________________________ Phone __________ Fax __________

Affiliation _______________________

Postal Address ____________________

I am/am not likely to attend myself.
I do/do not intend to submit a paper.
I will/will not require campus accommodation