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Our stands at the two recent conferences in Adelaide provided an opportunity for us to meet many of our interstate customers. Our thanks to those who attended our stands, to discuss their applications in person.

At the first, the 11th Conference of the Australian Optical Society, many distinguished Australian scientists contributed papers and held discussions. Among them were Professor Jim Piper of Macquarie University who gave the 1997 AOS Medal Lecture, and Professor Barry Luther-Davies of ANU who spoke on nonlinear optics and applications.

The second, the 5th International Congress on Sound and Vibration, sponsored by the International Institute of Acoustics and Vibration, the University of Adelaide and the Australian Acoustical Society drew a large number of speakers and delegates. Martin Johannsman, Polytec’s International Sales Manager flew in from Germany for the occasion.

New Single Photon Counting Module

The Single Photon Counting Module (SPCM) from EG&G Canada is a self-contained module, which detects single photons over a wavelength range of 400 to 1060 nm.

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Special thanks to the organiser Dr Peter Veitch, and diving colleagues at the University of Adelaide, Dept. of Physics who recommended some fabulous dives sites in search of SA’s native Weedy Sea Dragons and a dawn wreck dive 5km off Glenelg.
CONTENTS

3 PRESIDENT'S COLUMN

4 EDITORIAL

5 LETTERS

6 AROUND THE TRAPS

7 NANO-SCALE FERROELECTRIC MEMORIES

11 FASTS 'TEN TOP' FOR 1998

12 RUTHERFORDIUM - ELEMENTARY MY DEAR ERNEST

15 PRODUCT NEWS

16 SOLAR SELECTIVE COATINGS FOR SOLAR THERMAL ELECTRICITY

212 AIP BRANCH NEWS

23 A REMARKABLE MEETING

25 FIFTY YEARS OF PUBLISHING PHYSICS

26 OBITUARIES

28 REVIEWS

37 CONFERENCES & MEETINGS

The Changing of the Guard

James F. Scott

John Campbell

Angas Hurst

Edward Cherry

Richard O'Sullivan

Colin Keay

Cover: Self-assembled 150x150 nm nano-electrodes on the surface of a bismuth titanate film, pictured via atomic force microscopy (AFM).
Back at my desk, after a too brief respite, I have tried to reflect on the past year's achievements and the challenges ahead for the Institute.

During the past year the AIP Executive has continued to work hard in promoting our profession and furthering the goals of our Society. I have met with politicians and public servants to argue the case for maintaining and enhancing the profile of and support for the fundamental sciences in Australia. As a member of FASTS the AIP can benefit from and can have influence on FASTS lobbying activities. I have been a FASTS board member in 1997 and will continue through 1998. Your society continues to work to moderate threats to physics departments in universities and, through its accreditation program, to maintain a high level of quality and professionalism in our university degree courses. The Women in Physics Lecturer program has been successfully inaugurated. Cooperation between university departments has been encouraged and supported. The AIP has continued to support, morally and through seed funding, important international conferences. Through our support of ICM '97, The International Conference on Magnetism, the society will receive a substantial windfall, to be set aside as a conference support fund. The flow of information to our members and others has been enhanced through the establishment of a Web site. The production of The Physicist has been reduced in number of issues due to financial pressures, but the quality has been maintained. A new editor and production team have been successfully put in place.

Where do we head in 1998? Science awareness, funding and promotion will, in all likelihood, continue to dominate the agenda. The survey results, published in the last issue, will be followed up with direct approaches to policy makers and leaders of commerce and industry as well as to Vice-Chancellors of universities. FASTS will conduct a forum entitled "University Science in Crisis" on February 25 at the National Press Club, with a televised lunchtime address by a prominent figure. There is a proposal to conduct a national survey on "Physics and Industry", as a follow up to the last national survey "Physics: A Vision for the Future." I am personally convinced that the health of our society and of our profession depends on creating a new culture with ample career opportunities for physicists in the private sector. The AIP must continue to be a dynamic society, willing to anticipate and respond to change and seeking to provide relevance and service to its members. I will be seeking advice from the forthcoming Council meeting on many of these issues.

Let me close with some exhortations to members, or New Year resolutions.

1. Maintain your membership. If you are dissatisfied work to improve things.
   Do not drop out!

2. Pay membership fees promptly.

3. Recruit new members. Senior students should be encouraged to join the AIP.
   Industrial positions should recommend, if not require, AIP membership.

4. Work through your State Branch to promote the discipline and contribute to a
   vigorous society.

5. Support and attend the biennial AIP Congress.

6. Contribute material for *The Physicist*.

7. Above all remain optimistic and retain a joy for physics.

Jaan Oitmaa
THE CHANGING OF THE GUARD

On taking over the baton from Jak Kelly as Editor, I should first give him thanks, on behalf of all the readers of the magazine, for the sterling job he has done. He has devoted a large fraction of his time in retirement to running the journal, and has kept the flag flying bravely through some very difficult times for the profession. Jak was apparently a bit of an actor in his youth, and is renowned for his polished and witty speeches. His editorials were similarly witty and hard-hitting. These talents will be sorely missed!

At the same time, the publishing contract has been transferred from Impress Studios in Newcastle to the Cromulla Printing Company in Sydney. I would also like to thank Judith Nikoleksi and her team at Impress Studios for the smart and professional standards they maintained; and to wish Scott Williams and Leigh Wallbank at Cromulla Printing success for the future.

At the outset of my tenure, I should probably outline my aims as Editor. This is a period of doom and gloom in physics, especially in the university departments: the letter from Geoff Goodwin in this issue makes the point very clearly. It is all the more important, then, that we should highlight the positive aspects, the achievements, discoveries, and exciting new ventures which are occurring in the field, in order to maintain morale and cohesion in the community, and advertise our wares to the outside world. The magazine should be a showcase for physics in Australia and New Zealand, and together with the Associate Editors I will try to commission articles on contemporary topics of this sort.

The magazine should also act as a newsletter for the physics community, with news of appointments, promotions, vacancies, retirements, awards, new ventures and so forth. A news column entitled ‘Around the Traps’ begins in this issue, and I invite readers to contribute any items which they think might be of interest, sending them either to me or to one of the Associate Editors.

Education is another crucial issue, especially given the shortage of well-qualified physics teachers in high schools. Articles in this area are always more than welcome, and if we can generate enough of them, we may consider introducing a regular section on Education. Some topics of recurrent interest include the use of multimedia resources and computers, and distance education.

The magazine also provides a forum for the discussion of science policy, science education, and scientific theories and experiments. All sorts of thorny issues are being thrown up in these turbulent times, and FASTS and the AIP executive have been spending much time on them recently - see the FASTS press release in this issue. Any comments or discussion from our readers are more than welcome.

The book review section has flourished under Colin Keay’s tireless direction. Bert Bolton and others have provided interesting coverage of the history of physics in the Antipodes. I hope that these aspects of the journal will continue to thrive. Finally, reviews of new developments in physics are very welcome. Contributions in all these areas are invited.

Last but not least, the journal acts as a billboard for advertising new equipment, job vacancies, conferences, etc. Since this role can generate actual revenue, new advertisements will be actively encouraged.

Achieving success in these aims is not quite so easy as one might think. The letter in this issue from Jim Graham, a former editor, highlights some of the difficulties. The editor depends on the support of the rest of the physics community to provide material for publication, in the for of articles, news items, letters and advertisements. If the stream of voluntary contributions dries up, or solicited articles fail to appear when requested, the editor is helpless. The journal can only change course gradually, like the proverbial ocean liner under steam (though hopefully not the ‘Titanic’). But with the help of our readers and the Associate Editors, I hope that we will be able to produce a fresh and interesting magazine.

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LETTERS

ADVICE TO THE EDITOR FROM AN OLD HAND

Welcome to the helm of The Australian and New Zealand Physicist. Jani Oitmaa would like to see the ANZP publishing cutting edge physics, and reducing the number of historical articles and book reviews. While I agree that keeping up-to-date with current physics is a desirable aim for The Physicist, it is easier said than done.

1. The Editor can only print material that is submitted, and Australians need constant arm-twisting to produce any kind of commissioned article. A radical change in content would require full-time editorial staff.

2. The ANZP must act as a House Journal, giving details of Institute activities, policies, and personalia, and should, I feel, only carry material of interest to the majority of members. A physics education and history role therefore seems very appropriate. Or The Physicist could be reduced to a newsletter.

3. Research papers are published by the Australian Journal of Physics, and even then, Australians prefer to publish in better known and more prestigious overseas journals. We can’t take the AJP’s bread and butter, though there may be some future in investigating a combined Australasian Edition of the AJP incorporating some of the features of The Australian and New Zealand Physicist.

4. Perhaps a “Cutting Edge” Editor could act in a similar way to Colin Kuy’s splendid work with the book reviews; but where would you find such an efficient and enthusiastic treasure? The bait of a free book would not be available either. An occasional article appears in the newspapers of individual Universities in Australasia, and these could possibly be upgraded to suitable contributions.

5. Physics Today carries two pages monthly of “short abstracts (or reviews) for the non-specialist” in Physics Update; other material in this journal seems too specialised for the general reader. Suitable material is often found in Science, Nature and Physics World, although to my mind these articles could be simplified further. New Scientist may be too simplified. Scientific American usually introduces a poetic tone, and is often polemic. To comply with the President’s wishes, it would be necessary either to compete with these publications or come to some agreement about mutual use. Judging from my time as Editor of The Australian Physicist, there would be full co-operation from the American and British Physics Institutes, though the other journals would probably have strong objections to lifting their articles! I’m afraid Jani and the Editor have a very difficult choice to make.

Jim Graham UWA
Former editor of the Physicist

ROLE OF THE AJP

I read with interest the article, “Advancing the AJP”, by Ken Baldwin (ANZ Physicist, Sept./Oct. 1997, Vol. 34, No. 9/10). His suggestions for improving the role of the AJP are, of course, all very worthwhile. However, one could not escape the conclusion that from the viewpoint of the few remaining physicists at the University of South Australia, the suggestions simply amounted to skimming over the surface of what is a much deeper problem.

In the Physics area at the University of S.A., where the academic and technical staff has been decimated, the one-quarter of its size in the mid-1980s, there are more life-sustaining considerations. Morale is at rock bottom, and the threat is ever present of still more staffing cuts, additional to the particularly savage cuts of the past two years.

Physics has become a small appendage to Electronic Engineering. In 1997 and thereafter, the University of S.A. has banned enrolments into the Applied Physics degree and into Physics as a major stream in the B Sc degree.

Of course, Physics is hard-pressed, to a greater or lesser extent, in all Australian universities and scientific organisations. A basic cause of this malaise seems to be the end of the ‘Cold War’, in which Physics innovation, which could be translated into weapons design and defence relevance, was welcomed by governments with large defence budgets, who bestowed significant financial crumbs in the direction of science. Another contributing factor seems to be the generally accepted, but quite fallacious, opinion, sponsored by the ‘greenies’, that science and technology, including Physics, are somehow responsible for pollution and possible impending climate change on this planet.

Such factors have led to a decline in the number and quality of students electing to study Physics, in an economic atmosphere where universities are more interested on making short term financial gains, rather than maintaining the long-term academic quality of a Physics discipline which is suffering what Physicists, perhaps optimistically, anticipate is a temporary downturn. Fortunately, those universities and scientific organisations with more enlightened administrations, and possibly less strain on their financial commitments, have resisted the blinkered temptation to reduce Physics to a size that is below the ‘critical mass’. Sadly, in the University of S.A., Physics has been reduced below its ‘critical’ size from which it will be very difficult, if not impossible, to recover.

What is the solution to this battering of Physics? Of course, I don’t claim to have the answer to this problem, but I would like to summarise some suggestion which the ‘Physics survivors’ might like to consider.

(1) In the past, the University of S.A. (which incorporated the S.A. Institute of Technology) strongly fostered, under the Physics umbrella, two other disciplines, namely Radiography (now the School of Medical Radiations) and Civil Aviation. This innovative activity was a successful short-term, ‘stop gap’ measure, but was not enough to ‘save’ Physics in the longterm. However, Environmental Physics, Computational Physics, Astronomy, Agricultural Physics and other ‘trendy’ sub-disciplines should be fostered in university Physics departments, so that Physics is seen not to be stodgy and introverted, and the Physics presence is justified within the universities.

(2) One of the perennial problems in universities is that staff in engineering and health science disciplines believe that non-physicists, in their own ranks, can present whatever Physics is necessary for their courses. In the past, at the S.A. Institute of Technology, it was the enlightened policy that any subject or topic identified as being Physics would be presented by Physics staff. The same applied to Mathematics and Chemistry. I strongly recommend that Physics departments/schools, along with their Chemistry and Mathematics counterparts, should lobby their university administrations to ensure that Physics, in all courses, is given by Physicists in a strong Physics area.

(3) Politicians have difficulty in seeing beyond the next election. However, it would be desirable for the AIP to lobby federal politicians with evidence of the decline of Physics in this country. The Federal Government should be persuaded to provide university funding on the understanding that it is in the nation’s long-term interest for universities to maintain their support of basic science, in the form of Physics, Chemistry and Mathematics, regardless of the perceived short-term financial disadvantage to universities of providing such support.

Action is needed now to avert the looming crisis in Physics.

A/Prof Geoff Goodwin, FAIP
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Canterbury ring laser

A new C-II ring laser facility was opened last October 17 in Christchurch. The instrument is to be used for making precision measurements of the earth's rotation, and was built by Carl Zeiss. It was funded by the German Bundesamt für Kartographie und Geodäsie, with help from the Technische Universität München, the University of Canterbury and the Marsden Fund, as part of the New Zealand-German Science and Technology programme. The opening at the Cashmere cavern in Christchurch was attended by various dignitaries including Dr James Buwalda from the Ministry of Research Science and Technology, Prof Hermann Seeger from the Bundesamt, and Prof Bob Park, Deputy Vice-Chancellor of the University of Canterbury.

Later in the day a public lecture was held in the Great Hall of the Arts Centre, with the Canterbury Symphony Orchestra String Quartet providing some delightful interludes. Professor Geoff Stedman (University of Canterbury) discussed the theoretical interest in the ring laser project and Dr Ulrich Schreiber (Munich) described the results he had obtained during the commissioning of C-II. Results this year from Cashmere show that the Sagnac frequency can be stabilised to the order of a millihertz or better, and that the sensitivity of the C-II ring to rotation is approximately 4 nanoradians per sqrt(Hertz), at least an order of magnitude better than the best atomic gyros announced this year.

This set the scene for the dramatic announcement at this Lecture by Professor Seeger that, in view of this progress, on 29 September 1997 the Research Committee of the German Bundesamt had approved funding for the hoped-for big ring G (for Grossring). C-II is one metre square, G will be 4 metres square and will be installed at Wettzell, Bavaria. It will be several orders of magnitude more sensitive than C-II and is expected to measure short-term fluctuations in the rate of rotation of the Earth more rapidly than any alternative instrument.


We look forward to a report on results from Geoff Stedman at a later date.

Retirements at UNSW

A number of staff have taken voluntary early retirement at the University of NSW in the past year or so. Graham Bowden has gone back to England with his wife, and they have bought a house in the New Forest near Southampton, only a short walk from a medieval pub. Graham still holds a joint ARC grant with the group at ADFA, and will be seen occasionally revisiting these parts. John Dunlop continues his research and consulting in marine acoustics, and is still to be found haunting the corridors at both UNSW and Sydney. Peter Mitchell has more time to relax and enjoy his music, and plays a regular hand of bridge with other stalwarts of bygone days such as Jack McConnell. Veronica James is still playing a role in teaching physics over at Sydney. Peter Elliot is devoting more time to his passion for photography: his work was exhibited at galleries in Sydney and Tokyo within the last year or two.

And finally Ken Vost, who was always a bit of a globetrotter, has determined to see some more of the world. He is planning to begin teaching English as a second language either in Asia or Europe. We wish all of them happiness in this new phase of their lives.

Science Review at Melbourne

The Faculty of Science at Melbourne has undergone a review, which apparently accused the pure science schools of "hubris", an unusual crime. Does this mean nemesis is waiting in the wings? Further budget cuts are rumoured to be impending for Physics. Bruce McKeIl has resigned as Dean, and gone back to his research desk.

Hubble hunts for gobs of galaxies

NASA's Hubble space telescope is to use a "cosmic lighthouse" discovered earlier this year by Australian astronomers to look for unseen galaxies near the edge of the known universe, according to an article in the Sydney Morning Herald on December 15.

Dr. Brian Boyle, director of the AAO, said that they would use a novel technique to light up Hubble's look into the far reaches of space. Next October Hubble will be pointed at a quasar - a brilliant galaxy probably powered by a black hole - 10 billion light years away. As the quasar's light speeds to Earth, its light will be absorbed by anything it runs into, including swarms of remote galaxies. Analysis of the absorption spectrum will reveal the presence of the galaxies.

By comparing the newly seen galaxies, astronomers hope to learn how such objects evolved. "We will be doing cosmic palaeontology", said Dr. Boyle. "We will be looking for galaxies at unimaginable distances. Five years ago you would have thought this impossible."

The quasar was discovered after the AAO was commissioned to look for a suitable "lighthouse". The candidate was discovered after a three month's search using the observatory's Schmidt telescope.

Computational Science at Sydney

The University of Sydney has begun a new experiment in undergraduate education. From this year, all Science majors will be required to take a full-year course in Computational Science, including extensive hands-on experience in computer imaging, as well as the more standard exercises in computer programming. Other schools will be watching this new venture with interest, and we will look for a fuller report on it from Bernie Palitthorpe.

Kyoto

According to reports, the Federal government required virtually no input from the CSIRO in preparing their submissions to the Kyoto Conference on climate change. Yet Australian researchers such as Graeme Pearman and Barrie Pittcock are among the world's leading experts on climate change. The CSIRO has a co-ordinated program of research in the area involving the Divisions of Atmospheric Physics, Marine Research, Land & Water, and Plant Industries, which is run by Chris Mitchell. It seems strange that the government should spend hundreds of millions of dollars of taxpayers money supporting the CSIRO, and then fail to make use of its expertise on an occasion where it is most necessary and appropriate. Could politics be involved?

Astrophysics at Swinburne

Matthew Bailes has been lured to the Swinburne University of Technology in Melbourne as a Professorial Fellow to form a group working on Astrophysics and Supercomputing, together with Dr. Margaret Mazzolini who is already there, Dr. Matthew Britton and another postdoc yet to be appointed. The focus will be on computer processing of signals from detectors, aiming to study pulsars and other interesting entities. A graduate program in astronomy will be mounted online. According to AProf Dale Murphy, the head of School, the University is very impressed by Dr. Bailes' qualifications and expertise, and very enthusiastic about the project. Congratulations to Matthew. It is nice to see some real physics spreading in a new area, as opposed to the cutbacks and closures elsewhere.

Readers are invited to send items which might be of interest for this news column either to the Editor or to one of the Associate Editors.
Since 1986 there has been a minor renaissance in the study of ferroelectrics. Studied for a century in the form of single-crystals or bulk ceramics, ferroelectrics are now fully integrated in thin-film (100 nm or less) form in both Si and GaAs chips. Four embodiments have reached large-volume commercial production. A brief review of this field of device physics is given, emphasizing memory applications.

Types of Memories

There are fourteen generically different types of digital memories in use with computers at present. These range from the archival (slow, but cheap and very high density) tape and disk, to the high-density DRAMs (dynamic random access memories) and ultra-fast but relatively low bit-density SRAMs (static RAMs). As shown in Fig.1, each memory has a niche market based on its speed, density, and cost. The total worldwide market for these memories is approximately AUS $20 billion annually. Of special interest are non-volatile memories — those which do not lose information when power is interrupted. This share of the annual market is about AUS $600 million and is dominated by EEPROMs (electrically erasable programmable read-only memories). Other high-cost, value-added products include memories that are radiation-hard; ironically these are now of more interest for civilian use (e.g., computers in satellites) than for military applications.

In the 1950s it was of great interest in many industrial and government laboratories to make binary memories from ferroelectrics, epitomized by barium titanate (Fig.2), whose plus polarization could encode a “1” and whose minus polarization could encode a “0” in the Boolean algebra used by all large computers. However, early research was plagued by intrinsic problems: The thick single-crystals or bulk ceramics utilized required switching voltages greater than 5V, the standard “TTL” or CMOS (complementary metal-oxide semiconductor) logic levels of all silicon devices. Clever ways to circumvent this 5V operational level included internal “charge pumps” built into the chip, but these added cost and decreased reliability of prototype devices. Meanwhile, the silicon DRAM technology moved through like an express train, doubling...
2) ABO$_3$ ferroelectric perovskite structure.

its bit density every year or two and halving the cost per bit in similar time intervals.

Eventually, however, the most creative chip-designers started to reach physical limitations of the silicon itself, causing the advantages of ferroelectrics to be reconsidered. In a silicon integrated circuit, the transistors and resistors are relatively small, occupying only a few percent of the surface area of the chip. But the capacitors are large, necessitating complicated “stacking” and “trenching” in creative geometries merely to maximize the surface area of the capacitor. Capacitors in integrated circuits are almost always thin oxidized layers of the underlying Si, which produces ordinary quartz (SiO$_2$) under most conditions. Unfortunately the dielectric constant of quartz is about 4. If we could replace quartz with a high-dielectric oxide whose dielectric constant is 400, we could make the capacitor 100x smaller (perhaps eliminating stacking and trenching and reverting to a cheap “planarized” chip with several hundred fewer processing steps), or equally interesting, we could make a 4 Gbit memory instead of the present 256 Mbit devices. Most high-dielectric materials are ferroelectric oxides, which encourages us to revisit the ferroelectric technology that aborted in the 1950s, this time using very thin films that operate at 1 or 2V.

Basic Ferroelectrics

Ferroelectrics are crystals (including fine-grained ceramics) that are a sub-class of pyroelectrics. Pyroelectrics are in turn a sub-class of piezoelectrics. For example, quartz is a piezoelectric (it produces a voltage when squeezed, or vice versa), but not pyroelectric or ferroelectric — it has no net dipole (polarization). BaMnF$_4$ is piezoelectric and pyroelectric (net dipole along the a-axis) but it is not ferroelectric because its dipole will not “switch” (reverse by 180 degrees upon application of an electric field) — instead it shorts (breaks down) before the switching field (“coercive field”) is reached.

Ferroelectrics differ in important ways from electrets. Both exhibit hysteresis, but in an electret this electrical hysteresis in the polarization versus field P(E) is due to mobile charged defects and impurities. Consequently the two “bistable” states in the P(E) hysteresis curve of an electret are not thermodynamically stable. Instead, they will relax to a single ground state. By contrast, ferroelectric polarizations arise from two (or more) equivalent lattice configurations, which are equally stable thermodynamically. Unfortunately some leading textbooks fail to make this simple thermodynamical distinction.

Finally, ferroelectricity is a misnomer that has confused students for decades. Based upon a mathematical analogy with ferromagnetism, it is now an irreversible label. But ferroelectrics usually contain no “ferro” (iron atoms).

Types of Ferroelectric Memories

Ferroelectric thin films are used in three completely different memory embodiments, at present, but primarily still in prototypes — not in full commercial production. In DRAMs they are used simply as passive capacitors. As mentioned above, this is because their large dielectric permittivity (ca. 1000) permits great size reduction in the integrated circuit cells. A DRAM requires about 120 fF/μm$^2$ in order for the sense amplifiers to read a “one” or “zero”.

The principal requirement for the DRAM capacitor, other than high dielectric constant, is breakdown field. Good ferroelectrics such as barium strontium titanate (BST) or strontium bismuth titanate (SBT) exhibit breakdown fields of 3.8 - 5.8 MV/cm. Recent physics interest has centered on calculating this breakdown field and establishing its physical mechanism. The dependence of breakdown field $E_b$ upon temperature, voltage ramp rate (rise time), film thickness, and area are all complicated. The basic mechanism is that of avalanche, Avalanche is a hybrid mechanism involving electronic initiation followed by thermal run-away (like spark discharge in air). The leakage current is firstly limited by the electrode metal-ferroelectric interface (usually rectifying). At fields below 300 kV/cm the leakage is Schottky-limited, above that, dominated by Fowler-Nordheim tunneling. When leakage reaches ca. 50 mA/cm$^2$, thermal breakdown occurs. Whether this is “de thermal” or “impulse thermal” depends upon whether the second or first term respectively in Eq.1 below is dominant. (Most ferroelectrics have impulse thermal breakdown.)

$$C_v \frac{dT}{dt} - \nabla \cdot (K \nabla T) = \sigma E_b^2$$

(1.)

where the symbols have their usual meanings. At a few volts across 100 nm the basic current flow is exponential (not ohmic), characterized by a conductivity

$$\sigma(T) = \sigma_0 \exp(-\Phi/kT)$$

(2.)

In the impulse thermal approximation the breakdown field can be calculated analytically as

$$E_b = [(3C_v K)/(\sigma_0 \Phi_{t_c})]^{1/2} T \exp(\Phi/2kT)$$

(3.)

which for typical ferroelectric oxides gives ca. 8 MV/cm for breakdown, a reasonable estimate compared with the experi-
mental values of 3.8 - 5.8 MV/cm cited above (which are probably reduced slightly by defects and impurities).

The resulting breakdown field is strongly related to the contact potential (difference between the work functions of the metal electrode and the semi-insulating ferroelectric) as

\[ e E_B \lambda = c (\Phi_M - \Phi_{FE}) \]  
(4.)

(Here \( e \) is electron charge; \( \lambda \), mean free path; \( \Phi \), the work functions of the metal and of the ferroelectric; and \( c \), a constant of order unity.)

- a result given in simplified form by Von Hippel in 1935.

**NV FeRAMs**

Non-volatile ferroelectric RAMs use the ferroelectrics not as passive capacitors but as active memory elements. The “1” or “0” is stored as a + or - polarization in each small cell. The cells are arranged in a square matrix; a 1 Mbit square cell has a thousand rows and a thousand columns. (In reality it will be a non-square rectangle.) Each cell is isolated from its neighbors via a pass-gate transistor (to prevent cross-talk). Each bit is written by sending 1/2 the required switching voltage as a short voltage pulse along a row (“bit line”) and 1/2 along a column (“word line”). The pulses add up only at one particular addressed cell.

To read the bit, a positive switching voltage is applied in the same way. If the cell polarization is already +, only a linear non-switching response is measured (as a voltage across a 10-ohm load resistor — Fig.3a). If the cell is -, a switching response is measured; this is much greater than the linear response, because it contains the additional displacement current term \( \text{d}P/\text{d}t \), where \( P \) is the polarization (Fig.3b). The sense amplifier compares this response with that of a reference cell, which is always polarized +. In this way the 1 or 0 is read. Unfortunately, this is a “destructive” read operation; each time a bit is read it must be rewritten into its original state.

**Ferroelectric FET’s:**

An improved device would be one in which the ferroelectric replaces the metal gate in a conventional FET (field effect transistor). In this embodiment the bit can be read without switching or resetting — a “nondestructive read”. Such devices do not yet exist commercially, because they necessitate putting the ferroelectric in direct contact with the Si chip (not with a metal electrode), and the high density of surface electronic states (“traps”) on the ferroelectric makes charge injection a serious problem. This can be overcome to some degree by putting a thin buffer layer (e.g., SiO₂) between the ferroelectric and the Si. Unfortunately the buffer is then a small capacitor in series with the large ferroelectric capacitor; and as any student knows the voltage drop is then across the smaller capacitor, rendering the device almost useless.

**Thickness Limits**

There are two physical mechanisms entering the equations for minimum film thickness: First, it must not be short under the required switching voltage, as discussed above. Second, and more subtle, the depolarization field must not enter the thin film surfaces and destroy the ferroelectricity. The depolarization field calculation is classical physics, but tricky. Simple estimates of screening in the electrodes predict a minimum ferroelectric film thickness of 400 nm on semiconducting electrodes and ca. 4 nm on elemental metals (limited by the Fermi-Thomas screening length in the metal). But experimentally ferroelectric films switch down to 0.9 nm. Reasons for this reduction in minimum film thickness are moot at present but probably involve the theoretical neglect of surface states and/or ultra-thin (few atomic layers) insulating interfaces, i.e., a p-i-n or metal-i-n structure? Good ferroelectric memories can be made as thin as 25 nm routinely.

**Area Limits — Nano-Phase Ferroelectrics**

The limits in cross sectional area are as important as thickness limits. Fringing field corrections are important. A 1 Gbit chip requires that each cell be ca. 0.1 x 0.1 microns. A 100 nm thick film with such a capacitor on it is not a “thin” film; rather, it is a cubical box! And although one can solve Laplace’s equation for the equipotentials and field contours in such a box with appropriate boundary conditions (the sidewalls are different from the top and bottom electrodes), such solutions are invalid in the time-dependent case — so we get no information about
switching properties! The simplest estimate for these ultra-small devices is that the amount of switched charge \( Q \) in a rectangular capacitor with thickness \( c << \) rectangular edge \( a << \) rectangular edge is that it varies as \( \log a \), not linearly with \( a \).

## Prospects for the Future

The leading commercial devices using integrated thin-film ferroelectrics at present are: Integrated 0.8 - 2.3 GHz amplifiers (Panasonic) on GaAs MMICs for mobile digital telephones (Fig.5), at 5 million chips/month; a 256-bit "smart card" with the ferroelectric memory in the plastic card and no need for telephoned charge authorization (also a contactless 30-cm READ distance); a 4 Kbit SBT ferroelectric memory fully integrated (Panasonic) into a silicon microcontroller — going up to 32 Kbit in 1998; and 256 Kbit and 1 Mbit nonvolatile RAMs from Panasonic (and also Rohm) and NEC respectively, in prototype sampling production.

However, state of the art in minimum size is already 0.2 micron Pt electrodes (Tegal Corp.), so 1 to 4 Gbit ferroelectric RAMs seem feasible within three years.

![256 Kbit nonvolatile ferroelectric memory](image)

## Present Efforts at UNSW

Much of the device development R&D on these thin-film memories is being done at UNSW in The Surface Science Laboratory directed by Prof. Rob Lamb, with support from SONY Corp. in Japan, including a skilled Sony engineer, Mr. Koji Watanabe, here with us for 1997-8, from Symetrix Corp. in the USA, and from the ARC.

We are actively pursuing the quest to make the lateral area of individual cells as small as possible. The cover photos illustrate 150 x 150 nm nano-electrodes on the surface of bismuth titanate films, together with atomic force microscopy (AFM) photos. Their depth profiles and plan view areal distributions are both shown. These are pure metallic bismuth when the film is processed at high temperatures in vacuum, but they crystalize into square nanocrystals of bismuth oxide (simple cubic phase) in air, as shown. Surprisingly, they self-pattern preferentially along the \([100]\) axes of the underlying Si crystal substrate, providing that the bottom electrode of strontium ruthenate and the ferroelectric film are both perfectly epitaxial. In order to make these arrays of nano-phase capacitors be commercially interesting as memories, we must improve the ordering of these arrays so that they are nearly perfect rows and columns. In that geometry the cells can be easily addressed for READ and WRITE operation. If we succeed in ordering these nano-electrodes (e.g., by applied electric field or mechanical stress, or by narrow-beam ion-implantation of the Si substrate), we will have achieved a 1 Gbit memory with no submicron lithography, a neat trick.

## References

CALL FOR PM TO INTERVENE
1 January 1998

Australia's peak council for scientists and technologists today (Thursday) called on the Prime Minister to take a personal lead in selling the benefits of science to the Australian community.

Professor Peter Cullen, President of the Federation of Australian Scientific and Technological Societies (FASTS), made the call when he released FASTS' "Ten Top Policies for 1998".

He said that the issues were so important that it needed leadership from the top to resolve them.

"There are so many areas that need attention - science and mathematics education in our primary and high schools, the low level of investment by industry in R&D, the lack of venture capital to turn good Australian ideas into commercial reality," Professor Cullen said.

"The Prime Minister has shown a refreshing personal commitment to the functioning of his Science, Engineering and Innovation Council (PMSEC) and to industry policy. We'd like him to take on some of the burning issues confronting science today.

"There needs to be a whole-of-Government approach to address the market failures damaging our present S&T effort."

The funding crisis gripping science departments in universities heads the FASTS' list for 1998. Science departments are underfunded and poorly-equipped, and with mounting pressure on staff to teach more students with fewer resources, some departments are cracking under the strain.

Professor Cullen said that the price of letting university science run down is going to reverberate through future generations of Australians.

"If we have a future in this most competitive corner of a highly competitive world, it is by doing things better and smarter. Cutting back our investment in science and technology is not better for Australia, and it's certainly not smarter," he said.

"Investment requires a strategy, and it is clear to the industry and research community that this Government does not have a national strategy. So we have urged the Government - again - to determine a national vision for Australia, and to establish what science and technology is needed to support that future."

Other issues in the "Ten Top" call for industry, Government and the research community to work together to ensure a smooth transition into the workforce for Australia's young research scientists, and for the creation of a special rolling fund to provide for "big ticket" science.

"FASTS would like to see the earmarking of funds for these "big ticket" items that only come up occasionally, like buying a research ship to investigate the ocean's wealth around Australia," he said.

1. CRISIS IN SCIENCE IN THE UNIVERSITIES

FASTS urges the Government to resolve the funding crisis in the universities. Otherwise science departments will be closed in a haphazard manner by universities forced into excessive cost-cutting measures. If Government is unwilling to meet the true cost of maintaining science in all universities, then it should assist regions to coordinate scientific teaching and research.

2. A NATIONAL VISION FOR AUSTRALIA

FASTS urges the Government to determine a national vision for Australia, and to establish what science and technology is needed to support that future. This process may lead to "picking winners" - strategic investments to exploit strengths or remedy deficiencies in the economy's scientific and technological base.

3. BOOST INDUSTRY R&D

Industry investment in R&D is way behind that of comparable countries, with Australia ranking 19th out of 24 OECD and Asian nations. FASTS urges the Government to boost this investment in R&D by increasing the tax concession for business expenditure on R&D and allowing patent costs to be counted as R&D expenditure.

4. RAW DEAL FOR KIDS

Schools need an injection of younger and better-qualified teachers of science and maths. The Government should offer incentives like a "HECS holiday" (deferral of HECS payments) or higher salaries to teachers with higher qualifications, to encourage the best people to take up the teaching of science and maths.

5. GETTING RESEARCH TO MARKET

The CRC Program turns good science ideas into industrial reality, by bringing researchers and industry together to work on solutions. It is also training a new generation of young scientists for jobs in industry, and strengthening the weak links between science and industry. FASTS urges the Government to continue the CRC Program.

6. SCIENCE AWARENESS

S&T create wealth-generating industries and solve environmental problems, but the benefits are not fully appreciated. The Prime Minister should take a lead in selling the benefits by promoting science festivals, science education and careers, and media coverage of science and technology.

7. VENTURE CAPITAL

Industry needs encouragement to invest in high-risk, high-tech projects with high potential returns. Government's current contribution is a drop in the ocean, and FASTS calls for a boost through imaginative schemes such as tax deductibility for R&D investment income, extending the Factor Scheme to other industries, and making better use of Government purchasing.

8. JOBS FOR YOUNG RESEARCH SCIENTISTS

Job insecurity, lack of career paths and low salaries are driving good young scientists away from jobs in research. Australia is in danger of losing a generation of scientists. FASTS urges industry, the Government and the universities to work together to solve this waste of talent.

9. "BIG TICKET" SCIENCE

FASTS urges the Government to establish a rolling fund to provide for "big ticket" science, such as access to international telescopes and research ships to investigate the ocean's wealth.

10. HOW LOW CAN WE GO?

Only 19 per cent of the scientists who applied for Australian Research Council grants in 1997 were successful. ARC grants support basic science, which are today's ideas and tomorrow's money-making innovations. FASTS urges an immediate boost to ARC and National Health and Medical Research Council funding.

Mr Toss Gascoigne
Executive Director
Federation of Australian Scientific and Technological Societies (FASTS)
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Rutherfordium - After years of international haggling and horse trading, Ernest Rutherford has finally and formally become the only New Zealander to have a chemical element named in his honour.

First a little background in chemistry and physics. Our world and extensive galaxies comprise just 92 chemical elements. Of these only 81 are truly stable. Those heavier than bismuth are radioactively decaying away until there will be none left. Those existing naturally, such as uranium, do so solely because they are decaying at such a slow rate that there are still significant numbers of these atoms remaining today, some 15 billion years since the elements first formed.

For a hundred years we have known of the existence of the electron, the first object to be discovered which was smaller than an atom. For eighty years we have known that the chemistry of an atom is governed by the number of electrons in orbit about an atom. Just prior to that, it was Ernest Rutherford who showed that the atom was a nuclear entity, with almost all its mass in a nucleus less than a thousandth the diameter of an atom. (If the orbital electrons of the atoms making up our body were pushed into the nucleus, as happens in a neutron star, our body would fit into a small grain of sand.)

The nucleus consists of protons (the nucleus of a hydrogen atom) and neutrons. Ernest Rutherford was the first person to propose that neutrons had to exist, and one of his colleagues discovered them. Neutrons are electrically uncharged and, if isolated outside the nucleus, decay after eleven minutes into a proton and an electron. Atoms have as many protons in their nucleus as they have electrons in orbit. Hence the chemistry of an element is effectively determined by the number of protons in its nucleus, the atomic number, which ranges from 1 for hydrogen to 92 for uranium.

All atoms heavier than bismuth (atomic number 83) are unstable. Some decades ago, physicists predicted that the arrangement of particles in nuclei of atomic number around 112 should again be stable. But where were these elements? Extensive searches of nature failed to find them. Therefore it was decided to manufacture them for study, using large particle accelerators to smash a light element into a heavy element. To the discoverer went the honour of proposing a name for each new element. Neptunium (A = 93) and plutonium (A = 94) were natural successors to uranium. Names such as americium (A = 95), berkellium (A = 97) and californium (A = 98) commemorated the place of discovery. Curium (A = 96), einsteinium (A = 99), fermium (A = 100), mendelevium (A = 101) and lawrencium (A = 103) honoured the discoverers' scientific heroes. Nobelium (A = 102), claimed first by an international group working at the Nobel Institute in Stockholm (but never substantiated) was named in honour of the man who left his fortune for prizes to promote science.
The Berkeley version of the periodic table on a mug. Signed by the discoverer of Rutherfordium and, on the other side, by Glenn Seaborg for whom Seaborgium is named.

The early heavy elements were made in reactors where neutrons entered a lighter nucleus and the resultant nucleus decayed by beta decay, thus moving one higher in the periodic table. Fm257 was the heaviest isotope obtainable from reactors. Those beyond fermium became special. They could only be made by accelerating nuclei of around ten to twenty protons and neutrons to high speeds in large accelerators and smashing them into the heaviest nuclei abundantly produced in the reactors.

The heavier the element the harder its manufacture became and the shorter it survived, until only three laboratories specialized in this work: Berkeley in California, Darmstadt in Germany and Dubna in Russia. And from element 102 on, the controversies started. These were fuelled by the Cold War of the time.

In 1964 the Dubna group, led by G N Flerov, claimed to have manufactured one isotope of element 104 by smashing neon nuclei into plutonium. They proposed the name kurchatovium (Ku), in honour of the Soviet nuclear physicist Igor Kurchatov. Albert Ghiorso and co-workers at the Lawrence Berkeley Laboratory of the University of California spent a year attempting to repeat this work but finally had to conclude that element 104 could not have been manufactured by Dubna. In 1969 the Berkeley team produced element 104 in an entirely different way. They bombarded the world's supply of Californium with high speed nuclei of carbon atoms.

In November of 1969, at celebrations marking the centennial of Mendeleev, the father of the periodic table, Al Ghiorso proposed that element 104 be named rutherfordium (Rf) because Ernest Rutherford was one of his heroes. "We are suggesting that element 104 be called rutherfordium, after Lord Rutherford, the great pioneer of nuclear science. If, in the course of further experiments, contrary to our present expectations, we do confirm the earlier findings of the Dubna group of approximately three-tenths of a second spontaneous fission activity, we will withdraw our suggested name and accept that proposed by the Soviet group, kurchatovium."

This was most fitting as it was Rutherford who had first explained the nature of radioactivity, that one element was decaying into another. That concept had been such an advance in science that Rutherford had been awarded the 1908 Nobel Prize in Chemistry. Also he named the alpha particles. Their energy and half-life were unique to the nucleus in question.

For nearly two decades the world lived with three names for element 104. Each country used its own name, the Oxford Dictionary listed both but politically correct periodic tables used an interim name Unnilquadium, the Latin for one zero four, or Unq for short.

To solve the impasse, a Transferrmium Working Group, a joint committee of the International Union of Pure and Applied Physics and the International Union of Pure and Applied Chemistry, was set up in 1985 to determine precedence of discovery for all elements beyond fermium. This would allow unique names to be assigned. In 1992 the committee concluded that the two groups should share credit for discovery of the

<table>
<thead>
<tr>
<th>Element No</th>
<th>Name</th>
<th>Symbol</th>
<th>Named for</th>
</tr>
</thead>
<tbody>
<tr>
<td>104</td>
<td>rutherfordium</td>
<td>Rf</td>
<td>Ernest Rutherford, New Zealand physicist.</td>
</tr>
<tr>
<td>105</td>
<td>dubnium</td>
<td>Db</td>
<td>Dubna, Site of the Russian research laboratory.</td>
</tr>
<tr>
<td>106</td>
<td>seaborgium</td>
<td>Sg</td>
<td>Glenn Seaborg, American nuclear chemist.</td>
</tr>
<tr>
<td>107</td>
<td>bohrium</td>
<td>Bh</td>
<td>Niels Bohr, Danish physicist.</td>
</tr>
<tr>
<td>108</td>
<td>hassium</td>
<td>Hs</td>
<td>Latin for Ross, the German state containing Darmstadt.</td>
</tr>
<tr>
<td>109</td>
<td>meitnerium</td>
<td>Mt</td>
<td>Lisa Meitner, German physicist.</td>
</tr>
</tbody>
</table>
elements 104 and 105. This conclusion was bitterly rejected by the Berkeley group and others.

An August 1994 meeting adopted a new rule that no element could be named after a living person. Since both Albert Einstein and Enrico Fermi had been alive when they had had elements proposed in their honour, this move was a ploy to take the very much alive Glenn Seaborg’s name off element 106 so that the element could then be named rutherfordium. This left element 104 open to be renamed dubnium. Confusion reigned. Elements 104 to 109 were to be named but international arguments continued over most of these. As I had already set an exam question for 1994 based on element being named rutherfordium I supported the Americans.

Early this month a final compromise was reached and all phases of naming were passed. 104 rutherfordium (Rf), 105 dubnium (Db), 106 seaborgium (Sg), 107 bohrium (Bh), 108 hassium (Hs) and 109 meitnerium (Mt). There are still problems. Bohrium, rather than the proposed nielsbohrinium, has the same name as the element boron (bori) in both Russian and German. And the American group probably won’t in practice accept dubnium in place of hahnium which they had proposed in honour of Otto Hahn.

It is significant that both Niels Bohr and Otto Hahn first became internationally famous while working with Ernest Rutherford.

The suggestion has been made that future names be picked jointly by the Americans, the Germans and the Russians who work in the field. When the other two groups have repeated the work the discoverer will be asked to suggest a name which is satisfactory to all three. Only then will it go to the formal naming committee.

The naming of elements 110 to 112, all recently discovered, is being held over. Even so, the holy grail of stable heavy-nuclei still eludes their creators.

But our Ern has his element.

From its position in the periodic table, rutherfordium should have similar chemistry to hafnium. Its longest living isotope has a half-life of about 70 seconds. Only a few thousand atoms of rutherfordium have ever been manufactured and probably no more than 100 of these atoms have ever been chemically isolated using a special cation exchange column. As you read this there will most likely be not one atom of rutherfordium in existence, unless one of the three groups are painstakingly manufacturing it for other experiments.

Fame is but fleeting. However, it is too much of a gamble to hold back a favourite name on the chance that stable heavy-nuclei will eventually be manufactured.
PRODUCT NEWS

New Melles Griot 35m W Polarised HeNe Laser

Melles Griot, leading worldwide helium neon laser manufacturer, introduces a new line of 35mW polarised helium neon lasers in a new rectangular packaging. The lasers are specifically designed for easy drop-in replacement into OEM systems with convenient, universal mounting slots and industry standard 50.8mm bean delivery optical axes without system modification. The 05 LHP 928 linearly polarised and 05 LHR 928 randomly polarised lasers are offered at virtually the same price, with the addition of a rugged exoskeleton housing for superior power stability and repeatable performance.

These lasers use the Melles Griot hard-sealed internal cavity mirror construction for ultimate long lifetime and long term mirror alignment. They are ideal for high speed laser printing, Raman spectroscopy, long haul fibre break testing, holography and much more. As with all Melles Griot lasers, beam delivery systems and other accessories are available. Melles Griot offers these lasers through its worldwide service and distribution network along with a broad spectrum of other lasers and photonics products.

For further details, please contact Graeme Jones at Lastek Pty Ltd on Tel:(08) 8443 8668, Fax: (08) 8443 8427 or email: lastek@saschools.edu.au

Ultra High Resolution PZT Translator

New from PI (Physik Instrumente), are the PIco PZT Translators, closed loop, ultra high resolution linear actuators for static and dynamic applications. They combine the advantages of piezoceramic actuators and capacitive sensors in a small package, and at the same time provide the best combination of resolution, linearity, bandwidth and response of any linear actuator on the market.

PIco Translators have been developed for research and production engineers who are looking for a higher resolution than the PI strain gauge sensor equipped PZT actuators provide, but do not need the sophistication of their capacitive sensors equipped PZT Flexure Stages.

The translators are equipped with extremely reliable PZT ceramic stacks, protected by an internally spring preloaded non-magnetic stainless steel case. The motion of the tip is measured by an ultra-high resolution capacitive sensor for precise motion control. The PZT actuator, sensor and case materials are matched for optimal thermal stability.

Applications include, disk drive test stands, nano-automation, metrology, semiconductor test equipment, wafer steppers, microlithography and optics.

This device offers sub-nanometer resolution and repeatability, an integrated capacitive displacement sensor, travel to 60 μm, fast response for maximum throughput, ultra-high linearity and long term stability.

Further information is available from Warsash Scientific
PO Box 1652 Strawberry Hills, NSW 2012
tel: (02) 9319-0122 or fax: (02) 9318-2192
email: warsash@ozemail.com.au

Melles Griot Long Working Distance Lenses

The new Melles Griot Extra Long Working Distance (ELWD™) Macro Invaritar® lens is a low-distortion, telecentric lens for C-mount CCD cameras. An adjustable iris diaphragm greatly extends gaging depth-of-field compared to conventional micro-objectives. These ELWD lenses work well with front or back lighting. The long working distance permits easy integration of coaxial or ring lighting. All models accept standard 52mm photographic filters or windows.

The telecentric design provides constant magnification over a large depth-of-field, allowing a constant perspective or viewing angle across the entire subject. This lens is especially useful for critical inspection inside deep bores and cut-outs. Melles Griot Optical Systems is the world's foremost designer and manufacturer of telecentric imaging lenses and systems for inspection, projection and machine vision applications. Melles Griot is also a leading optical systems designer and manufacturer for laser image-setting, machine vision, clinical instrumentation, material process and semiconductor fabrication applications.

For further information, please contact Graeme Jones at Lastek Pty Ltd on Tel: (08) 8443 8668, Fax: (08) 8443 8427 or Email: lastek@saschools.edu.au

Do You Need to Observe and Record High Speed Events?

Cordin manufactures a wide variety of high speed and ultra high speed, high resolution, electro-optical research equipment. Cordin's specialty is manufacturing instruments to record events with great precision in space or dimension, time, and even colour or spectral distribution.

When it comes to extreme levels of information recording, the high speed camera has no equal. Products include film cameras with recording rates from 200 to 25,000,000 full frames per second, CCD cameras giving high resolution digital pictures at rates of 100 to 100,000,000 frames per second and image converter streak cameras able to measure light pulses to an accuracy of 1ps or 2ps.

The systems are useful in studying events, which are too fast, or complex, to be correctly observed and analysed by more conventional methods. Some applications may include:

- High Speed Mechanical Motion
- Ballistics & Explosive Studies
- Hydroshock Dynamics
- Laser Radiation Effects
- Crack Propagation
- Plasma Studies
- Internal Combustion Studies
- Fluorescent Photochemistry
- Stress & Shock Failures
- Propellant Studies
- Time Resolved Spectroscopy
- Chemical Reactions

To discuss your application or if you require further information please contact:
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Solar thermal electricity systems utilise solar radiation to generate electricity by photothermal conversion. There are three main solar thermal electricity systems: solar towers, dishes and parabolic troughs. Parabolic trough solar thermal electricity technology has been commercialized on a substantial scale. Solar thermal power plants of the LUZ Solar Electric Generating System (SEGS) type have been constructed in Southern California since 1984. Nine plants with a total net electricity capacity of 354 MW are in operation feeding electricity to the grid of the regional utility. They account for over 90% of the world’s solar power production and have produced 5500 million kWh of electricity to the end of 1995.

The LUZ SEGS basically includes a solar field, steam generating system and power block. The solar field consists of a larger number of parallel connected independent collector loops. Each loop is made in modular form by Solar Collector Assemble (SCA). A silver surfaced parabolic trough reflector concentrates sunlight onto a solar collection tube located along the trough’s focal line. The solar collection tube consists of an inner tube and a glass envelope with the space between them evacuated, to eliminate thermal conductance loss. The outer surface of the inner tube is coated with a solar selective surface which absorbs solar radiation and converts it to thermal energy.

Despite its technical success the cost of solar thermal electricity still exceeds that of conventional electricity generation. From LUZ experience, the investment costs for the actual LUZ 80 MW solar thermal power plants, of about US$3000/kW, are triple that of an 80 MW oil fired power plant. The cost of the solar collection tubes and solarparabolic reflectors are the two main reasons for the extra investment costs, and considerable effort has been spent trying to reduce these cost.

We have recently made two very significant inventions for the improvement of solar selective coatings. In 1991 we developed double cermet layer structures for solar selective surfaces which had the world’s highest photo-thermal conversion efficiency. In 1995 we invented solar selective coatings incorporating new cermet materials deposited by a novel dc magnetron sputtering technology. The costs of high-temperature solar collection tubes manufactured by this new method should be 5 to 10 times lower, than those produced by LUZ for solar thermal electricity applications, and only about 10% more than low-temperature solar collection tubes currently mass-produced for hot water application.

In this article we will first discuss the general principles of solar selective coatings and the main developments during the 1970s and 1980s and then give a detailed discussion of our new inventions.

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Solar Selective Absorbers

All bodies emit thermal radiation. Figure 1 shows a solar radiation distribution AM1, and the blackbody radiation spectra for temperatures of 100, 300 and 400 °C. An ideal solar selective surface absorbs most of the incident solar radiation while simultaneously suppressing its own emittance losses. Such an ideal surface would follow the reflectance spectrum step function shown in Figure 1. Commonly used performance parameters for selective surfaces are solar absorptance and thermal emittance. The angular dependent solar absorptance α and thermal emittance ε are defined, respectively, by

\[
\alpha(\theta) = \int_0^\lambda A(\lambda)[1 - R(\theta, \lambda)]d\lambda / \int_0^\infty A(\lambda)d\lambda
\]

\[
e(\theta, T) = \int_0^\lambda E(T, \lambda)[1 - R(\theta, \lambda)]d\lambda / \int_0^\infty E(T, \lambda)d\lambda
\]

were \(A(\lambda)\) is the solar spectral irradiance, and \(E(T, \lambda)\) the spectral blackbody emissive power. \(R(\theta, \lambda)\) is the angular dependent spectral reflectance. For a real solar selective surface the absorptance is normally calculated in the wavelength range of 0.3 - 3.0 μm, and emittance is calculated in the range of 1 - 50 μm at a given temperature. The hemispherical emittance is given by

\[
e_{h}(T) = \int_0^{\pi/2} E(T, \lambda)sin(2\theta)[1 - R(\theta, \lambda)]d\theta / \int_0^\infty E(T, \lambda)d\lambda
\]

The photo-thermal conversion efficiency η can be calculated using the following formula,

\[
\eta = \alpha - e_{h} T^4 / (C_l)
\]

where \(\alpha\), \(T\), \(C_l\) and \(l\) are the Stefan-Boltzmann constant, operating temperature, flux amplification or concentration factor, and solar flux intensity, respectively.

The solar radiation distribution AM1, and the blackbody spectra for temperatures of 100, 300 and 400 °C. Spectral optical reflectance spectra of an ideal selective surface and a calculated Mo-Al₂O₃ cermet selective surface are also shown.

A very large number of selective surfaces were intensively studied during the 1970s and 1980s [1,2]. Most selective solar absorber coatings use metal-dielectric composites, known as cerments, as the absorber of solar energy. They vary mainly in their optical properties and thermal stability. Electroplated black chromium and nickel-pigmented anodic Al₂O₃ solar absorbers are two popular solar selective absorbers. These two kinds of solar coatings are cheap to produce and are hence widely used in flat plate solar collectors. However, the emittance of both coatings is higher, around 10 – 20% at 100 °C.

Solar selective coatings with excellent optical properties can be made by sputtering technology. Selective surfaces incorporating dc reactively sputtered stainless steel-carbon (SS-C) were intensively studied at the University of Sydney during the 1970s to 1980s [3,4]. Evacuated all glass solar collection tubes, with sputtered graded SS-C cermet coatings, have been mass-produced by Shiroyki in Japan since the 1980s. Other successful solar coatings are reactive sputtered Al-N cerments [5,6]. The evacuated all glass solar collection tubes with dc reactive sputtered graded Al-N cermet selective surfaces have been mass-produced in China. Cylindrical dc magnetron technology has made the manufacture of these evacuated tubes inexpensive. They have been used in solar hot water and steam applications.

The solar collection tubes for LUX solar thermal electricity plants use a Mo-Al₂O₃ cermet as solar absorber, because of its excellent thermal stability at high operating temperatures, 380 - 500°C. Planar magnetron technology has been used to deposit these cerments onto solar collection tubes. Seven planar targets, including 3 metallic targets and 4 ceramic targets, are used to manufacture the Mo-Al₂O₃ cermet solar collection tubes in a commercial-scale coater [7]. The Mo-Al₂O₃ cermet solar coatings are deposited onto a rotating tube, located at the centre of the chamber. The Mo metal component in the cermet is deposited using dc sputtering and the Al₂O₃ ceramic component is deposited by rf sputtering.

Double Cerment Layer Structure for Solar Selective Surfaces

All of these commercially produced selective solar absorbers have a graded composite absorber. Reflectance from the composite absorber layer is reduced by increasing the metal volume fraction, and hence refractive index from surface to substrate [8]. Through fundamental analysis and computer modelling we have devised a new cermet solar selective surface structure with better solar performance than surfaces using a homogeneous cermet layer or the conventional graded film structure [9-11,12]. A typical film structure, Figure 2, from substrate to surface consists of:

- a metal infrared reflecting layer composed of an excellent infrared reflector such as copper, aluminium and molybdenum which reduces substrate emittance;
- an absorbing layer composed of two homogeneous cermet sublayers with different metal volume fractions. The layer near the metal infrared layer has a high metal volume fraction (HMVF) and the layer near the anti-reflection layer has low metal volume fraction (LMVF); and
- an anti-reflection layer composed of a transparent dielectric material that enhances solar absorption.

Australian & New Zealand Physicist Volume 35, Number 1, January/February 1998
to that of an ideal solar absorber. The reflectance spectrum corresponds to a solar absorptance of 0.965 and normal emittance of 0.03 at 20°C. In the numerical calculation of reflectance spectrum, the Bruggeman (BR) theory of the dielectric function of a composite has been employed. For identical spherical particles immersed in a host medium the average complex dielectric function of a composite in the BR approximation, \( \varepsilon^{BR} = \varepsilon_1 + i\varepsilon'' \), is given by,

\[
\left( \varepsilon_1 - \varepsilon'' \right) \left( \varepsilon_n + 2\varepsilon'' \right) + \left( 1 - f \right) \left( \varepsilon_n - \varepsilon'' \right) \left( \varepsilon_n + 2\varepsilon'' \right) = 0
\]

(5)

where \( \varepsilon_1 \) and \( \varepsilon_n \) are the complex dielectric functions of particles and host medium, respectively. The filling factor \( f \) represents the volume fraction occupied by the particles.

Many double cermet solar absorbers, using different cermet materials, have been deposited [10,11,13]. These new cermet layer structures have attained considerably better solar performance than other published results.

We have recently developed a sophisticated computer model for solar selective coatings which allows for the temperature dependence of the complex refractive indices of metals and cerments, using the Sheng (SH) approximation [14] for the dielectric function of composite materials [15].

The dielectric functions of a metal are divided into free-electron parts and interband parts. The interband transition is assumed to be temperature independent. The dielectric function contributed by the free-electron part is considered as temperature dependent. The dielectric function of a free electron metal, \( \varepsilon^{FE} = \varepsilon' + i\varepsilon'' \), is given by the Drude formula,

\[
\varepsilon^{FE}(\omega) = \varepsilon_0 - \frac{\omega_p^2}{\omega^2 + i\omega\tau}
\]

(6)

where \( \omega_p \) is the plasma frequency, and \( \tau \) the relaxation time. The \( \varepsilon_n \) is the low-frequency contribution from the high-frequency interband transitions. The \( \omega_p \) and \( \tau \) are assumed to be temperature independent. The relaxation time \( \tau \) is temperature dependent. When \( \tau \to 0 \), it is known that the Drude electrons are scattered in three ways: by phonons \( \tau_p(T) \), by the surface \( \tau_s \), and by other electrons \( \tau_e(T,\omega) \) [16]. The resultant relaxation time is obtained by assuming that these scattering mechanisms are independent, hence

\[
\frac{1}{\tau(T,\omega)} = \frac{1}{\tau_p(T)} + \frac{1}{\tau_s} + \frac{1}{\tau_e(T,\omega)}
\]

(7)

Two theories that have been widely used to analyse the dielectric function of composite materials were proposed by Maxwell Garnett (MG) and by Bruggeman (BR). The MG theory predicts the existence of an optical dielectric anomaly. However, the MG theory does not yield a percolation threshold in granular metals. The BR theory predicts a percolation threshold, but does not produce an optical dielectric anomaly. Sheng's theory, another effective medium theory approximation, displays both the optical dielectric anomaly and the percolation threshold.

Sheng's theory introduces a probabilistic growth model for grains in a composite.
film. The film is modelled as a mixture of two types of coated oblate spheroidal units, dielectric-coated metal spheroids described as type-1 units and metal-coated dielectric spheroids described as type-2 units.

Figure 3 shows predicted film structures for Mo-Al₂O₃ cermet solar coatings. An optimisation program searched for a maximum photo-thermal conversion efficiency at 350°C under a concentration factor of 26. In Figure 3, the dashed line, $P_0$, presents the optimised film for the ten layer structure. The dot-dashed line, $P_{10}$, is for an initial ten step graded film structure from which the optimizing calculation started. The optimised structure for the double Mo-Al₂O₃ cermet layer structure (solid line, F3) is also included for comparison. It is clear that the optimised ten layer graded structure closely approaches a double cermet layer structure. Both optimised films for nine cermet layers and double cermet layers have the same solar absorptance and photo-thermal conversion efficiency of 0.96 and 0.91, respectively.

Calculated film structures have been used as a guide for the deposition of Mo-Al₂O₃ selective surfaces. Figure 4 shows a near normal reflectance spectrum of a deposited film (dot points). This reflectance spectrum corresponds to a solar absorptance of 0.96, and near normal emittance of 0.032 at room temperature. For comparison, Figure 4 also shows a calculated normal reflectance spectrum. Both deposited film and calculated film have the same film structure: Al₂O₃/Mo-Al₂O₃ (LMVF)/Mo-Al₂O₃ (HMVF)/Cu. This calculated film has a solar absorptance of 0.96 and normal emittance of 0.031 at room temperature which are nearly the same as those of the deposited film.

### New Cernet Solar Selective Coatings by a Novel DC Sputtering Technology

We have recently developed a series of new cermet materials for solar selective coatings deposited by a novel two-target dc magnetron sputtering technology. The ceramic and metallic components in the cermet are simultaneously deposited by dc sputtering, running two metallic targets. The ceramic component is deposited by dc reactive sputtering and the metallic component by dc non-reactive sputtering. A series of metal-aluminium nitride (M-AIN) cermet solar coatings have been deposited using a planar magnetron sputtering apparatus [17-19]. The chemical reactivity of aluminium with nitrogen is very high, and it is easy to nitride aluminium to form aluminium nitride in nitrogen gas. An Al metal target is used to deposit AIN, the ceramic component in the cermet, by dc reactive sputtering in a gas mixture of argon and nitrogen. Other metallic targets, including stainless steel, tungsten, Ni₃SiCr₄O and molybdenum based alloy TZM (Mo₆Ti₃Zr₃Al₃), which have good nitriding resistance, are used to deposit the metallic component in the cermet by dc non-reactive sputtering in the same gas mixture. During the deposition of a M-AIN cermet both Al and M targets are run simultaneously in the gas mixture of argon and nitrogen. By substrate rotation a multi-sublayer system, consisting of alternating M and an AIN sublayers, is deposited. This multi-sublayer system can be considered as a multi-homogeneous cermet layer because the thickness of each sublayer is very thin, less than 2 nm.

The M-AIN cermet selective surfaces with a double cermet layer structure were deposited. For the deposition of a solar selective film, an Al (or Cu) metal infrared reflecting layer was first deposited onto the glass substrate by dc sputtering in the pure argon gas. Two M-AIN cermet layers with high and low metal volume fraction were deposited using the method described above. Finally, an AIN ceramic anti-reflection layer was deposited by dc reactive sputtering in a gas mixture of argon and nitrogen. The solar absorptance of 0.94 - 0.96, and normal emittance of 0.03 - 0.05 at room temperature has been achieved for the M-AIN cermet selective coatings [20].

### Commercial Development

The author at Sydney University and Prof Zhao of Peking University and Beijing TurboSun Company have cooperated on the commercial development of these coatings since 1995. A commercial-scale cylindrical magnetron sputterer has been developed and constructed [21]. This coater was installed at Peking University in December 1995. Figure 5 shows a cross-section of the coater, set up for SS-ARN cermet solar coatings. The vacuum chamber accommodates 32 tubes each 1.2 m long and of 37 mm inside diameter. Three cylindrical cathodes of aluminium, stainless steel and copper tubes are separated by screens to prevent cross contamination. A sputtering argon gas inlet is located near the SS target and the reactive nitrogen gas inlet near the Al target. The 32 tubes...
rotate around the chamber central axis in a planetary mount which rotates each tube about its own axis to ensure coating uniformity.

During the deposition of an SS-AIN cermet layer both the Al and SS targets are run simultaneously in the gas mixture of argon and nitrogen. The nitrogen partial pressure is just high enough to ensure that the AIN sublayer is deposited by dc reactive sputtering. The tube rotation system enables a multi-sublayer system, consisting of alternating SS and AIN sublayers, to be deposited onto the surrounding tubes. Each sublayer thicknesses can be controlled by SS and Al target currents and the speed of rotation.

An SS-AIN cermet layer is usually first deposited onto the tubes to increase adhesion of the Al metal infrared reflecting layer to the substrate. Two SS-AIN cermet layers with different metal volume fractions are deposited in a gas mixture of the argon and nitrogen. Finally, an AIN ceramic anti-reflection layer is deposited by dc reactive sputtering. For better thermal stability of the solar collection tube at high temperature, a copper, or molybdenum metal infrared reflector layer can be used, instead of aluminium.

Excellent results have been obtained [21,22]. A solar absorptance of 0.94 - 0.96, and emittance of 0.05 – 0.07 at 100°C has been achieved for normal production of SS-AIN cermet selective surface coatings with an Al metal infrared reflector layer. The absorptance variation along the length of tubes is less than 1%.

The deposition efficiency is very high. Coating 32 tubes takes only 40 minutes. This coater is much cheaper than the LUZ planar sputtering coater. A commercial system for manufacturing solar collection tubes, including the sputtering coater, evacuation and bakeout equipment, and other relevant equipment, costs about CNY12 million, equivalent to about A$200,000.

This commercial technology is also suitable for several other metals and alloys which have low chemical reactivity with nitrogen. Initial laboratory results show that the solar selective coatings incorporating dc sputtered tungsten and dc reactively sputtered aluminium nitride components in a cermet are stable up to 500°C [19]. Using this commercial-scale coater, it would be possible to produce W-AIN cermet solar collection tubes. The procedure for deposition of the W-AIN cermet solar coatings is similar to that for SS-AIN cermet coatings. In order to improve further the thermal stability of the solar coatings at high temperature, it is also possible to deposit a metallic tungsten layer as the infrared reflector layer by running the tungsten target in pure argon gas. Such solar coatings with the film structure AIN/W-AIN/W should be stable to even higher temperature.

A cross-section schematic of a cylindrical magnetron sputtering coater for the deposition of the SS-AIN cermet selective surfaces onto tubes. Three cylindrical cathodes of aluminium, stainless steel and copper tubes are separated by screws to prevent cross contamination. An argon inlet is located at the side of the SS target and the reactive nitrogen inlet at the side of the Al target.

On the basis of these results, the TurboSun Company has produced evacuated solar collection tubes in China under a license agreement with the University of Sydney. Currently this company manufactures SS-AIN cermet solar collection tubes. The SS-AIN cermet solar collection tubes are expected to be stable at temperatures of 350 – 400°C and will be used in the test units for solar thermal electricity generation. However, they will initially be made available for the solar hot water and steam market and should be competitive with existing products. Using this production line, after minor modifications, it would be possible to produce high-temperature solar heat collection tubes based on high-melting point transition metal and AIN cermet for solar thermal electricity generation plants in China and Australia.
Acknowledgements

The author wishes to acknowledge the financial assistance of His Royal Highness Prince Nawaf Bin Abdul Aziz of the Kingdom of Saudi Arabia through the Science Foundation for Physics within the University of Sydney. The author is very grateful to Prof K Zhao and his group members of Peking University for commercial development, and the TurboSun Company for financial support.

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VIC
Pulsar Timing and General Relativity

The November Branch Meeting featured a fascinating talk on pulsars by Dr Matthew Bailes from the School of Physics, University of Melbourne. Dr Bailes introduced the topic in a dramatic manner by using the amplified radio bursts from the pulsar PSR J0437-4715 to drive a speaker. Surprisingly, there was a noticeable variation in the periodicity of the pulses. Although the pulses repeat with very high accuracy (better than 1 part in 100 million), the amount of energy in a pulse varies considerably, with complete pulses sometimes missing from the sequence. Following this engaging entry to the topic, the audience was shown some remarkable images of the large scale structure of the Universe (e.g., clusters of galaxies). The composition of galaxies was then discussed, with particular emphasis on our own galaxy (the Milky Way). The 100 billion stars in our galaxy exhibit a wide variety of luminosities, masses and lifetimes. Of particular interest is what determines the evolution and ultimate fate of stars?

Dr Bailes presented various scenarios for star deaths, showing that what happens to a star depends on its mass at death. For stars with up to 1.4 solar masses, a white dwarf is expected; a neutron star forms if the mass is typically between 1.4 and 3 solar masses, and finally, a black hole forms when the mass exceeds about 3 solar masses. The presentation of this material was enlivened considerably by the use of helpful graphics and spectacular astronomical images.

The remainder of the talk discussed the formation of neutron stars, their structure and evolution. With a mass of up to 3 solar masses, and a radius of about 10 km, a neutron star is an extraordinary astrophysical object. Rotating magnetic neutron stars, spinning up to 38,000 rpm, radiate electromagnetic energy and can be observed as pulsars. The first pulsar was discovered by Jocelyn Bell (later Burnell) in 1967 while conducting research as part of her PhD. Although Anthony Hewish and Martin Ryle were awarded the Nobel Prize in Physics in 1974 for their work on pulsars, it is generally acknowledged that Jocelyn Bell was pivotal in the discovery and subsequent investigation of pulsars (see e.g., "Burnell, Jocelyn Bell CWP", http://www.physics.ucla.edu/~cwp/ for more details).

Perhaps the most well known pulsar is that in the Crab Nebula, which is the site of the famous supernova in 1054 AD. To date however, over 700 radio pulsars have been discovered, with periods from about 1.6 ms to nearly 5 s. It is noteworthy that over half of the known pulsars have been discovered in Australia, with Dr Bailes' recent all southern sky survey revealing 101 new pulsars. A particular interest of Dr Bailes' group is the so-called millisecond pulsars which were not observed before 1981. These pulsars are thought to be old and companion to another star in a binary system. In this manner a neutron star can accrete matter from the companion and alter its rotational period. A number of exotic scenarios (e.g., the Black Widow scenario) were presented for the accretion mechanism and concomitant spin history of a neutron star.

Finally, the lecture discussed the incredible long term stability of pulsars, which makes them suitable as clocks. An extraordinary observation of the pulsar PSR J0437-4715 gives its period as 5.75745182525623(6) ms, with the Earth-pulsar distance measured to 150 m per observation! This makes pulsars a very useful vehicle for testing general relativity. For example, if a pulsar is not symmetric it will radiate gravitational waves; this places significant constraints on the asymmetry of a pulsar, whereby the diameter of a pulsar (viewed from above) measured along two perpendicular directions cannot differ by more than 12 micrometer. The remarkable precision afforded by pulsar observations promises to provide many new insights and discoveries in astrophysics.

In conclusion, what made this talk truly memorable was the judicious use of graphics, animations and engaging demonstrations, which were used to illustrate specific abstract ideas. The interested reader may want to view these images, and is urged to visit Dr Bailes' Web Site at: http://www.ph.unimelb.edu.au/~mbailes/publi c/webquist.htm, where one can also find more details of the lecture.

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**Australian Journal of Physics**

**Contents**

**Volume 51**  Number 1  1998

**Editorial:** Fifty years of publishing physics

**General Physics**

C. G. Miller

Some physical implications of the gravitomagnetic field in the fractal space-time theory. M. Agop, V. Grigo, C. Gh. Bucea, I. Petrescu, S. Bucea, C. Marian and R. Resedecu

Structure of the world crystal. M. Agop, V. Grigo, C. Gh. Bucea, N. Resedecu, S. Bucea, A. Zacharias and I. Petrescu

**Elementary Particles and Fields**

Gluon spectrum of SU(3) lattice gauge theory by plaquette expansion. M. W. Wilson and D. L. Hollenberg

**Nuclear Physics**

A nonlocal potential form for s-wave α-α scattering. R. Amos and M. T. Bennett

**Atomic and Molecular Physics**

Ab initio investigations of the electronic structure of H$_2$NH$^+$ and H$_2$NH$^{2+}$. Jason M. Hughes and Eliko I. von Nagy-Poloszki

**Plasmas and Electric Discharges**

Ion confinement in a toroidal heliac. J. L. V. Lewandowski

**Tokamak equilibrium model with finite toroidicity effects. J. L. V. Lewandowski**

**Fluids, Plasmas and Electric Discharges**

Effects of the dust charge fluctuation and ion temperature on large amplitude ion-acoustic waves in a dusty plasma. Y. N. Noj enf

**Effects of boundary and electron inertia on the ion-acoustic wave in a plasma: A pseudopotential approach. K. K. Mondal, S. N. Paul and A. Roy Chowdhury**

**Large amplitude Alfven soliton in the solar wind and Painleve analysis. A. Roy Chowdhury, B. Dutta and B. Daaghata**

**Condensed Matter**

Magnetic transition and spin correlation in Mn oxides at low temperatures. J. E. Jiang

**Astronomy and Astrophysics**

Luminosity selection effects and linear size evolution in the quasar/galaxy unification scheme. A. A. Esbalenkov and A. N. Ogurov

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22

Australian & New Zealand Physicist  Volume 35, Number 1, January/February 1998
A REMARKABLE MEETING

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At the beginning of 1952 I returned to Melbourne to take up a position of Senior Lecturer in the Mathematics Department after completing a PhD at Cambridge in mathematical physics. This was an echo of what my father did 29 years earlier. Then he had also completed a PhD at Cambridge – the first South Australian and only the third Australian to have done so at the time – in surface chemistry under Eric Rideal. That was however the end of his scientific career for there was nothing in Australia for him to go to. There were not even any jobs in the universities, let alone any work in a field so new. For much of his working life he was senior biochemist with the Commonwealth Serum Laboratories, a position outside his tastes but where he formed enduring friendships with Dr Tom Cherry (father of Professor Tom Cherry) and Hugh Ennor (later ANU and Secretary to the Minister for Science).

My situation was better because the mathematics department in Melbourne was a very good one although not very large by international standards. However the teaching load was not light, and to the best of my knowledge there were no others there with similar research interests to mine. If I wasn’t to follow in my father’s footsteps I had either to try to work by myself or change my research field.

1952 and 1953 were spent preparing and giving lectures with not much space for anything else. There was no tradition of departmental seminars in mathematics nor in physics, so the future for my research did not look very promising.

Early in 1953 I received a letter from Professor Oliphant telling me that the next ANZAAS meeting was to be in Canberra in early 1954 at the newly formed Australian National University, and asking me if I would be able to come. There was no money for visits to conferences, so it would all have to come out of my nearly empty pocket, but as such an invitation appeared close to a royal command I decided to go. This was for me a turning point of my life, and possibly the same was true for quite a number of other Australian theoretical physicists.

Canberra at the beginning of 1954 had a population of about 30,000 and was well described as a number of suburbs in search of a city. Attendees at the meeting were lodged at the Canberra Boys Grammar School in Red Hill, and were taken to the meetings by a bus which brought them back in the late afternoon. If one slept in, or was not interested in the early sessions the alternative was the public bus service, which my memory tells me ran about two or three times a day, or to walk. Walking from Red Hill was an interesting experience, as there were plenty of well made suburban roads, with nice concrete gutters, but with no sign of footpaths or houses or habitation of any sort. As it was January and there were then few trees in Canberra, walking was hot work.

The physics meetings were conducted in the Institute of Anatomy, and as this was really the first physics meeting after the war, each department took the opportunity to display their wares. Huxley gave an account of the new research programs which he had set up in Adelaide to investigate the upper atmosphere and the atomic processes likely to be encountered there. I remember being very impressed by the ideas he presented and the methods being used to follow them up. Hopper talked about his work on cosmic rays using balloon flights, and it was then I first became aware of the tensions which existed in the Australian physics community. The Sydney physics department was at the beginning of a new era utterly different from anything it had experienced before. Harry Messel had been appointed to the principal chair, long vacant following the retirement of von Willer, and he had brought in a crowd of new people. These newcomers were in the main people who had come to Australia because they did not much like the place they had left behind, and they were eager to make a big impression here. The operative word is “big” and not “good” because they proceeded to jump all over the speakers from the established departments. Hopper was the first to be on the receiving end of what could almost be called heckling, and being basically a rather gentle person he was stunned by the onslaught. A similar attack on another speaker from Melbourne provoked Martin into a very heated defence of the nuclear physics program which had been started using the just completed van der Graaf. Inall described the program for the design and building of the big accelerator at the Research School of Physical Sciences at the ANU. Even then it was clear that heroic efforts were going to be needed to get it going. He laconically remarked that because the peak currents
would be about one million amps the leads should be kept short! As if to provide a comment from higher powers his talk was interrupted by one of the most violent electrical storms I have experienced.

This was all very interesting, but it gave no encouragement to the theoretical physicists who were there. Someone, probably Stuart Butler, who was then at ANU, organised a session for theoretical physicists on one morning, in one of the many wooden huts which dotted the site. It was then I realised what an impressive group of theoreticians were now in Australia. There were Harry Messel, John Blatt and Dick Makinson from Sydney Physics and Bruce Bolt from Sydney Maths. Butler and Ed Salpeter were at ANU, Bert Green, John Ward, Ken Potts and Ian McCarthy from Adelaide and Courtney Mohr and myself from Melbourne. I always had enormous regard for Courtney, as a person and as a scientist; he always behaved with impeccable courtesy and loyalty and was always very supportive. As it was not part of the formal ANZAAS program, there is no record of who spoke or what were the subjects. I do remember that Bert Green talked about some ideas he had on Fredholm integral equations and perturbation expansions in quantum field theory, in which he concluded that the suspected divergence of the latter was due to a confluen of singularities - an intriguing idea. Ian McCarthy spoke about his work on parastatistics, which formed the basis of his PhD thesis - one of the first theoretical PhD's in Australia. Bruce Bolt talked about some topic in quantum field theory and suffered a heavy attack from John Ward. There were several other speakers, including myself, but at this distance in time I have no idea what they were. The really important fact was that the meeting was held. The links which were established by this meeting were immediately reinforced by a social evening which was held at Stuart Butler’s.

The immediate outcomes were few, but it was the first indication that mathematical and theoretical physics had at last got a firm foothold in Australia. The formation of the Australian Mathematical Society two years later made explicit reference to mathematical physics, with Bert Green being on the first Council, and the journal has continued to be an outlet for mathematical physics papers. The Summer Research Institute in Canberra in 1967 on Mathematical Physics had the then record attendance of over 150, and was illuminated by stars such as Dalitz, Yang, Dyson, Pais, and Shirkov from UK, USA and the Soviet. Perhaps the final recognition of what was started in Canberra in 1954 is the fact that Australia was chosen ahead of China to hold the International Conference in Mathematical Physics in Brisbane in July 1997, the first time it has been held outside Europe (with one exception at Boulder USA) for twenty years. Out of the well over 300 mathematical physicists from all over the world who came, there was a sizable Australian contingent, who were highly praised for the quality of the organisation. It was a long way from Canberra 1954 but there is no doubt that they are causally connected.

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**MICROGRAVITY WORKSHOP**

The first Pan-Pacific Basin Workshop on Microgravity Sciences will be held at Waseda University, Tokyo, July 8-11, 1998. This workshop will be held every two years in different countries in the Pacific Basin to provide a forum for discussions and cooperation among microgravity researchers mainly in the Pacific Basin region. It is also open to researchers from other countries outside this region. The charter for the Workshop and the venue for the year 2000 conference will be discussed and finalized in the Executive Committee meeting to be held simultaneously during the First Workshop.

The Pan-Pacific Basin Workshop is the result of the expansion of the established Japan-China Workshops which have been held since 1993 on the same subject matter. The Fourth Japan/China Workshop on Microgravity Sciences will also be held in conjunction with this conference.

Full details can be found at:-

http://science.msfc.nasa.gov/colloquia/ppbwms/announce.htm
In March 1998 the Australian Journal of Physics celebrates its fiftieth year of publication. The first issue of the journal, Volume 1, Number 1, was in fact published early in 1948 under the name of the Australian Journal of Scientific Research. The journal was a cooperative effort by the Council for Scientific and Industrial Research (later to become the CSIRO) and the Australian National Research Council (the forerunner of the Australian Academy of Science), both of which saw the need for Australia to have its first truly national journal for scientific research. As announced in a foreword to the first issue: ‘The aim is to encourage scientific endeavour in the Commonwealth and it is believed that both quality and quantity of material available for publication will justify the step now taken.’

In its style and appearance the Australian Journal of Scientific Research was modelled directly on the famous Proceedings of the Royal Society of London, not surprising given the very close relationship between Australia and Britain at the time, especially in science. Initially the journal was published in two series covering papers in the physical sciences (Series A) and the biological sciences (Series B). The first issue of Series A (see the Contents page) reflects this broad sweep with papers ranging from nuclear physics to the chemistry of a certain species of gum tree! There is also a paper on cosmic radio emission from a source in the region of Cygnus, which can be said to mark the beginning of radio astronomy in Australia. Over the next few years the journal grew steadily and, by 1953, had become large enough to split into two distinct journals, the Australian Journal of Physics and the Australian Journal of Chemistry, both of which continue to prosper.

Much has changed since these early years, not least the technological innovations which are revolutionising journal publishing. The AJP has kept pace with these changes and in 1997 we began an experimental electronic edition of the journal on the world wide web. Following the success of this trial, we are proud to announce the launch of a full electronic service for our readers in 1998. We invite you to celebrate our fiftieth birthday, and to help take our journal into the future, by making sure your institution subscribes to both the print and electronic editions of the Australian Journal of Physics.

Peter Robertson
Editor, AJP
OBITUARY
RICHARD ORMOND CHERRY
1903 - 1996

This obituary was written by Dick Cherry’s son, A/Prof Edward Cherry, Dept of Electrical & Computer Engineering, Monash University. Communicated by Prof. G.I. Opta FAA.

Richard Ormond Cherry was born on 6th June 1903 at his parents’ home in Glen Iris, the fourth of five children.

Richard’s mother’s family was academic. Edith Sarah Gladman was one of the very early women graduates from Melbourne (1891) and a pillar of the Lyceum Club, and her father F.J. Gladman had been the first Director of Education in Victoria (1877-1884).

Richard’s father’s family was more varied. His grandfather Edward Cherry of Gisborne was a tradesman, still remembered for the ubiquitous Cherry Butter Churn, and Edward’s wife Annie is believed to have been the grand-daughter of an African slave; photographs from the 1860’s support this belief, but there is no irrefutable evidence. Richard’s father was Dr. Thomas Cherry, physician, surgeon and cabinet-maker, microbiologist and cancer researcher, committee of the Classical Association of Victoria (1932-1945), acting Registrar of the University for a period following the Dickson frauds (1904), foundation Professor of Agriculture (1911-16).

Richard Cherry’s early schooling was at Adwalton in Malvern, and then Melbourne Grammar. He matriculated in 1921 with Ist-class honours in algebra, geometry and trigonometry, and a scholarship to Ormond College. He began engineering but a year later transferred to science, completing B.Sc. in 1925 with the exhibition in Natural Philosophy (now Physics). Awarded a research scholarship, he completed M.Sc. with the exhibition in 1927.

Cherry was an athlete. He was awarded a University Blue (1926), played rugby for Victoria (1924-25), and had beer mugs for collegiate cricket, billiards, golf, rowing and tennis. Like so many of today’s players his football career ended with a knee injury, but he continued cricket with the South-Suburban Church Cricket Association, making a century as late as 1957. He played A-grade pennant squash for the Naval and Military Club into the 1960s.

From 1929-32 he was a physicist with the Radio Research Board. He bought a 1927 “baby” Austin car (it could be lifted bodily by 6 students, as he subsequently found), fitted it out as a field-strength-measuring station, and drove it all over Victoria checking the then-new station 3LO. Somehow he failed that unfortunate little car to the summit of Flinders Peak in the You Yangs. The loop antenna was recycled as a 3rd-year physics experiment of the 1950s.

Cherry stayed on in Ormond as tutor in physics, eventually reaching 11 years continuous residence - a college record. In 1932 he left to marry Alice Louise Varley. Alice was never in paid employment after her marriage although she undertook voluntary work, including the University’s Staff and Distaff Association of which she was a long-time committee member and sometime President. She made a home for Richard and their three sons, she epitomized the good woman who stands behind every successful man. The night before Richard left Ormond, the said students lifted Baby Austin onto high table for dinner.

R.O. Cherry M.Sc., F.Inst.P., A.M.I.R.E. set up practice as a consulting physicist in 1934. No records have survived; he may have founded the Associated Testing Bureau; he certainly consulted on acoustics and noise abatement, and it appears that he ranged as far afield as the drying of plaster board. Evidently the practice was highly regarded by 1939, and was beginning to prosper. Cherry retained a reputation for the next 30 years: he was called repeatedly throughout the 1950s and 1960s as expert witness, his advice was sought in connection with a variety of physical problems.

Cherry had joined the University Rifles in 1924, and continued service with the Militia. At the outbreak of war in 1939 he was offered command of the 2/1 Australian Survey Regiment. This was a technical unit, whose function was to locate enemy guns and other installations by flash spotting and sound ranging, and plot these positions on an accurately surveyed grid. Recruiting began in May 1940; Cherry had notices placed in the universities to attract men suitable for the anticipated tasks, and personally interviewed many of the enquirers. Professor Laby made available the resources of the Natural Philosophy Department, to design and manufacture certain essential components for the sound-ranging equipment, most notably a 100-Hz vacuum-tube maintained tuning-fork oscillator to supply accurate timing information. The regiment sailed for the Middle East in April 1941, aboard the Queen Elizabeth.

The Regiment served in Palestine, Lebanon, and Syria, and place names such as Baalbek, Beyrouth (sic), Damour, Damascus, Gaza, Tobruk and Tripoli feature in the official history*. This history also records that Colonel Cherry “… brought to his command the additional

strength of a man of the utmost integrity and strong religious faith. His manner was strict, authoritarian and Spartan. Perceptive gunners appraised their leader and found, behind the stern presence, traits that they admired. They dubbed the 37-year-old ‘Uncle Dick’.

The Regiment was brought back to Australia early in 1942, after Japan entered the war. It became apparent that "... a Survey Regiment on a Corps basis was unsuitable for the disposition of formations likely to exist in Australia and that, as opportunities for sound ranging in the South-West Pacific Area would be limited, it would be more profitable to use these personnel elsewhere." Accordingly the 2/1 Survey Regiment was disbanded, and its personnel "... were distributed widely among other units and areas of service." Cherry himself went to radio location work, MGRA Branch, and spent the rest of the war in Australia.

By the time of Cherry's discharge from the army in 1946, the consulting physics practice had ceased to exist and he and Alice had three sons to educate. He therefore applied to the University for a lecturership in the Physics Department, and here he remained until he retired. He also examined in Matriculation English Expression.

As a lecturer, Col. Cherry developed the reputation of a dragon: it was said that he could control even the engineering students! In fact he was kindness itself, after that initial breath of fire. He spoke plainly, which intimidated some students, although one student told me in 1956 that what he really liked about my father was, if he thought you were being a silly bugger, he said just that. In 1953 a female student came to me one lunchtime, crying, because she and her partner had that morning connected a lead-acid accumulator to the wrong terminals of an expensive bridge: smoke! How best to inform the Colonel? The pair did confess their sins, and the matter ended with the dragon demonstrating how to wind bifilar resistance coils and trim them to a precise value, the girls making one coil each, and the Department having both the replacement and a spare.

Cherry renewed his association with Ormond College, resuming his post as tutor in Physics. He lunched there every day, and tutors in non-technical areas spoke of his contribution to high-table discussion. Cherry had something of his father's breadth of interest, he was a man's man, he told a good story. By my own later high-school days, his college entrance scholarship exams had acquired a reputation for asking innocuous questions which probed the understanding: "What determines the area of a bicycle tyre which is in contact with the road? What agency transmits the force from the wheel to the road?" In the mid 1950s (precise date lost) and I suspect with devilment aforethought, Cherry drove Baby Austin to a College reunion where she and high table were re-united!

Cherry loved tinkering: old cars and old clocks were particular passions. He could not pass anything lying on the road, his storage sheds and workshop at the family home in East Malvern occupied 60 square metres. In retirement, when he divided the house into two flats, the total capital outlay was about $200; over the years he had picked up and repaired everything else that was needed — even the hot-water service. He had the right tool for almost any job and, when he didn't, he could improvise.

Cherry was a member of St. John's Anglican Church, East Malvern, for over 50 years — many as vestryman, churchwarden, and parochial representative on Diocesan committees. In the Biblical story of Martha and Mary, he sympathised with Martha; he believed in action, and maintained the vicarage, cleared blocked sewers, kept the derelict organ functioning, looked after elderly parishioners.

For a couple of years following his retirement in 1968, Cherry provided a link between the Physics Department and the architects of the new building, a position for which his knowledge both of the Department's needs and of building practice made him the ideal choice. After that he appears to have cut all ties with the University. His later years were spent in his beloved workshop, repairing things for friends. He died leaving one task unfinished: restoration of the grandfather clock which had been presented to his own father by the Department of Agriculture, to mark his retirement in 1911.

Edward M. Cherry

Australian & New Zealand Physicist Volume 35, Number 1, January/February 1998 27
OBITUARY

JOHN JOSEPH MILLAR
- ERRATUM

The obituary for John Millar which appeared in the last issue unfortunately emerged in a garbled form, and four paragraphs were omitted. We apologize profusely to any relatives and friends of John Millar who may have been distressed by this mistake, and to Richard O’Sullivan who compiled the article. The missing paragraphs, which cover nearly 20 years of John’s career, appear below.

There was a very active scientific life in Arizona with weekly readings and discussion of draft chapters of John Cowley’s Diffraction Physics textbook. There were also exciting graduate course lectures to attend on different physics topics such as Solid-State Physics (John Page jar), Statistical Mechanics (David Hestenes), Applied Maths (Bill Kaufman). This was combined with a very enjoyable outdoor and social life in which John and Denise made some very special friendships with staff such as the Hansons, the Pages and with other graduate students such as Bonny & Henry Shuman from Philadelphia and Peter Traxler. The Millars, the Wilkinsons, the Moons, the Shumans and Peter had a wonderful year hiking in the desert whenever they could and travelling around the South West of the United States. Highlights included a visit to the spectacular Monument Valley and a raft trip through the Grand Canyon. The friendship and support given by John and Robbie Cowley was also greatly valued. A special event during the year was the wedding of Steve and Linda Wilkins.

In 1973, having returned to Melbourne and completed his PhD, John was appointed a lecturer in the Physics Department of the (then) Bendigo Institute of Technology and became active in both teaching and research. At that time, staff research was very much a secondary activity, but John was determined to pursue research which he believed was of benefit to both the department and the institution. He focussed his attention on applications of electron microscopy, and obtained a discarded Mark I RCA instrument to support his efforts. In 1979 he convinced funding authorities of the necessity for a Cambridge SEM - the first major item of research instrumentation purchased by the Institute. The microscope became an important vehicle for research not only in physics but in other areas also, notably microbiology. John was active in research and consulting in which he pursued his interest in the applications of physics to a wide range of phenomena. His areas of interest included techniques used to measure the diameter of mohair fibre, wheat quality, soil moisture and microstructure of materials. He was particularly interested in industrial applications of physics and tireless in his efforts in promoting the Associate Diploma in Scientific Instrumentation to both industry and potential students. In 1987 he was a member of the winning team in the Victorian Enterprise Workshop, which also included his former colleagues from Melbourne University, Geoff Hudson and Kingsley Allen. He spent 1988 on leave working for a year with Geoff and Kingsley as marketing manager in the commercial development of the Hudson Card, the subject of the winning entry, an optical device using sophisticated techniques to store large quantities of data.

John was appointed Head of Department in 1987, after John Roberts stepped down from the position. John Millar’s enthusiasm and interest in instrumentation led to the inclusion of an Instrumentation major within the Applied Science degree as well as the establishment of the Centre of Instrumentation. As Head of the Physics Department, John’s style was forthright and direct, but always fair-minded. He had an intense determination to achieve the goals he had set himself, and many staff will remember John for the vigorous debates they had with him on a variety of issues as he pursued those goals. John had a particular interest in overseas students, a number of whom he supervised in higher degree programmes and maintained contact with many years after graduation. In almost 20 years of teaching at Bendigo, John was an exemplary mentor to the postgraduate students whose work he supervised and a lifelong influence on the many undergraduates to whom he imparted his knowledge and joy of physics. His postgraduate students included one of the university’s first postgraduate students, Stuart McLure, as well as Bregas Budianto and Frank Brink.

Not all of John’s interests at the Bendigo College of Advanced Education, as it later became, were academic. One highlight for him was his participation in the production by a group of staff members of David Williamson’s play, “The Department”. The play is about university politics, in particular a cold war waged between the Physics and Engineering Departments of a mythical university. It was a huge success with audience members feeling that many cast members slipped very comfortably into the roles they played. One cast member was John’s colleague from the Chemistry Department, Brian Taylor, who sadly also died of Motor Neurone Disease in 1990.

John and Denise’s children, David and Rachel, were born in Bendigo. John was very involved in his children’s school, Girton College, initially in the Parents Association and later on the School Council, and played a significant role in the relocation of Girton College to its Strathdale campus. He was very saddened by the subsequent closure of Girton College and sale of the Strathdale site some years later after he had moved to RMIT. He was very supportive of the work done to establish the new school, Girton Grammar. The family was also actively involved in the local chapter of the student exchange organisation, APS, with John taking on the role of president for several years. The family enjoyed skiing together, and participated in the Great Victorian and Great Tasmanian Bikerides.

Erratum - “Ice Crystals in the Sky”

The figure captions in the article "Ice Crystals in the Sky" in the previous issue of the ANZ Physicist (ANZP, vol 34, pp 186), by Max Boccafs and John Storey, contained a number of errors, as follows:

Cover picture: This was printed rather light, making the 46 degree halo difficult to see. It is there, honest...

Figure 1. The correct spelling is "parhelion"

Figure 3. The included angle shown in the upper figure is 60 degrees.

Figure 4. The caption should read: "Light reflected from the vertical faces of plates..." 

Figures 5 and 6. The figures should be interchanged, but not the captions.
A Delightful Dip for Debunkers

Here is a book to bring joy to dedicated debunkers, and shake up some loopy beliefs in those with scant respect for the laws of physics. It is mainly a book describing the results of radiometric dating techniques and their conclusions. Titled “In Search of Lost Time” it is entertainingly written by a practitioner and innovator in the science (or is it art?) of dating materials by means of one or other of the radioactive clocks that tick away the centuries within them. Every single one of the sixteen chapters in this delightful book carries a message and most of them provide a succinct rebuttal of many pseudo-scientific claims.

The very first chapter presents a condensed appraisal of the calendric function of the Pyramids and Stonehenge, then moves on to supporting evidence from the other side of the world, namely the ancient Chinese Oracle Bones. The upshot of this tour is the most telling rebuttal of Velikovsky nonsense that I have ever seen in print. It is much too good to reveal in this review, but I wish I knew about it decades ago when the cult of Velikovsky was at its height.

Then come three chapters which are guaranteed to render apoplectic the fundamentalist interpreters of religious works. They detail the steady improvement in radiometric dating during the present century which has fixed the age of our planet with a precision totally convincing to any sensible person.

Author Derek York then moves on to the next two chapters to the dating of once-living material, with emphasis on our early human ancestry. He is well abreast of recent developments, bringing in the dating of a four million year old missing link discovered as recently as 1995.

Following an interesting chapter on meteorite craters and the periodic extinction hypothesis is a chapter about the Oklo nuclear reactor in Africa. This fascinating experiment conducted by nature almost two billion years ago proves that high level nuclear waste can be successfully immobilised for extremely long periods.

Then comes another chapter of compulsive reading: Gulliver’s Travels and Martian moons. It contains the best explanation of Jonathan Swift’s amazing prediction that I have seen anywhere. Next I learned that playwright J B Priestley was one of the discoverers of the modern concept of chaos. And then York moves on to a discussion of time and the concept of entropy, which was the first place in his book where I felt a trifle uncomfortable. He could have explained the non-closed nature of living systems a little more clearly. Mention of the role of the Sun would have been enough.

All told, this is a marvellous little paperback to read then keep at hand. It is published by the Institute of Physics in England for 7.95 pounds and has the ISBN 0-7503-0475-8.

Colin Keay
Reviews Editor

From Newton’s Sleep

Joseph Vining
Princeton University Press
Princeton NJ 1996
xvii + 398pp, US$16.95 (paperback)

The words on the back cover “This is a book on the legal form of thought and its meaning for science and religion” increased my initial attraction to the title From Newton’s Sleep and were sufficient inducement to review this book. I also welcomed the alternative to the usual university administrative circular and the precision of physics.

The work is presented in eight chapters, covering the language, the logic, the personal aspects, the activity, the force, the organisation and time in legal thought. An excellent seventeen pages of references, extensive suggestions for further reading and a twenty one page index are obviously helpful and will be particularly useful to students of law. Each chapter contains from sixteen to forty four sections which could, and probably should, be read non-sequentially. My initial enthusiasm was quickly lost because of the need for extensive editing of what appears to be hastily compiled notes under numerous, and often poorly related, headings. That compendium of notes strikes the reader within a few pages. I expect an author to collate the material better for public consumption. If the reader is prepared to wade through some excess verbiage and survives the first chapter, then the true wisdom and scholarly approach of the author will make the task worthwhile.

The attraction of Newton’s Sleep, that is the form of thought acknowledging Newton as the great source and a somewhat invariant opinion, was again short-lived. The notion of Newton’s Sleep, originating with William Blake (1802), is no longer topical; we live in a rapidly changing world in which the challenge of new knowledge and survival, not the ‘presence of law in the human mind’, will keep us progressing.

The aim of presenting the legal form of thought is accomplished well by discussion of the phenomenology of law as a connection between language, people and actions. But it is not a new (or different) form of thought and is readily reduced to an ability to explain cause and action precisely even though Vining challenges the notion that law can be reduced to processes and rules. It would be unfair, of course, to comment that precisely such reduction occurs, for example, in conveyancing and probate of wills which provide routine income for the legal profession.

After reading parts of the first chapter, then sampling subsections with attractive headings, I put the book into my briefcase for anticipated spare moments of an impending trip to China. The book cannot be read in one sitting. However, some months later during a visit to London coupled with a growing conscience about Newton’s prolonged sleep and an anxious editor, I ventured into the Tate Gallery to seek inspiration. Viewing the frontispiece of the book, and an image of Newton, I
felt suitably inspired to awaken a legacy of Newton's Sleep.

The introduction will deter some readers. For example, in Vol. 3, entitled 'Partial Insight' is but three lines: "Not a lawyer", observed Flaubert, playing with the connection between poetry and law and resisting its strength, "but carries within him the debris of a poet". What a wonderful quotation, and how apt to illustrate 'partial insight', but surely a more extensive insight is needed to establish the author's thinking and the thought needs to be related to the preceding and subsequent sections of the book.

The author continues with this minimalist presentation when he comes to 'Science' which is dismissed summarily in about seventy words. Again I quote the whole section on Science! "An old lady does eggs. She enjoys the bit of money that comes in, but she does eggs mostly because she wants to see people every day. She picks up an egg in the daily round and for the first time feels its shape and warmth, pauses and notices it. She puts a mark on time. A satisfaction comes through her. Science has nothing to say about any of this, nothing whatever." This is all the author presents in section 1.16 on Science! Consequently any pretense that there would be a serious discussion on the significance of the legal form of thought for Science was lost. I was unsympathetic to the author from this point. Of course, the old lady has made a simple scientific experiment which was significant for her!

The author's story could have many interpretations and consequences, just as a religious sermon may, but it is not appropriate to draw such a negative conclusion about the relationship to science. A little later Vining, still searching 'Science' for thought processes common to law, quotes Freeman Dyson as an exemplar of modern science on cosmological thought. He reduces the thoughts to process and pattern and then tries to relate 'saying' to 'doing' but fails with cosmology and the place of life in the universe.

The link between law and religion is pursued through their pervasive nature but pursued more strongly than the comparison with physics which the author dismisses with "the door is closed ... at 5.00 or 10.00 in the evening." Could he expect any sympathy from a physicist thereafter? The sacred and often unquestionable texts of religion, in contrast to the texts for law which are ever-changing with prior statements, receive a gentler treatment than science for which I suspect the author has less understanding and belief. Vining's approach to science and religion is worlds apart from that of Paul Davies, for example.

Apart from the comments on science and religion, there are sections with appeal to those working in a 'devolved environment'. The thoughts on self-governance, the decision-making process, the effects on future generations and the connection between the value of decisions and their binding effects on others will strike resonance with current mood amongst managers and those who are managed.

However I wonder if the author really intended to achieve part of his goal in the way he has for me. The section on the language of legal thought has much in common with the language of science and particularly in multi-authored papers, for example, the hermenutics, the literal and 'the agreed' meanings. Since this is a book review, and books communicate through language, I have selected a passage from the section on 'the language of legal thought', to illustrate what you will find in the book. If you like reading such language then the book is for you! "The very essence of hermenutics is the securing of the correct text - not correct in the sense of conventionally established, but correct in the sense that it is a text that makes possible words reading, as no text can be that is a net of adventitious omissions and interpolations stitched in without communion. Reading is interpretation, which is translation, which is rewriting, which is writing, but reading begins with a text that is an expression, not a linguistic phenomenon."

Whether the author has achieved part of his goals in inviting the reader to see if science and religion have as much reason, to look to law as law has to look to science and religion, I leave to the courageous reader. While my comments have given attention to those aspects of the book, it is the author's intellect and scholarly approach on critical analyses of language that make the book good reading. Scientists, or at least physicists, will recognise the similarities of Vining's analyses and deductions with their own when translating observations into reports.

The book will fill in the odd moment for those interested in law and for those seeking to refresh or exercise their logical thought processes and analytical language skills. I would recommend this book to my graduate students and colleagues.

Jim Williams
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Reviews

Superlattices &
Other Structures
Second Edition

E L Ivenchen & G E Pikus
Springer-Verlag, Berlin 1977
xxi + 382 pp., DM 48 (hardcover)
ISBN 3-540-62030-3

This is a new text. Its first edition appeared in 1995, the present review concerns the updated version published in 1997. The book is devoted to optical phenomena in semiconductors from the standpoint of the theory of symmetry. Key topics covered include optical phenomena in quantum wells, superlattices and other heterostructures.

The first two chapters in the book are comparatively elementary. The second chapter particularly, which expounds the theory of group representations and characters appears to offer a reasonably brief but comprehensive and detailed presentation of the material, where excessive use of formalisms is a rule rather than an exception. In chapter IV the authors drift away from the typical coverage of the subject area and begin what the present reviewer thinks is most valuable in their book - namely coverage of largely uncharted territories at least in book form. It is true that their text is in a sense a compilation or review of the field, but the field is summarised with a great deal of care and with attention to presentation of necessary details only, very difficult in this vast research area.

The fine balance that the two authors achieved in this book is its most striking quality. The presentation of theory is detailed but explained with a non-specialist in mind, while the choice of topics in each of the chapters, particularly in the second part of the book is driven by richness of phenomena and variety normally found in experimental texts. The latter is particularly pleasing and makes this otherwise very dense text a pleasure to read.

The final result is an outstanding and rare volume, which meets high standards in both these areas.

Having said that one should be aware that the concept of a wide readership was clearly not on the authors' minds. The aim was rather to present a full insight into the rich and mature field of optics in quantum confined structures. As a result the book is targeted at senior graduate and post-graduate level and it is most likely to be useful to scientists working in this field.

An extensive and current list of (mostly
Fourier Series in Mathematical Physics
TS Belozerova and VK Henner
AIP Physics Academic Software
viii + 34pp, US$100
(binder + disc)
ISBN 1-56396-180-6 (DOS version)

The interactive "Fourier Series" program which comes with a reasonably detailed manual, is intended to give the user some experience beyond simple analytical textbook examples in generalized Fourier series analysis and orthogonal polynomial expansions. The program is MS-DOS based and requires a PC with a "386 or higher CPU". This is not a program which takes advantage of the typical processing power of a modern PC. The basic idea is that students can input some simple one dimensional function, either in data format or as an equation (using an equation editor) and find the expansion in terms of a Fourier series or one of the classical orthogonal polynomials (Legendre, Chebyshev (I and II), Jacobi, Laguerre and Hermite). One can specify various parameters such as the interval of numbers in the series and the desired accuracy. The program will then calculate and display the coefficients and a measure of the overall error in fitting the function. One can graph the results to compare the function with the series expansion, or display a histogram of the relative weights.

The manual first gives an introduction into the basic terminology of Fourier series (general and trigonometric classical orthogonal polynomial systems and their weight functions) and the applied examples of the Dirichlet problem on a circle and forced oscillations. All this material is contained in eight pages which I feel is too short. Chapters 2 and 3 are essentially notes on running the program. Possible problems one may encounter are discussed in the last chapter. An "instructor's guide" is included as an appendix.

The program itself is quite clear and easy to use, but I soon found several bugs which caused it to abort (could this be an incompatibility with Windows 95?). Also, the equation editor is fairly limited in the length of the string it can handle and the maximum number of terms one can use in any expansion is fixed at a value which does not give the curious student much room for experimenting.

This software package does have problems, but there may be a corner of an undergraduate curriculum which may require a short computer based tutorial on Fourier series. However, in an age of sophisticated mathematical and data processing packages I would certainly not, as the authors do, recommend that this software be useful for scientific research.

Lloyd Cl. Hollenbach
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Lectures on QCD
F Lenz, H Griesshammer & D Stoll (eds)
Springer-Verlag, Berlin 1997
vii + 276 pp, DM 92 (hardcover)
ISBN 3-540-62654-3

This is the first volume of two dealing with an introductory overview of QCD (Quantum Chromodynamics), the theory of strong interactions. Volume 1 deals with lattice gauge theory, anomalies, finite temperature field theories, sum rules, the Skyrme model and supersymmetric QCD. Volume 2 will deal with applications of QCD to the phenomenology of hadrons. The eight articles are based on workshop lectures delivered with the aim of introducing novices to QCD (indeed the workshops were held in a former monastery over the years 1992-1995). The articles are very pedagogical and were developed in conjunction with graduate students attending the workshops. This ensured that the notes were particularly explicit.

Very noteworthy is the article by P Hasenfratz (Fascinating Field Theory) which gives a delightful discussion from a functional integral point of view of what are quantum field theories, their relationship to classical critical phenomena, the renormalisation group and fixed point behaviour. This chapter is illustrated with some very insightful diagrams. The chapter by JW Negele (Lattice Gauge Theory) is also very impressive and replete with good diagrams and examples. The articles dealing with the Skyrme Model and Supersymmetric QCD are somewhat out of place because of their marginal relevance.

These articles reveal considerable effort by the authors and the graduate student 'checkers' and have resulted in a collection of material that is of a higher standard than normally achieved in the usual textbook. Indeed I consider that this set of Lecture Notes would form an ideal Quantum Field Theory Honours or Graduate level topic text, and would be a valuable addition to any personal library.

RT Cahill
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Flinders University

Conformal Field Theory
P Di Francesco, P Mathieu & D Senechal
Springer-Verlag, New York 1997
xxi + 890pp., DM138 (hardcover)

Conformal Field Theory is a very active area of theoretical physics that has its origins in the celebrated paper of Belavin, Polyakov and Zamolodchikov in 1984. Although it is a relatively young field of study, Conformal Field Theory has undergone a rather dramatic and explosive development in the intervening years. It has important applications in the areas of string theory, statistical physics, condensed matter physics and in addition has been the source of many elegant developments in pure mathematics.

This wonderful book is the first really comprehensive textbook on Conformal Field Theory and is proof positive that the discipline has come of age. It is directed to graduate students and researchers in the areas of quantum field theory, string theory, statistical physics, condensed matter physics and mathematical physics. There is every indication that this book is destined to become a classic and it is hard to avoid comparisons with that other classic, Quantum Field Theory, by Itzykson and Zuber. Both are written in that very clear French didactic style though, in this case, French-Canadian might be a more accurate description.

The book is encyclopaedic in its scope and it contains all the material you would expect to see in a major work on Conformal Field Theory. The authors are to be congratulated on completing such a mammoth project.

The background material of the first 100 pages of the book is followed by substantial chapters on conformal invariance, operator formalism, minimal models, Coulomb-gas formalism, modular invariance, Wess-Zumino-Witten models, fusion rules and cosets. Each chapter is a delight to read and concludes with a set of exercises and brief notes.

There are also concise chapters on the more mathematical topics of simple and affine Lie algebras tomake the book self-contained. While references to all the key papers are given, the authors have been
somewhat selective in their list of references. For a book directed to current researchers in the field, I would have preferred to see a much more extensive bibliography as a gateway into the current literature but the book offers so much that one shouldn’t be critical. I highly recommend the book to anyone with an interest in Conformal Field Theory and I eagerly await the promised second volume.

Paul A Pearce
Department of Mathematics and Statistics
University of Melbourne

How Nature Works

Per Bak
Copernicus, New York, 1996
xi + 212pp., DM 44 (hardcover)
ISBN 0-387-94791-4

The subtitle of this book is “The science of self-organised criticality”, a field in which Per Bak has been a pioneer. In the period since the original paper by Bak, Tang and Wiesenfeld on self-organized criticality appeared in Physical Review Letters in 1987 it has become one of the most cited papers in physics.

Here Bak explains the key ideas in a popular style, with the use of only a few simple equations. There is a bibliography for each chapter for the reader inspired to pursue the literature.

The idea of self-organised criticality is very simple. The prototypical example is the sandpile model. This theoretical model in which grains of sand are added to a sandpile and simple local rules has inspired a number of experiments on real sand and rice piles. The numerical simulations of the model indicated that the sandpile organises itself into a poised state that evolves by intermittent sand slides, or avalanches. The distribution of avalanche sizes is governed by a power law, which is characteristic of critical behaviour.

The book describes how the key idea was developed and how it may be correct for the real world. Bak argues that we must accept instability and catastrophe as inevitable in biology, history and economics. He provides a number of examples in which similar power law behaviour can be found. Some I mention here include traffic jams, the distribution of earthquakes, the extinction events and Conway’s Game of Life. The work on mass extinctions and punctuated equilibria as a model of evolution in a fitness landscape is ongoing and particularly provoking.

The book is thus very much about physics impinging on other areas of science. One wonders what scientists from other fields will make of it. Two other reviews I am aware of are by PW Anderson in the 31 October 1996 issue of Nature and by K. Sigmund in the 30 November 1996 issue of New Scientist. Like the book itself, they make very interesting reading. Anderson in particular is an advocate of the subject as a whole, although he takes Bak to task on a number of points.

Bak is a firm believer in ‘science is fun’ which is reflected in his enthusiastic style. He is not afraid of expressing his views. You might not agree with all of Bak’s views, or be entirely convinced by his reasoning, but you should at least read his book.

Murray T Batchelor
School of Mathematical Sciences
Australian National University

Magnetic Ions in Crystals

KWH Stevens
xi + 233 pp., US$92.95 (paperback)
ISBN 0-691-02692-0

Nearly 50 years after the introduction of the ‘Spin Hamiltonian’ used so extensively in electron paramagnetic resonance (EPR), one of the early contributors to the underlying crystal field theory (CFT), Emeritus Professor Ken Stevens from Nottingham University has written a monograph aimed at deriving a form of the Spin Hamiltonian that is properly consistent with quantum mechanics. It was motivated in part by an observation perhaps 40 years ago by JC Slater who expressed concern about the validity of the whole procedure on the grounds that “... it distinguishes the electrons on the central ion from those on the ligands and thus violates the uncertainty principle...”. The chapter on atomic theory is unnecessarily lengthy given that it is a topic well treated more than 60 years ago by Condon and Shortley and repeated adequately in many texts on atomic physics and quantum mechanics since that time. Tools from group theory and perturbation theory are introduced before a brief foray into old fashioned crystal field theory which the reader is reminded is not the point of the book and which is not seriously used these days in any case. The central chapters on ‘Second Quantisation’ and ‘From Generic to Spin Hamiltonian’ lead to the derivation of the new book second quantisation Spin Hamiltonian which appears to apply to ‘isolated’ ions, important in EPR, as well as to coupled systems in magnetic and conducting materials, including high $T_c$ superconductors. A final chapter addresses the matter of nuclear symmetry, usually neglected in treatments of electron systems. There are very few recent publications cited and only scant reference to the superposition model (SPM) as one important extension of CFT introduced 30 years ago by DJ Newman and used mainly by physicists. Equally, there is no reference to the related angular overlap model (AOM) popularised for Chemists by Gerloch (Gerloch, M. (1983). Magnetism and Ligand Field Analysis. Cambridge University Press). As an aside, both the President (and colleagues) and the Vice-President of the Institute are cited, though in the latter case the reference contains errors. People working in EPR are likely to ignore this book and are unlikely to use the new spin Hamiltonian though it might provide helpful insights to magnetism theorists. Although Stevens has succeeded in developing a new approach to the Spin Hamiltonian, this book is unlikely to be a best seller.

JR Pilbrow
Department of Physics
Monash University

Indistinguishable Classical Particles

Alexander Bach
Springer-Verlag, Berlin 1997
viii + 157 pp., DMS 8 (hardcover)
ISBN 3-540-62027-3

It is often considered that indistinguishable particles belong to quantum mechanics: the Boltzmann-Maxwell (MB) statistics describes distinguishable classical particles, while Fermi-Dirac (FD) and Bose-Einstein (BE) statistics apply to indistinguishable quantum particles.

The author argues that this way of thinking is based on a historical coincidence: modern quantum theory and indistinguishability both came into prominence in the mid-1920's - and points out that Boltzmann had in 1868 used BE statistics to derive the Maxwell velocity distribution in two dimensions. He further takes issue with the traditional viewpoint that for N particles distributed into D cells, BE and FD statistics must be formulated at the level of occupation numbers (how many particles are in each cell), whereas MB statistics can be formulated at the deeper level of particle configurations (which particles are in which cells). Indeed, he writes down specific configuration distributions which generate the usual BE and FD statistics.

A new definition of ‘indistinguishability’ is therefore proposed: a system of identical particles is indistinguishable whenever its state is symmetric with respect to the particles. The claimed advantages of this definition are its applicability to both quantum and classical systems; new clas...
Physics of Oscillations
Simple Systems

E Butikov
Physics Academic Software
Rayleigh NC 1996
xv + 93 pp. + disk, US$100.00 (binder)
ISBN 1-56396-654-9

This fine package enhances the tradition of useful software published by the
American Institute of Physics. The software examines the different aspects of the
physics of oscillations, including free and forced oscillations in a linear system,
forced oscillations using a square-wave external force and parametric excitation of
oscillations. As the name implies, it covers simple systems. A second part covering
systems with several degrees of freedom and non-linear systems which exhibit
chaotic behaviour will be published at a later date.

The presentation is impressive and is a step up from previous packages that I have
seen from Physics Academic Software. The whole deal includes DOS and Windows
versions of the software on 3.5 inch floppies as well as a 158 page user's manual and
93 page instructor's guide in a ring-binder.

I found installing and using the Windows version of the software very simple.
Oscillations are then explored using a torsion pendulum. The parameters of a sim-
ulation, e.g Q factor, initial conditions are chosen using a slide bar. A typical screen
then shows the movement of the pendulum, as well as graphs of angle and angular
velocity as a function of time. The trajectory in phase space and the energy may
also be plotted as well as the harmonic components for square wave excitation.

The most impressive aspect of this offering is the documentation. Each section is
fully reprinted with relevant mathematics, physical explanations, description of
electromechanical analogues and, most importantly, sets of questions, problems
and suggestions. As the time of academics in Physics departments gets increasingly
squeezed, it is nice to see a package which, without further development, can be
used to educate and challenge students. There is a range of difficulty and familiar-
ity across the sections - free and forced oscillations in a linear system could be used in first year University laboratory courses whilst other examples
would be best dealt with in later years. Visually the package is very good, so it
also lends itself well to lecture demonstrations in senior high school and univer-
sity.

Bruce King
Physics Department
University of Newcastle

Photonic Networks

Giancarlo Prati (ed)
Springer-Verlag, London 1997
xii + 487pp., UK£60.00 (hardcover)
ISBN 3-540-76143-8

"Photons" is the control, manipulation, transfer and storage of information using
photons. Virtually all long-distance communication within Australia and New
Zealand and abroad is now via photonic networks. The rate of growth in capacity
on new and upgraded existing networks is limited only by the ingenuity of scientists
and engineers, and by cost considerations.

This book represents a snapshot of the state of the art and science and technolo-
y) at a particular moment in 1996. As a compilation of papers presented at a
workshop on Digital Communications held in Italy in September 1996, it con-
veys the excitement and dynamism of a rapidly evolving field. It also suffers from
all the shortcomings of an edited compilation of camera-ready contributions from
many writers; diversity of style, level of detail and quality of writing. Incomplete
and repetitious coverage of some topics, and total lack of indexing. There are
papers which merely enumerate the problems in some area, and list references
which address these problems. And there are papers which describe in considerable
detail the physics and engineering of some technique, component or network
configuration.

To the non-specialist reader wishing to see where photonics networks are (or
were) in 1996, the book can be casually browsed; it demonstrates the combination
of amazing progress (eg 1 Tbit/s data transmission over 100km through a single
fibre) and the significant problems (eg what to do with a packet of optical pulses
arriving at a network node which is fully occupied?). To the specialist the book
offers authoritative papers by a cross section of the field's practitioners, and
includes a wealth of references.

A word of warning to the uninstructed reader: the text abounds with TLAs (three
letter acronyms) and DPLAs (the dreaded four letter acronyms).

Photonic Networks is full of informative material. Read it before it becomes obso-
lete.

Peter A Krug
Australian Photonics CRC
University of Sydney

Physics of Structural Phase Transitions

M Fujimoto
Springer-Verlag, New York 1997
xi + 247pp., DM108 (hardcover)

The behavioural property that some ma-
tter exhibits of changing crystal structure
(whilst still remaining a solid), usually
triggered by modification of external
physical conditions, is known as a struc-
tural phase transition. The sub-section of
solid state physics forms an important and
interesting topic for research that is
presently very active.

This book brings together the physics of the
general background, theoretical, and ex-
perimental aspects of structural phase
transitions. It describes the various tech-
niques that have been applied to investi-
gate and understand the processes that
initiate the onset of the transition proc-
eses and discusses the structural changes
that result.

The format of the presentation consists of
two major parts, spread over ten chapters,
the first five dealing with the basic con-
cepts such as the Landau theory of phase
transitions and an extensive treatment of
pseudo spin. The remaining five chapters
cover relevant experimental studies.

The author has produced a well structured and
clearly written text that draws together
into a single volume the various ele-
ments appropriate to its subject to form an
integrated treatment and thereby fills a
Hydrogen in Metals III
Properties and Applications
Topics in Applied Physics
Volume 73
H Wipf (ed)
Springer-Verlag, Berlin 1997
xiii + 314pp., £119.00 (hardcover)
ISBN 3-540-61932-1

The four earlier volumes in the same series (Hydrogen in Metals I and II, and Hydrogen in Intermetallics I and II) are familiar to specialists in hydrogen technology and contain articles which are still used as references in current research papers. The most recent of these was published in 1992, also by Springer-Verlag. This new volume contains six chapters and a short introduction by the Editor. The first four chapters cover aspects of diffusion in metals (tunnelling, and low-temperature diffusion), nuclear magnetic resonance and neutron diffraction. The last two chapters are concerned more with practical aspects of the subject, namely hydrogen related material problems and finally an extensive critical review of metal-hydride technology. This is a high quality text and is recommended reading for scientists who specialise in this area. It would also be a valuable text for the materials sections of university libraries. The only weaknesses appear in the Editor’s introductory chapter. He opens with a rather sweeping generalisation that “the ability to absorb hydrogen is common to all metals” and makes much of the fact that the number of new and important results since these earlier works were published (in 1992, see above) is large and that (presumably) this more recent work is covered in the new book. However, in the first two chapters, on the theory of tunnelling and diffusion of light interstitials and hydrogen in metals, very few (approximately 7) of the 302 references listed are more recent than 1992. The later chapters are more up to date. The book is a useful update of information on both the science and the technology of hydrogen in metals. The first four chapters are for the specialist while the last two are presented in a form suitable both for those new to the subject as well as readers who are more experienced in the field. The price is not unreasonable for the libraries of research laboratories and universities.

DH Bradhurst
Institute of Materials Technology and Manufacturing
University of Wollongong

JJ Thomson and the Discovery of the Electron
EA Davis & JJ Falconer
Taylor & Francis, London 1997
xxv + 256pp., £99.50 (paperback)
ISBN 0-7484-0720-0

Flash of the Cathode Rays
A History of JJ Thomson’s Electron
Per F Dahl
JOP, Bristol, 1997
xvii + 562pp., £99.50 (hardcover)
ISBN 0-7503-0453-0

JJ Thomson (1856-1940) is something of an enigma. His life and work mark the extraordinary transition from nineteenth to twentieth century physics, although we still lack a worthy, modern biography. Educated in the mechanical philosophy and analytical dynamics of the Cambridge Mathematical Tripos, his ability found early expression in the notion of electromagnetic mass and the suggestion that matter might be composed of vortex rings in the aether. Later, following his unexpected appointment as Cavendish Professor of Experimental Physics (aged only 28), he ‘discovered’ the electron (the first subatomic particle to be identified, thereby prompting a period of unprecedented activity in subatomic physics), and established the Cavendish as the premier physics laboratory of the twentieth century.

Initially unskilled and inexperienced, Thomson became an outstanding experimentalist and fertile interpreter, with the able assistance of his laboratory technician, Ebenezer Everett, and a string of exceptional research students (Rutherford, Townsend et al). Free to investigate any topic, Thomson chose electric discharge through gases (fit only for ‘cranks and visionaries’ – Schuster), to which he devoted the rest of his life with great success. Rather than the measurement of physical constants to ever-increasing accuracy, Thomson found order-of-magnitude experiments and creative theorising both fruitful and liberating.

It seems clear now, but back then there were endless mysteries: atoms, ions, cathode-rays, X-rays, β (particles or waves?), electricity, electrolysis, the photoelectric effect, on and on. Many tried to make sense of it all, and even with respect to the c/em value of cathode-rays we encounter Perrin, Schuster, Hertz, Kaufmann, Wiechert, Zeeman, Townsend and more. In the end, the ‘discovery’ went to Thomson, who measured c/em and e, and in a manner that answered most of the earlier uncertainties. And it wasn’t just the one 1897 experiment with crossed E and H fields beloved of physics text books that did the trick. After a long preparation, there were a number of experiments extending over five years (1895 to 1899); and even then it took some time for Thomson’s ‘corpuscles’ to be identified with the ‘electrons’ of Larmor and Lorentz.

This is a difficult story to tell. But these two books do an excellent job despite their very different approaches. I prefer the one by Davis and Falconer. It concentrates on Thomson and the discovery, and it is a focussed, well-balanced, historian’s account (90pp of text), informed by Isobel Falconer’s 1985 thesis on Thomson, and greatly enhanced by reproductions of his pivotal papers (20pp), delightful photographs (28pp), and an illuminating Foreword by his grandson.

By contrast, Dahl’s book is comprehensive almost to excess: 366 pages of text and 200 pages of end-notes and bibliography. Its central focus is Thomson and the discovery, but it also retreats 400 years to review the nature of electricity, and its second half is devoted (as the title suggests) to the period following the discovery: β particles, N-rays, positive-rays, Milikan’s experiment, the atomic nucleus, and a final chapter up to about 1940. It is a good reference book for the library – a history of people and events – but it lacks the historian’s insight and it is too detailed for preparing a centenary talk on the discovery of the electron or for relaxed, bed-time reading.

John Jenkin
School of Philosophy
La Trobe University
REVIWES

The Fire Within the Eye

David Park
Princeton University Press,
Princeton NJ 1997
xiii + 377 pp., US $29.95 (hardcover)
ISBN 0-691-04332-9

The nature of light is one of the enduring themes in the history of science. Because of its central role in our experience, it has important connotations in philosophy, religion and art, and arguments about the nature of light have continued from the Ancient Greeks to the present century. In his book *The Fire Within the Eye* David Park presents an historical essay on the nature and meaning of light, spanning the earliest known examples of scientific thought in Ancient Greece, the Egypt of Ptolemy, Biblical and early Christian scholars, Arab philosophers, and the Renaissance in Europe, through to the Science of the present day.

Park begins with an unusually detailed and carefully footnoted explanation of the various approaches used by philosophers such as Aristotle, Plato, Epicurus and Euclid, to explain the process by which we see, or the origin of rainbows, as well as light itself. He shows that the geometrical approach which the Greeks used for calculation lends itself to studies of rays in optics, and that the "ray theory" has a very long history, even though Euclid, for example, believed that the rays emanated from the eye. (Starting with 4 postulates, Euclid proved 58 propositions on vision, such as proposition 5: "Objects of equal size and unequally distant appear unequal, and the one lying nearer to the eye always appears larger"). In each section, Park presents both what was believed, and also the flaws or omissions of the model.

Later parts of the book consider the development of perspective in art and architecture, studies of the structure and function of the eye, and the invention of optical instruments such as spectacles or telescopes, amongst other topics.

The latter third of the book concerns the sequence of ideas and experiments described by Newton, Young, Maxwell, and Einstein, and others, finishing with the laser and the Hubble telescope in the 1990's. I believe that the ideas in this section, briefer in coverage, are familiar to most readers. Throughout the book, the paradigms of light current at the time are discussed, in the light of new ideas and evidence.

In the final chapter, Park neatly returns to an early question on the nature of light: "Is light substance or accident?" and shows that the particle-wave duality can be understood as a paradox in human mental behaviour. Park's conclusions, as well as describing our current understanding of light, are about the nature of Science itself. From the ultimate truth sought by the Ancient Greeks, Science has become a body of knowledge. "People are learning to ask questions that have some hope of being answered..."

The book should appeal to those with an interest in the history of science, but is probably too detailed for the casual reader, who might instead be referred to *The Light Fantastic*, by Peter Mason.

J M Dawes
School of Mathematics, Physics, Computing and Electronics
Macquarie University

Eureka!

*Physics of Particles, Matter and the Universe*

Roger J Blin-Stoyte, FRS
IOP Publishing
Bristol 1997
xii + 226 pp., UK£12.00 (paperback)

This book will probably be sold as popular science, but it is much more than that, it is a concise, authoritative, well written review of physics, in all of its branches from Newton to Hawking.

Such books on physics are scarce, most are on some branch of science such as astronomy (the favourite) or geology, biology, botany, even chemistry. *Eureka!* compares favourably with *Six Easy Pieces* which is a summary of the lectures given by Richard Feynman to first year physics students at the California Institute of Technology in the early 1960's.

The eleven chapter headings set the scene, ranging from *Understanding the World Around Us*, to *Astrophysics and Cosmology* and *Finally Reflections on Physics and Physicists*.

This book is incredibly condensed - so much so that it leads Blin-Stoyte into saying something he didn't mean to say, when introducing the concept of angular momentum without first defining the rotational analogues of mass, velocity, momentum etc, he states that centrifugal force is directly proportional to the radius of a circle instead of being inversely proportional. It took Gribbin two whole books, In *Search of Schrodinger's Cat* and *In Search of the Big Bang*, to convey the concepts of quantum mechanics and mathematics, whilst Blin-Stoyte squeezes them into a few chapters.

*Eureka!* (in my opinion) is not for the novice. Some basic understanding of classical physics is essential to begin to comprehend the concepts of modern physics, remembering always that understanding should not be confused with memorising. Blin-Stoyte would certainly be expert at setting examination questions to distinguish between the two.

The book has a truly excellent glossary, but a few more diagrams would be acceptable, and maybe even a few photographs - a radio telescope, particle accelerator, high voltage power line, even a steam engine? Also, it is considered that even a little secondary school mathematics can greatly assist in understanding relationships difficult to express in words.

Who will profitably read *Eureka!*? From his position as Professor Emeritus, Blin-Stoyte nominates "school pupils, college or university students, teachers at all levels and any lay person who wishes to know about physics".

I would leave out the school pupils and lay persons, but add people such as your reviewer, who picked up a BSc in maths and physics some 55 years ago, and needs a book such as this to show how little he knows.

John Collacott
Retired

The Critical Point

Cyril Domb
Taylor & Francis, London, 1996
xvii + 376 pp., UK£55.00 (hardcover)

When Andrews identified the critical point of a liquid-gas system (CO2) in 1869 he would have had no conception of the seminal role that critical points and critical phenomena would play in 20th century theoretical physics, in unifying many aspects of the behaviour of strongly interacting systems of particles and in spurring such overarching concepts as universality, scaling and renormalisation.

Professor Domb's group at King's College, London was, for some 20 years from the mid 1950's, the mecca for theoretical research in critical phenomena. Many of the leaders in the field passed through that centre, as students, postdocs or visitors. Included among them are a number of Australians who continue to contribute to this country's strength in the field. Professor Domb and his colleagues played a pioneering role in the development of systematic series expansion methods, and made major contributions to the development of scaling ideas.

The book is subtitled: "An historical introduction to the modern theory of critical phenomena." Indeed the book is deliberately written to include the actors and not just the final polished outcomes, and it is quite unique in this.
Fisher, in his Foreword, pays tribute to Domb as a "teacher and expositor" and the appropriateness of this is abundantly clear from the book. The book would be well worth reading just for the historical record, and as a nice case study of the development of scientific thought. However, it is much more than that. The Critical Point is a comprehensive account of the subject from its origins, through the classical "mean-field" era of van der Waals, Maxwell, Weiss, Ornstein and Zernike, through the "Onsager revolution" and the post Onsager explosion in the field, and finishing with the current "Renormalization Group" unification. There are only one or two other books which attempt this and do not, in the reviewer's opinion, succeed nearly as well. Usually the material is constrained to 2-3 chapters of a graduate-level book in statistical mechanics (enough to tantalize but not to satisfy) or to technical articles (fine for experts but hard going for graduate students or physicists in other fields wanting to learn the subject). A level of statistical mechanics usually reached in Australian undergraduate courses is assumed. The book could provide material for an Honours course, covering a selection of topics, or for a graduate course either given formally or through prescribed reading.

The first third of the book (Chapters 1-4) covers the experimental basis, phenomenology, and classical "mean field" theories of bulk equilibrium properties and of fluctuations, correlations and light scattering.

Chapter 5, entitled "The Onsager revolution", describes the solution of the 2-dimensional Ising model by Onsager, covers series expansion methods and the results obtained for critical exponents for different lattices. This continues naturally into Chapter 6, where ideas of universality and scaling are developed and the first attempts to unify everything under a common microscopic description are presented.

The final 100 pages constitute Chapter 7, entitled "Renormalization Group". Domb himself did not contribute directly to this most recent development of the subject, but watched "from the sideline". This puts him, arguably, in a better position to give a pedagogical account to others and I think he succeeds admirably, in this. Of course some of the details will have to be found in the original literature but the overall philosophy, lines of thought, conceptual framework, results and limitations are all there as clearly as anywhere.

I enjoyed reading this book immensely. On the historical side I learnt a bit more about the "Onsager stories", which I and other instructors tell students each year. The technical material provides a valuable reference source in many areas of the subject. All libraries should hold this volume. In paperback, and perhaps with some challenging problems after each Chapter, it would be irresistible.

J Olmata
School of Physics
University of New South Wales

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Victorian Telescope Makers
The Lives and Letters of Thomas & Howard Grubb
15 Glass
Institute of Physics Publishing
Bristol 1997
xiii + 279pp, UK£30 (hardcover)

The worst thing that I remember about using the old Grubb astrograph at Sydney Observatory is the sector drive. This had to be rewound every few hours and the telescope repointed at the sky. Invariably the sector reached its end just as everything else was ready to start an exposure. Otherwise, for an instrument manufactured in 1890, it was easy to use and had excellent stability and pointing accuracy.

I learnt from this book by Ian Glass that the sector drive was Howard Grubb's standard system. In spite of complaints by the astronomers who used the telescopes, it was not until 1899 that Grubb produced a telescope with a continuous circular wormwheel. I also learnt some details of the difficulties that Grubb experienced in making the objective lenses for the astrographic telescopes. His main difficulty was to create the relatively wide field required (2°) and still correct for spherical and chromatic aberration.

The book is not an ordinary biography of Howard Grubb and his father Thomas as it is based on edited extracts from their letters. Many of these letters come from an extensive correspondence between Howard Grubb and David Gill, who for a long period was in charge of the Royal Observatory at Cape Town. Consequently, there is a strong South African emphasis, but at least the chapter on the Great Melbourne Telescope is of particular relevance to Australia.

Victorian Telescope Makers is not a substitute for a full biography of Thomas and Howard Grubb. It is, however, a pleasant read and gives a sound insight into nineteenth-century astronomy.

Nick Lomb
Sydney Observatory/Powerhouse Museum

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New Books

Quantum Chromodynamics and the Pomerons
JR Forshaw & DA Ross
Cambridge University Press
Cambridge UK 1997
xvii + 248 pp., A$54.95 (paperback)
ISBN 0-521-56880-3

Time's Arrows and Quantum Measurement
LS Schulman
Cambridge University Press
Cambridge UK 1997
xviii + 346 pp., A$47.95 (paperback)
ISBN 0-521-56775-0

Simulations for Solid State Physics
R H Silsbee and J Drager
Cambridge University Press
Cambridge UK 1997
xvii + 348 pp., A$39.95 (paperback)
ISBN 0-521-59911-3

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<td>July 5-10</td>
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<td>July 3-8</td>
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