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PRESIDENT’S COLUMN

SUPERCONDUCTIVITY AND RELATED NEW MATERIALS

Report by the House of Representatives Standing Committee on Industry, Science and Technology

There is much in this Report* that will please physical scientists. In addition to making recommendations that are specific to the topics of superconductivity, rare-earth magnets and metallic glasses - the last two being “representative of related new materials” - the Committee has made a number of more general observations and recommendations that could benefit much wider areas of research in Australia. The Sub-Committee of Members who undertook the inquiry - Dr. Michael Wooldridge and Messrs. Peter Baldwin and David Hawker - deserve congratulations for a well-argued and well-written Report that is very supportive of many of the arguments and attitudes being publicly promoted by the scientific community.

General conclusions and recommendations made by the Committee include:

- stressing the need for the Government to co-ordinate a national strategy to maximise benefit to the national economy arising from the economic and technological impact of advances in these areas;

- urging the Government, in consultation with State Governments, research organisations and industry, to explore the setting up of an autonomous National Superconductivity R&D Centre which would, inter alia: involve participation by researchers, manufacturers and potential end-users; coordinate funding from all available sources; provide a research information data base;

- urging the Australian Research Council to implement a fast-track method of awarding grants to research projects in rapidly developing fields of potential importance to the national economy;

- re-stating an earlier Committee recommendation that the tax incentive scheme for R&D expenditure be further altered for at least five years from July 1991 to ensure stability and predictability for business in making its investment plans;

- urging the institution of a 0.125% levy on turnover on the electricity generation industry to fund research into new technologies which would benefit the industry (this would yield some MS10 of new funding per annum; I understand that Electricorp in New Zealand already are providing about NZS0.5 of funding of research into high-temperature superconductors over two years);

- urging Australian scientists and technologists to play a more positive role in the formulation of public policy by ensuring that they are publicly represented by a well recognised peak council (i.e. we must continue actively to support FASTS).

Most of the above recommendations espouse views put forward by this Institute in its submission (and, no doubt, by other bodies also). This is pleasing. I am disappointed, however, that the Committee did not take the opportunity to endorse our call for action to improve the supply of trained research scientists in Australia by providing more incentive for local post-graduate training in our tertiary institutions.

The Committee’s recommendation to deal with the perceived “long-standing shortages in Australia of scientists and engineers” is that the Government should “act to expedite procedures for processing immigration applications by scientific personnel!” This is a quite inadequate response, that completely misses the point.

The Report sets a very sensible and workable policy framework within which Australian research into superconductivity and related new materials could prosper to the national benefit and without detriment to other equally worthy areas of research. The Institute, its individual members, its specific interest group in condensed...

Continued on page 55
HECS OR HEX!
Tertiary students this year are facing even more paperwork than usual as they enrol for their studies. For new students in a strange environment, enrolling is a daunting enough task without the additional form-filling demanded by the new Higher Education Contribution Scheme (HECS). Students have the choice of paying course fees up front or signing a contractual agreement with the Government to pay extra tax from future earnings. Something like 85 to 90 percent of new students (many of them under protest) are choosing to sign the contract.

One wonders whether the long-term impact of HECS has been thoroughly thought out. If the scheme is not abandoned in the meantime, there will be increasing numbers of graduates in the workforce paying a surcharge on their income tax. You bet your boots that certain professionals (need I go into detail?) will regard the HECS tax surcharge as a cost to be passed on to their clients. And will do exactly that. Inevitably there will be resentment by graduates not in a position to pass on their extra tax burden. They will say “Why should I pay X’s graduate tax through the fees I must pay him for his services, and have to pay my own as well?” Many, many union award claims have been based on less compelling logic than this.

Most members of the Institute of Physics belong to unions. Some do not. It is a real possibility that non-union members of our Institute will look to their professional body for assistance in obtaining what they would perceive as wage justice. Why not? The professional engineering institutes have for years been industrial advocates for their members. It would be a new role for our own Institute, and many members would be sorry to see such a development. On the other hand, a change in Government might scrap the HECS legislation, but in these days of user-pays philosophy, I wouldn’t hold my breath waiting. There is always the possibility that the tax might have some beneficial effect within our halls of higher education that would justify its continuation. The realisation that failing grades ultimately must be paid for in hard cash may introduce a more responsible attitude in many students. These are the ones who are a pain in the neck to their tutors and lecturers. These students usually hold a form belief that the University owes them a degree, and that a fifty percent grade in all of their subjects is perfectly adequate. Nobody seems to have pointed out to them that they are population pass implies half of what they might have got wrong! The thought of striving for academic excellence fills them with horror, yet they freely acknowledge that top athletes must exercise for hours and drive themselves to the brink of pain to gain their coveted honours. On the intellectual side, it can be said with absolute certainty that the bearers of such attitudes are the wrong stuff for future physicists.

Maybe the apathetic student syndrome is symptomatic of attitudes widespread in a society where failure is rewarded with handouts. The trouble is that such students take at least twice the teaching effort required for conscientious students, and occupy places that could be better filled by some of the 40,000 out there for whom there are none, according to Government estimates. Therefore, it beats me why Mr. Dawkins did not favour a more explicitly reward-based scheme for tertiary fees.

Noting that the HECS scheme aims to recoup only 20 percent of the cost of providing tertiary education, it seems to me that the same return could flow from a system of paying full fees for failed courses. Instead of making the payment post hoc and punitive, the fees could be covered by a merit bursary which is renewed each year on the basis of performance. There is nothing new in this sort of incentive scheme which, from my experience of it in other countries, is a strong deterrent to the type of student who comes along for the ride and doesn’t care a damn for the student sitting in the next seat who wants to hear the lecture.

Nobody, not even Einstein, mastered physics without working at it. Correct me if I’m wrong, but HECS or any other fees scheme will do nothing to assist our halls of learning unless it effectively encourages and rewards hard work.

Colin Keay
University of Newcastle

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THE NATURE AND ROLE OF INNOVATION
IN THE ECONOMY

A REPORT ON THE THIRD FORUM OF THE NATIONAL SCIENCE AND TECHNOLOGY
ADVISORY GROUP (NSTAG), CANBERRA, NOVEMBER 3-4, 1988

R. Payling, FAIP, on behalf of the AIP Science Policy Committee

The Forum recommends: an extension to the 150% tax incentive scheme for industrial R&D, a tax on companies not doing enough R&D, greater coordination between government departments on S&T policy, an end to the tax on honours-year students and post-graduate students, steps to make science and engineering more attractive as career options for school leavers, a re-appraisal of the cuts in funding to CSIRO, and the inclusion of a Science and Technology Statement in the Budget papers.

The third and most successful NSTAG Forum to date was held in Canberra on November 3-4, 1988, in the Dome of the Australian Academy of Science. The Forum was chaired by Professor Arthur Birch of the Academy and its theme was 'Innovation in the Economy'. Its aims were twofold: to provide an opportunity for a large number of representatives from the public service, from government research laboratories, from academia, and from industry, to hear each other's points of view on current science and technology (S&T) issues, and to generate an array of recommendations on S&T policy which could assist the NSTAG Committee in the formulation of its own policy statement. Since NSTAG purports to speak on behalf of Australia's 200,000 scientists, technologists and engineers, these were worthwhile goals.

The key to the success of the Forum lay in the instructions given to the invited speakers: they were to concentrate on recommendations and issues rather than on their prepared papers, which were available separately in the Forum's Briefing Papers. This allowed time for the audience, of over two hundred people, to have its say on the points raised by the speakers. The Forum thus acted like an enormous informal committee; and the success of such a lengthy and, at times, unwieldy process was not assured until Dr. Peter Robinson, Group General Manager - Technical of MM Metals Ltd., presented the Summary (or Conclusions) of the Forum, during the final session. With skill and sensitivity, Dr. Robinson had sifted through the two days of discussions to arrive at a set of recommendations which achieved, if not universal, then at least widespread acceptance by the meeting.

DAY 1
The Forum was opened by Senator Button, the Minister for Industry, Technology and Commerce. In a speech which contained little new but which was nevertheless a worthwhile restatement of the Federal Government's position, Senator Button concentrated on the need for the restructuring of the Australian manufacturing sector, to move it from an industry based on a domestic market with a low emphasis on technology and innovation to one open to the world market and to faster technological development. Government initiatives in this area, such as the 150% tax incentive scheme for Industrial R&D, the Licensed Management and Investment Companies (LMICs) scheme, changes to defence requirements, to Telecom, etc., were bearing fruit, and further industrial advances would lead to greater opportunities for research. I am not sure if he realised how cynical this remark sounded but in a sense it was the reverse of the traditional argument from scientists: that it was greater R&D which would lead to greater industrial development.

SESSION 1: 'SCIENCE, TECHNOLOGY & ENGINEERING IN THE BUDGET'
The first session, on 'Science, Technology and Engineering in the Budget' was chaired by Professor Ron Johnston, Director of the Centre for Technological and Social Change at the University of Wollongong. In his opening remarks he said that now was a crucial time for science and technology in Australia. Australia was behind in its restructuring and now was the time for radical policies and for the setting of priorities. Mr. Bill Rourke, Chief Executive of the Institution of Engineers Australia (IEAust.), followed, and agreed that the rate of structural change was too slow in Australia, relative to overseas. He recommended increases in Government funding for R&D (from 0.65% GNP to 0.8% GNP), additional support for post-graduate research, and a concentration of the government-funded R&D effort into areas of competitive advantage. Finally, he recommended that an S&T statement should appear in the Budget papers (as part of the Budget process) in preference to the review of Budget outcomes currently produced by the Department of Industry, Technology and Commerce (DITAC), some months after the Budget.

Professor Geoff Wilson, Rector of the University College of the Australian Defence Force Academy, argued that merely shifting money around was not enough, that what was needed was more money. To increase the competitiveness for research funding within the whole of the higher education sector, and to increase the concentration on national objectives, required more money; the Australian Research Council (ARC), in particular, because of its special responsibility in these areas, needed more money. Someone in the audience warned that a further shift of general university funds into the ARC would only
endanger the infrastructure which supports university teaching and research. 

Mr. Andrew Podger of the Department of Finance began by stressing the tough financial position faced by the Government. The R&D community, he considered, had fared rather well, in such a climate, with increases above the CPI. This statement, wrongly I believe, considers R&D merely as a financial debt, and neglects the need to compare the level of government support for R&D with measures of the size of the economy, such as with GDP. Increased effectiveness in R&D, he continued, necessarily means the shifting of funds between areas, specifically, a shift from basic research to applied research. There should be more discussion of priorities and performance rather than the size of allocations. The general murmurs from the audience during Podger’s talk convinced me that the battle for basic research, carried out in recent years, has largely been lost; many academics are now resigned to doing applied research. One can only hope that a reasonable balance results. In the discussion which followed, comments were made on the danger to the university infrastructure, mentioned above, on whether the concentration of R&D resources should be aimed at preferred research groups or at priority research areas, and on the need for more money for science policy research to study such things as priorities and performance.

SESSION 2: ‘TERTIARY INSTITUTIONS AND TRAINING’

After lunch, Professor Nancy Mills of the University of Melbourne introduced the session on ‘Tertiary Institutions and Training’, by saying that the primary role of tertiary institutions is fundamental insight, and that research skills come from doing an ‘apprenticeship’ with a skilled supervisor or within a skilled research team, a position I strongly identified with. Professor Don Watts, President and Vice-Chancellor of the Bond University, called for greater depth and breadth in research training and training for other than ‘academic’ research. Dr. Michael Deeley, Managing Director of ICI Operations Australia Ltd., said that the problem of training at universities did not lie with the skills of the few scientists required for research but with the training of the many more scientists required in industry for quality control, production, etc. Mr. Tony Ryan, President of the Council of Australian Postgraduate Associations, was concerned with the tax on honours and post-graduate students and with the average of 5.5 years for post-graduate work in Australia. Dr. Mathew Morell of the Australian National University painted a depressing picture of science as seen by high-school and post-graduate students. Science was no longer an attractive career option, as could be seen in the low entrance scores required for science by tertiary institutions.

SESSION 3: ‘THE MANAGEMENT OF RESEARCH’

The final session on Day 1 was entitled ‘The Management of Research’. It began with Professor Don Aitkin, Chair of the Australian Research Council, describing the role of the ARC. The ARC, he claimed, was set up by Government to administer government policy: to allocate grants and to advise government, not to lobby government for more money. He saw this as a job for FASTS (the Federation of Australian Scientific and Technological Societies). I had the uncomfortable feeling that I was listening to the voice of the Government rather than to the voice of the scientific community which had pressed for the setting up of the ARC in the first place. The Australian public, Professor Aitkin continued, wanted lower public expenditure, and the universities had not provided adequate justification for the support for basic research.

Professor Ken McKinnon, Vice-Chancellor of the University of Wollongong and recent critic of the ARC, followed with a variety of comments on: the inadequate funding for post-graduate research; the fragmentation of S&T policy-making in government departments; a need to support university promotions through teaching excellence as well as research excellence; and a call for young people to be on the ARC. Dr. Laurie Hammond of the Victorian Institute of Marine Science was also critical of some aspects of the ARC, especially the ARC being housed in the Department of Employment, Education and Training (DEET). He called on the scientific community to be more supportive of the policy initiatives of ASTEC (the Australian Science and Technology Council).

DAY 2:
SESSION 4: ‘ST&TE POLICY DEVELOPMENT’

Day 2 began with a session on ‘Science, Technology and Engineering (ST&TE) Policy Development’, chaired by Mr. Jan Kiln of NER&D&C (the National Energy Research, Development and Demonstration Council), who remarked that over the past 20 years the biggest problem in ST&TE policy in Australia has been the gap between private and public sector R&D. Dr. Rod Badger of DITAC added that the NSTAG Forum should concentrate on drawing out and documenting such major problem areas, rather than on itemising lists of wants from government. In 1983 the major problem in R&D had been recognised, both by the Government and by those talking to the Government, as the low level of industrial R&D, and subsequent major government initiatives had been aimed at overcoming this problem.

Professor Ray Martin, head of ASTEC, outlined the role of ASTEC in providing commentary and confidential advice to the Prime Minister, to Cabinet, and to the Budget planners. To maintain the credibility of its position as an independent advisor to government, ASTEC could not afford to act as a lobby for the S&T community. This again was a job for FASTS or IEAust. Recently, ASTEC has begun to look again at the task of defining National Priorities, a task it abandoned in 1981 through lack of interest from the government of the time.

Dr. Max Lay, Chair of the Engineering R&D Standing Committee of IEAust, suggests the government should take 1% of turnover from companies not doing their own R&D. This idea was later supported by Professor Frank Larkins, President of FASTS, who said that only 5% of Australian companies conducted R&D in excess of 1% of turnover. The money collected should go towards the collective IR&D effort. During the discussion which followed members of the audience commented on the low participation (14%) by industry in the Forum; privately, I noted that only 7% of the audience was female, another sign of imbalance in the make-up of the audience, I thought.
Meanwhile, others called for greater mobility of staff between private and public sector R&D, possibly through shared, or Adjunct, Professors.

SESSION 5: ‘THE URGENCY TO RE-DEVELOP INDUSTRY’

The second session of Day 2 was entitled, ‘The Urgency to Re-develop Industry’. Mr. Ian Sheddion, Managing Director of Sheddon Pacific Pty. Ltd., presented a dismal picture of the Australian economy related to small business. He claimed that the Australian manufacturing industry was in disarray, that venture capital had practically disappeared since the stock-market crash, and that an inevitable, future drop in commodity prices would once again place Australia in dire trouble. His comments seemed out of place amongst the more optimistic accounts of the restructuring of the Australian manufacturing sector.

Amongst a series of recommendations, he suggested that the MICs program should be improved to foster companies specifically aimed at the export market or at import replacement. Dr. Peter Robinson, of MM Metals Ltd., as a representative of big industry, concentrated on the need for the restructuring of the manufacturing base. To some extent this was occurring, he said; for example, in 1986-87 manufacturing exports had risen to 29% of total exports. However, while current levels of industrial R&D were adequate to sustain current industries, he added, they were insufficient to bring about the required structural change.

Professor Frank Larkins listed a number of concerns: the urgency for redevelopment, and the key role of R&D in this process; the need for clear government policies, unlike the confused beginnings of the 150% tax incentive scheme; the un-informed attitude of many company managers towards R&D; the impact of high interest rates and the high Australian dollar; and the need for increased cooperation between Australian companies. Dr. David Charles, Secretary of DITAC, outlined promising signs of reconstruction: manufacturing industry had shown good growth since 1982, expenditure on plant and equipment was up, manufactured exports were growing, though import replacement was slow. The five areas currently driving the manufacturing trade were iron and steel, non-ferrous metals, transport equipment, communications, and food processing. The time for change, he stressed, was limited, and the skill base needed to support it had emerged as a high priority concern. During the discussion, Mr. Campbell Cee of the Industrial R&D Group, which represents 57 of Australia’s largest companies, spoke in support of the 150% tax incentive scheme.

SESSION 6: ‘CONCENTRATION OF RESOURCES AND CRITICAL MASS’

The third session of Day 2 was entitled, ‘Concentration of Resources and Critical Mass’. Dr. Ken McCracken, Director of the Office of Space Science and Applications, said that over the past 10 years a general consensus had emerged that our R&D resources were spread too thinly. He spoke of innovation teams, of focused research, priority setting, and the desirability of forming 2 or 3 large national projects. Some members of the audience responded that good research was often done in small rather than large groups. Dr. Roy Green, Director of the CSIRO Institute of Natural Resources and Environment, reviewed current thinking on Technology Parks, the need for continuing assessment, and the concern over State rivalries. Ms. Susan Oliver, Manager of the Technology Strategy Group of Invotech, spoke on the latest high-technology fad: the Multi-Function Polis (MFP) - a high-technology satellite city. Australia, she considered, was not in a good position to take advantage of a large investment in MFPs because of the lack of a strong manufacturing base to support them.

FINAL SESSION: ‘SUMMARY OF FORUM’

Finally, Dr. Peter Robinson presented his Summary of the Forum: a series of about 20 recommendations, carefully chosen from all those presented during the Forum. The enthusiastic applause which greeted the end of his talk showed how well Dr. Robinson had gauged the spirit of the meeting, which thus ended with the happy sense of having achieved its objectives. The NASTG Committee now has the raw material for a strong and comprehensive policy statement. Amongst the recommendations were: that a science and technology statement should be contained in the Budget papers; that the 150% tax incentive scheme should be extended as 5 years was too short for its full implementation; that the cuts to the CSIRO budget should be reviewed by NASTG; that there was a need for greater co-ordination between government departments on S&T policies; concern that the graduate tax, low remunerations and career prospects were strong disincentives for post-graduate work in science and technology; that the ARC should look to longer term planning in higher education R&D; and that there should be a larger industrial participation in the NASTG Forum.

VICTORIAN JUNIOR SCIENCE AND TECHNOLOGY FESTIVAL

ANZAS recently conducted the first Victorian Junior Science and Technology Festival, in conjunction with Swinburne Institute of Technology. The festival, designed for students at the upper primary level, was held over two days in October during 'Science in Schools' week. It was also supported by the Ministry of Education, CSIRO, educational institutions and bodies, professional associations (including the AIP), and several industrial organisations.

The festival’s aim was to introduce primary students to science and technology. Through small group activities, students were exposed to some simple scientific concepts and then encouraged to experiment with them. It was hoped that in this way the students would develop an enthusiastic appreciation of science which would help them to meet the challenge of future technological advances.

The author represented the Victorian Branch of the AIP on the organizing committee and also prepared a set of six experiments for the two AIP stands.

A student teacher at Footscray Institute of Technology demonstrates the importance of air for sound propagation.
AIP NEWS

at the festival. The AIP’s theme was 'The Air Around Us', and the experiments explored the effects of pressure in moving and static air, and the propagation of sound in air. Students were asked to predict the outcome of each experiment before performing it. This led to some surprises for most students, creating genuine excitement and resulting in many questions to the presenters.

Over 2000 students from 33 schools attended. Unfortunately, well over the same number again missed out on places due to limited resources. The students were well organised, well behaved and very attentive. Students, teachers and presenters all found the festival very rewarding, and we eagerly look forward to the next festival in 1989!

Alex Mazzolini

VICTORIAN BRANCH NEWS

The 26th Annual General Meeting of the Victorian Branch of the AIP was held on 24th November, 1988 in the Hecules Lecture Theatre of the University of Melbourne. The official formalities again lasted for less than 15 minutes primarily due to the ‘kindness’ of an enthusiastic Prof. Fred Smith, who often proposed a motion to be passed even before it was presented to the meeting! The following Office bearers were elected: see below.

After the AGM, the outgoing Chairman of the Victorian Branch, Prof. Bruce McKellar, FAA, treated the audience with a most interesting and stimulating talk on “The Funding for Research”. A summary of this lecture was prepared by Prof. McKellar, upon special request, for inclusion in the Australian Physicist (See Opinion Column, this issue.)

M.A. Chaudhri

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ASPAP News

Editorial Board Meeting
Bangkok 10/1/89

I attended this meeting as the Australian Representative. It was held as an adjunct to the Third International Conference on "Path Integrals from keV to MeV". Prof. V. Saksan was our host. A/Prof. S.C. Lim, the Editor of the Asia Pacific Physics News (ASPAP News), acted as Chairman of the meeting and editorial board members from Japan, Philippines and Singapore were also present.

Apart from minor editorial matters, discussion centred on the possibility of the journal becoming the newsletter for the Association of Asia Pacific Physical Societies, AAPPS, which is fast becoming a reality. It was agreed that S.C. Lim would act as editor of this newsletter if requested by the AAPPS.

Although I have always been convinced that the AIP must take an active role in discussions on the future of physics in the region, I had not been aware of the enormous responsibility we owe to our northern colleagues. As the Association will be conducting all its business in English, Australia and New Zealand will be the 'repository' of the language. As a physicist whose first language was not English, this made a great impact. I realised that it is up to us to provide facilities to our colleagues to help with learning this second language. I would, therefore, like to suggest that this can be achieved by having physicists (final year undergraduates through to postgraduate level) spend their summer vacation (June to August) here, thus enriching the work of the physics departments. Rather than stay in hostels they should stay in physicists' homes forcing them to speak English and many friendships could result. The English language in its great subtleties would then be better understood and exert its influence on the conduct of the Association. Please give this matter some thought.

I would like to thank the AIP for partial financial support and my hosts in Thailand for their excellent hospitality.

Trudi Thompson

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Acceptance Speech, Professor R Delbourgo

Professor Klein, Professor McKellar, ladies and gentlemen...I cannot really express how honoured I feel to be receiving this prestigious award from the Australian Institute of Physics, all the more so as I have been informed that theorists have now scooped three of the first five awards. This is quite remarkable in a country where theoretical physicists are numerically overwhelmed by their experimental colleagues, but I am certain that this statistical anomaly will be corrected in future years! Nonetheless, I hope that other Australian particle physicists will share in my pride, for the recognition of the work we have been engaged in for many years and at such a great distance from the famous particle accelerator centres in Europe and America. Please thank the President and the Council of the AIP for seeing fit to bestow this award on a quantum field theorist.

It is a misconception that theoreticians can work in total vacuum armed with just paper and pencil. Instead, it bears repeating that we feed on experimental facts and need to be aware of the most recent data; we need to form part of a group of well-informed colleagues with whom we can have heated debates about the significance or otherwise of the latest ideas. This being a public occasion and because the Walter Boas Medal is awarded on the basis of the last five years' research, I would like to take the opportunity and express my debt to Australian collaborators who have shared their thoughts with me and inspired new lines of investigation. Specifically I would like to mention three colleagues and good friends, Peter Jarvis, Brian Kenny and George Thompson, who have written numerous papers with me and given me the benefit of their insights. Last but not least, I must record my thanks to the several gifted postgraduate students whom it has been my privilege to supervise: the freshness and vitality of their approach has stimulated and often given new direction to my own work.

In my 'Walter Boas Lecture' I have decided not to cover all the areas of quantum theory in which I have been involved. Such a talk would be of value to no one: not to the layman nor to the expert. Rather I have chosen to concentrate on a particular facet, dealing with anticommuting variables, which turns out to be firmly rooted in elementary quantum mechanics.

I have a strong suspicion that this aspect of particle theory will turn out to be quite important in future, so I will give a brief description of its origins and where I foresee the next developments will lie. Much of the material is taken from work carried out jointly with Dr Ruibin Chang.

Does Nature Have Hidden Anticommuting Coordinates?

Professor R Delbourgo, Department of Physics, University of Tasmania

When teaching a first course on quantum mechanics, one of the trickiest concepts to get across is the notion of spin. By the time one has reached that stage of the act, the student will have learned about spherical harmonics and radial wavefunctions. One first makes a conceptual leap into matrix mechanics by discussing the (discrete) components of the wave functions in the orbital momentum (l,m) basis and then one makes an enormous leap to spin (s,ζ) by extending the idea to half-integer angular momentum. Double-valuedness of the spinors is a sign that this intrinsic property is not directly related to space-time and indeed one lays special stress on the fact that the spin operators commute with position and momentum observables. In practice what this means is that one cannot make a transformation of spinor components to anything like spherical harmonics—there is no similarity between them because the corresponding coordinates do not exist! In this article I shall indicate how one can append extra (fermionic) dimensions to space-time and fully exhibit the 'spin harmonics'. I will go on to propose that this device of attaching further (anticommuting) coordinates to the ordinary (commuting) coordinates x, t may have much deeper meaning and might in principle lead to a complete understanding of internal and other symmetries. If nothing else, it leaves no loose threads and allows us to picture what is going on!

Let me begin with elementary classical analysis. We are all familiar with the fundamental Fourier expansion of a function that is periodic in one variable. For simplicity, taking this variable to be the azimuth θ, with period 2π, one writes

$$\psi(\theta) = \sum_m \psi_m(\theta) \epsilon^{im\theta}$$

with the converse transform,

$$\psi_m = \int \psi(\theta) \epsilon^{-im\theta} d\theta/2\pi$$.

A basic observation is that the expansion functions $\epsilon^{im\theta}$ are eigenfunctions of $-i\partial / \partial \theta$ with integer eigenvalues m. It is not too difficult to generalise the concept to functions defined over a solid angle. Adopting the usual polar and azimuthal coordinates $\theta$ and $\phi$, with $0 \leq \theta \leq \pi$ and $0 \leq \phi < 2\pi$, one ends up with the 'multipolar' expansion

$$\psi(\theta,\phi) = \sum_{l=0}^{\infty} \sum_m Y_{lm}(\theta,\phi) \psi_m$$

where the multipole coefficients are given by

$$\psi_m = \int \psi(\theta,\phi) Y_{lm}(\theta,\phi) \,(\cos\theta)\,d\phi$$

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The expansion functions are none other than the spherical harmonics

\[ Y_{\ell m} = \text{e}^{im\phi} P_\ell^m (\cos \theta) \]

arising via the Laplacian; they are eigenfunctions of the angular operator

\[ (\sin \theta)^2 \left( \frac{\partial^2}{\partial \theta^2} - \frac{\sin \theta}{\sin \theta} \frac{\partial}{\partial \theta} \sin \theta \frac{\partial}{\partial \theta} \right) + \frac{\partial^2}{\partial \phi^2} \]

having eigenvalue \(-\ell(\ell+1)\), where \(\ell\) is a nonzero integer. (The \(P_\ell^m\) are the associated Legendre functions and are defined for \(1 \leq m \leq \ell\).) All this is perfectly standard nineteenth century stuff.

Quantum mechanics came on the scene in the twentieth century and such expansions took on a new meaning. The spherical harmonics were construed to be eigenfunctions of the angular momentum operator \(L = X \times P\), which acts like the differential operator \(-i\hbar (x \partial / \partial x)\) on coordinate wave functions. In particular, since

\[ L_\phi = -i\hbar \partial / \partial \phi \]

and

\[ L^2 = -\hbar^2 \left( \frac{1}{\sin \theta} \frac{\partial}{\partial \theta} \sin \theta \frac{\partial}{\partial \theta} + \frac{\partial^2}{\partial \phi^2} \right) \]

it is remarkable that

\[ L_\phi Y_{\ell m}(\theta, \phi) = m\hbar Y_{\ell m}(\theta, \phi) \]

and

\[ L^2 Y_{\ell m}(\theta, \phi) = (\ell+1)\hbar^2 Y_{\ell m}(\theta, \phi) \]

so the quantisation rules for \(L\) and \(m\) (for single-valued wave functions) are automatic! Well-established classical theory of differential equations and generating functions tells us how to work out the harmonics; the first few of these are written below, up to normalisation factors:

\[ Y_{00} = 1, \quad Y_{10} = \cos \theta, \quad Y_{11} = \sin \theta \text{e}^{i\phi}, \]

\[ Y_{20} = 3\cos^2 \theta - 1, \quad Y_{21} = \sin 2\theta \cos \theta \text{e}^{i\phi}, \quad Y_{22} = \sin^2 \theta \text{e}^{2i\phi}, \quad \text{etc.} \]

The beauty about these expressions is that one can view the harmonics in real space. Figure 1 depicts the directional properties of the functions, giving credence and providing substance to the chemists' picture of atomic bonding. We would be poorer without these pictures of the (charge) distribution in space. As an aside, useful for later discussion, let me mention that the harmonics \(Y_{\ell m}\) can be neatly described as traceless \(L\)-tensor products of the unit vector \(\mathbf{n} = (x_1, x_2, x_3)\); setting \(x_3 = x_1 x_2\) we have for instance,

\[ Y_{20} = 3x_1^2 - 1, \quad Y_{21} = x_1 x_2, \quad Y_{22} = x_2^2, \quad \text{and so on.} \]

Figure 1. Spherical harmonics (up to \(L = 2\)) can occupy all directions.

From this point of view, the expansion over solid angle can be interpreted as a Taylor series in the arguments \(x_1\) and \(x_2\);

The classical expansion over solid angles can also be elegantly comprehended in Dirac's quantum mechanical formalism. In his notation, there are the angular position kets \(|\theta \phi\rangle\) and the angular momentum kets \(|m\rangle\), as well as their dual bras. Each of these forms a complete set of states and provides a resolution of the identity operator. The solid Fourier expansion is merely the transformation from one representation to the other of the general state \(\psi\); thus

\[ <\theta | m \psi> = \sum_{lm} <\theta | l \psi> <l | m \psi>, \quad \text{or conversely,} \]

\[ <l | m \psi> = \int d\phi \, d\theta \, \cos \theta \, e^{i\phi} \psi \, <\theta | m \psi> \]

The spherical harmonics \(Y_{\ell m}\) are therefore to be understood as the transformation coefficients between angular coordinate and angular momentum states, \(<\theta | m \psi>\) in much the same way that the plane wave Fourier coefficients

\[ <\text{dp}> = \exp(i\mathbf{p} \cdot \mathbf{x} / \hbar) \]

allow us to pass from Cartesian position to Cartesian momentum.

After teaching that the orbital operators \(L = X \times P\) obey the commutation relations \( [L \times L] = i\hbar L\), I pass on to the more general class of angular momentum operators \(J\), obeying the same \((SU(2))\) algebra, \(J \times J = iJ\). In deriving algebraically the representations \(|J m \psi>\) for general \(J\) (\(m = -J, -J+1, ..., J-1, J\)), I point out that there is no bar to the occurrence of half integer \(J\)-values. This is how I try to make the transition to spin appear quite natural; I argue that the experimental data shows that elementary objects are endowed with an intrinsic angular momentum \(S\) which satisfies the corresponding algebra

\[ S \times S = i\hbar S \]
DOES NATURE HAVE HIDDEN ANTICOMMUTING COORDINATES?

even in the rest frame of the object. And because this property has nothing directly to do with the motion of the object, the spin operators necessarily commute with position \( X \), momentum \( P \) and angular momentum \( L \) operators, and there is no reason why the \( s \)-values are constrained to be integral. Hence

\[
S_x |S\rangle = i\hbar s_1 |S\rangle, \quad S_y |S\rangle = s(s+1)\hbar^2 |S\rangle, \quad s = 0, \frac{1}{2}, 1, \frac{3}{2},
\]

with the total angular momentum operator, \( J = L + S \), being the generator of full rotations. Another fact that I am obliged to pull out of the hat at undergraduate level is the spin-statistics connection: I promise explanation in an advanced course on relativistic quantum field theory.

I then follow the canonical route and describe nonrelativistic spinors as the projections of the wave function on to the spin states. For spin \( \frac{1}{2} \) we encounter two-component spinors,

\[
\begin{align*}
\langle \frac{1}{2}, + \frac{1}{2} | \psi \rangle &= a = \text{Prob. amp. for spin up} \\
\langle \frac{1}{2}, - \frac{1}{2} | \psi \rangle &= b = \text{Prob. amp. for spin down},
\end{align*}
\]

on which the spin generators are represented by \( 2 \times 2 \) Pauli matrices. We soon become very proficient at manipulating these matrices and extracting all the necessary information from them; and with more experience we become equally good at handling higher spins. However, the best students spot the blemish in this treatment: they ask, 'Where is the analogue of the 10\( \Phi \) states?' The stock answer which we mostly offer (and which always makes me feel uneasy) is that they just do not exist because spin lies 'outside of space'.

I would now like to suggest a remedy for this failure of the traditional treatment. Since spin is disconnected from space, let me venture to append two new coordinates to space-time, say \( \xi_1 \) and \( \xi_2 \). (They are 'real' in a sense to be defined presently.) Here I have already anticipated the fact that all known elementary matter fields have spin half — the gauge fields and the graviton carry integer spin — and require two degrees of freedom, at least nonrelativistically. Also I know in advance that these fermion fields must anticommute so I will assume that these new \( \xi \) also anticommute: they are Grassmann variables in the mathematicians' terminology.

Grassmann operators are not unknown in physics: in second quantised theory, the operators \( a(x), a^*(x) \) which respectively destroy and create a fermion have to anticommute in order to produce antisymmetric states obeying Fermi-Dirac statistics. The difference now is that the concept is being extended to the coordinate arguments themselves. Because they behave quite differently from the commuting coordinates \( x \), this may be one reason 'why we cannot see' the \( \xi \). Now

\[
\xi_1^2 = \xi_2^2 = \xi_1 \xi_2 = \xi_2 \xi_1 = 0,
\]

so any function \( f(\xi) \) has a miraculously terminating Taylor expansion

\[
f(\xi) = c + a\xi_1 + b\xi_2 + d\xi_1\xi_2
\]

which we will use to our advantage. The rules for differentiating Grassmann variables are now well established; providing that one is careful with the order of the derivatives so

\[
\frac{\partial}{\partial \xi_1} \frac{\partial}{\partial \xi_2} f(\xi) = -\frac{\partial}{\partial \xi_2} \frac{\partial}{\partial \xi_1} f(\xi),
\]

and applies the curious Berezin integration formula,

\[
\int (c + b\xi) d\xi = b,
\]

the Grassmannian formalism is perfectly consistent. As a matter of fact, Grassmann variables act like negative degrees of freedom in several respects. For my case there exists the antisymmetric metric \( \eta^{12} = -\eta^{12} = 1 \) which leads to the invarient 'symplectic', \( \xi_1 \eta^{12} \xi_2 = 2\xi_1 \xi_2 \). It enables one to define the coordinates with raised indices, \( \xi_i^\dagger \eta^{12} \xi_i \), so \( \xi_2^\dagger = \xi_2 \) and \( \xi_1^\dagger = -\xi_1 \).

I now do my best to mimic ordinary quantum mechanics. First I define a Grassmann position operator \( \Xi \), whose eigenvalues are \( \xi_1 \) and construct a Grassmann momentum operator \( \Pi \), which acts like the displacement operator \( -i\hbar \partial \partial \xi_j \) on 'wave functions'. In this way I maintain a perfect analogy with the Heisenberg commutators:

\[
\begin{align*}
\{\Xi, \Pi_j\} &= 0 & \text{cf} & \{\xi_1, \xi_2\} &= 0 \\
\{\Pi_i, \Pi_j\} &= 0 & \text{cf} & \{P_x, P_y\} &= 0 \\
\{\xi_1, \Pi_j\} &= i\hbar \delta_i^j & \text{cf} & \{x, p\} &= i\hbar,
\end{align*}
\]

the Dirac notation,

\[
\begin{align*}
\Xi \xi_1 &= \xi_1 \Xi & \text{cf} & x k_x &= k_x x, \\
\Xi \xi_2 &= \xi_2 \Xi & \text{cf} & x l_x &= l_x x, \\
\Pi \xi_1 &= \xi_1 \Pi & \text{cf} & P p_x &= p_x P,
\end{align*}
\]

the correspondence principle,

\[
\langle \xi_1 | \Pi_i | \xi_2 \rangle = \delta(i-\delta_1^{\xi_i} \delta_2^{\xi_j}) \quad \text{cf} \quad \langle x | p \rangle = \exp[-ip \cdot x \hbar],
\]

the transformation coefficients,

\[
\langle \xi_1 | \Pi_i | \xi_2 \rangle = \delta(i-\delta_1^{\xi_i} \delta_2^{\xi_j}) \quad \text{cf} \quad \langle x | p \rangle = \exp[-ip \cdot x \hbar],
\]

the normalisation convention,

\[
\begin{align*}
\langle \xi_1 | \xi_2 \rangle &= \delta(\xi_1 - \xi_2) \quad \text{cf} \quad \langle x | x \rangle &= \delta(x - x'),
\end{align*}
\]

and the completeness relation,

\[
1 = \int \xi_i d\xi_i \langle \xi_i | \xi_i \rangle \quad \text{cf} \quad 1 = \int dx p \delta(x \cdot x).
\]

The stage is now set for introducing Grassmann angular momentum. With the reminder that orbital momentum operators are antisymmetric products of \( X \) and \( P \), namely \( L_{ij} = X_i P_j - X_j P_i \), and bearing in mind that we are now dealing with anticommutators, what is more natural than to define the new rotation operators, as symmetric products of \( \Xi \) and \( \Pi \),

\[
L_{ij} = \Xi_i \Pi_j + \Xi_j \Pi_i
\]

of which there are three since \( r \) and \( s \) run from 1 to 2. These are readily found to obey the commutation rules (commutation because they are bosonic):

\[
\begin{align*}
[\Xi_1, \Pi_2] &= -i\hbar L_{12} \quad \text{cf} & [S_x, S_z] &= 2iS_y, \\
[\Xi_2, \Pi_1] &= +i\hbar L_{21} \quad \text{cf} & [S_y, S_z] &= 2iS_x, \\
[\Xi_1, \Pi_1] &= -i\hbar L_{11} \quad \text{cf} & [S_z, S_x] &= 2iS_y,
\end{align*}
\]

The identification of the new orbital operators with spin is now staring us in the face: let \( L_{11} = 2S_z, L_{22} = 2S_x, L_{12} = 2iS_y \). Equivalently regard the components of spin as the set of operators:

\[
\begin{align*}
S_1 &= (\Xi_1 \Pi_1 + \Xi_1 \Pi_2)/2 \\
S_2 &= (\Xi_1 \Pi_1 - \Xi_1 \Pi_2)/2i \\
S_3 &= (\Xi_2 \Pi_1 + \Xi_2 \Pi_2)/2i.
\end{align*}
\]
Note that the remaining (antisymmetric) \( \Xi \Pi \) product can be taken to be
\[
D = (\xi_1 \Pi_2 - \xi_2 \Pi_1)D \rightarrow (\xi_1 \partial / \partial \xi_1 + \xi_2 \partial / \partial \xi_2)
\]
and it acts like a scale operator on 'spin wave functions of \( \xi \). In fact it is easy to show from above that
\[
S^2 = 3h^2 D(D + 1)/8.
\]
Therefore when acting on linear functions of \( \xi \), like \( \psi(\xi) = a \xi_1 + b \xi_2 \), we obtain the correct result, \( S^2 = 3h^2/4 \) and confirm from
\[
S_1 \xi_1 = \frac{1}{2} h \xi_1, \quad S_2 \xi_2 = \frac{1}{2} h \xi_2
\]
that we are truly dealing with spin \( \frac{1}{2} \).

One last important point concerns conjugation. We would like our wave function to be normalised in the conventional manner:
\[
1 = \langle \psi | \psi \rangle = \langle a^2 + b^2 \rangle
\]
Since the \( \xi \) states form a complete set in Grassmann space, we must require
\[
1 = \int \langle \psi | \xi \rangle d \xi_1 d \xi_2 = \int (a_1^* a + b_2^* b_2) d \xi_1 d \xi_2
\]
all things being equal. For consistency we are obliged to take
\[
\xi_1^* = - \xi_2 \quad \text{and} \quad \xi_2^* = \xi_1, \quad \text{or} \quad \xi_1^* = \xi_2.
\]
And this means that we are effectively manipulating two real degrees of freedom. Since \( \xi_1^* = \xi_2 \) is inevitable, we see that conjugation is just an extra term in real time that can be neglected; but that is a technical point.

In summary, we can perceive an elementary spin \( 1/2 \) particle as possessing a wave function which is a linear combination of the anticommuting coordinates \( \xi_1 \) and \( \xi_2 \), in much the same way that elementary orbital momentum \( (l=1) \) is tied up with wave functions which are linear combinations of \( x_1, x_2, \) and \( x_3 \). For example an electron with spin up and in an orbital state \( l=m=1 \) can be represented by the complete wave function, \( \psi(x, \xi) = x_1 \xi_1 \), and so on. Observe that there are other types of spin functions which are associated with integer spin; in particular, a spin \( 0 \) state has to be described by the combination
\[
\Phi(\xi) = \sum \phi^\dagger \Phi = (1 + \xi_1 \xi_2)/\sqrt{2}
\]
to guarantee that
\[
1 = \langle \phi | \phi \rangle = \int \phi^\dagger(\xi) d \xi_1 d \xi_2 \phi(\xi).
\]
Figure 2 pictures these spin combinations and wavefunctions.

The situation is so much simpler than for spherical harmonics because of the terminating character of the spin harmonics.

A collection of identical spin \( 1/2 \) particles will be described by a multiparticle wave function, \( \psi(x_1(1), x_2(2), \ldots) \). If we wish to retain the spin-statistics connection, then we have to insist that the total \( \psi \) is fully symmetric under an interchange of the arguments \( x \) and \( \xi \) simultaneously. The point is that the \( \xi \) automatically anticommute, so the resulting spatial parts acquire the correct symmetry property. To illustrate, suppose that we are dealing with two electrons both with spin up, one in orbital state \( \ell_m \) and the other in state \( \ell_n \). Applying full symmetrisation,
\[
\psi_{\text{symm}} = \psi_{\text{symm}}(\ell_m 1, \ell_n 2) \times \psi_{\text{symm}}(\ell_n 1, \ell_m 2)
\]
we discover that the spatial part is antisymmetric (in the spherical harmonics), in accordance with the system having total spin \( S=1, M=1 \).

These Grassmannian ideas can be exploited in a number of different ways and I shall sketch out the principal developments to date.

(1) Incorporation of electromagnetic forces

When a charged \( (q) \) object is placed in an e.m. field, we easily account for the interaction by making the minimal substitution rule,
\[
P \rightarrow P + qA
\]
as detailed in the standard texts. For instance, in a uniform magnetic field \( B \), the vector potential can be taken to equal
\[
A = \frac{1}{2} B \times X, \quad \text{and the substitution yields the familiar Zeeman coupling:}
\]
\[
P^2 \rightarrow (P + qA)^2 = P^2 + qB \cdot L + (qB \times X)^2/4
\]
The spin-magnetic field interaction is missing above. We can remedy the defect by adding the Grassmannian kinetic energy \( \Pi_1 \Pi_2 \) to the Hamiltonian and invoking the analogous substitution rule. This reads (allowing for an unknown g-factor),
\[
\Pi \rightarrow \Pi + g \alpha \Theta \quad \text{with} \quad \alpha = B \times \xi \quad \text{a new spinor with components,}
\]
\[
\alpha_1 = \frac{1}{2} B_2 \xi_1 + \frac{i}{2} (B_1 + i B_2) \xi_2
\]
\[
\alpha_2 = \frac{1}{2} B_1 \xi_2 - \frac{i}{2} (B_1 - i B_2) \xi_1
\]
Hence the contribution to the kinetic energy from the anticommuting coordinates is
\[
\Pi_1 \Pi_2 + g \alpha B \cdot S + (g \alpha B)^2 \xi_2 /4
\]
which correctly adds to the orbital interaction. One can go on to determine the eigenfunctions and eigenvalues\(^4\). I have to leave this as 'an exercise for the reader' as I must press on.

(2) Relativistic Generalisation

It is not enough to study the rotation group when treating relativistic motion; the Lorentz transformations between time and space must be considered as well. Since the full Lorentz group is isomorphic to the SL(2,c) group it becomes necessary to double up (ie complexify) the spinors. It turns out that we now need four anticommuting coordinates:
\[
\xi_1, \xi_2, \xi_3, \xi_4 \quad \text{obeying the conjugation rules}
\]
\[
\xi_1^* = \xi_2, \xi_3^* = -\xi_3,
\]

and now capable of describing spin wave functions for particles and antiparticles. The nice thing about the Grassmannian formalism is that one can view the Dirac gamma-matrices as homogeneous differential operators acting on \( \psi(\xi_1, \xi_2) \). For instance,
\[
\gamma_0 \rightarrow i(\xi_1 \frac{\partial}{\partial \xi_1} + \xi_2 \frac{\partial}{\partial \xi_2}) + \xi_1 \frac{\partial}{\partial t_1} + \xi_2 \frac{\partial}{\partial t_2}
\]
\[
S_2 = \frac{1}{2} i h y_1 \gamma_5 \rightarrow \frac{1}{2} h \left( \xi_1 \frac{\partial}{\partial \xi_1} + \xi_2 \frac{\partial}{\partial \xi_2} + \xi_1 \frac{\partial}{\partial t_1} + \xi_2 \frac{\partial}{\partial t_2} \right)
\]
The Dirac equation is one of a possible set of relativistically invariant equations that \( \psi \) can satisfy; other cases may involve spin zero and spin one fields. Although one can go on to devise a Fermi–Bose supersymmetric version, there is no obligation to do so.

### (3) Quantisation of gauge fields

When quantising massless vector gauge theories, it becomes necessary to include fictitious or ‘ghost’ scalar fields in intermediate states to ensure that the nonphysical degrees of freedom of the vector are cancelled appropriately and that probability conservation is maintained. These ghosts turn out to obey Fermi statistics in order that the cancellation mechanism may operate. Now it is an interesting fact that one can imbibe the ghosts very naturally in an extended space-time with two extra anticommuting coordinates. And the ensuing (BRS) symmetry structure of the quantised theory finds a very simple exposition in this enlarged x-\( \xi \) space. Although this application is rather different from what we discussed previously, it is an active area of research and I could not avoid mentioning it.

### (4) Isospin

From a study of nuclear forces, we find that the proton \( p \) and the neutron \( n \) are but two facets of a ‘nucleon’. \( p \) and \( n \) are only distinguished from one another by their different electromagnetic properties (charge, magnetic moment, etc.). If we form an isodoublet out of \( p \) and \( n \), we learn that the strong Hamiltonian is ‘blind’ or invariant with respect to isospin rotations between them. In other words, the strong forces are not affected by the isorotation,
\[
\begin{pmatrix}
    p \\
    n
\end{pmatrix} \rightarrow \begin{pmatrix}
    \text{Rotation or} \\
    \text{SU(2) Matrix}
\end{pmatrix} \begin{pmatrix}
    p \\
    n
\end{pmatrix}
\]

These days the proton and neutron are no longer viewed as elementary particles, rather the quarks have usurped that role. Nevertheless, we still assume that when electromagnetism is neglected the strong interaction between the quark doublets in the three generations, \( (u,d), (c,s), (t,b) \), is isosymmetric. The question then arises: “What coordinates as such are being rotated?” The standard answer—an evasion of the question—is that these coordinates belong to an ‘internal’ space, which cannot be seen directly.

I would like to suggest that the internal coordinates are merely a further set of anticommuting coordinates which are every bit as significant as the coordinates which I introduced before for picturing spin. To get a good grasp of isospin we should append two more Grassmann coordinates; call them \( \eta_1 \) and \( \eta_2 \), corresponding to isospin up and down respectively. The isorotations may then be visualised as taking place among these \( \eta \) and of course we can construct three isospin operators \( I \) (orbital momenta in \( \eta \)-space) just as we did for spin in \( \xi \)-space. We may readily write down wave functions for different particles now: a u-quark with spin down is represented in total space by \( \psi(\xi, \eta) = \xi \eta_1 \).

### (5) Chromodynamics

Translated to the quark level, strong interactions are nowadays equated with the colour force; this is deemed to be symmetric among the coloured quarks: red, green, and blue, say. The chromrot onation of the quark fields corresponds to an SU(3) transformation of the type,
\[
\begin{pmatrix}
    q_{ud} \\
    q_{gn} \\
    q_{blue}
\end{pmatrix} \rightarrow \begin{pmatrix}
    \text{SU(3) Matrix}
\end{pmatrix} \begin{pmatrix}
    q_{ud} \\
    q_{gn} \\
    q_{blue}
\end{pmatrix}
\]

So far as the underlying space is concerned, I shall suppose that this is again Grassmannian: that there are three (complex) anticommuting coordinates hiding there which describe the colour degrees of freedom. Call these new coordinates \( \xi_1, \xi_2 \) and \( \xi_3 \). A blue quark wave function (down with spin up for instance) can be explicitly written down, namely \( \xi_1 \eta_2 \xi_3 \). And it is straightforward to construct three-quark compositions, such as the nucleon, by combining the various quark wave functions; a proton contains
\[
\xi_1(\eta_1) \delta(\eta_2) \eta_3 \cdot \xi_2(\eta_2) \delta(\eta_3) \eta_1 \cdot \xi_3(\eta_3) \delta(\eta_1) \eta_2
\]

### (6) General Relativity

Experts will say that one is by no means compelled to introduce anticommuting coordinates in order to understand spin, isospin, colour, etc. One can get by quite happily if one simply enlarges the field components and if one makes various assignments under certain transformation groups. That is perfectly true; the only advantage of Grassmannian coordinates is that they provide a concrete picture of what is happening. But there is one way where they do lead to interesting new concepts: this has to do with force unification and is the last area I want to touch upon.

To kick off, let me remind you about some rather old ideas about unification of gravity with internal forces, ideas which have undergone resurrection and burial. The original scheme was hatched by Kaluza: he conceived adding a fifth (bosonic) coordinate \( x_5 \) to space-time. Because this dimension is nowhere to be seen, Klein suggested that \( x_5 \) is very small scale (Planckian dimensions of 10^{-35} m) and is curled up on itself into the compact dimensions of a circle—though how this eventuates is anyone’s guess! By making a five-dimensional generalisation of Einstein’s theory of general relativity, using an invariant separation of events,
\[
dS^2 = dX^2 + G_{\mu \nu} dx^\mu dx^\nu
\]
invoking the ansatz
\[
\begin{pmatrix}
    G_{\mu \nu} \\
    G_{\mu 5} \\
    G_{55}
\end{pmatrix} = \begin{pmatrix}
    g_{\mu \nu} - e^2 A_\mu A_\nu \\
    -e A_\mu \\
    -e A_5
\end{pmatrix}
\]
Kaluza was able to interpret the electromagnetic field \( A_\mu \) as the off-diagonal part of the gravitational field. Although nowadays rigorous treatment shows that a further scalar field is also required in the 55 sector, the main point is that one can choose a coordinate system in which all the dependence on \( x_5 \) is carried by the four-dimensional gravitational field \( g \) and by other ‘sources’ \( \phi \). Charge symmetry is to be understood as
rotational symmetry around the fifth dimension and all $x_5$
dependence can be Fourier resolved:

$$\phi(x_5) = \sum_j \phi_j(x) e^{in_5}.$$ 

The $x_5$ independent components are the massless modes of the
expansions and the other $(n)$ modes have masses of the order of
magnitude,

$$M^2_n = \frac{n^2}{G_{\text{Newton}}} = 10^{16}\text{Gev} n^2.$$ 

The unfortunate aspects of the Klein-Kaluza models (and their
non-abelian generalisations to chromodynamics, electroweak
forces, ...) are (a) the supermassive particles which are dredged
up, (b) the fact that there are an infinite number of them, (c)
their inability to accommodate chiral multiplets and (d) their
renormalisation problems, no better than gravity by itself.
Because of these diseases, people have turned to other
unification ideas, the latest venture being strings.

However, suppose that the additional coordinates are
anticommuting; then the Fourier expansions terminate very
quickly and there are just a finite number of massive modes—
which is a world of difference from having to tackle an infinite
number of them! Furthermore the question of having to
'compactify' the additional dimensions simply does not arise.
The first task is to show that one can mimic the Klein-Kaluza
construction; this we have accomplished recently. The
extended space-time coordinates are none other than $X^M = (x^a,$
$\xi^\alpha)$, having bosonic and fermionic parts. The supermetric
ansatz turns out to be

$$
\begin{pmatrix}
G_{\mu\nu} & G_{\mu\xi} \\
G_{\nu\xi} & G_{\xi\xi}
\end{pmatrix}
= 
\begin{pmatrix}
\delta_{\mu\nu} - e^{2\phi/\xi} \epsilon_{\mu\nu\alpha} A_{\alpha} & -e(A_{\mu}\xi) \\
-e(A_{\nu}\xi) & \eta_{\xi\xi}
\end{pmatrix},
$$

and the gauge potential $A$ is the off-diagonal Bose-
Fermi piece, multiplied into $\xi$. We can again
demonstrate that electromagnetic gauge invariance is
connected with rotations in $\xi$ space and that the
Hamiltonian works out correctly. We have succeeded in
extending our scheme to encompass colour and
electroweak forces by including further $\eta$ and $\xi$
Grassmann coordinates. Indeed we have managed to
erect a highly economical SU(5) grand unified model
in which all the field representations (matter, gauge, Higgs,...)
come out rather neatly (as powers of $\xi$) in
terms of just 5 complex $\xi$ coordinates and the action
drops out properly.

To conclude, I ought to answer the title of this article.
Yes, it seems to me as though nature does have hidden
anticommuting coordinates. These extra degrees of
freedom help one to visualise spin and internal
symmetry and they allow for general relativistic
models which can unify all the forces of nature,
thereby avoiding some of the more unpleasant
features of conventional Kaluza-Klein constructions.

References

1. E.T. Whittaker and G.N. Watson, A Course
of Modern Analysis, Cambridge University Press,

2. P.A.M. Dirac, The Principles of Quantum

3. G. Parisi and N. Sourlas, Phys Rev Letters

4. G.V. Dunne and I.Halliday, Phys Letters 193B, 247,


6. P.P. Srivastava, Supersymmetry, Superfields and
Supergavity, Adam Hilger, Bristol, 1986.

R. Delbourgo, P.D. Jarvis and G. Thompson, Phys Letters


9. R. Delbourgo and R.B. Zhang, Phys Letters 202B, 296,
(1988).

10. R. Delbourgo, S. Twisk and R.B. Zhang, Mod Phys Lett,
to appear.
FASTS MEETS WITH THE 'SMITH' COMMITTEE

On Thursday, 12 January, FASTS met with the Committee to Review Higher Education Research Policy, chaired by Professor Bob Smith who also chairs the National Board for Employment, Education and Training. This committee was established late in 1988 and will report to the Minister, John Dawkins in April, 1989.

FASTS and many of the Member Societies had sent written submissions to the Committee. FASTS’ views were sympathetically received and part of the reason for this is the active support FASTS has from its Members. Many of the points made by FASTS in general form had been supported by specific examples provided by Member Societies, in, for example, the benefit provided by a number of smaller projects funded by the discretionary funds of institutions.

Points stressed by FASTS at the hour and a half meeting with the entire Committee membership included:-
- the need for a Committee of Ministers with research portfolio interests chaired by the Prime Minister, to formulate an overall framework for research and so end the policy vacuum;
- the need for improved post-graduate awards to attract people back into research. In addition, a mechanism should be put in place whereby students could off-set their Higher Education Contribution Scheme liability (graduate tax) through successful completion of post-graduate studies in minimum time;
- opposition to the transfer of discretionary institutional funds to central research funding agencies. These funds were needed for libraries, equipment and technical support which were assumed to exist by granting bodies when they provided funds for research;
- support for small-scale research undertaken with institutional discretionary funds;
- the gap in funding between ARC grants, typically of $25,000, and GIRD grants in the millions; medium-sized grants and funds for large equipment were missing from the spectrum;
- the need for an industry levy for research, retention of the 150% tax incentive for R&D and a ten-year framework for research in the private sector;
- greater emphasis on the training aspect of research.

THE ADELAIDE CONNECTION

Albert Pryce is a retired chemist in Adelaide and he has agreed to act as the SA liaison for FASTS. This could involve the establishment of local activity on for example, numbers of students going on to mathematics, science and technology in senior school and tertiary education. Perhaps there are other specific SA concerns that FASTS should look at. We would like to hear from people interested in FASTS’ activities in Adelaide.

OBSERVERS TO FASTS

A number of organisations are interested in FASTS’ activities as the success of FASTS greatly affects their members. If FASTS can generate greater support in industry and government for science and technology this will mean more jobs in these areas and the chance for improved working conditions.

Two organisations which have shown interest in FASTS to the extent of applying for Observer status are the CSIRO Officers’ Association and the Federation of Australian University Staff Associations (FAUSA).

Corporate and Associate Membership to FASTS is limited by FASTS’ Constitution to national professional scientific and technological societies. Observer status is open to most other organisations and allows them to provide input but not to vote. FASTS welcomes CSIRO OA and FAUSA as Official Observers at Board meetings.

Temperature up on high $T_s$.

Dear Editor,

I was interested to read the AIP submission on high-temperature superconductors and related materials in the Australian Physicist of October 1988. I am a little surprised that you suggest that "bounties" be paid to people to work in this field, implying that this area is more important than other research areas. Of course, this goes along with the general hysteria and hype that has surrounded this research since it was announced at the MRS meeting in Boston in 1986. This hysteria is no justification for giving superconductor research any elevated status. I could think of a number of areas where research could lead to material advances that would benefit Australia in a much shorter time scale than high $T_s$.

Further, the claims that people have made about the possible uses of high $T_s$ have been a little misleading. I can understand these claims when they see large research dollars being offered when the times have been tough. I am not suggesting that there should be no research into these materials as they are of immense interest from a physics perspective. From a commercial view point, I personally do not see much hope for large-scale usage in the next 15-20 years, if at all. In thin films there is a little more optimism and some applications will come quickly in this area.

With commercial applications, the over-riding justification of these materials has to be if replacing normal wires with superconductors will be economic. Power transmission is an oft-quoted example for the use of superconductors. There is approximately a 10% electrical loss in overhead transmission lines and I do not think that the cost of installing superconducting transmission lines, remembering that they will be underground and at liquid nitrogen temperatures, can be justified for this small saving of power. The other large-scale uses of high $T_s$ from maglev trains to energy storage, should also be examined. Liquefiers, insulation, etc. are not a major fraction of the overall project costs and liquid helium handling is not an insurmountable hurdle. Generally the problems are not in the superconducting technology but in the economics, and high $T_s$ have not altered this.

I think that it is time that some realism is introduced into this topic and high $T_s$ treated for what they are, a very interesting area of research but certainly not the holy grail of physics.

P.J. Picone
Optoelectronics Division
SRL, DSTO, Adelaide SA
RESEARCH FUNDING
BHJ McKellar

This article was specially prepared by the author following his address at the 26th AGM of the Victorian Branch 24/11/88.

The 'Science and Technology Indicators' produced by DITAC contain much interesting material regarding the levels of science funding in Australia. If you got past the first section which purports to show that Government funding for research is not too bad in comparison with similar countries—largely on the basis of the imputed research component of University salary costs—you find other statistics which suggest that all is not well with funding of research in higher education.

According to the Department of Science 'Pilot Study of Research Equipment in Australian Higher Education' (September 1986), which surveyed physics, physical chemistry and biochemistry departments, serious deficiencies in the research equipment in the departments surveyed were found—only 30% of the equipment in the departments was state of the art, 18% were technically inadequate and 15% were in poor condition. Three estimates were made of the expenditure necessary to rectify these deficiencies. (See Table 1).

The total bill for updating the equipment in the department concerned should not be obtained by adding these estimates, since that would certainly lead to double counting. The total cost is probably M$70 to M$100.

Attempting to extrapolate to the entire higher education sector, we first note that there is an inconsistency in the data in 'Measures of Science and Innovation', DITAC 1987. Table 2.11 says that in 1984 the HERD expenditure on equipment and consumables was K$11.4 per researcher, and table A2.8 gives 15396 researchers—i.e. M$175 as the total expenditure on consumables and equipment in HERD.

<table>
<thead>
<tr>
<th>Country</th>
<th>Tertiary Student-Staff Ratio</th>
<th>Secondary Student-Staff Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>F.D.R.</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>New Zealand</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>Greece</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>1.33</td>
<td></td>
</tr>
</tbody>
</table>

This suggests that the academic staff in the tertiary sector should be increased by a factor of 2.38 to bring it into line with the mean of the other countries. From 1975 to 1985 the student-staff ratio in the tertiary sector increased by 15%, that in the primary and secondary sectors decreased by 20%.

Merely to bring the student-staff ratio in higher education to parity with that in the secondary sector would require an annual expenditure of about M$250 - equal to the research component imputed to the academic salary bill. To go to the modest point of inverting the present ratio requires about M$300 annually, while the increase by 23.8% requires just over M$1000.

A consequence of the run down of funding for staff in universities in the last decade is that university staff are all growing old together—see figure 3.2 of 'Measures of Science and Innovation'.

This pattern of a bulge passing through the age distribution will repeat itself unless measures are taken now to begin hiring the staff to replace the large fraction of tertiary staff who will retire in the 1990s. If the higher education institutions (and CSIRO) enter the job market at the same time for research staff, inevitably a fraction of less-qualified people will be hired. This can be avoided if the problem is anticipated, staff are hired now, and reversion rules are relaxed to permit hire of senior staff to return the age distribution to the equilibrium distribution.

For both the reasons of increasing the student-staff ratio to a reasonable figure, and of smoothing the age distribution, an increase in the recurrent grant to accommodate an

Continued on page 68
OF INTEREST

Getting to grips with plasma

The H-1 heliac – Australia’s biggest plasma bottle

One cubic metre of plasma – nature’s most energetic state of matter, and nearly as tricky to bottle as ectoplasm – will soon reside within a huge stainless-steel vacuum tank at ANU. Physicists at the School have plans to begin experiments next year with this country’s biggest plasma-containment vessel.

Using an intricate arrangement of powerful magnetic fields, they will confine about 1000 litres of glowing plasma at temperatures of several million degrees. Under such conditions, every atom is completely stripped of its electrons and only a seething mixture of nuclei and electrons – a plasma – remains.

For earth-bound mortals, plasmas are exotic creations requiring special conditions for their production and confinement. But as explained by Dr Sydney Hamberger, head of the Plasma Research Laboratory, the bulk of the universe resides in the plasma state. Stars – including our sun – burn brightly as their hot gases, ionised into plasma, undergo nuclear fusion.

One day, humankind will learn to harness the bountiful energy-producing reactions of the stars, Dr Hamberger thinks, but it will be some decades before we do. His new apparatus, called the H-1 heliac, will not be capable of producing thermonuclear fusion – it would need to be at least 10 times larger and more powerful for that to happen – but it should be perfect for studying the still poorly understood physics of plasma confinement.

That will be its principal function. But, in furthering that understanding, it may just bring a little bit closer the day when safe, pollution-free nuclear power becomes available. For this reason, H-1 forms part of a worldwide program of research into this type of device co-ordinated by the International Energy Agency. Astrophysicists may also learn something of stellar furnaces.

How on earth do you hold a plasma together in one place when its temperature will vaporise any known material? The only answer: use a magnetic bottle. Most people are familiar with the tokamak, which uses a magnetic bottle in the shape of a doughnut. The Plasma Research Laboratory conducted research on tokamaks between 1965 and 1984, and much work continues to be put into these promising devices, particularly in Russia (where they originated), Europe, the USA and Japan.

But one of the problems of a tokamak is that it relies on a large direct current flowing through the plasma to help produce the right magnetic field (usually by making the plasma act as one turn of a transformer). This makes continuous operation extremely difficult, so that tokamaks normally work intermittently; however, the large plasma current remains as a dangerous source of instability.

A neat alternative is to produce a magnetic bottle of the correct toroidal shape entirely by coils placed outside the plasma: devices which do just this are called stellarators. Now the major

Opinion - continued from page 67

expenditure of MS500 on staff is advocated.

This makes it reasonable to argue for an increase in the recurrent grant for higher education of at least MS700, together with a one-off injection to cover equipment of about MS600. Such an increase may not be politically acceptable in the present economic climate, but there is a case that saving the money now will only lead to worse problems in the future.

problem is to choose a containment shape that best resists the tendency of the plasma to escape when its pressure rises (a high pressure will be necessary for sustained thermonuclear reaction).

Enter the heliac - a stellarator in which the doughnut is severely twisted in all directions at once. The plasma spirals several times around a circular axis before joining up with itself; this makes the plasma feel a stronger magnetic pressure near the surface of the enveloping field. The 'magnetic well' helps stop plasma particles from wriggling out of the bottle, and is one of the effects to be studied in H-1.

While the concept of a heliac is pretty complicated, the execution is probably worse! Dr Hamberger describes its assembly as like putting together a Chinese puzzle.

The diagram shows why. In H-1, the centres of 36 coils 80cm in diameter and weighing over 200kg must be accurately positioned in a helix around a central circular conductor 2m in diameter. Since the central conductor physically links the 36 others, somehow or other it must be constructed in place.

When operating at full power, 500,000 amper-turns are created in the main conductor, and 130,000 in each of the others. Over 13 tonnes of copper have been used, mostly material left over from the 1950s when Sir Mark Oliphant was planning his particle accelerator (to be powered by the huge homopolar generator).

Other parts of the puzzle include a helical control-winding wrapped around the central conductor and vertical field coils at top and bottom. By adjusting the currents in the various coils, the shape of the magnetic bottle can be changed.

The whole configuration is placed within a cylindrical vacuum tank nearly 4m in diameter and 3m high. It was built of stainless-steel plate at Metropolitan Engineering Pty Ltd in Sydney and transported to Canberra for final machining by School technicians.

... it may just bring a little closer the day when safe, pollution-free, nuclear power becomes available.

Vacuum in the tank is excellent, and pressures as low as \(10^{-11}\) atmosphere have already been attained. At switch-on, a small amount of high-purity hydrogen will be injected between the coils, and - all being well - plasma will form.

The coils will run for a few seconds every few minutes, using up to 10 MW from the mains. At full tilt they create a magnetic field of 1 tesla, which in turn exerts a force on each coil of 5 tonnes. Built entirely in the School, the water-cooled coils are supported by a structure so strong they will deflect less than a millimetre when current is applied.

The School was fortunate to have procured six surplus radio transmitters from OTC. Together, the transmitters can feed 200 kW at 4-26 MHz into the tank, causing plasma to form and light up.

Only one other large heliac has ever been constructed, a Japanese unit, not as big as H-1, built recently by Hitachi for Tokyo University. Euratom plans to build another heliac, about the same size as H-1, in Spain.

They all follow on from SHEILA, the School's trail-blazing heliac built in 1984 by Dr Hamberger and Dr Les Sharp. Although this table-top device holds only about 4 litres of plasma, experiments with it have been very successful and encouraged the School to build some 500 times more powerful.

Although the basic ideas for heliacs go back to the 1960s, enthusiasm for them was lacking because, apart from being hard to build, their asymmetric configuration made theoretical analysis a nightmare. Now supercomputers have come on the scene, and modelling them is not such a problem any more, though still a formidable task.

Dr Boyd Blackwell, Dr Robert Dewar and Dr Tou Tek-Yong, of the School, have spent a good deal of time on the University's Fujitsu VP100 making calculations of heliac field lines and of expected plasma behaviour.

When H-1 is finally turned on in 1989, a moment keenly anticipated by Dr Hamberger and his colleagues, a lot of planning and hard work will reach fruition. A new domain for research will open up.


**Survey indicates extent of brain drain**

A study of top mathematics students at the ANU suggests Australia has lost almost an entire generation of its most outstanding scientists overseas.

The survey, conducted by Dr John Hutchinson, a senior lecturer in mathematics in the Faculty of Science, traces the careers of 62 students who graduated with first-class honours in mathematics between 1970 and 1987.

It found that 45 of the group have completed, or were completing, a PhD degree and 35 are currently working in research and/or new technology development areas. Of the 35 working in research and development, eight are in 'pure' mathematics and the remainder are in other areas such as statistics, expert systems, computer hardware design, physics, neurobiology, numerical analysis, hydrology and linguistics.

Slightly more than half of the 35 have gone overseas, 40 per cent of them to positions in university or government-funded institutions, and 11 per cent into private industry. Of those remaining in Australia, none works in the private sector.

The survey shows that the brain drain is most serious among the most recent graduates. Seventy-one per cent of those who graduated in the five-year period to 1974 are still in Australia, compared with 40 per cent in the five years to 1977, and 31 per cent in the five years to 1981.

When only the figures relating to those in science/technology areas are considered, the situation appears to be much worse. For example, of those who graduated in the five-year period to 1981, only three out of 14 (21 per cent) in this group are currently in Australia.

Dr Hutchinson acknowledged that the sample was small, but said it was typical of other departments around Australia.
ACOLS '89

ACOLS '89, the first joint conference incorporating the Australian Spectroscopy Conference, Australian Laser Conference and Australian Optical Society Conference, is to be held at the University of Adelaide from 25-29 September, 1989. It follows the highly successful ACOLS '87 Conference held at Surfers Paradise, which incorporated the Australian Spectroscopy Conference and Australian Laser Conference. Areas to be covered by the conference include Atomic and Molecular Spectroscopy; Molecular Dynamics; Electron Spectroscopy; Non-linear and Ultrafast Spectroscopy; Laser-assisted Collisions; Laser devices; Non-linear and Quantum Optics; Laser Applications; Plasmas and Plasma Diagnostics; Medical Applications of Lasers; Optical Computing; Fibre Optics; Thermal Imaging and Carbon Coating; Thin Films, Holography and Interferometry; Astronomical Optics; Optical Devices; and Optical Design, Fabrication and Testing.

Further information regarding the conference can be obtained from the organising secretary, Dr Warren Lawrance, School of Physical Sciences, Flinders University, Bedford Park, S.A. 5042. Telephone (08) 275 2029, Fax (08) 277 5523.

MG5: The Fifth Marcel Grossman Meeting

8/8/88 - that was the pleasingly symmetrical date on which some 350 physicists, astronomers and mathematicians met in Perth for the opening of the Fifth Marcel Grossman Meeting. To compound the symmetry, this major international conference began in the University of Western Australia's Octagon Theatre.

According to the original program, the speakers at the opening session were to include Murray Gell-Mann, Nobel Prize winner and a founder of the 'eighthfold way' theory describing elementary particles in terms of quarks - but the symmetry was slightly broken, since Professor Gell-Mann preferred to speak at the second plenary session, on the following day.

The Marcel Grossman Meetings are the brainchildren of cosmologist and black-hole expert Professor Remo Ruffini of the University of Rome. They are held at three-year intervals, the first four having been at Rome (twice), Trieste and Shanghai. These events are devoted to developments in general relativity, ranging from underlying mathematical methods to experimental tests of theories of gravitation, including other branches of physics that have a bearing on general relativity and cosmology. The University of Western Australia's Department of Physics was selected to host MG5 because of its prominent position in research into the detection of gravitational radiation and in closely related work on precise time measurement - the development of a sapphire clock, potentially accurate to one second in 30 million years, which may be used to provide reference time signals for very-long-baseline radio astronomy.

Who (you might ask) was Marcel Grossmann? - hardly one of the household names of science. Marcel Grossmann was a mathematician who played a key role in the birth of general relativity. He was born in Budapest in 1878, the year before Albert Einstein, and they were classmates at the Zurich Polytechnic, where they became friends. Einstein benefited from Grossmann's lecture notes and became a regular guest of the Grossmann family. Grossmann's senior wrote a letter of recommendation to the Director of the Swiss Patent Office in Bern, leading to Einstein's appointment as a patent examiner.

In 1912, Einstein called on Grossmann for help in the mathematical formulation of general relativity; Grossmann was an expert on the tensor calculus, which happened to be precisely the branch of mathematics that was required for general relativity. In 1913 they published a paper with an unusual structure; it is divided into Part I, by Einstein, on the physical basis of general relativity, and Part II, by Grossmann, on the mathematical aspects of the theory. This division into the mathematical and physical is reflected in the structure of the scientific program at the Marcel Grossman Meetings.

The Fifth Marcel Grossman Meeting was officially opened by the Governor-General of Australia, Sir Ninian Stephen, in the Art Gallery of Western Australia. A highlight of this event was the performance of a piece of music, commissioned for the occasion, which involved live signals from a pulsar, PSE 1749-28, beamed from the Molonglo radio telescope in NSW.

At the opening plenary session, participants were welcomed by Senator John Button, the Federal Minister for Industry, Technology and Commerce. This ceremony included the presentation to the University of Western Australia of a Marcel Grossmann Meetings Award, for its contributions to relativistic astrophysics. These efforts began with observations at Wallall, on the northern coast of the State, of deflection of starlight by the Sun during the 1913 solar eclipse, and continue today with the work on gravitational radiation detection and precise time measurement.

The University's annual series of public lectures, the Octagon Lectures, were held this year in association with MG5, and were an unprecedented success. They opened with Michael Dopita of Mount Stromlo Observatory speaking on 'Supernovae and the Elements of Life', continued with John Wheeler of the University of Texas on 'Gravity: What is its Role in the Scheme of Existence?', John Schwarz of Caltech on 'Superstrings: A Theory of Everything' and David Malin of the Anglo-Australian Observatory giving 'A Guided Tour of the Visible Universe', and ended with Paul Davies on 'The Cosmic Blueprint'. The 650-seat Octagon Theatre was unable to cope with the public demand - several of the lectures were given twice and an extra lecture, by Remo Ruffini on 'The Intermediate Large Scale Structure of the Universe', was added.

The Meeting ran for 6 days, with 1 day devoted to a trip by steam train to the historic country town of York, to give participants the opportunity for extended informal discussions in a characteristically Australian setting. Prominent topics at MG5 included progress towards detecting gravitational radiation, the 'fifth force' (a possible modification to gravity acting over distances of tens to hundreds of metres), Supernova 1987A, and millisecond and binary pulsars. In short, MG5 continued the series's tradition of an intriguing mixture of abstract mathematics, exotic astrophysics, cosmological speculation and high-technology experimentation.

Ron Burman
UWA

Reprinted from Southern Astronomy

Australian Physicist Volume 26, Number 3, March 1989
Non-linearity - a meeting of physics and metaphysics

If the world were linear, as physicists pretend (most of the time), then it would be a very 'straight' place - predictable and boring - for us all. Thankfully, there are always more things in heaven and earth than are dreamt of in anyone's philosophy.

Recently, an increasing number of scientists have begun to tackle the nonlinearity inherent in the world. Some members of the Research School of Physical Sciences are among them.

'Nonlinearity seems to give rise to a fierce struggle between order and chaos, being and nothingness,' says Dr Bruce Henry, of the School's Department of Theoretical Physics, 'but dealing with bifurcations, chaos, fractals, ergodic seas and the like inclines us to think we are getting closer to what makes the world tick.'

We all know linear: any situation where the size of the effect increases in direct proportion to the size of the cause is called linear. Anything else is nonlinear.

Unfortunately for physicists, the world is inescapably nonlinear. And nonlinear equations are, for the most part, mathematically intractable (which is why, until recently, the subject has been swept under the carpet).

Enter the electronic computer, and last we had a way of analysing a nonlinear system. Dr Robert Dewar, of the Department of Theoretical Physics and the Plasma Research Laboratory, gives that explanation of why nonlinear dynamics - and its offspring, chaos, bifurcations, strange attractors, and so on - have become popular over the last decade. He recalls that it was only in 1977 that the first international conference of physicists interested in nonlinear dynamics and chaos took place at Lake Como, Italy.

As it happened, Dr Dewar was there. 'You could say I've been a "groupie" of the field ever since,' he confides. 'Plasma physicists were among the first scientists to go wholeheartedly into the new field of chaos research.'

Why? Because to study plasma you need to confine it far from a state of thermodynamic equilibrium. This means that the usual damping forces that keep less energetic systems stable and orderly are either negligible or often working the wrong way - and so the plasma, caught in a collective feedback loop - goes unstable.

Dr Roderick Boswell, of the Plasma Research Laboratory, has watched the onset of chaos in an experiment involving a beam of plasma. Like every other inquiry, it soon put him face-to-face with fundamental questions about the universe, life, and everything.

No, the answer isn't '42': it seems more to do with $X_{n+1} = F(X_n)$, where the function on the right is a nonlinear one - for example, $rX_n(1-X_n)$. This surprisingly simple iteration seems to capture the essential features of Dr Boswell's experiments - the system feeding back on itself and nonlinearity.

Many surprising features of the world, with much of its richness, can be modelled by such simple 'difference equations' or 'maps'.

For instance, we sometimes notice that events in the real world suddenly depart from regular behaviour and act wildly - the stock market moves from a steady trend to erratic fits and starts; an asteroid decides to veer off towards the earth; an anticyclone takes a mind of its own and stays put as a 'blocking high' rather than continuing to move with an easterly trend.

Just so, when we feed nonlinear equations into our computer, it may first come up with regular cycles, then jump between two or four 'orbits', and finally engage in wildly erratic behaviour. The transition from order (in Greek, 'kosmos') to disorder (kaos) follows a typical pattern, which physicists can follow closely. An example would be a liquid's transition from laminar flow to turbulent flow as the flow rate increases. The amazing thing about all stages of the pattern is that it is deterministic. That is, even during wildly erratic movement - corresponding to turbulence - the new position follows exactly from its previous one according to the equation.

What would Newton have made of all this chaos?

(Illustration by Dr Bruce Henry)

The catch is that calculating the final position requires a degree of precision that even the University's supercomputer lacks, because an accepted definition of a chaotic system is one in which minutely different initial conditions lead, eventually, to profoundly different outcomes.

Dr Dewar explains that we can take a little comfort in 'the shadowing theorem', which tells us that the plotted trajectory may be followed by some particle, but there's no way to accurately predict the final position of any given particle.

Of course, the big question then is: does the universe have adequate precision to determine the particle's next position? Is the universe deterministic, or is there randomness that prevents determinism?

We can calculate that the quantum mechanical uncertainty in the position of one electron at the known limit of the universe can - gravitationally -
lead to a 90-degree error in the direction of a gas molecule on Earth after 50 collisions with other molecules. Now considering that inherent uncertainty: is it but a limitation to our human knowing, or could God know something about that electron's position that is not available to us to find out?

Albert Einstein put it well when he said that God does not play dice. According to him, the universe was deterministic. Quantum mechanics was an incomplete theory, and something else was needed to fill in the 'hidden variables', the source of apparent randomness.

Dr Boswell admits that he is an Einsteinian. The world is perfectly deterministic, following Newtonian cause and effect, he thinks. He finds it satisfying to conceive of the world as strictly lawful - no room for randomness here - yet, at the same time, there is room for free will.

'You see, no one, but no one, can know what the future will hold,' he said. The whole system is so sensitive, so chaotic, that we can't predict what will happen next. The only way to find out what will happen is to let it happen. And that applies to God too - the universe is God's computer!

'Why does this giant computer of a universe exist? The reason, of course, is that there is no way to know the answer to some question any faster than what's going on. The Cosmic Deity can't just think about it for a minute and realise what's going to happen. There's no short cut. He's got to make the universe to get the right answer. It's like the mice in The Hitch-Hiker's Guide to the Galaxy using the Earth as their computer - except in our case it's the universe and everybody in it that's the calculation!

Dr Henry has garnered powerful evidence to suggest that the world doesn't just appear uncertain to us, but that it fundamentally is, in and of itself, jittery. Not even God can pinpoint one electron.

The evidence staves us in the face in the laws of thermodynamics. Consider that hot things cool to the temperature of their surroundings; never does a hot region separate out of a sea of cold. Why should this be, when energetically this is not disallowed? Thermodynamics answers that all complicated systems are irreversible. In this way their disorder, or entropy, constantly increases.

But why is it irreversible? On the level of the individual molecules, they obey Newtonian laws of motion, which are theoretically reversible. If we were to reverse time we should still observe the same behaviour.

Of course, without access to a time machine, the experiment is hard to do. But Dr Henry has done it on a computer. He has taken 17 particles - hardly the $10^{23}$ particles in a lung full of air, but never mind - and studied their approach to equilibrium, their thermodynamics, when they interact nonlinearly.

He and his colleague, Dr John Grindlay, ran time forwards for up to 1000 computer 'seconds', then backwards.

When time ran forward, the 17 particles behaved in a non-remarkable way and moved towards thermodynamic equilibrium via an intermediate equilibrium state. But when time was reversed, a curious behaviour showed up. At first, the particles retraced their past paths perfectly, moving from the intermediate equilibrium towards an ordered state, a behaviour seen by us only when a film is run backwards.

But after further reversed time, the recovered order began to turn to disorder, and the system headed towards thermodynamic equilibrium again. The cause of this, of course, is the limited precision of the computer calculation - 16 or 32 decimal places in this instance - which allowed the non-linear modes of the system to couple. The 'round-off error' permitted chaos to win out over order.

And so it might well be in the real world, Dr Henry reasons, that the world's built-in uncertainty, its fuzziness, is the germ of its irreversibility and the laws of thermodynamics. If the world were built like clockwork, running it backwards would be no problem!

Alas, perfect precision is only of the mind of a Plato, not of the world; and so the moving finger, having writ, moves on.

Dr Reinout Quispel, from the Department of Theoretical Physics, is a colleague who also analyses chaos in reversible dynamical systems. He has found that, depending on the initial conditions, such a system may either conserve energy or dissipate it.

Applications of the theory turn up in lasers, gas flames, and in the intriguing reaction-diffusion chemical processes called Belousov-Zhabotinski reactions.

What has all this to do with plasmas? Well, Dr Boswell was forced into studying chaos by experiments with electron beams and magnetic fields in his WOMBAT vacuum chamber. At low beam currents, the beam behaved normally, but as the current was raised, troublesome instabilities arose - non-reproducible behaviour that Dr Boswell couldn't explain. First, the beam would oscillate at its normal frequency, then at half the frequency, and then become 'noisy'.

Dr Boswell thought his apparatus was jinxed by a gremlin. Only when he plotted out his data did he see that it followed a pattern reflecting nonlinear dynamics. He immersed himself in the literature of chaos and was surprised to discover that three-fold cycles, although suggested by theory, had never been observed experimentally before. Moreover, a simple predator/prey model could exactly describe his results. Nevertheless, despite the model, the fascination remains. Dr Boswell, even with diligent searching, was unable to discover the nature of the 'prey' (the

Like sand on the seashore, this computer plot shows chaos in a reversible dynamical system.
phenomenon that was providing the feedback). He’s still on the lookout for
gremlins.

Dr Dewar finds plasma physics a rich
source of chaos and other nonlinear
phenomena. He likens the task of con-
fining a plasma to that of confining a
roomful of rowdy schoolboys. You can
get one to behave properly by putting
him in detention, but put them all in
one room and each tends to disrupt the
orderly behaviour of the others. In the
same way, a magnetic bottle may keep
a single charged particle in; put a real
live plasma in the bottle and collective
instabilities tend to result.

Studying those instabilities is the
challenging undertaking that Dr Dewar
has set for himself. He wants to math-
ematically model the way in which
current instabilities in a plasma feed
back to alter the shape of the magnetic
bottle

(and create
more instabili-
ites).

Although he’s
made some at-
tempts to describe
plasma turbulence with
mathematical approxima-
tions, the equations con-
cerned are intractable. The
only satisfactory way of
modelling what goes on is with a
supercomputer.

He and his graduate student – now
Dr Ritchie Parker in Switzerland –
used it to construct a ‘bifurcation dia-
gram’ for a major nonlinear plasma
instability called the tearing mode, found
in the Earth’s magnetosphere.

In the usual tokamak configuration,
the bottle is usually doughnut-shaped
(a torus). But interest in the School
has now focused on heliacs, in which
the doughnut is twisted into a helix.
With symmetry broken this way, more
opportunities for instability arise, and
chaotic behaviour is rife.

Dr Boyd Blackwell, of the Plasma
Physics Laboratory, is involved in su-
percomputer modelling of heliac pla-
mas. He gets the computer to select a
magnetic field line and follow it round
and round to see what pattern evolves.
Invariably, chaotic patterns are the or-
der of the day. The diagram on Page 7
shows the result of one such modelling
effort.

He has analysed the behaviour of the
magnetic field lines that loop like
bunched spaghetti in the interior of a
heliac. Some field lines loop back
on themselves after a small number of
turns – these are called periodic orbits.
Others – quasi-periodic – never return
to where they started and fill the plas-
ma volume.

It turns out that periodic orbits de-
stroy themselves completely by res-
sonance. Those quasi-periodic ones that
are sufficiently irrational persist. The
result are areas of stability inter-
mingled with ‘islands’ of insta-
bility devoid of field lines.

Dr Bob Bitmead, of the
Department of Systems
Engineering, has also
studied chaos as it aris-
es with complex feed-
back controls. As
explained in the
August 1987
issue of
Advance,
Dr Bitmead
has dis-
covered that
when chaotic behaviour develops in an
adaptive control system, perhaps from
slight inaccuracies in the feedback sig-
naal, useful control of the system is,
surprisingly, still possible.

Is the universe God’s
computer?

Dr Bitmead and his collaborator, Dr
Iven Marceis, have found that the
chaotic dynamics of the feedback signal
still quench the overall system very
well.

If you would like to know more
about non-linearity, a good popular ac-
count is given in: Chaos - Making a
New Science by James Gleick (Viking

NEW ORIEL CATALOGUE

Oriel Corporation (Connecticut, USA) has released a new catalogue for Lasers and Accessories.

This catalogue features diode laser systems as well as small HeNe lasers, beam aligners, mini-mounts and high power laser beam expanders.

It also includes the INTRASPEC diode array detection system which is available in 512 and 1024 element configurations with or without TE cooling.

Other new products are a low cost lock-in amplifier, chopper and specialised integrating spheres for laser work.

For a copy of this catalogue, contact Lastek Pty Limited, tel (08) 231 2155, fax (08) 231 2169.

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LECRY ANNOUNCES 25TH ANNIVERSARY CATALOGUE

LeCroy Corporation, the world leader in nuclear research instrumentation, has published a 340 page illustrated Nuclear Products Catalogue describing their extensive line of electronic research instruments. The new catalogue celebrates the 25th anniversary of LeCroy.

The Nuclear Products Catalogue contains a complete summary of LeCroy’s Research Systems Division’s product line including technical data sheets and specifications, application notes, examples of use and ordering information. The introductory tutorial, complete with glossary, provides the scientist and engineer with a base for understanding and using modern research instrumentation.

Product areas covered include several high-speed data acquisition systems, high performance components, fast pattern recognition/trigger electronics, and several high voltage systems.

The 1989 LeCroy Nuclear Products Catalogue is available from ETP-Oxford, tel (02) 858 5122.

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NEW STABLE LASE

ORIEL CORPORATION of Stratford, Connecticut announces their new Laser Intensity Stabilizer, Stable Lase™. This smart new product stabilizes and attenuates CW lasers from 400 to 800 nm up to 10 W of power. Stable Lase™ transmits up to 75% throughout its operable range.

ORIEL’s Stabilizer stabilizes and attenuates laser intensity at a predetermined level. Beam fluctuations are reduced by a factor of 400:1 at DC. You can remotely set the intensity level to automate repetitive measurements. Unlike laser power control of intensity, there is no change in the laser mode pattern. The power range of this unit is 0.1 mW to 10W, and it has a 2 mm clear aperture.

Stable Lase™ can be used with HeNe, Diode, HeCd, Argon Ion, Dye and Nd-Yag CW lasers. It enhances and opens new areas of use for these lasers.

For information on ORIEL’s Stable Lase™ contact Lastek’s Ralph Hahnheuser on (08) 231 2155.

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HANDHELD CLIP-ON POWER METER

Warsash Pty Ltd of Sydney (sole Australian distributors for HEME International Ltd of England) announce the release of a very powerful new multifunctional diagnostic tool for electrical and electronic design, manufacturing and maintenance engineers responsible for both ac and dc power measurements.

The HEME 1000P power meter is the most advanced instrument designed to measure almost all the parameters associated with power plants, and electrically operated installations, without the need to break the current circuits, to interrupt operations or processing.

The true rms measurements provide for current (dc and ac), voltage, and hence power readings which are accurate almost regardless of the waveform shape, to a crest factor of 7.

Through the use of Hall effect sensors in the magnetic field of a conductor, together with a pair of sturdy probes, both dc and ac power can be measured and displayed on a large 3½ digit LCD.

Current values can be displayed on an oscilloscope, chart recorder or other measuring instrument. Either true rms or instantaneous value (waveform) can be selected for the analogue output.

Autotuning for all measuring ranges, automatic display of sine wave or polarity to indicate ac or dc, low battery indication, 2 range for surge current reading (display or maximum measured value) and an auto switch-off all help to make the HEME 1000P a user-friendly, versatile, measuring tool.

Only by making use of the very latest CMOS microprocessor technology and the background in Hall Effect devices which HEME have acquired has made it possible to pack so many measuring functions (current, voltage, power factor, active power, apparent power and frequency and automatic self calibration) into such a compact, hand-held device.

To cap it all the HEME 1000P provides for an analogue output for both true rms or instantaneous value (waveform) to be switch-selected.

Further details are available from Warsash Pty Ltd, tel (02) 30 6815, fax (02) 365 0650.
FROM THE MAESTRO: AN EVEN BETTER PERFORMANCE

MAESTRO™ II is the 'Second Generation' of Multichannel Analyser Emulation software from EG&G ORTEC. It is the software component in the ORTEC ADCAM® architecture of multichannel analysers in which the functions of data acquisition/storage and display/analysis are shared between task-specific hardware and a personal computer, all under the direction of the MCA Emulation Software.

The MAESTRO II software furnishes all the features of a high-performance multichannel analyser: live, high-resolution, colour display with scrolling cursor and user-selectable colours; logarithmic and linear display modes; control of data acquisition with multiple preset types; and semi-quantitative analysis of spectral data, including fast Peak Search, Nuclide Identification and Region-of-Interest Analysis. The ability to define automatic sequences of 'job streams' is a standard feature.

MAESTRO II is compatible with the EG&G ORTEC ACE MCA plug-in cards for the IBM PC, the NIM module-based ADCAM 100 hardware, and also with the new SPECTRUM MASTER™ family of computer controlled acquisition for nuclear spectroscopy.

MAESTRO II performs with IBM PCs, PS/2s and compatibles. Colour brochures for MAESTRO II and other companion hardware products are available on request. Call Peter Douglas at Laserex International, your local EG&G ORTEC representative for more information on (02) 439 6188.

NEW DISTRIBUTORSHIP

Elmeasco Instruments Pty. Ltd. is happy to announce that they are the Australian distributor for the optical disk drive application interface OPTIDRIVER manufactured by Optisyx Inc. in the U.S.A. Optidriver is an applications interface for attaching optical disk drives to an IBM PC/XT/AT or compatible computer system. It allows the user to attach and use on optical disk drives as another magnetic peripheral storage device. Optidriver is structured for low memory usage, using approximately 50KB of system memory for the

E.G. & G. Ortec
Spectrum Master

master program. With the Optisyx directory management scheme, a buffered version may be used. The buffering can be directed to either DOS memory or magnetic memory. Optidriver uses approximately 40 Bytes per directory-entry buffered.

Optidriver is an exceptional program, being much more versatile than a typical device driver. With this approach, Optidriver does not have to adhere to any DOS limitations such as number of files, or a 32Mb file/partition limitation.

Optidriver supports disk drives manufactured by Opticem ATG, LMSI, Mitsubishi, Optotech, Ricoh, Isi, Maxtor, Panasonic and Sony with drives for Fujitsu, Hitachi, Kodak and Toshiba currently being certified.

Optidriver is available in both MDOS and Novell versions. It interfaces to the host computer using a SCSI adaptor.

For further information, please phone Elmeasco Instruments Pty Limited, Trevor Crunkhorn, Opticem Product Manager, on (02) 736 2888.

A NEW MCA FAMILY, SPECTRUM MASTER

EG&G ORTEC announced the personal-computer-based, SPECTRUM MASTER family of data-acquisition products for nuclear spectroscopy. The SPECTRUM MASTER family represents the second generation of products from EG&G ORTEC based on the now-familiar ADCAM architecture, in which the functions of a traditional MCA are divided between hardware and software in the PC environment.

The 92X SPECTRUM MASTER is a high-performance, computer-controlled integrated gamma spectroscopy system for use with germanium detectors. The functions of amplifier, bias supply, digital spectrum stabilizer, sample changer control, ADC, and memory are provided in a single, neat package.

The accompanying high-resolution, Multichannel Analyzer Emulation Software, MAESTRO II, which is an integral part of the entire product family, provides live spectral display, control of hardware and such advanced features as Nuclide Identification/Peak Search, and 'Job Streams' as standard features. The software is easy to use, and is MENU DRIVEN.

The 919 SPECTRUM MASTER is a high-performance NIM Module providing the functions of digital stabilizer, ADC, and MEMORY. The integral four-input, high-speed multiplexer and 64K-channel data memory is optimal for both ultra-high count-rate or multiple-detector applications.

The MCA-on-a-card family member, called the SPECTRUM ACE, consists of an ADC, data memory, and microprocessor. Available is 2K, 4K and 8K memory versions, the cards fit inside any IBM-compatible PC.

For further information contact Laserex on (02) 439 6188.
CYGNET JUKEBOX
Elmeasco Instruments Pty, Ltd, is happy to announce the availability of the Cygnet range of high performance optical disk jukeboxes and subsystems to enhance their optimum range of 12" format WORM drives. There are two series in the range. The cygnet 1800 series expandable jukebox is a robotic component of 161 GByte utilising either single-sided or double-sided 12" optical disks through associated optical disk drives. Some features are:
- modular, configurable design
- field upgradable
- extensive diagnostics
- fast performance
- interfaces RS-232C @ 9600 baud

The Cygnet 5000 series jukeboxes utilise a unique design that allows it to exchange disks faster than any other 5.25" optical jukebox on the market today. The jukebox supports one to two drives in addition to one or two auxiliary drives that can be manually loaded or unloaded. The system accommodates 28 to 32 optical disk cartridges and provides up to 31 Gigabytes of storage. The system is available with either a SCSI or RS-232C interface to the host computer.

Both the 1800 and 5000 series jukeboxes are compatible and both series will support almost all major manufacturers of optical drives available on the market today.

For further information on the Cygnet range of Optical Disk Jukeboxes and Subsystems please contact Elmeasco Instruments office on:
(02) 736 2888 (Sydney)
(03) 879 2322 (Melbourne)
(07) 875 1444 (Brisbane)
(08) 344 9000 (Adelaide)
(09) 470 1855 (Perth)

PIEZOELECTRIC MICROMETER ADAPTER
Many laboratory and production facilities align optical components with small, inexpensive micrometer driven stage assemblies. These set-ups are easy to use; however their resolution and repetitability are limited by their micrometer drives to about 5 microns. Applications requiring increased precision often force the user toward more expensive systems containing unnecessarily complex control electronics.

Burleigh is pleased to announce the availability of a new piezoelectric device designed specifically for use on micrometer-driven translation stages. The PZA-30 is a low-voltage piezoelectric element which can easily be mounted to either Line Tool, Newport or Klinger stages. These adapters mount between the micrometer and stage, and permit both coarse (micrometer) and fine (piezoelectric) motion.

The PZA-30 moves the stage 30 microns with the application of 150 volts. Burleigh’s PZ-300 Low Current Driver can independently or simultaneously control up to three devices with a resolution of better than 0.005 microns.

Applications include: single and multime fibre optic positioning, integrated optics, laser beam steering, and laser diode alignment.

For further information, contact Paul Wardil at Laserex International tel (08) 271 7966, fax (08) 272 8581.

AUTOMATED SPECTRO-RADIOMETER SYSTEMS
Optronic Laboratories has released the Autospec series of automated spectral measurement systems. The systems are of a modular design and consist of a research-grade single or double monochromator plus a variety of input/output options to configure the system to a particular measurement task.

Standard measurement capabilities include source spectral-analysis, detector spectral-response, diffuse reflectance/transmittance and specular reflectance/transmittance. Wavelength coverage is from 0.28 to 20 microns. The entire measurement sequence is performed under computer control with software packages available for the standard measurements described above.

For further information, please contact Paul Wardill at Laserex International, tel (08) 271 7966, fax (08) 272 8581.

JIMS SOFTWARE FOR CYGNET OPTICAL DISK JUKEBOXES
JIMS (Jukebox Interface Management System) will integrate Cygnet’s Optical Disk Jukeboxes into any application environment quickly and reliably without having to worry about the complexities of managing cartridges, robotics or even multiple jukeboxes.

With JIMS software as part of your optical disk based system, you can add new applications more drives or even additional jukeboxes with a minimum of effort. The interface to JIMS is available as a set of library routines that are simply linked to your application. This programmable interface makes the task of integrating jukeboxes into your optical disk system so simple that it can be completed in days or weeks and not years. JIM’s built-in error management and recovery facilities ensure maximum system integrity and trouble-free operation. JIMS has been developed to operate on a SUN Series 3 environment and has been designed for easy portability to UNIX System V, XENIX System V, BSD 4.2 or 4.3 and VMS. JIM’s can be ported to a PC host operating under UNIX.

For further information, please contact Elmeasco Instruments Pty Limited, Trevor Crunkhorn, Optimum Product Manager on (02) 736 2888.

4-CHANNEL RS-232 MODULE
KINETIC SYSTEMS has released a Four-Channel Communication CAMAC Module with RS-232 ports.

This new module interfaces the CAMAC Dataway to as many as four separate RS-232 serial ports. The Model 3344 FOUR-CHANNEL COMMUNICATION INTERFACE is designed to link your CAMAC system to such remote RS-232 devices as a CRT terminal, a modem communication link, smart instruments, and character-oriented serial equipment. It can also provide the data link between two CAMAC systems. Sixteen data rates on the 3344, from 30 to 19,200 baud, are programmable from the Dataway on a per channel basis, as are the number of data bits (from five to eight), the number of stop bits (one or two), parity error checking, and control character recognition capabilities.

Two 1024-character buffers are provided for each channel, one for input and one for output. These buffers provide elastic communications between the Dataway and remote devices. As a diagnostic aid, input can be echoed back to the output as well as sent to the computer. The echo feature is a programmable option.

For further information, please contact Fred Blake at ETP-Oxford on (02) 858 5122.
Prompt Critical

"A Little Might Not Hurt You"

I believe it is possible to eat uranium in the form of yellow cake without coming to much harm. But I would not be game to try without some pretty solid reassurance from a reputable toxicologist - including John Lenihan. Oddly enough, in a delightful book dealing with the toxicity of humans to naturally occurring elements, John Lenihan fails to mention uranium.

John Lenihan, I should explain, is a physicist who was at one time Professor of Clinical Physics at the University of Glasgow and is now Senior Research Fellow in its Department of Nursing Studies. This somewhat eclectic career has given him an extraordinary insight into a fascinating field: the role of trace elements in human nutrition and their toxic effects when over-supplied.

Little did the author, actors or audience of the hilarious "Arsenic and Old Lace" stageplay and movie realise that their supposedly deadly element is actually essential in the human diet - a fact discovered only as recently as 1975. John Lenihan explains that ingestion of some arsenical compounds, notably the tasteless trioxide, is deadly if the quantities are great enough, but the same is true of many other beneficial elements such as selenium and molybdenum.

At the conclusion of a book brimming with amusing anecdotes and historical dirty deeds, all highly pertinent to his trace element theme, John Lenihan briefly describes the origin of what astronomers collectively describe as metals. Metals are of low abundance in the cosmos, which leads Lenihan to observe that "Abodes of life - particularly of intelligent introspective life - are curious anomalies. We ourselves are no more than traces - the mere crumbs of creation".

Don't get the idea that Lenihan's "The Crumbs of Creation" is merely a mishmash of the stories an academic accumulates during a lifetime at the lectern. It is far more. Its pages contain carefully chosen tables of data that would be difficult to dig out of the literature easily. A pity some of it is not more widely known, such as the typical trace element concentrations in the human body, blood and hair. Hair, in fact, plays an important role in the excretion of excess trace elements.

The contribution of physical techniques, such as neutron activation analysis, to the solution of crime and the unravelling of historical mysteries, is beautifully handled. Whether the application is forensic or epidemiological, trace element analysis is a powerful tool in competent hands, as John Lenihan demonstrates so convincingly.

Highly recommended, "The Crumbs of Creation" was published in 1988 under the Adam Hilger imprint by Institute of Physics Publishing Ltd. Containing xi + 157 pages in hardcover, it costs £12.50 pounds sterling and is a must for any good library. Trouble is, the jolly cataloguers will want to bury it in 612 - Medicine - and make it hard to find.

Colin Keay
Book Review Editor

BOOK NOTICES

Atomic Physics of Lasers
Student Edition
Derek Eastham
Taylor & Francis Ltd., London 1989
ix + 230 pp, UK £16.00

This is a softcover reprint of the hardcover version which was published in 1986. A review of it by B.J. Dalton of the University of Queensland appeared in the March 1988 issue of The Australian Physicist. Although soft, the cover is durable and by keeping the cost down increases its suitability as a student text. The diagrams and typography are beautifully clear.

Reviews

Electrostatics: Principles and Applications
Jean Cross
Adam Hilger, Bristol 1987
xii + 500 pp, Stg. 50.00 (hardcover)

Electrostatics is a subject which seems to attract relatively few textbook authors. Thus this book is a very worthwhile addition to the literature on electrostatics, and achieves its aim of complementing the earlier outstanding work edited by A.D. Moore, Electrostatics and its Applications (Wiley InterScience 1973). The number of references provided is larger than is usual, and there is copious use of excellent diagrams. It is generally well written and interesting.

I will be recommending it to my students as a reference, as a link between theory and application via experiment, and particularly as a means of accessing the literature on the subject. I will be adding a word of caution, however. There has in some cases been a loss of rigour and generality, in the process of explaining the physical principles in simplified...
BOOK REVIEWS

models of the Nucleon
R.K. Bhaduri
Addison Wesley, 1988 xvii + 360 pp,
US$38.95 (hardcover)

The author has attempted a massive task here, namely to present a textbook summary "for the nuclear physicist" of the various models of nucleon structure and their experimental basis. In order to present any unifying theme there is also a brief introduction to gauge field theories, the Weihberg Salam model and Quantum Chromodynamics. All of this is done without recourse to quantum field theory.

Needless to say the task the author has
set himself is a difficult one and the quality of the treatment varies
enormously. The discussion of deep-inelastic scattering is rather weak and is effectively disconnected from the rest of the book. On the other hand the non-relativistic quark model and the MIT bag model are well treated. There is a diversion into the difference between Dirac and Majorana neutrinos which seems a little out of place. In the thorough discussion of chiral symmetry the $\sigma$-model, which is a beautiful text book model, is endowed with rather too much physical significance for my taste, and the conclusions of Witten that the nucleon might be a soliton built from weakly interacting meson fields are uncritically repeated.

To be fair to the author there are many models and concepts which are clearly explained in this volume. It would be of considerable interest as a reference book for graduate students working on other areas of physics.

Nils Bohr's Philosophy of Physics
Dugald Murdoch
Cambridge University Press,
Cambridge, 1987
x + 294 pp, $117 (hardcover)

This book offers a thorough, scholarly philosophical examination of Bohr's philosophy of physics, but one which is also competent in quantum physics itself.

The first five chapters trace in some detail the development of Bohr's views on wave-particle duality and complementarity from the early years of this century until the establishment of his mature views in the early 1930's. Murdoch considers that kinematical complementarity is the most important feature of Bohr's position. Bohr's main argument for it rests on two premises, one of which is that the interaction between the object and the instrument of measurement is indeterminable. Of this argument Murdoch says that Bohr's grounds for holding these two premises are strong and without convincing counter-examples "Bohr's argument, based on these two premises, not only provides a plausible justification of the uncertainty principle, but also explains exactly and in detail how the uncertainty, and hence kinematical-complementarity arises... "

One may concur - but with this caveat: The wholeness of the quantum of action to which Bohr appealed and the resulting indeterminacy of intermediate states during quantised transitions precisely cannot explain the specific probabilistic structure which quantum mechanics assigns. Quantum mechanics has this remarkable non-classical property: From a specific value for any one (maximal) observable, the probabilities for all other values of all other (maximal) observables follows. Bohr's arguments for complementarity cannot help us to understand this, and certainly not in the amazingly precise and rich structural detail which quantum mechanics provides. But to pursue such issues might take us down Einstein's line toward generalised theories to replace quantum mechanics instead of towards Bohr's notion of quantum mechanics as a 'rational generalisation' of classical physics.

The second half of the book is devoted to an exploration of Bohr's specific doctrines of measurement, physical properties and to the wholeness or (perhaps) non-locality of quantum physics as it emerged from the debate between Einstein and Bohr. Murdoch views Bohr's philosophy as a weakly realist, weakly instrumentalist and (perhaps) weakly Kantian one, and weakly pragmatist. Some such eclecticism seems right, the various preceding major works on Bohr (see Murdoch's preface) all agree, emphasising one or two, now the other, aspect. The values of physical properties are objective enough but only under the conditions for which the presuppositions of their conceptual well-definedness are physically realised. Bohr is seen to have to relinquish the view that physical properties inhere intrinsically in quantum systems as the price of avoiding the conclusion of the Einstein-Podolsky-Rosen argument.

Murdoch concludes by considering selected competing approaches to the interpretation of quantum mechanics which, unlike Einstein's approach, agree in accepting quantum mechanics as it is, in particular the many-worlds and quantum logic approaches. He concludes that Bohr's position is preferable to these (when they do not themselves reduce to it).

The book is clearly written and well annotated. (Though this reviewer hates the practice of confining all references to notes, so that no convenient alphabetised bibliography is available.) It may well be wholly error-free. For
BOOK REVIEWS

those interested in current debates in the interpretation of quantum mechanics will have limited value since it confines itself to these only insofar as they may throw light on the nature of Bohr's approach. But for those interested in understanding Bohr's approach this will prove a thoroughly worthwhile volume.

C.A. Hooker
Philosophy Department
University of Newcastle

The Magnetic and Electron Structures of transition Metals and Alloys
V.G. Veselago and
L.I. Vinokurova (Eds)
Nova Science Publishers,
New York, 1988
viii + 216 pp, US $70 (hard cover)

This book is Volume 3 in a series by the Institute of General Physics of the USSR Academy of Sciences and takes the form of seven extended research articles on magnetic and electronic structures of transition metal (TM) alloys. Over half the book is devoted to the composition dependence of the complex magnetic structures, magnetic phase transitions and kinetic properties of compounds such as PtFe and RhFe. Various experimental techniques are employed including high-field magnetisation, susceptibility, neutron diffraction, magnetoresistance, resistivity and Hall effect. The end results are composition-temperature magnetic phase diagrams of these systems. The effects of pressure on the complex magnetic structures are also studied. One very interesting feature of this work is the discussion of 'chaotic' magnetic states consisting of 'cluster-glasses' embedded in an antiferromagnetic matrix.

The remainder of this book is concerned with electronic properties in TM-based systems, dealing with (i) a de Hass-van Alphen study of the sensitivity of the Fermi surfaces in Fe,Co,Ni and Cr to pressure (a very useful description of the methodology involved is included), (ii) a theoretical study of spin density wave effects on band magnetism resulting in a theory of antiferromagnetism in alloys of rare-earths with transition metals which lies somewhere between the localised Heisenberg approach and the delocalised Stoner approach and (iii) a brief but interesting remnant

magnetisation relaxation study of (Zn,Cd)Cr$_2$Se$_4$, an 'arbitrary-bond' spin glass.

This book is well written, with each chapter presenting a good introduction to the problem; about 270 references are cited! The exhaustive experimental work is of good quality and is well indexed. The book is both interesting and useful — but only to band-magnetism aficionados!

J.M. Cadogan
CSIRO Division of Applied Physics
Lindfield

While the papers are uniformly good, as would be expected from the able group of senior scientists who taught in the School, I cannot recommend purchase of the book by libraries or by individuals. Students would be far better served by recourse to the original literature.

T. Sabine
Physics Department
University of Technology, Sydney

On Functions and Functional Equations
J. Smital
Adam Hilger, Bristol and Philadelphia
viii + 155 pp
UK £12.50 (hard cover)

The pace of developments in the natural sciences has isolated much modern mathematics from physicists. The time and effort required to maintain an informed understanding of what has been achieved and what is being attempted in any field not closely related to one's own specialisations is daunting, and most of us have been daunted. Therefore it was refreshing to read this little book, less than 160 pages long, that takes the reader from the familiar ideas of undergraduate mathematics to the newest ideas in its subject without losing either the integrity of the subject or the reader's comprehension.

Functional equations in one or more variables and iterative maps of an interval are the subjects of this book. These subjects have developed rapidly in the last fifteen years mainly from the needs of applications in physics and biology. Smital's style is clear and spare. Proper definitions are given and theorems are fully enunciated. When the proof is a theorem is acceptable it is given, otherwise references are given. The definitions and theorems maintain the integrity of the subject but the examples make it come alive. Examples are used to introduce new topics and to motivate new ideas and theorems. They have been well chosen. Smital clearly delights in his subject and any reader, equipped with pen, paper and calculator, can share in this delight. I heartily recommend this book.

J.V. Corbett
School of Mathematics
Physics Computing and Electronics
Macquarie University
CONFERENCES AND MEETINGS

1989


April 13-14  Molecular Films: an interdisciplinary conference, Sydney. Dr Bernard Pailthorpe (02) 692 3863.


June 19-21  Inaugural Asia Pacific Composites Congress, Adelaide. Mike Ridout, Techsearch (08) 267 5466.

June 26-29  14th Australian Radiation Protection Society Annual Conference, Perth. Mike Rafferty, Conf. Sec (09) 389 2262.

July 3-7  International Conference on Martensitic Transformations, ICOMAT 89, Sydney. Prof. N. Kennon, University of Wollongong (042) 270 457.

July 5-7  Conference and Workshop on Antarctic Weather and Climate, Adelaide. Dr N.A. Stretton, Bureau of Meteorology, GPO Box 1289K, Melbourne 3000.

July 10-14  International Conference on Ion Sources, Berkeley, California. Dr Ian Brown, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720, USA.


Sept 23-27  Conference & Workshop on the Teaching of Optics at the Tertiary Level — Asia Pacific Education Network (ASPEN). Prof. G.J. Opat, School of Physics, University of Melbourne, Parkville, Victoria 3052, Australia (03) 344 5721.


Oct 16-20  Solar-Terrestrial Predictions Workshop, Sydney. Dr Richard Thompson, IFS (02) 269 8613.


Quality Management and Data Analysis in the Laboratory. For dates in your city contact: Ivan Waples, NATA (02) 411 4000.

For information about Institute of Physics future meetings, contact: The Meeting Officer, IOP, 47 Belgrave Square, London SW1X 8QX.

1990

Jan 6-19  21st International Cosmic Ray Conference, Adelaide. Secretariat, Department of Physics and Mathematical Physics, University of Adelaide, 3001.

Feb 6-9  5th International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans, New Delhi, India. Dr S. Singal, CI-NPL, New Delhi, 110012.
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Stanford Research Systems, Inc.

For further information on the complete Stanford Research Systems product range contact NORMAN JONES or PAUL WARDILL at our Adelaide office. Telephone (08) 271 7966 P.O. Box 177 Unley 5061 South Australia Facsimile (08) 272 8581
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