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This month's front cover picture was taken near the UNSW-ANU Automated Astrophysical Site Testing Observatory at the South Pole. It shows a variety of optical effects caused by the refraction and reflection of sunlight from the numerous tiny ice crystals in the air. The circumzenithal arc, the parhelic circle, Parry's arc, halos and other phenomena seen here are explained in the article by Boccas & Storey on page 186 of this issue.
To 1998 With Optimism

In writing the final President’s column for 1997 I look back on the past year’s work and also forward to next year. It has not been a good year for Physics, or for Science in general, in this country. University Physics departments have suffered massive funding cuts, staff losses and restructuring and some of this seems certain to continue. The survey results, reported in this issue, show the magnitude of the problem. Despite this there is determination within departments to survive and prosper. Student numbers in physics may have declined in some departments but the overall picture is, in my view, fairly sound. There are signs from overseas of a return to the basic sciences, and we may hope for the same here. Nevertheless departments need to be both aggressive and imaginative in presenting their wares. Your Executive and Science Policy Committees continue to pursue a number of initiatives promoting the profession. The forthcoming Council meeting, to be held in Melbourne on 12-13 February next year, will have an agenda item devoted to new initiatives. If you have any suggestions please discuss these with your Branch Chair or contact me directly. The West Review, which many of us hoped would give a lead, appears to be largely a fizzle. Political publicly predict that the whole project will be shelved. There is no evidence that the Government has any vision for Science and Technology, as argued in the Stocker review and by FASTS.

The last few months have been as hectic as always. In early October I attended the annual Heads of Departments Meeting, held at the Australian National University. There is a report on this successful meeting in this issue. Thanks to John O’Connor for doing a great job with the organisation. The next HOD’s meeting will be held in Perth, in association with the ‘98 Congress. I attended the FASTS annual Council meeting in Canberra on 20 November. Professor Peter Cullen was elected to serve as the President of FASTS for the next two year period. He is Director of the CRC in Freshwater Ecology at the University of Canberra, and will, I am sure, be an effective advocate for Science and Technology. I will continue as a Board Member of FASTS in 1998, representing a group of six societies in the physical sciences area. The Council heard addresses from Martyn Evans, Shadow Minister for Science, from Senator Natasha Stott Despoja, and from Paul Wellings from DIS, representing the Minister John Moore. John Stocker, Chief Scientist, also gave an address and participated in vigorous discussions. Several sessions were devoted to revision of the FASTS Policy Document, being coordinated by Dr Ken Baldwin, one of our active members, and this discussion continued at the Board Meeting the following day. In my view FASTS has been very effective in lobbying for and promoting science and will continue to provide the AIP and the other member societies excellent value for their investment.

The morning of 27 November saw me in Canberra, together with Erich Weigold and Steve Thurgate, meeting with Mark Latham, Shadow Minister for Education. We were able to express our concerns at the effects that funding decisions are having on Physics departments in our Universities, and the risk this entails to an essential part of the scientific underpinning of a high-technology future for the nation. In the afternoon I chaired a meeting of the AIP Executive in Melbourne.

In my last column I reported the change to the Editorship and production of The Physicist for 1998. It is appropriate to thank and applaud Jack Kelly for the outstanding job he has done as Editor since October 1992. His five years of service to the AIP in this demanding role will be remembered not only for the witty and pertinent editorials but for the continuing high quality of the journal. At the same time I want to thank Judith Nikoleski and the rest of the production team at Impress Studios in Newcastle. This association goes back to the first issue of 1989 - almost a decade of high quality production. Most readers will be unaware of the difficulties and frustrations this job must often entail, in trying to meet schedules with often late material and last minute changes. Thank you Jack and Judith!

In closing I would wish members of the Institute and their families all the best for the Christmas Holidays. I hope the New Year will be bright and rewarding, both for you personally and for Physics in Australia.
Time is a Great Teacher, but unfortunately it Kills all its Pupils

Towards the end of the year in many papers and magazines illustrations of dodging old father time carrying an hour glass and leaning on his scythe were once common. He was often gazing fondly at a grinning baby, representing the new year, who was about to take over. Perhaps the decline in popularity of this December image is associated with the current pressure to look modern at all costs and the diminishing number of readers who know what a scythe is. An old woman wearing a digital watch and leaning on a two stroke Whipper Snipper doesn’t have the same appeal does it.

The appeal of this benign symbolic picture of age yielding gracefully to youth remains, even if it is out of fashion and often at odds with reality. In the real world, power and influence is frequently in the hands of the old who are reluctant to give it up, having worked so hard to get it. They tend to hang on past their use by date. The young are impatient with the outdated behaviour of those they must displace to gain their place in the sun. Scornful of the mistakes they see being made they are keen to begin making new and original mistakes of their own. The age division is a classic divide and has been made wider by media advertising which makes fortunes out of selling trendy rubbish to insecure adolescents and cutting them off from advice outside their peer group.

It is the great advantage of the graduate student system that it combines the strengths of different age groups rather than pitting them against each other in fruitless disputes. Ideally the energy and enthusiasm of the student combines with the supervisors knowledge of where to apply them most effectively. In science the system has worked so well for such a long time that it will survive the widely reported cases of when it breaks down and trendy fluctuations in how universities are run.

Divide and conquer has always been a successful ploy and when we see subgroups being set against each other we should always question if this time honoured strategy is being intentionally brought into play. Competing for ever more limited resources, as the universities and the ABC for example are at present being forced to do, is a standard way of fermenting disputes. It keeps the peasants squabbling amongst themselves rather than combining to change the system.

But to return to December. Is a good time for editors. It enables them to rehash all sorts of old rubbish and get a second run out of material at little cost. Of course they never admit to this. It is said to be the traditional time to review past achievements and to look forward, optimistically, to the new year that is to come. We can’t take advantage of this practice in The Physicist as, of course, we never publish rubbish and there is no cost saving in rehashing, as our contributors are not paid.

As well as being the end of the year, this is the end of my term as editor. When I, somewhat reluctantly, took over as editor I did not think I would be doing it for this length of time. The Physicist, to borrow Spike Milligan’s analogy, is like an empty vase which our authors fill with flowers, and occasional weeds. All an editor can do is to try and arrange the flowers to best effect and, if lucky, encourage new flowers to bloom. There is nothing more boring than those Academy Awards speeches in which the breathless winner thanks everyone they can think of, so I won’t attempt to list all those who have made The Physicist what it is, they are predominantly the authors, on which our journal depends. It would however be churlish not to especially thank Judith Nikoleski of Impress Studios, our publisher for many years, of which this is the last. She has always been a source of good advice to editors and has frequently performed beyond the call of duty when problems occurred. To those who have helped with The Physicist over the last few years my sincere and profound gratitude. To those who have not, my forgiveness, on condition that you deluge our new editor Chris Hamer with all those articles on cutting edge physics of today, which you have been withholding.

Time to put down my quill, pick up the scythe and depart.

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LETTER

Jobs for Physicists in Industry 1996-97

A strange and disquieting observation is emerging from my employment survey carried out for the AIP (ANZP July/August 1997 issue). Since June 1996, although the advertisements for positions suitable for physicists has continued at about the same rate as last year, the employment opportunities for physicists in Industry and Commerce has practically dried up. This is clearly shown both in the absolute and relative numbers of positions advertised in the Australian.

In the nine months to the end of March, ie the first three quarters of the current financial year, the total number of such positions advertised has been twelve. In the same three quarters for the five previous years, the average number of positions was 41.6 ± 5.9. By any statistical test, the 1995-96 figure does not belong to the same population.

It is even worse than it looks on the surface: three of these were for sales- and-service positions, five for managerial-type posts, albeit with a physics flavour and, of the remainder, all but two could well be filled by an engineer.

Put in its stark reality: for nine months Australian industry and commerce has offered only five posts in which a physicist would be directly involved with research and development activities concerned with the creation of new wealth. This is bad enough as it affects us individual physicists: on the broad scale it is a damning indictment of the attitude of Australian Industry and investors.

One hesitates to say that this is due to the Government's decision to change the tax break on R & D from 150% to 125% but a better explanation does not come immediately to mind. Is it too much of a coincidence that the drop in advertising corresponded to the Government's Budget announcement?

In my 1996 job survey (ANZP 33, 42-46) I discussed the impact of Cooperative Research Centres on physics recruitment. These were set up to encourage the participation of industry, government and university groups in applications-oriented scientific and engineering research and education. They are expected to contribute to national objectives, particularly the development of internationally competitive primary, secondary and other industry sectors.

A major aim is to provide the leverage that will see an increase in research and development undertaken by the private sector. Most of the money comes from the Federal Government but the goal is that the average level of participation by business enterprise will reach 25% of the total resources when they are fully established.

An average of 26 CRC posts suitable for physicists has been advertised since 1992 in the corresponding three quarters and 18 have been advertised in the period under discussion. This avenue at least is still open.
ICE CRYSTALS IN THE SKY

MAX BOCCAS & JOHN STOREY

The remarkable wide-angle photograph on the front cover shows the Automated Astrophysical Site Testing Observatory, AASTO (to the right), and the two aircraft pallets of liquid propane (left) that provide heat and power to the AASTO for a full 12 months at the South Pole. The dramatic optical effects in the sky are all the result of tiny ice crystals. Such displays are rare (and even more rarely noticed) in most parts of Australia, but examples have been reported from New Zealand in a recent issue of this journal [1]. They are common in colder climates when an abundance of tiny ice crystals ("diamond dust") fills the air. At the South Pole, where the air is the clearest on earth, the visual displays can be exquisite and awe-inspiring.

1 Key to the various components of the atmospheric display on the front cover.

In this picture can be seen a sun pillar, the 22 degree halo, the 46 degree halo, two parhelia ("sun dogs"), a segment of the parhelic circle, the upper tangent arc, Parry's arc and the circumzenithal arc. Figure 1. What follows is a very brief description of how these effects are created by reflection and refraction of sunlight by ice crystals. For a more comprehensive treatment of ice halos, including some convincing ray-tracing simulations, see Tape [2]. Ice halos, together with a whole range of other atmospheric optical effects, are discussed in detail by Greenler [3], and by Lynch and Livingston [4]. All three books are well illustrated, and describe in simple terms the physics behind these extraordinarily beautiful natural phenomena.

Ice is a hexagonal crystal, and in clouds usually takes the form of flat "plates" or longer "columns". As the ice crystals fall, aerodynamic forces cause them to orient themselves such that the plates fall "flat" (with their one short axis vertical) while the columns fall with their one long axis horizontal (and would therefore be perhaps better called "rows"?), Figure 2.
Ice is a hexagonal crystal, and in clouds tends to form either "plates" or "columns".

Light reflected from the top and bottom surfaces of plates that are falling almost horizontally produces the parhelic circle.

Light can either be reflected from an external face of an ice crystal, or can enter the crystal by one face and exit through another. The refraction that takes place in passing through the prism gives rise to many of the wonderful effects seen. When light enters through one prism face and leaves by the next but one face, it is effectively passing through a 60 degree prism. The angle through which it is bent, or angle of deviation, depends on its angle of incidence. The minimum deviation to its original path occurs when the light enters and leaves the crystal symmetrically and for ice, with a refractive index of around 1.32, this "angle of minimum deviation" is around 22 degrees. For both greater and smaller angles of incidence, the angle of deviation is always greater than 22 degrees.

The 22 Degree Halo

Because the minimum angle of deviation through the 60 degree prism is 22 degrees, refraction mechanisms can only scatter light toward an observer by bending it through at least this angle (Figure 3). The result is a halo, of half angle 22 degrees, centered on the sun. Inside the halo there is little scattered light, and the sky appears darker than it is outside the halo. Because the crystals have random azimuthal orientations, there will be a concentration of the refracted light at 22 degrees, tapering off with increasing angle from the sun. In order to create a full halo at least some of the crystals need to be tilted to a slight extent. Because the refractive index of ice is slightly less in the red than in the blue, so too is the angle of minimum deviation and thus the inner edge of the halo is tinged red.

The 46 Degree Halo

This is created in a similar way to the 22 degree halo, but this time involves light entering a prism face and leaving by the end (of a column) or top or bottom surface (of a plate). The light thus encounters a 90 degree prism, for which the "angle of minimum deviation" is 46 degrees.

Parhelia ("Sun Dogs")

Most of the plates are falling flat. There is thus a strong enhancement of the 22 degree halo to either side of the sun at the same elevation as the sun. These sundogs can be extremely bright and colourful. 

[Image of ice crystal and diagrams]
Parry's arc is caused by refraction of light through "Parry aligned" columns; those columns that fall with their long axis horizontal and a pair of prism faces looking straight up and straight down.

Light refracted through the 90 degree prism of a plate or column creates the circumzenithal arc.

The Parhelic Circle

Because plates are predominantly falling "flat", their prism surfaces will be vertical, though with random azimuthal orientation. The observer thus sees an enhanced scattering in a thin line parallel to the horizon at the same elevation as the sun, due to the simple external reflection of sunlight from these faces (Figure 4). The parhelic circle is colourless.

Parry's Arc

Many of the columns not only fall with their long axis horizontal, but with opposing prism faces exactly horizontal (Figure 5). As implausible as this may sound, the evidence is found in the existence of "Parry's arcs". Although several such arcs are known, the most common is the upper suncave Parry arc. Together with the upper tangent arc it forms a football shaped object above the 22 degree halo.

The Upper Tangent Arc (or Circumscribed Halo)

This effect is due to the columns, which mainly fall with their long axes horizontal. Light again enters a prism face and leaves by another face angled at 60 degrees to the first, and hence undergoes a minimum deviation of 22 degrees. The brightest scattering is thus tangent to the 22 degree halo at the top. To either side of the sun's azimuth the upper tangent arc curves first upward, then downward.

The Circumzenithal Arc (CZA)

The CZA, or Bravais' arc, is formed by light entering the top face of a plate, and leaving through one of the prism faces (Figure 6). The light ray experiences refraction by a 90 degree prism, with the resulting dispersion creating a spectacular rainbow effect. The CZA is brightest when the sun is 22 degrees above the horizon - close to its elevation at the South Pole in January when this photo was shot.

Chemistry Prize for Physics Professor

Professor John Pilbrow, who is Vice President of the AIP and also Head of the Physics Department at Monash University, is to receive the 1998 Royal Society of Chemistry ESR Group Bruker Prize and will give the Bruker Lecture at the Royal Society of Chemistry ESR Group Conference in Manchester next April. The award is for contributions in the field of electron paramagnetic resonance (EPR or ESR) with particular reference to applications of importance in inorganic and bio-inorganic chemistry. Professor Pilbrow is one of four physicists to have won the Bruker Prize since it was instituted in 1985. Both the Prize and the Lectureship are financed by Bruker Analytic, Karlsruhe, Germany.

References

SCIENCE PRODUCTIVITY AND THE INTERNET

DAVID MADISON

The Internet has changed the way many people work and do business. In the scientific professions, Internet access is close to 100% and has been for some time. Anecdotal evidence has sometimes suggested that there is concern that Internet usage can be counterproductive. Some reasons given for this have been a perceived lack of 'quality' information, excessive use by some individuals (which is not always for work-related purposes) and information overload by excessive email and other communication. To determine what Internet users in the condensed matter feel about these issues, it was decided to conduct a survey to examine these and other factors. It is expected that the findings would also be applicable to other disciplines as well.

Methodology

At Wagga '96 a survey was presented to assess both Internet usage patterns and whether condensed matter scientists feel that there are productivity gains to be made using the Internet. A brief summary of some of the findings, as reported at Wagga '97 at Pakata Island, New Zealand [1], is provided below. The questionnaire was designed to assess several aspects of Internet usage including the types of Internet services commonly used, email usage patterns, inappropriate use, productivity changes, video conferencing and newsgroup usage.

Results

Internet Services Used

Activity on the Internet fell into several main categories. The most popular activities were email, FTP (file transfer), Telnet and World Wide Web and Newsgroup usage.

The most common frequency of use for email was in the range 6-20 times per week reported by 65.3% of respondents (n=49), followed by 21-40 sessions per week reported by 20.5%. File transfer (FTP) was used most commonly <1 times per week by 49.0% of respondents (n=49) followed by 1-5 times per week by 26.5% of respondents. Telnet was used 36.7% of respondents 1-5 times per week and 6-20 times per week by 24.5% of respondents (n=49). The World Wide Web (WWW) was most commonly perused 1-5 times per week by 36.7% of respondents (n=49) followed by 6-20 times per week by 32.7% of respondents. Newsgroups were most commonly not used by 40.8% of respondents (n=49) followed by 24.5% who used them 1-5 times per week and by 20.4% who used them <1 time per week (although 59.2% use newsgroups).

The Internet was used extensively to follow research interests with such use being reported by 91.8% of respondents (n=49). Another significant use was to follow private interests with this being reported by 63.3% of respondents.

Email Usage Patterns

Daily email traffic averaged 3.7 items sent and 6.2 items received (n=49). Email was the preferred form of communication for routine correspondence by 89.8% (n=49), formal correspondence, 22.5%, personal correspondence, 63.3% and 'other' 8.2%. No respondents reported not using email. Most respondents, 93.6% (n=47), considered that email saved their organisations time and money and 54.2% (n=48) thought that email contributes to unnecessary communication within their organisation.

Inappropriate Use

Of managers who responded, 40.9% (n=22) have been concerned that their employees or students spent too much time on the Internet pursuing non-work interests. Action has been taken by 16.7% of respondents (n=18) to correct this problem.

Productivity Changes

Many examples were cited of the Internet being used to improve research productivity, common among which were

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correspondence with colleagues and collaborators, getting information of all kinds, searching databases, data transfer, obtaining software, arranging visits (or being able to avoid them), finding other workers with similar interests and avoiding work replication. Considerable time savings were reported. The Internet was considered to have helped collaboration with 95.2% of respondents (n=42). Overall productivity was thought to be greater with 85.4% of respondents (n=48), the same in 14.6% of cases and not less in any case. Managers thought productivity of staff and students was greater with 82.6% of respondents (n=23) and the same in 17.4% of cases. Information is now exchanged with others by 68.9% (n=45) which would not have been feasible to exchange before the Internet. The majority of information on the Internet was thought to be useful by 57.5% of respondents (n=47) whilst 18.6% (n=43) would prefer to be exposed to less information. “Information overload” was thought to be a potential problem by 57.1% of respondents (n=42).

Video Conferencing

Whilst video conferencing isn’t widely available at the moment, it is expected to become more widely available in the near future. Desktop video conferencing for the purpose of conference participation was considered acceptable in principle to 74.2% of respondents (n=43) and 65.1% (n=43) would be prepared to participate in a 30 person conference by this method and 16.7% would be prepared to participate in a 1000 person conference (n=42). Video conferencing was considered acceptable for person-to-person conferencing by 88.1% (n=42).

Newsgroups

Newsgroups were considered a source of primary news by 47.8% of respondents (n=46). The frivolity in otherwise-serious newsgroups was of concern to 51.2% of respondents (n=43). The usefulness of the Internet was considered to have been reduced by 30.4% (n=46) now that virtually anyone can connect to it. The concept of an academics-only sub-net was acceptable to 42.2% of respondents (n=43).

Discussion

Of all Internet activity, email is the most common and all respondents used it. Nearly 94% of respondents considered that email saved time and money whilst over 54% thought that it contributes to unnecessary communication. Whilst the claims of excessive communication by email are not surprising, a lot of “junk email” is relatively easy to ignore, but it would be beneficial for organisations to adopt policies to minimise such email.

World Wide Web usage and Newsgroup usage are also very frequently used. Newsgroups were a source of primary news by about 48% of respondents. Overall, the Internet is very important in keeping up to date with research interests with nearly 92% of respondents using it for that purpose. It is clear from this finding that the Internet is no longer a curiosity, but a very important scientific information service similar to a library.

The proposition that the Internet contributes to wasting time in some cases is born out by the fact that over 41% of managers have been concerned that their employees or students spent too much time on the Internet pursuing non-work interests and action was taken by nearly 17% to correct this problem. However, there is no suggestion that this is a common problem and in relation to the issue of productivity, discussed in the next paragraph, no respondents thought the Internet reduced productivity.

There was little doubt among respondents that productivity was improved by the Internet. A majority (over 85%) of respondents thought that the Internet improved their overall productivity and the remainder thought it was the same. A similar proportion of managers thought similar productivity gains applied to their subordinates.

Types of information exchange which were not feasible before the Internet are now conducted by nearly 69% of respondents. This suggests new types of work patterns may be emerging because of the Internet, opening up whole new possibilities for collaboration. Nearly 58% of respondents think that most information on the Internet is useful but just under 19% would prefer less information exposure. “Information overload” was thought to be a potential problem by around 57% of respondents.

Desktop video conferencing will become more common as Internet bandwidth improves and the cost of cameras reduces. This has further potential to improve productivity and may offer opportunities to lower costs or improve communications. Video conferencing was considered acceptable for communication to around 74% of respondents and about 65% would be prepared to participate in a small conference by this method and about 17% would be prepared to participate in a 1000 person conference. Video conferencing was considered acceptable for person-to-person conferencing by about 88%.

Conclusions

It is clear from the above findings that the Internet is an essential tool for conducting scientific programs and its appropriate use should be encouraged. Virtually all aspects of Internet usage when used appropriately can result in productivity improvements. As reported, around 85% of respondents thought their own productivity and that of their subordinates was improved, but no respondent thought it decreased overall productivity. The Internet offers new possibilities for working and communicating and should continue to help the scientific effort.

Reference

1 Twenty First ANZIPI Condensed Matter Physics Meeting, Pakataa Island, New Zealand, 4-7th February, 1997, Conference Handbook ISSN-1037-1214
INTERACTIONS

Physics HOD Meeting 2-3 October 1997

This meeting brought together 31 Heads of Physics Departments (or their representatives) from around Australia. This high level of participation demonstrates the enthusiasm for collective discussion and cooperative activities. Physics is facing serious challenges and it is by sharing experience and knowledge that we can support each other. I would like to thank all who participated for their time, support and commitment.

The purpose of this meeting was to establish the true state of affairs in Physics departments around Australia, establish strategies to face these challenges and identify a task force for each strategy to ensure that progress is made. The majority of the work was accomplished in a workshop mode with the key strategies evolving from the presentation and discussion phase.

The program included workshops on Finance and Resources, Linkages with other communities, Physics Teaching and Service Teaching and Employment in Physics. As well there was a presentation by David Booth on the present state and future directions of the AIP accreditation processes and one on Mario Zadnik on trends and developments in teaching methods.

It is not possible to present in a document of this form the full detail of discussions, presentations and debates. I can never hope to capture the spirit of over 30 pages of butchers paper from the workshop sessions and the many pages of notes I made. I will focus on the strategies formulated and how they will be brought to a result. In this I now seek your support to implement them.

A key feature of the discussions was that the solution had to come from within our own community of physicists. No one else is going to solve our problems for us and so most strategies have a champion or facilitator assigned to them. This person will facilitate the actions required to get a result. They are not expected to do all the work, but to coordinate the actions of volunteers, you, to see it through.

This is the key element to the process, because without following through with the implementation of the strategies, a meeting of this form, involving considerable expense in travel and time, is wasted. I strongly urge you to find a strategy that strikes a chord with you and sign up to contribute to its success.

There is a reporting time-line for these activities, with the first early in the new year, and the major one for the Heads of Departments meeting in Perth next year in conjunction with the AIP congress.

Some of the strategies acknowledge that we alone do not have the clout to make a big impact on government or the community so we will seek to work with other like-minded organisations to lobby government for change.

**Strategies**

Promote the importance of education in Science and Technology.

In particular focus on the need for scientific literacy in a time when literacy has government and media focus.

**Champions** John Pittrow and Jaan Oitmaa to seek support from the RACI and Jaan Oitmaa to approach the Institution of Engineers.

Develop a national campaign for In-Service training of science teachers.

This is to support scientific literacy and to offer teachers an opportunity to inject.

**Champions** Bill Zealley and Dick Collins.

Use the issue of global warming to focus attention on the need to increase funding to Science and Technology.

Other major issues were identified as candidates and any further suggestions would be most welcome.

**Champions** Dick Collins (Academy of Technological Sciences), Erich Weigel (Academy of Science), Jaan Oitmaa (FASTS).

Seek to establish a levy on manufactured output to generate research funding for industrial research.

Levies are already used in primary industries to generate considerable funds which are then applied to research projects which benefit the whole industry.

**Champion** Jaan Oitmaa (FASTS).

National Physics Promotion Campaign. Bring together all the individual activities we are involved with on a local basis and give it a national strength. The initial elements of this are part of the AIP Science Policy Committee submission (Switch on to Physics) to the Federal Government's Science and Technology Awareness Program but there is a potential to broaden the concept.

**Champions** None! Volunteers sought!

Make the role of physics in industry and employment more visible on the internet. Place a collection of individuals' "Stories" on careers in industries. Establish a dossier on the routine analysis involving physics to show the role physicists play in industry. Generate a database of companies which might employ physics graduates and monitor graduate destinations.

**Champions** Ken Doolan, Geoff Smith, Mario Zadnik, HOD's.

Encourage students to respond to the national Graduate Destinations survey. Great emphasis is placed on the statistics which come from this survey, so it is in our best interests to encourage graduates to complete these forms and return them.

**Champions** HOD's.

Establish an employment prospects package for schools and undergraduates. Rather than each department seeking out statistics on employment rates, job prospects, etc. establish a web site which can be accessed by a broader range of individuals and can be downloaded when an individual is preparing a presentation on careers in Physics.

This will improve industry perceptions of what physics can do for them.

**Champions** None! Volunteers sought!

Promote the use of the PHYSICS-EMPLOYMENT mailing list to disseminate quickly and efficiently positions available.

Encourage industry and government to use this form of distribution. Ensure that all university physics positions are placed on this mailing list.

**Champions** HOD's, all AIP members.

Collate information on exchange or cooperative teaching arrangements between physics departments in different institutions. The aim of this proposal is to promote resource sharing between departments in different institutions. This is in place in some regions but there is the potential to expand this form of activity to achieve the current educational objectives but reduce the teaching load. This will become more important as labour intensive computer-based teaching becomes more prevalent.

**Champion** Dick Collins.

Collate details of special subjects, in the nature of science awareness subjects, offered to other faculties with a view to sharing experience and expertise. There are many courses offered by physics departments on computing, cosmology and astronomy which are presented to non-scientists to promote an appreciation for this art. By sharing the details of these topics it
may be possible to offer them at a greater range of institutions in a non-competitive manner. Only those departments who contribute details of their subjects of this nature will receive in return the full details of all offerings submitted. Where departments do not currently offer such subjects, but still want to participate, they can submit details of subjects that they are currently contemplating.

Champion Dick Collins

These are the key areas in which the heads of departments felt significant progress can be made to the benefit of the community as a whole. You are no doubt reading this and saying “but why didn’t they consider...?”. We probably did as there are many other issues which arose that I have not covered. On some of them we could not come to a consensus as the best strategy differed from institution to institution. The difference between institutions is very significant and there is a great case for someone undertaking a more global comparison than has been performed before. Address such issues as what share of the DEETYA income gets to the coal face and where the rest is spent. This and more fundamental educational issues were discussed.

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Workshop on Bose-Einstein Condensation
January 19 - 20, 1997
Conference Centre
University of Auckland
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THE DIDJERIDU

NEVILLE FLETCHER

The didjeridu of the Australian aboriginal people is an ancient and deceptively simple instrument, consisting of a length cut from a narrow tree trunk or branch and hollowed by the successive action of fire and termites. Skilled players, however, are able to produce a wide repertoire of interesting musical effects including a rhythmic drone, striking timbre changes, and sounds that are voiced as well as played. This paper outlines the passive acoustics of the didjeridu tube, the active acoustics of the sound-production process, and the mechanisms by which the various musical effects are produced.

To play the didjeridu, the musician seals the narrow end of the tube around his mouth, blows, and vibrates his lips under muscular tension in very much the same way as used in playing a brass instrument such as the tuba. The didjeridu uses air at rather a high rate so that, to play a sustained tone, the player adopts the technique of "circular breathing". After playing normally for a few seconds, he expands his cheeks with air, seals off his mouth from his throat with the back of the tongue and, while using the stored air to maintain the tone, takes a quick breath through his nose. This technique is common on certain other instruments, such as Indonesian flutes, and is now used routinely by oboists and even flute players to play without breath breaks for as long as several minutes. In these instruments, with their much smaller breath demand, the objective is to maintain an even tone and cover up any effect of the breathing. With the didjeridu, however, the player makes a virtue of necessity and emphasises the rhythmic breathing cycle to produce

The three types of simple pressure-controlled valve. Air flow direction is shown with an arrow.

(-, +)  (+, -)  (+, +)

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a pulsating drone. The pulsations are usually further decorated by tongue vibrations, so that the player effectively says unvoiced words such as "ritor" or even "didjeridu", with the final "u" sound prolonged. The westernised name "didjeridu" for the instrument perhaps arises from this circumstance, though it may perhaps be a word from some aboriginal language, now extinct.

There has been only a little written about the acoustics of the didjeridu [1,2] or about its playing techniques [3,4]. The instrument itself, however, has become increasingly used in popular music by groups such as Goodwanaland, and was earlier made widely known on television through the efforts of Rolf Harris. A few simple calculations and measurements, however, allow us to understand a good deal about this interesting instrument.

**Passive Acoustics**

It is a good approximation to treat the didjeridu as a truncated conical horn of length $L$. Suppose that the diameter of the smaller end is $d_1$ and that of the larger end $d_2$. Then if we imagine the cone to be continued to its apex, the distance from this apex to the smaller blowing end of the instrument will be $x_1 = d_1 L/(d_2 - d_1)$. Since the players' lips form a pressure-controlled valve, the preferred sounding frequencies are those at which the acoustic pressure at this end, and thus the acoustic impedance, is a maximum. These frequencies $f_n$ can be shown [5] to be the roots of the equation

$$ k_n L' = n\pi - \tan^{-1} k_n x_1 $$

(1)

where $k_n = 2\pi f_n / c$, $c$ is the speed of sound in air, and the acoustic length $L' = L + 0.3d_2$ includes the end-correction at the open end.

If the flare is extremely small so that the horn is nearly cylindrical, then $x_1$ becomes very large and $\tan^{-1} k_n \pi$ approaches $\pi/2$. The resonance frequencies are then $f_n = (n - \frac{1}{2})c/2L'$ which form the series of odd harmonics that we expect, for example as the playing frequencies of a clarinet, starting with a quarter of a wavelength equal to the tube length. More generally, if the flare is fairly small, we can expand the result (1) to arrive at the approximate expression

$$ f_n = (n - \frac{1}{2}) \frac{c}{4L'} \left( 1 + \left[ 1 + \frac{4(d_2 - d_1)}{\pi^2 d_1(n - \frac{1}{2})} \right]^{1/2} \right). $$

(2)

We can see that the frequencies of the lower modes, and particularly that of the fundamental, are raised relatively more than those of the higher partials, so that all the mode intervals are compressed. For moderate flare, only the lowest mode frequency is significantly affected. For the range of end diameters found in the typical didjeridus of Table 1, this fundamental-mode frequency is raised by a factor between about 1.06 and 1.38 relative to a cylindrical tube of the same length. The ratio of second to first mode frequencies, which would be a perfect twelfth (1.50) for a cylindrical pipe, ranges from about 1.30 (about a tone flat of a perfect twelfth) to about 1.43 (a little less than a semitone flat). The greater the flare, the flatter the second mode appears relative to the drone fundamental.

<table>
<thead>
<tr>
<th>TABLE 1. Typical didjeridus [1]</th>
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</thead>
<tbody>
<tr>
<td>Length $L$ (cm)</td>
</tr>
<tr>
<td>Diameter $d_1$ (mm)</td>
</tr>
<tr>
<td>Diameter $d_2$ (mm)</td>
</tr>
<tr>
<td>Frequency $f_1$ (Hz)</td>
</tr>
<tr>
<td>Drone pitch</td>
</tr>
</tbody>
</table>

These mode-frequency predictions are confirmed by the measured drone frequencies of three typical didjeridus from Arnhem Land as listed in Table 1. The effect of flare is easily seen in the case of the second and third instruments—the second is only 3 percent shorter than the third, but its fundamental frequency is 25 percent higher because of its large flare. Unfortunately the second-mode frequencies were not recorded, but the pitches agree qualitatively with the theoretical predictions [1].

It is interesting to note that traditional makers and players seem to have little concern with either the drone frequency or the interval to the second mode—the first two instruments in the table are actually by the same maker. Indeed, a good player can produce most of the nuances of traditional performances on a piece of plastic pipe of appropriate diameter and length! When used in popular Western music, however, it is necessary to select a didjeridu of appropriate pitch to match the keyboard instruments, though in some multi-track recordings the didjeridu is actually recorded first and then pitch-shifted, the player having made some adjustment for the associated change in tempo. Breaking with tradition, Graham Wiggins has made the perhaps obvious extension of building a didjeridu with keys to open one or more holes near the foot and so allow the drone pitch to be changed.

**Sounding Mechanism**

While much of our understanding of the sounding mechanism of wind instruments dates back to the time of Helmholtz a hundred years ago [6], it is only recently that these mechanisms have been studied in detail. There is a clear distinction between three types of pressure-controlled valves, as illustrated in Fig. 1. In the first two types, air pressures acting on the two faces of the valve have opposite effects, tending to either open or close the valve, while in the third type excess pressure on either face tends to open the valve. If we represent a closing action of excess pressure by the symbol $-$ and an opening action by $+$, then the first two valves have classification $(--, +)$ and $(+, -)$ respectively, and the third has classification $(+, +)$. 

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The familiar reed valves of oboes and clarinets are of the 
\((-\,+,\,+)\) type, as also are the metal reeds used in organ reed-
pipes. The human vocal folds are usually modelled as hav-
ing the configuration \((+,\,+)\), as are the vocal organs of birds
(the syrinx), though the models used are generally more com-
plex than this. The lips of players of brass instruments, such
as the trumpet or tuba, and of the didjeridu, are either of
configuration \((+,-)\) or \((+,\,+)\), and possibly change char-
acter between different playing regimes [7]. It is probably
necessary to use a rather complex model for the vibrating
lip valve, such as has been developed for the human vocal
folds [8], but this has not yet been attempted. We must
therefore be satisfied for the present with simpler models.

If we define the acoustic admittance of a pressure-controlled
valve under blowing pressure, as viewed from the instru-
ment, to be the ratio of the small-signal acoustic flow out
of the instrument to the small-signal acoustic pressure in
the instrument mouthpiece, then there is the possibility of self-
sustained oscillation if the resistive part of this impedance
(the acoustic conductance) is negative, to overcome the
losses in the system, and if the reactive part can be bal-
ced by the reactive admittance of the instrument tube and
the players mouth, taken together. In all cases, the first con-
dition requires that the blowing pressure should be greater
than some threshold value determined by the tension of the
lip muscles, which itself depends on the pitch of the note
being played [9,10].

Provided a blowing pressure greater than this minimum is
used, then the acoustic admittance of a lip-valve generator
can be shown [9] to have a form like one of those shown
in Fig. 2. For such a \((+,-)\) or a \((+,\,+)\) valve, the acoustic
conductance—the real part of the admittance—is large and
negative at a frequency either just above or just below the
resonance frequency of the lip-valve, which is determined
by lip mass and muscular tension. At other frequencies the
conductance is relatively small and may be either positive or
negative. The magnitude of this peak negative conductance

![Acoustic conductance of a (+,-) valve (full line) and of a
(+,+) valve (broken line). The resonance frequency for
free vibration of the valve is shown.](image)

is sufficiently large that it is able to overcome the positive
conductance losses in the rest of the system and force it into
oscillation. While this can happen over a considerable fre-
quency range if the lip resonance frequency is adjusted—a
skilled trombone player can play a glissando without moving
the instrument slide—the oscillation is most easily sustained
near an impedance maximum of the tube, where its posi-
tive conductance is least. The acoustic impedance of the
player’s mouth also plays an important role in sustaining
the lip oscillation—a role that can be appreciated when we
realise that it is possible to buzz the lips at their resonance
frequency even in the absence of any instrument tube [10].

This is the operating regime for a didjeridu—the player
adjusts lip tension so that the lip resonance is close to the first
tube resonance. To produce the second mode, the player
must use a much higher lip tension to raise the lip reso-
nance frequency, and this requires, in turn, a greater thresh-
old blowing pressure. The actual pressures used are, of
course, well above the threshold value. Measurements [1]
show that a didjeridu player typically uses a pressure of
about 1–2 kPa (10–20 cm water gauge pressure) for the
drone note and about 4–5 kPa to produce the second mode.
Some players can produce the third mode and even higher
modes, but they are rarely used. Indeed, even the second
mode is only employed for brief accents, and not as a sus-
tained tone.

### Sound Quality

The discussion above is essentially linear and expressed
in terms of linear quantities such as acoustic admittances.
Sound production in wind instruments, however, is a non-
linear process [5,11], and this nonlinearity is responsible for
generating the upper partials of the tone. The process has
been examined for brass instruments such as the trumpet
[12] and trombone [13] and much of this discussion can be
applied to the didjeridu.

Because, unlike the reed valve in a clarinet, the lip valve
operates at very nearly its resonance frequency [7,9,10], the
motion of the player’s lips is nearly sinusoidal. The aver-
age lip opening is determined by the blowing pressure, and
the amplitude of the lip vibration is such that the lips just
about close once in each cycle. If \(p_0\) is the steady blowing
pressure, \(p\) the pressure just inside the mouthpiece of the
instrument, and \(x = a_0 + a \sin 2\pi ft\) the lip opening, then
the volume flow \(U\) through the lip valve is

\[
U \approx \gamma x (p_0 - p)^{1/2}
\]

where \(\gamma\) is a constant. The pressure \(p\) inside the instrument
mouthpiece is approximately \(RU\), where \(R\) is the acoustic
resistance of the instrument tube at the resonance frequency $f_1$, and we can substitute this back into (3), along with the expression for $x$, to find, after a little algebra, that if $a < a_0$ the flow has the form

$$U \approx \frac{p_0}{R} - \frac{p_0^2 / R^2}{(a_0 - a \sin 2\pi f t)^2}. \tag{4}$$

This expression cannot be taken too literally in the limit as $a \to a_0$, but the shape of the flow waveform is essentially as shown in Fig. 3.

Clearly such a waveform has many harmonics, and this accounts for the rich sound of the didjeridu, and of lip-excited instruments in general. The relative strengths of the upper harmonics are not well predicted by this simple flow waveform, however, for several reasons. The flow waveform gives a spectral envelope which is initially nearly constant and then declines at about 12 dB/octave. The assumption that $R$ is constant, however, is not very good, and this resistance is less for the upper harmonics than for the resonant fundamental, except for accidental near-coincidences with higher horn resonances. Finally, the transfer function between flow spectrum and acoustic radiation rises at 6 dB/octave at low frequencies and is then flat above about 3 kHz for the didjeridu horn. Despite these reservations, however, this simple treatment does give a fair idea of spectral behaviour.

Note that the sound spectrum of the didjeridu, as for all sustained-tone instruments (except when playing “multiphonics” or other special effects), is strictly harmonic. The fact that the upper modes of the pipe are not in harmonic relation to the fundamental affects only the strength of certain harmonics. If one of the upper pipe modes is sounded instead of the fundamental, then this sound will itself be accompanied by its own set of harmonics.

We should now consider the effect of the player’s mouth cavity on sound quality. The player’s lip opening varies nearly sinusoidally with time, as we have seen. The time spent at each opening is inversely proportional to the lips speed at that opening. If the lips close each cycle so that $a = a_0$, the fraction of time spent at opening $x$ can then be shown to be proportional to $\frac{1}{x(2a_0 - x)}$ which is sharply peaked at $x = 0$ and $2a_0$, so that the lips spend most of their time either fully open or nearly closed. Seen from the instrument tube, therefore, the player’s mouth is mostly either blocked off by the closed lips or else forms a Helmholtz resonator consisting of a closed volume vented by the lip opening. The resonance frequency of this resonator can be estimated from our experience with whistling, in which the whistle frequency is the resonance frequency of the same Helmholtz resonator. Since the lip opening is similar, within a factor of less than ten, in the two cases, the attainable resonance frequencies should be the same within about a factor three. We therefore expect that it should be possible to vary the resonator frequency over a range from about 500 Hz to about 3 kHz by changing the mouth volume with the tongue.

It is fairly easy to understand the effect of such a resonator on the lip-valve flow and hence on the radiated sound spectrum. The resonator is rather highly damped by the flow resistance through the lip valve so that its bandwidth encompasses the frequencies of several harmonics of the drone frequency. The acoustic flow through the lip valve will be enhanced for these harmonics, so that the acoustic spectrum will exhibit a “formant band” rather like those of the human voice and, indeed, arising from similar causes. Details are more complicated than this, of course, because the opening from the mouth to the instrument is changing with time.

While the didjeridu can be played with a dull drone, lacking obvious formants, this is not usual for good players. Fig. 4 shows two examples of such formants, which play an important role in producing the characteristic sound of the didjeridu. In the first example, there is a pronounced formant band at about 1500 Hz, while in the second example the player has reduced the volume of his mouth so as to raise formant frequency to about 2.2 kHz. In each case there is some evidence for a lower vocal-tract formant at about 500 Hz. Because the frequency range of these formants is similar to that of human vowel formants, they have a similar aural effect. In normal playing, using circular breathing, these formants are produced in a rhythmic manner as the mouth volume changes, but they are often made a tonal feature of the performance.

These formant phenomena are much more pronounced in the didjeridu than in Western brass instruments, principally because trumpets, tubas and the like have a cup-shaped mouthpiece with a narrow constriction between it and the main bore of the instrument. This mouthpiece, as well as providing a comfortable support for the lips, functions as a Helmholtz resonator in its own right, and its resonance produces a broad formant band, typically with a centre frequency around 500 Hz for a trumpet [5]. The mouthpiece cavity also functions as a filter which reduces any influence
that mouth resonances might have on upper partials of the sound.

There is one other aspect of performance technique that deserves detailed acoustic comment. This is the use of vocal sounds to augment the drone of the didjeridu. Because of the acoustic coupling between the vocal folds in the throat and the player’s vibrating lips, the interaction is quite complex. Suppose that the player’s vocal folds vibrate at a frequency $f_V$. Then this produces pulses of flow in the same way as described for the lip valve and illustrated in Fig. 3. The flow entering the mouth, and therefore the mouth pressure $p_m$ of (4), thus contains all harmonics $n f_V$ of the vocal-fold frequency. When this flow is convolved with the nonlinear flow through the lips, which are vibrating with frequency $f_L$, as in (4), the result is the production of all frequencies $n f_V \pm m f_L$, those with greatest amplitude having small integer values (1 or 2) for $m$ and $n$.

The simplest example of this frequency mixing occurs when the player sings a steady tone at a frequency simply related to the drone frequency. A typical example is the singing of a note that is a just major tenth (frequency ratio 5/2) above the drone fundamental. The cross term $f_V - 2f_L$ then has a frequency $f_L/2$ and this is accompanied by all its harmonics from the other cross terms. The sound is therefore an octave below the original drone frequency. There is not be much radiated energy in this sub-octave fundamental, but the subjective pitch is generated strongly from the sequence of harmonics. Because of the low pitch and the strength of the higher harmonics, the sound has a rough rasping quality which is very effective. A rather similar result can be obtained by singing a note a perfect fifth (frequency ratio 3/2) above the drone fundamental.

Finally, we should remark that players of the instrument often use it to accompany traditional songs or stories and, to this end, embellish their playing by adding the sung sounds of barking dingos, brolgas and other animals. The pitch of these vocal sounds is rather high so that frequency mixing does not have such a pronounced effect, and the sounds can be made easily recognisable.

Fig. 5 shows a spectral display of a short passage of didjeridu playing. In this representation, time is along the horizontal axis and frequency on the vertical axis, with the density of shading indicating the sound pressure level. Two things are immediately obvious. The first is that the harmonic structure of the sound is clearly evident in the closely spaced dark bands running horizontally in the figure. The second feature is the formant bands, which show up as darker regions on the plot and vary with time. Articulation and circular breathing divide the time record into repeating segments. Features of this type will be familiar to anyone involved with human speech analysis.

### Conclusion

Although the didjeridu is physically a simple instrument and its makers appear to accept wide variations in its physical dimensions and therefore in its tuning, it supports a wide variety of subtle performance techniques. We have considered here the acoustics of only the most important of these, but it is clear that there is a great deal of interesting understanding to be derived. I hope that this paper may serve as an example of the sort of results that can come from cooperation between acousticians and musicologists.
Acknowledgements

The work on which this paper is based was completed a long time ago and has, for the most part, already been published elsewhere [1]. It is a pleasure to acknowledge the help I have received from conversations with Trevor Jones, a distinguished musicologist and expert didjeridu player, and with Graham Wiggins, a physicist turned didjeridu virtuoso. Some of the analysed examples were played by Trevor and some were collected in the field by linguist Bill Hoddinott. I would also like to thank Suszanne Thwaites for assistance with the measurements.

References


OF INTEREST

Debunking Some Myths of Physics Departments, Students and Employment

Physics has been one of the most exciting sciences of the 20th century. Many of the revolutions in science, technology, and modes of thought have been led and influenced by developments in physics: relativity, quantum mechanics the Big Bang, the theory of the universe, and quarks, the new building blocks of matter, just to name a few. Physicists have paved the way for the invention of transistors, lasers, nuclear power, electro-optical communications, magnetic resonance imaging, and much more. Since the end of World War II, after the success of American scientists in aiding the defense of the nation with the atomic bomb, the government and industry have placed a high value on physics and generously supported basic and applied research.

In the 1990s, with the end of the Cold War and fierce global competition in all aspects of high technology, the nation finds itself developing new modes and justification for science funding. It is clear that the knowledge provided by physics is in great demand and that research challenges are backed with a substantial base of government and industrial support. However, employment patterns for PhD scientists and engineers are changing. There are fewer opportunities for academic positions due to budget limitations, but there are documented growing needs for flexible and broadly trained physicists in many aspects of the world of high technology and business.

There has been much written about the changing paradigms in science funding. My focus is on some of the myths surrounding physics departments, physics majors and the employment of physicists.

Myth #1

The fact that there are very few undergraduate physics majors - relative to many other undergraduate disciplines - at most universities is a clear indication that physics department faculties are too large.

The American Institute of Physics (AIP) has collected data indicating that there are approximately 800 colleges and universities offering undergraduate degrees in physics, with about 5,000 baccalaureate degrees awarded annually—an average of six per institution. Thus, most physics departments across the nation have few physics majors. To within ±15% this has been the situation for over 30 years. While it would be worthwhile for physics departments to make their undergraduate curricula more attractive and broadly based, it seems unlikely that, on a national level, the numbers of physics majors could be increased significantly. Even a factor increase of two would still leave physics with a small number of majors. A much fairer yardstick for the size of the physics department faculty and necessary support should include a weighted matrix of the following factors:

- The enrolment in introductory non-science major courses.
- Considerable faculty support can be generated by first-rate physics courses in astronomy, contemporary physics topics, or such specialised topics as the physics of music, physics of sports, or the physics of how things work.
- The physics service courses for engineering, math, and computer science majors, as well as the pre-med, pre-dental and nursing majors.
- The number of graduate students and yearly PhD production.
- The amount of externally funded grants and support it provides for undergraduate and graduate education, and the resulting quality of the research on campus.
- The efforts of the department in education reform, research and outreach to local teachers and schools, as well as efforts to nurture and increase the numbers of physics majors who are women and minorities.
- The involvement of the department in cooperative industrial research and the impact it has on local, as well as national, economic development.
- The level of national recognition of the quality of the program and faculty.

If such a matrix were to be applied, most physics departments would fare quite well, in spite of the relatively low number of physics majors. However, it would be important for department leaders and the faculty to develop strategies to improve their standing in each of the eight categories listed above. Each department should develop a strategic plan, in cooperation with the local administration, focusing on a matrix approach to determine appropriate size and the degree of support needed.

Myth #2

Physics majors at all levels have poorer employment opportunities than those majoring in other sciences, math, engineering or computer science.

This myth is a partial result of the excellent and continuous data collection, interpretation and wide dissemination by AIP’s Educational Employment Statistics Division. As a result, potential physics majors, as well as students in general, are aware of up-to-date and accurate information on employment prospects for physicists. Unfortunately, similar information, especially the dissemination of “hard data," is not equated for many of the other scientifically based professions. Thus, many students have gotten the impression that the difficult employment situation for physicists is unique. This is not the case. A more accurate statement would be that demand for science and engineering talent in all fields remains tight, inasmuch as it relates to basic research in industry, government and academia.

In comparing median annual earnings of bachelor degree graduates between the ages of 35 and 44 by major field of study, the December 1995 Monthly Labor Review found that among 29 professions, physics was rated fifth (the highest among all the physical and natural sciences), and was one of only five fields of study showing mean earnings over $50,000. Other degree majors from the arts or social sciences have average salaries 20 to 30% below that of physics majors. This is solid evidence that employers place a high value and premium on the physics degree.

Myth #3

There is little demand (or salary) for graduate students in physics, and thus physics graduates do not get good jobs that make use of their physics degree or advanced training.

The oft-declared oversupply of PhD physicists does not truly describe the situation. More accurately, there is an initial mismatch between the expectations of recent physics PhDs for traditional jobs and the strong marketplace demands for their talents. While quality data disseminated by the physics community indicates it is more...
If one were to present the data for mean salaries of professionals with PhD degrees, the market premium for physics would be similar to that of the undergraduate physics majors discussed above. During the past few years, the world of business, finance and management consulting have discovered the talents of PhD physicists, and as a result many firms are specifically recruiting them to make use of their problem-solving skills, their work ethic, their ability to stick with complex problems, and their analytical and computer skills. Unlike many other PhD fields of study, when a physicist is "forced" to take a job in business or finance, for example, instead of traditional academia, the starting salary approaches $100,000 per year and involves no typing.

(See Physics Today, January 1997, p42-46)

Myth #4
Most public universities have a relatively large number of foreign graduate students, who don't speak English well, don't get good job offers, don't remain employed in the region or nation, and return in large numbers to their native countries.

There is presently a strong xenophobic undertone in the US. There has not been such a large influx of ethnic minorities in physics since before World War II, when many scientifically capable Jewish and European refugees fled Hitler and came to the US, with many bringing important contributions to such major projects as radar and the atomic bomb. Currently the US is benefiting from the large numbers of the best students from China, India, the former Soviet Union and other nations around the world studying and contributing to Science and engineering research and development. Data indicates that foreign physics students admitted score high on the TOEFL exam for English proficiency and score very well on the GRE physics exam. The data on post PhD employment indicates that foreign graduate students get good jobs at attractive salaries in both traditional and non-traditional employment sectors, and that few of them return to their country of origin.

Each of the myths discussed above has some slight "ring," of substance, but not of truth. They are not presented in context, nor are they informed with data to determine their reality. Yet these myths continue to be propagated and believed by administrators, and in some cases, are having a deleterious effect on faculty morale and on-campus support for physics. At many universities, the situation for maintaining the quality of physics programs is quite fragile. It would be worthwhile if all relevant parties would become informed and work with physics program leadership to develop a realistic strategic plan to maintain the excellence of physics departments nationwide.

Brian B Schwartz

Brian B Schwartz is a professor of physics at Brooklyn College of the City University of New York and former Associate Executive Secretary of the APS. He operates an NSF-sponsored program aimed at enhancing the employment prospects for PhD physicists. Professor Schwartz can be contacted via email at schwartz@aprs.org.

Reprinted from American Physical Society News.

The 1997 Walter Boas Medal

This year's Boas Medal has been awarded to Professor Keith Nugent of the University of Melbourne and Dr Stephen Wilkins of CSIRO Manufacturing Science and Technology for their contributions to x-ray and light optics.

In 1989 Professor Nugent, Dr Wilkins and their colleagues pioneered a novel form of 'lobster-eye' x-ray optics based on capillary arrays of reflectors. During the past four years Professor Nugent and his group have further developed these techniques to the stage where they are to be used in a proposed international collaboration to develop a new form of x-ray telescope and a LOBSTER satellite which should allow much improved all-sky x-ray astronomical surveys. During this period Professor Nugent and his colleagues have also developed a new and direct approach to the determination of optical phase from intensity measurements which promises to have important applications in astronomy and x-ray imaging.

Dr Wilkins and his team at CSIRO have developed new techniques of x-ray imaging, based on phase-contrast, which initially relied on the use of perfect-crystal optics but more recently have progressed to methods requiring only conventional polychromatic (microfocus) x-ray sources. In contrast with conventional x-ray absorption imaging, phase-contrast imaging probes the refractive index of the medium and can give strong contrast for weakly absorbing materials including biological tissue. The method has potentially important applications in clinical medicine, the biological and physical sciences, and industry.
Winston Churchill Fellowship Award for 1998

Congratulations to Peter White, Head Teacher of the Open High School, for being awarded a Winston Churchill Fellowship to study science distance education practices in Canada and the USA during 1998. He is one of three NSW teachers who were given this award to improve their teaching skills by overseas study.

Peter has been leading the implementation of innovative communication technologies such as Interactive Cable/Satellite using OPTUS Local Vision to produce a series of 30 minute HSC Physics programs and the Apple Classroom of Tomorrow ACOT project into science distance education teaching and learning practices. He will have an opportunity to complete the ACOT teacher training course in Nashville, Tennessee USA and observe its implementation in schools.

Workshop on Bose-Einstein Condensation
January 19-20, 1998
Conference Centre, University of Auckland

The Workshop will commence at 9.00 on Monday 19 January.

Registration starts at 8am.
A registration fee of NZ$100 covers morning and afternoon teas, lunches and a conference dinner (Monday night). The deadline for Registration is January 9th, 1998. Accommodation should be arranged by individuals. Conveniently located lodgings are:

The Whittaker Lodge
Motel style, NZ$103 single, NZ$113 double
Tel (64-9) 377 36 23, fax (64-9) 377 36 21

Aspen Lodge
Bed & Breakfast NZ $39 single, NZ$62 double
(shared facilities) Tel (64-9) 379 66 98
Fax (64-9) 377 76 25

Recreation
A recreational trip to local rainforest and surf beaches will be arranged for Wednesday January 21st.

Workshop Secretary
Dr Lev Plimak, l.plimak@auckland.ac.nz

Workshop Directors
Dr Fiona Harrison, f.harrison@auckland.ac.nz
Prof Dan Walls, d.walls@auckland.ac.nz

Workshop on Bose-Einstein Condensation
Registration Form

Name .................................................................
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Registration fee of NZ$100 (enclosed). Please make cheques payable to "Quantum Optics Symposium"

Return Registration form to
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THE FUTURE STATUS OF PHYSICS TEACHERS IN AUSTRALIA

PETER LOGAN

On the 20 June 1996 the Status of Teachers was referred to the Employment, Education and Training References Committee of the Australian Senate for an inquiry. The Senate Committee sought the view of the public by 9 May 1997 and is expected to report on or before the last sitting day of the Autumn session 1998.

The background notes for the Inquiry included the following (the full details can be found at the web site http://senate.aph.gov.au/committee/eet_cite/currimq.htm#sot):

"There has been a discernible change in the status of teachers over the last twenty years, a change measurable by several indices including: community attitudes towards teachers; salary relativities; choice of teaching as a career; age profile of teachers; recruitment and retention, and resources and policy support for schools.

"There has also been a significant change in the nature and range of a teacher's work, largely in response to the societal and technological context in which teaching is carried out, but arising also from policy and administrative changes demanded by governments and from higher retention levels.

"It seems timely to assess the current state of play with teaching, as there are indications of a dramatic shortage of teachers emerging within the next five years. This has implications for all aspects of the profession from training and recruitment to career management and systems administration.

The Committee was to look at the status of teachers and the development of the profession during the next five years. The issues under investigation were to include:

- The levels of supply and demand which should guide the workforce planning for teachers into the next century.
- The tertiary entrance levels of teacher trainees and the quality of their subsequent classroom practice.
- The induction of newly-trained teachers into schools and on-going professional development.

The matter was referred to the Education subcommittee of the NSW Branch of the AIP by the Branch President. The subcommittee discussed all aspects of the inquiry especially those relevant to Physics teachers, and prepared a submission for the NSW Branch. This was discussed at a subsequent meeting and the following submission sent to the Senate inquiry by the Branch President.

Submission to Senate Committee on the Status of Teachers

A submission from the NSW Branch of the Australian Institute of Physics (AIP). (The AIP is the one professional body of physicists in Australia, and as such represents the interests of all physicists - teachers, University academics, research scientists and those working in the high technology industries.)

The AIP is concerned about a number of issues relating to the status of teachers. Some are general issues affecting all teachers, others are more specific to Physics teachers.

General issues include the following:-
The AIP is concerned:-
- that teaching should be seen as a challenging and rewarding career
- that young people should be attracted into the teaching profession
- that the teaching profession is apparently ‘aging’

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THE FUTURE STATUS OF PHYSICS TEACHERS IN AUSTRALIA

with reduced number of recent graduates entering the profession.

- that many ‘older’ teachers express unease with communications/information technology.
- that there is a general perception that University courses training Science teachers have quite low TER cut-offs and hence the teaching profession is not attracting the teachers it needs in both quantity and quality. This situation is made more difficult by recent changes to HECs.
- that the stress on teachers due to increasing workload, the narrow strictures of the syllabus, adverse publicity, the greater expectation by society of their ‘in loco parentis’ role due to the increase in family breakdowns, the changing structures and the swinging pendulum of pedagogies, is detrimental to the education of children and the job satisfaction of teachers.
- that a number of excellent teachers with 5–10 years experience are leaving the profession for more lucrative and fulfilling positions outside teaching.

Issues specifically related to Physics teachers

The AIP is concerned:

1 that in some Australian States, a physics graduate, who is most likely a major in Physics and Mathematics, must decide between becoming a mathematics teacher OR a science teacher. Science teachers are required to teach Biology, Geology, Chemistry and Physics.
- that the education of young people in Australia should be of the highest priority, and that Physics, one of the essential bases of high technologies, be taught by teachers adequately trained in Physics.
- that as physics is the gateway to the high technologies and as a matter of equity, adequate Physics teaching should be offered to all Australian children regardless of whether they are attending a wealthy school, a selective school, an underprivileged school or a rural school.
- that all students at the end of their secondary schooling should have a sufficient understanding of Science to enable them to make informed decisions concerning technology.
- that the standard of Physics education gained by students completing high school should be sufficient to enable further study in the subject and related high technology areas.
- that the calibre of teachers should be such as to motivate the students in the Sciences.
- that all members of the AIP, whether in University or Industry, have a role to play in the in service training and professional development of teachers.
- that the Science syllabus material presented throughout the K–12 course should exemplify the use of science in the world of the student and highlight the applications of the principles.

The AIP recommends:

1 that all Australian State governments should allow trained Physics teachers, with adequate training in Mathematics, to be recognised as either Mathematics/Physics or Science/Physics teachers.
2 that teachers of Physics in Years 11 and 12 be certified to teach Physics at that level. This certification should be carried out by the relevant Educational authority and in the case of Physics, to be certified would require a minimum qualification of 2 years of University Physics.
3 that if there are insufficient physics teachers, even after recommendation 1 has been implemented, that teachers be upgraded with addition tuition (to the level of recommendation 2) in order to teach Physics in Years 11 and 12. The AIP would be active in assisting to construct appropriate upgrade courses.
4 that students of good academic background be recruited into teaching by innovative means such as teacher scholarships for those areas where there is a dearth of adequately trained teachers.
5 that individuals with sound physics background and experience in research, academia or industry be recruited in teaching with an appropriate incentive scheme.
6 that a full nationwide collection of statistics concerning age profile, detailed academic background, where the teachers are working, and the kind of school they are working in, be carried out as a matter of high priority.
7 that all Science teachers have Government funded internet access in their Science staff common rooms, and where feasible be able to access the internet from home, via the school facilities.
8 that after every 5 years of teaching, a teacher may compete to be granted a six month secondment to a University department, a research institution or industry as a way of assisting in their on-going professional development. (Professional societies, like the AIP, should be involved in that secondment.)
9 that following on from recommendation 8, the feasibility of an exchange program between academia, and industry and the classroom be investigated.

A program should be set up to implement these recommendations. With appropriate funding and encouragement the AIP could play a role in the following:
- in-service training for adequately trained science teachers.
- the establishment of special foundation courses for teachers without certification asked to teach Years 11 and 12 Physics.
- the production of appropriate web pages including study guides for students and supplementary material for teachers.
- a continuation of its role as coordinator of youth lectures and the centre for assistance for teachers.

Acknowledgments

The author would like to thank the NSW Branch AIP committee for the part they played in preparing the submission, and especially its Chair Professor Ross McPheffer and two members of the Education, subcommittee, Anna Binnie and Terry Freeman.
AIP/NATIONAL COMMITTEE FOR PHYSICS
Survey of Australian Physics Departments – July 1997

JAAN OITMAA & ERICH WEIGOLD

Following discussions between Professor Erich Weigold, Chair of the National Committee for Physics of the Academy of Science and Professor Jaan Oitmaa, President of the Australian Institute of Physics, a questionnaire was sent to Heads of Physics Departments.

The ten questions asked, Appendix A, sought information on recent structural changes in departments, staff and student numbers, factors which are having a harmful effect on departments and staff morale. Respondents were advised that individual departments would not be identified specifically in this report.

As of 18 August 25 replies had been received of which 23 provided information in sufficient detail to be useful. Every effort will be made to obtain the outstanding replies but the trends and conclusions are unlikely to be significantly changed. Some of the information, eg on staff morale, is a subjective view from the Head of Department which hopefully, but not necessarily, reflects the views of other staff.

Previous Surveys

There have been numerous previous surveys involving Australian Physics Departments. Jennings et al [1] have provided comprehensive information on 3rd and 4th year and postgraduate enrolments over the period 1991-96. This information provides an accurate view of the nation’s production of professional physicists, and on the attractiveness of physics degrees to incoming students. Millar [2], following the Heads of Department meeting in 1995, carried out a survey of Physics teaching to determine relative teaching loads between physics majors and service teaching, based on 1996 data. Data for total EFTSU taught are also provided. Delbourgo [3], on behalf of the National Committee for Physics, obtained limited data on staff and student numbers, comparing the years 1995 and 1996, and reported to the Academy. The present survey provides comparisons over a longer time frame, 1994 to 1997 with projections beyond, and seeks qualitative responses to other factors.

Structural Changes

Most of the larger Physics departments have retained their identity both as a budget unit and as the academic unit offering undergraduate and postgraduate Physics programs. In a few Universities changes in Faculty structure or name have taken place but with little or no immediate impact on Physics.

Smaller departments have experienced greater change and some of these processes are continuing. There have been amalgamations, with other disciplines into a single unit, transfers to Engineering Faculties and other large changes. While not all of these are necessarily bad, smaller departments do feel under threat. It is not clear that all Universities will continue to offer a professionally acceptable Physics degree.

Staff and Student Numbers

Almost all departments, including those that might be thought of as the “top rank” departments have experienced large staff losses over the period 1994-1997. Figures 1 and 2 show this graphically. The data show a 16.5 % loss in academic staff (from 310 to 259) and a 18.7 % loss in general staff (from 278 to 226).
negotiations either completed or in train. This will happen even if student numbers remain unchanged. The survey asked for projections for 1998, 1999 but little useful information was provided.

The statistics on which Figs 1-3 are based is included as Appendix B.

### Physics Majors

Previous surveys [1,2,3] have included, inter alia, information on number of students majoring in Physics. In the present survey Heads were asked to provide information by year and to identify trends. The trends are unclear. The larger departments appear steady, many report a downturn but the numbers are small and fluctuate from year to year. A much more careful study is needed to draw definitive conclusions but the evidence supports an overall decline in interest in Physics programs, with greatest effect in the medium size departments. Many departments have very small numbers and this must be an issue of concern both to them and to the profession.

### Service Teaching

Virtually all Physics departments depend on their service teaching role. Heads were asked whether there had been any recent losses or threats of losses.

Almost all responses indicate major concerns in this area, and some refer to major losses in service teaching before 1994. In recent years there have been some losses to Medicine (due to Medicine becoming a postgraduate course) in some institutions and to Engineering. Other departments have made small gains, primarily from Engineering, and in other cases a move to place Physics in an Engineering Faculty is seen as a positive move in terms of retaining or increasing service teaching.

With departmental budgets driven almost totally by student load there will continue to be moves by other units to take back service teaching. The profession needs to work for a clear policy in all universities that physics material must be taught by physicists. Some, but by no means all, Vice-Chancellors appear to have accepted this policy.

### New Programs

Heads were asked whether their department had been successful in generating additional EFTSU through new programs. Almost all departments are attempting to do this, with a variety of offerings: astronomy, other liberal
arts subjects, B.Tech. programs in instrumentation, optoelectronics, medical applications, courses for biology majors and biophysics.

The student numbers are generally fairly small but such initiatives have maintained student load and, in the case of some smaller departments, may be essential to maintain a physics presence.

These initiatives should be encouraged by the profession.

### Major Factors Harming the Performance of Departments

The survey asked all department Heads to identify the major factors that were harming the performance of departments.

The major areas of concern, in roughly decreasing importance, were:

- funding cuts, leading to staff reductions and increased teaching loads.
- decreasing enrolments in physics (particularly in regional and younger universities).
- reduced research capacity, resulting from other demands on time.
- difficulty of obtaining research funding, and low numbers of research students.
- demands on time for “non-academic” activities
- poor community image of physics, poor industry involvement and difficulty of suitable careers.
- harmful effects of excessive competition, loss of academic ethos in a climate of economic rationalism and poor Government attitude to Universities.

Other points mentioned included:

- poor High School preparation in Science and Mathematics
- ageing staff and lack of new blood.

Of course these represent the concerns expressed by Heads of departments and it is difficult to gauge the views of other staff.

Nevertheless we would expect the issues to be valid across the whole sector.

### Staff Morale

Heads were asked to comment on staff morale in their departments.

Several replies gave ‘good’ without qualification but the overall response was ‘moderate’ and ‘precarious’.

Four departments replied ‘poor’.

Again the views of department heads may or may not reflect the general view.

### Conclusions & Recommendations

Physics in Australian Universities continues to be under stress. This is, in part and perhaps the largest part, because of reduced Government funding to Universities and refusal to fund current salary increases. However, the move to formula funding based on student load is also having major impacts on the experimental sciences, including physics.

The issue of service teaching continuous to be extremely important. Without the funding that flows from that many of the smaller departments could cease to exist and even the larger departments would become marginal.

Some years ago Sir Sam Edwards is reputed to have said that 25 academic staff is the critical mass for a sound Physics department. By this criterion, apart from the Research School at ANU, there are only six departments above or close to critical size. Clearly this is arguable but must be a concern to both the departments and the profession.

While it is difficult to draw definite conclusions about physics student numbers (physics majors and research students) the data obtained by Jennings et al [1] does suggest a downward trend. If this continues it will impact on the viability of departments, since no department can depend totally on service teaching for its survival. Departments need to market their courses vigorously and revise course structure and content to meet current needs and to produce highly employable graduates. The profession must continue to play an important role here.

### References


2 J Millar Survey on Teaching in Physics Departments in Australian Universities, Heads of Departments Meeting 1996.

3 R Delbourgo: Report to Academy of Science based on survey of staff and student numbers in Australian Physics Departments in 1995, 1996.
Appendix A

Questionnaire on Factors Affecting Physics Departments in Australian Universities

1. Name of Department/Name of University

2. Which of the following best describes the budgetary status of your department?
   (a) autonomous department with 1 line budget
   (b) autonomous department with salaries paid centrally
   (c) department forming part of a budget unit (please explain)
   (d) no separate unit identifiable as Physics
   (e) other (please explain)

3. Has your department been restructured, renamed, broken up, or shifted to a new faculty over the last 5 years? Are there plans to do so in the next 1-3 years?

4. Please provide, as best you can, the following information

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5. Provide information, as best you can, on changes and trends in the numbers of Physics majors over the period 1994-1999, projected where necessary.

6. Has your department lost a substantial component of service teaching in recent years, or is this under immediate threat? Please elaborate and quantify if possible.

7. Has your department been able to generate additional EFTSU through new programs in recent years? Please elaborate.

8. In terms of decreasing importance, list 3-4 factors which have had/are having a harmful effect on the performance, viability or standing of your department.

9. Describe the current level of morale in your department.

10. Please add any other comments.

Appendix B

Australian Physics Departments Survey 1994 & 1997

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Workshop on Future Directions in Quark Nuclear Physics

10 -20 March 1998, University of Adelaide

Contact Dr K Tsushima
email kisushima@physics.adelaide.edu.au or

Workshop on Nonperturbative Methods in Quantum Field Theory

2 - 13 Feb 1998

University of Adelaide
Special Research Centre for the Subatomic Structure of Matter and the National Institute for Theoretic Physics

Contact Dr Andreas Schreiber
email aschreibe@physics.adelaide.edu.au or
JOHN JOSEPH MILLAR

1946-1997

John Joseph Millar was born at Traralgon, Victoria, on 21 January 1946. He was the second of four children and his early years were spent on the family farm at Kilmany, south of Sale. His father died when he was four years old and the family relocated to Sale. John attended St Patrick's College where he developed a love of the sciences, especially physics. He was always a keen sportsman, playing football and basketball during his school years. He and his brother, Mick, trained with the Victorian schoolboys basketball squad. John matriculated in 1962 but because of his young age, remained in Sale for another year before proceeding to study at the University of Melbourne. He commenced his Bachelor of Science degree in 1964 at the University of Melbourne, majoring in physics and mathematics.

At university John met his wife Denise. They were married in 1969, just after John had finished his Masters thesis. He later converted from a Masters degree to a PhD. John's thesis topic, set by John Cowley and carried out under the supervision of Zvi Barnea, was the study of x-ray diffuse scattering by radiation induced defects in BeO — a longstanding unsolved problem which had arisen in the early days of nuclear reactor development. Using a precession camera and a special monochromator he had developed, John carried out diffuse scattering studies of neutron irradiated BeO with consummate skill and care. Some of the precession photos obtained were amongst the finest of their kind and provided him with very valuable data for trying to model the dislocation structures in BeO. A masterful and detailed analysis of the precession method as it affected the interpretation of diffuse scattering followed. This work formed a part of his thesis entitled "Diffuse Scattering of X-rays by Radiation Induced Defects" for which John was awarded a Ph.D. in 1973.

Lasting friendships were formed at this time with Peter Prager and Sylvia Mair. In the latter stages of John's PhD, Professor John Cowley took up an appointment at Arizona State University and it was decided that John and friend Steve Wilkins would complete the final stages of their theses with John Cowley in Arizona. Other Melbourne friends who moved to Arizona included Jeff Sellar, Tony Moon and Glen Shirley. John and others were interviewed by This Day Tonight as part of Australia's brain drain.

There was a very active scientific life in Arizona with weekly readings and discussion of draft chapters of John Cowley's Diffraction Physics textbook. There were also exciting graduate course lectures to attend on different physics topics such as Solid-State Physics (John Page jnr), Statistical Mechanics (David Hestenes), Applied Maths (Bill Kaufman). This was combined with a very enjoyable outdoor and social life in which John and Denise made some very special friendships with staff such as the Hansons, the Pages and with other graduate students such as Bonny & Henry Shuman from Philadelphia and Peter Traxler.

The Millars, the Wilkins, the Moons, the Shumans and Peter had a wonderful year hiking in the desert whenever they could and travelling around the south west area of the United States. Highlights included a visit to the spectacular Monument Valley and a raft trip through the Grand Catar. He moved to RMIT and was very supportive of the work done to establish the new school, Girton Grammar.

In July 1992, John was appointed Professor and Head of the Applied Physics Department at RMIT. John had four years at RMIT, sadly too short a time to see many of his plans fulfilled. He led the Department through a time of change as RMIT was given university status and worked hard to improve the cohesiveness and focus of the Department and also its linkages to industry. He oversaw the amalgamation of the Applied Physics department with the >
OBITUARY

physics section of the Department of Natural Science and Technology of the former Phillip Institute of Technology and introduced the new Instrumentation Stream of the Applied Physics Bachelor's degree course. He enthusiastically embraced the introduction of quality assurance procedures, setting up staff teams for each course and course year, and led the department in the development of two new Context Curriculum subjects which were offered to students across RMIT.

He played an active role in the acquisition of two major new instruments: a Fisons Scanning Auger Nanoprobe and a Phillips XXX Scanning Electron Microscope and fostered links between the department and industry.

With the collaboration of his colleague Marek Kijek, who had come from Bendigo to RMIT at about the same time, he continued his research using electron microscopy techniques for the identification of gunshot residue and supervised two postgraduate students, Gobert Lee and Harald Wrobel.

He was very proud of the achievements of staff members and students. Together with Richard O'Sullivan, he also collaborated with the RMIT Centre for Design on the development of energy efficient commercial devices, including the Kambrook AXIS electric kettle. He was proud to see several staff promoted to full professorships and associate professorships over these years.

John's Motor Neurone Disease was diagnosed in August 1995. By October, he was forced to step down as Head of Department. John bravely battled his disease, continuing to go to work daily and keep in touch with colleagues and students during 1996. However, by this stage he was confined to a wheelchair and life was becoming very difficult. He continued to go to work for the Wednesday seminars up until November, when he retired. He died in January 1997.

John Millar will be remembered by his many colleagues and friends in the physics community as an enthusiastic teacher, a lively friend and an energetic advocate of physics and its vital role in for Australia's industry.

Compiled by Richard O'Sullivan, based on contributions from David Millar, Zwi Barnea, Steve Wilkins, Peter Searle and Ian Bubb.

REVIEWS

Prompt Critical

Non-Computable Physics of Human Consciousness

Here we have a book which reminds me somewhat of the type of disputations that went on in the middle-ages, when too little was known about physics and astronomy to make much progress in understanding the structure of the universe. In his latest foray into explaining human consciousness, mathematician Roger Penrose further pursues his belief that quantum gravity holds the key. He started in 1989 with The Emperor's New Mind, dealt with his critics in 1994 with Shadows of the Mind and now in The Large, the Small and the Human Mind he presses forward in a debate with two philosophers and Stephen Hawking. Commencing with a discussion of space-time, there is little dispute with Hawking until he gets onto what he calls the "objective reduction" (OR) of the state vector, that is to say the collapse of the wave function. Penrose considers it related to quantum gravity, which Hawking disputes. Mix in Turing machines, Godel undecidability and the postulated non-computability of quantum gravity and the brew becomes heady indeed.

The rub of applying it all to the brain is to identify structures where the required physical effects mightoperate. Penrose considers that they happen in the microtubules within the branches of neurons which lead to the synapses where adjacent neurons are influenced. Nobody can really say whether he is right or wrong. Neurobiologists need to better understand these and search for other appropriate structures in the brain which might be involved.

And, of course, physicists need to develop what Penrose regards as a major revolution in physics, developing quantum gravity to the point where the two disciplines can begin to talk to each other. Penrose does not see any room for conscious mentality in our present-day world view. Hence the call for a revolution. This is where the rest of the book gets rather bogged in philosophy which boils down to which discipline, biology or physics, will come up with the answer. But does physics subsume biology? Will they do it together? You had better read the book.

Avid Penrose fans will not be at all surprised to flip the pages and see diagrams of chess boards and polyominous tiling the plane. I was greatly taken by his pictorial use of Dirac's bra-ket notation - a nice way of presenting it to students! I think I could read "The Large, the Small and the Human Mind" a hundred times and still be fogged in places. But if I wasn't, I might be well on the way to solving that supreme mystery myself.


Colin Keay
Reviews Editor

Perfect Form

Don S. Lemons
Princeton University Press
Princeton 1997
xii + 117pp., US$29.95 (paperback)
ISBN 0-691-02663-7

This is a brilliantly written introduction to the use of variational methods in elementary physics at the undergraduate level. It starts by enticing readers with little mathematical preparation into its first chapter. Accordingly, only the concepts of path length and principle of least (stationary) time are initially used to discuss simple optics problems, which are already known to undergraduate students. Only after having entranced the reader by the use of such methods, within a simple physical context, is the calculus of variations developed and a beginning made to analytical mechanics.

Perfect Form is the perfect book for self-study. At a time when many physics departments are retrofitting their teaching methodologies, the present text allows a directed introductory reading program to cover such material. As a self-reading book, Lemons is much more user friendly and physically intuitive, although more elementary, than say Weinstock, Lanczos or Yourgrau and Mandelstam (all available in Dover paperback in the same price range). In analytical mechanics it covers material at similar depth to Kibble but not as thoroughly as Goldstein. The book deals with Euler-Lagrange equations but not with Hamilton-Jacobi equations, generalised co-

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Australian & New Zealand Physicist Volume 34, Number 11/12, November/December 1997
Atoms and Their Spectroscopic Properties
VP Shevelko
Springer-Verlag, Berlin 1997
x + 202pp., DM168 (hardcover)
ISBN 3-540-61789-2

This book is volume 18 in a popular and diverse series of monographs on Atoms and Plasmas. Unlike many others in the series (e.g. Volume 1 - Kessler's book on Polarised Electrons) it is clearly a reference book, intended for the serious worker in the fields of Atomic Physics, Gaseous Electronics and Plasma Physics. It consists of a large collection of tabulated values of atomic collision cross sections and radiative characteristics of neutral and weakly ionised atoms. Each section is accompanied by a brief introduction to the terminology that is used and the way in which the data that is presented for a limited number of systems can be extrapolated to others by the use of suitable scaling laws. For this a reasonable proficiency with quantum mechanics and spectroscopic classification and notation is required.

The first two chapters, on Atomic Structure and Spectra and Oscillator Strengths and Transition Probabilities contain much useful, tabular information on ionization potentials and binding energies of atomic shell, electron affinities of stable and metastable atomic negative ions, fine and hyperfine-structure splittings, isotope shifts, radiative lifetimes and oscillator strengths. The remaining three chapters cover processes such as photoionization and radiative recombination, dipole polarizabilities of atoms and ions, static dipole polarizabilities, Bremsstrahlung, electron-atom and electron-ion scattering, and ion-atom scattering. These are by no means comprehensive data compilations but focussed, for example in the case of electron and ion scattering, on tabulations of collision cross sections for H and He. Whilst the bibliography is extensive and useful I also found some of the references and tabulations a trifle dated although this is no doubt an occupational hazard for a book such as this which relies heavily on prior data compilations (e.g. International Atomic Energy Agency Journals).

This is a useful reference book for scientists in the fields of atomic and plasma physics but it is certainly not a textbook for these fields.

Contemporary Nuclear Shell Models
X-W Pan, DH Feng & M Vallieres
Springer-Verlag, Berlin 1997
xii + 409pp., DM98,00 (hardcover)
ISBN 3-540-62551-8

The Shell Model is one of the cornerstones in Nuclear Physics and as this volume illustrates it continues to provide an active and dynamic area of research.

The book, which is part of the Springer lecture note in physics series (No 482) has evolved out of a two day workshop held in Philadelphia in April 1996. This workshop brought together 36 participants from 10 countries with the aim of reviewing contemporary methodologies and current applications of the nuclear shell model. The reviewers have sought, and to a large degree succeeded, to provide an up to date source book of what are the current issues in the area as well as providing, in reasonable detail, the approaches being used.

This is not a volume for beginners in the area, but anyone working in the area of nuclear shell model theory is likely to find it of interest.

With only two exceptions all the articles have an extensive reference list with many of these dating from 1995 and 1996, making it very useful for someone wishing to update their knowledge of the area.
1018, it is sufficient that the calculations are beginning to provide a shell model description of collective rotation. Indeed, Zucker and others present large scale "traditional" shell model descriptions of backbending which are comparable to that from the Hartree-Fock-Bogoliubov approach.

One disappointment was the absence of the article by Koonin on "Shell Model Monte Carlo Methods" which is to appear independently in Physics Reports. As this area is one of the more significant new approaches, I am sure the editors were also disappointed that it could not be included to make their volume more comprehensive.

While the book is primarily for devotees of nuclear theory, the article by Brown on "Order and Disorder in the Nuclear Shell Model" probably deserves wider readership.

On balance: an excellent book for the experts!

Aidan Byrne
Dept of Physics/Nuclear Physics
ANU

Why Toast Lands
Jelly Side Down
Zen and the Art of
Physics Demonstrations
Robert Ehrlich
Princeton University Press
Princeton 1997
x + 196pp., US$14.95 (paperback)
ISBN 0-691-02887-7

If you have given up doing demos in your classes/lectures because you lack time to find or assemble complex apparatus, or because they are too dangerous to risk nowadays in a litigating society, or perhaps because they are more likely to illustrate Murphy than Newton, take heart and read this book! The author of Turning the World Inside Out and 174 Other Simple Physics Demonstrations (1990), as well as other works, Ehrlich's passion is to get us all back to demonstrating our science classes and lectures. Although the "Zen" in the subtitle was initially a little off putting, it turned out to simply refer to the author's belief that the best demos are "simple ones, based on everyday objects and phenomena."

While many of the demonstrations presented are accessible to high school students the mathematics and formulation assumed suggests that most are pitched at the first year of undergraduate study. One of the things I liked about this book with its emphasis on utilising common items and appliances, is the clear message, albeit one which students are so prone to forget, that physics involves everyday actions, items and events.

The book commences with a most valuable section on how to design and customise your own demos, with an modest emphasis on "Erlich's three laws", namely: keep it simple, make it pedagogically sound, and please, get the physics right! This is followed by 109 demos in mechanics (of course), optics, thermodynamics, and even modern physics. Each is treated under three headings: Demonstration, Equipment, and Discussion. My favourite? Hard to choose but for something esoteric try the anti-Hero engine constructed by pushing slanted holes in an aluminium soda can, weighting it with a taped down steel ball, and watching it begin to rotate as it sinks in a bucket. For something really simple that you should have thought of yourself, how about demonstrating parabolic trajectories by rolling a ball slowly up a slightly inclined overhead projector surface.

Not only is the effect of gravity effectively slowed down for easier assimilation but the whole class gets the benefit. (Overhead projectors are great sources of heat as well!)

The book reads clearly, the illustrations, while smaller than I like from my students are reasonably clear, and it does not have many typos. Good value for any physics shelf.

Lynden J Rogers
Avondale College
Coomabong, NSW

Quantum Mechanics on Phase Space
FE Schroeck, Jr
Kluwer Academic Publishers
Dordrecht 1996
xvi + 696pp., US$295 (hardcover)
ISBN 0-7923-3794-8

This necessarily mathematical exposition of a new formalism of quantum mechanics is not for the faint hearted. Indeed, on a first reading, the "physicist" is urged to skip the most of the fairly dense mathematical detail in the first two thirds of the book. The viability of that strategy is not entirely clear, even for a first reading one needs greater commitment to begin to appreciate the scope of research contained in this book.

The author's main aim is to bring together recent work on the formulation of quantum mechanics on phase space and to put the new formalism in context by uncovering the connections with traditional approaches to quantum mechanics. To this end Chapter 1 is a "basic" review of quantum theory requiring the reader to be comfortable with swift transitions between projection valued measures and positive operator valued measures on Hilbert space, for example. To the less mathematically prepared, this Chapter and its associated mathematical appendix serves as a good introduction to these concepts. The same is true for Chapter 2 which deals with the experimental foundation of quantum mechanics and the interpretive view that leads to the motivation of this extension to the theory.

Chapter 3 is pure mathematics: group representation theory, Weyl algebra, and representations of the Galilei and Poincare groups. Chapter 4 provides some relief from the rigor of the previous chapter with discussions on various consequences of the formalism, including the connection to classical mechanics, quantum field theory, and an instructional and amusing section titled 'Spring cleaning in the house of quantum mechanics'. The final chapter deals with foundational relationships to quantum logic, measurement theory and philosophical aspects.

From the foregoing it should be clear that the audience for this book would be solely composed of researchers and postgraduate students. Certainly, for the specialist whose interest lies in this or the related areas of geometric quantisation and quantum logic, this is a book of great significance. However, as this book contains a large amount of useful review material and does not deal with the current status of quantum theory, as well as excellent and extensive introductory material on the mathematical foundations, it would make it a valuable addition to a departmental library as a reference text, or, as suggested by the publishers, a reading supplement for a graduate course in quantum mechanics.

Lloyd CL Hollenberg
School of Physics
University of Melbourne

Dosimetry of External Beta Rays for Radiation Protection
ICRU Report 56
ICRU Publications
Bethesda MD 1997
xii + 133pp., US$60.00 (paperback)
ISBN 0-913994-55-6

Several years ago I would have thought that the dosimetry of beta rays external to the human body would have been mainly of academic interest only. However, the reactor accident at
REVIEWs

Chernobyl, where external beta radiation significantly contributed to the death of several workers, changed that view overnight. Beta ray dosimetry has always been more complicated than photon dosimetry and ICRU Report 56 summarises measurement techniques and calculation methods to determine the dose distribution of external beta rays in humans. The "critical" organ for external beta irradiation is the skin and the ICRU Committee under the chairmanship of W. Cross devotes two of the ten sections of the report to the radiobiological basis of skin dosimetry and the resulting quantities relevant to beta ray determination. Like the whole report, these sections are very comprehensive and so they are not necessarily suitable as a general introduction to the field. They are followed by a review of beta sources and the physical interaction of electrons with matter. Monte Carlo calculations are the focus of a section on calculation of dose distributions, however, the main part of the remaining report is devoted to measurement techniques. This is an excellent summary of currently available techniques ranging from extrapolation chambers to solid state detectors. As with many ICRU reports, "Dosimetry of External Beta Rays for Radiation Protection" is primarily a very valuable resource for everyone concerned with radiation safety. The text sections are complemented by five appendices presenting a huge amount of data such as tables of stopping powers and dose distributions for various beta source arrangements. For those still not satisfied, some 15 pages of references are provided to allow everyone to follow up on points of interest. Next time I have to deal with beta rays, my first port of call will be this report.

Tomasz Kron
Newcastle Mater Hospital

Convex Analysis

R Tyrrell Rockafellar
Princeton University Press
Princeton NJ 1997
xxxi + 451pp. US$22.95 (paperback)
ISBN 0-691-01586-4

Rockafellar's Convex Analysis, first published in the Princeton Mathematical Series in 1970, has seen ten reprints and is now available in their prestigious "Landmarks in Mathematics and Physics" series. This text has been a foundational "bible" to all interested in the theory of optimisation; a subject developed from a study of those extremal problems which arise in so many areas of applied mathematics and are the concern of economists, engineers and physicists.

'Terry' Rockafellar has been a father figure to a generation of mathematicians working in optimisation. For over twenty years he has attracted to the University of Washington Seattle a large active group of research students whose influence has spread throughout North America, Europe and Australasia.

The text is the first systematic presentation of material centred around the basic concept of convexity of functions and sets. It is dedicated to Werner Fenchel, a pioneer in this area. The material is organised into subject matter by parts. The applications in Parts VI and VII on constrained extremum problems and minimax theory will be of most interest to physicists and the early theory can be referred to for fuller explanation where necessary. A useful index has been included for this purpose. A constraint is that the material is in the text is confined to n-dimensional Euclidean space. Nevertheless, much can be readily generalised for a dimensionless treatment, Rockafellar's best known disciple is Frank Clarke from the University of Montreal who developed much of his teacher's theory for a non-smooth analysis of locally Lipschitz functions and in a dimensionless context. This work has application in the calculus of variations and optimal control.

It is a pity that the book is only a reprint, even the bibliography has not been updated. But maybe a new edition attempting to discuss the work that has resulted from this text would be a mammoth task running into several volumes.

Nevertheless, this remains a seminal text and indispensable to workers in any associated field.

J R Giles
Department of Mathematics
University of Newcastle

Wave Interference

Mike Moloney
Physics Academic Software, AIP
New York 1996
vi + 45pp + DOS disk, US$100.00 (dinder)
ISBN 1-56396-586-0

Many designers of Physics courses are currently considering using computer software in parallel with lecture courses, to enable students to experience an approach via simulation which complements the equation-based approach of lectures or experimental investigations in laboratories.

A range of software packages with accompanying manuals are available, and these generally offer instructional benefits combined with drawbacks.

One such drawback is the absence one often finds of an appropriate balance between the soundness of the physics and the slickness of the graphics and user interface. Students are used to software with a sophisticated interface, offering good control over inputs and outputs, and an on-line help feature which obviates the need for reading the manual. Instructors will want the software to illustrate well the salient points of the topic, and to offer a number of different approaches to difficult areas, to enable students to work first around, then through conceptual stumbling blocks. Another drawback is the necessity of the software and manual offering value for money. Very often the student will need a textbook for the lecture course as well as the program and manual for the computational physics or simulation sessions. If the combined bill for these approaches $200, then a substantial amount of user resistance and resentment will be evident, particularly if the topic involved is a minor element of a full year programme in physics.

Given these preliminary comments, it is hard for me to be too enthusiastic about Wave Interference in the context of Australian physics courses. At around $A130, it is a very expensive option, as it covers only one aspect of optics or wave physics. Its user manual is no more than that, and students would certainly need a good textbook to accompany it. Furthermore, the software uses essentially only one approach to wave interference, using phasors. According to the manual, "A rotating vector is referred to as a phasor. Phasors are useful because they can be treated as vectors and added vectorially to find the sum or resultant of the disturbances produced by two or more waves propagating through a region."

Phasors to me are one way an instructor might consider using in teaching interference and diffraction. I don't find them particularly helpful, as my mental model of interference is based on waves on a pond or plane waves, but they will be of use to some students. I would expect a range of other approaches to supplement phasors in a satisfactory software package teaching interference and diffraction.

Another criticism of Wave Interference is that it covers only enough of interference and diffraction to be of use in first or second year courses. The only diffraction topics it treats are the circular aperture, and fabric as a 2-D grating.
A more viable offering as a computational physics text and program covering areas of optics is “Waves and Optics Simulations”, from John Wiley and Sons, part of the series Consortium for Upper-level Physics Software. This has the disadvantage of requiring a Borland Turbo Pascal compiler, but it has enough material in it to permit usage in both second and third year physics courses. We have used it in our courses for two years now, and have sent a very substantial list of corrigenda to Wiley, so the second edition should be very well worth your consideration.

As a final comment, I believe we are at the moment in an unsatisfactory transition phase. In a couple of years, publishers will offer textbooks integrated with software, so that for $140 we will get both. It is very hard to ask our students to buy both the textbook and the software at current prices, and this is holding back the impact of computers in physics teaching and disadvantaging our subject.

Ross McPhedran
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Coronal Physics from Radio and Space Observations
Gerard Trotter (ed)
Springer-Verlag, Heidelberg 1997
xvi + 226pp, DM88 (hardcover)
ISBN 3-540-62797-9

This book, of thirteen chapters, each by a different set of authors, presents the proceedings of the CESRA Workshop held in Nuan le Fuzeller, France, June 1996. The first 8 chapters summarise the observational results and conclusions presented by each working group, and the last 5 describe proposed, or recently upgraded, ground-based radio observatories.

These latter five chapters will provide interesting and easy reading to general astronomers, but the preceding eight chapters will be comprehensible to solar specialists only. This is not because of a lack of writing skills in the authors, but because of the difficulty of the topic. A workshop naturally concentrates, not on that which is understood, but on the thorny problems at the battle front. But that is only part of the problem, solar physics seems to be a ‘mature’ subject, solar flares radiate energy in almost every conceivable form, from radio to gamma-rays, from super-thermal electrons to relativistic protons, and from mass motion to shock waves, etc, yet as Bastian & Vlahos say, despite decades of effort, ‘the basic physics of these phenomena and their relationship to each other remains a vigorous area of inquiry’. An old sceptical solar physicist, such as the reviewer, seems to be hearing similar confusing evidence and the same inconclusive debates as those he was hearing when he left the subject 15 years ago.

All the authors are optimistic that more detailed observations will break the impasse. Almost certainly some advances will occur, but nonetheless, the underlying problem may be more fundamental. In many areas physics has been extraordinarily successful in providing precise understanding and consequent forecasts. In other areas, such as turbulence and weather, behaviour has proved to be unstable and largely unpredictable. The reviewer believes that solar activity is of this latter kind.

RA Duncan
Australia Telescope National Facility

New Books

States of Matter- States of Mind
A Barton
IOP Publishing, Bristol 1997
xiii + 384pp, £25.00 (paperback)
ISBN 0-7503-0418-9

The Emergence of Complexity in Mathematics
Physics, Chemistry and Biology
B Pullman (ed)
Princeton University Press
Princeton NJ 1996
xviii + 472pp, £39.50 (paperback)

The Theory of Superconductivity in the High-Te Cuprates
PW Anderson
Princeton University Press
Princeton NJ 1997
xii + 446pp, £55.00 (hardcover)

Quantum Field Theory in Condensed Matter Physics
AS Tewelk
Cambridge University Press
Cambridge UK 1997
xvi + 332pp, £47.95 (paperback)
ISBN 0-521-58989-4

QCD and Collider Physics
R K Ellis, WJ Stirling & BR Webber
Cambridge University Press
Cambridge UK 1996
xiv + 433pp, £80.00 (hardcover)
ISBN 0-521-51899-3

Computational Physics
Problem solving with Computers
RH Landau & MJ Paez
John Wiley & Sons, New York 1997
xxviii + 520pp, + disk, £41.50 (hardcover)
ISBN 0-471-11590-8

Californium-252
Isotope for 21st Century Radiotherapy
JG Zierhacker
Kluwer Academic Publishers,
Dordrecht 1997
xxi + 300pp., US$170.00 (hardcover)
ISBN 0-7923-4543-6

Information Dynamics and Open Systems
RS Ingarden, A Kossakowski & M Ohya
Kluwer Academic Publishers,
Dordrecht 1997
ix + 307pp., US$154.00 (hardcover)
ISBN 0-7923-4543-6

Gravitation and Cosmology
S Dharandhur & T Padmanabhan
Kluwer Academic Publishers,
Dordrecht 1997
ix + 303pp., US$137.00 (hardcover)

The Quark Machines
How Europe Fought the Particle Physics War
O Fraser
Institute of Physics Publishing
Bristol 1997
xvii + 219pp., £55.00 (paperback)

35TH ANNUAL GENERAL MEETING

The 35th Annual General Meeting of the Australian Institute of Physics will be held at

1/21 Vale St, North Melbourne

February 12th 1998
at 12.30 pm

Agenda

1 Apologies, recording of proxies
2 Minutes of the 34th meeting
3 Business arising from the minutes
4 President’s report
5 Treasurer’s report
6 Appointment of Auditors
7 Any other business.

Moira Welch
Honorary Secretary

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1998

Jan 19 - 20  Workshop on Bose-Einstein Condensation
Conference Centre, University of Auckland
Contact Workshop Secretary Dr Lev Plimak, l.plimak@auckland.ac.nz

Feb 2 - 13  Workshop on Nonperturbative Methods in Quantum Field Theory
Special Research Centre for the Subatomic Structure of Matter and the
National Institute for Theoretic Physics, University of Adelaide
Contact Dr Andreas Schreiber, email aschreib@physics.adelaide.edu.au or

March 10 - 20 Workshop on Future Directions in Quark Nuclear Physics
Special Research Centre for the Subatomic Structure of Matter and the
National Institute for Theoretic Physics, University of Adelaide
Contact Dr K Tsushima, email ktsushima@physics.adelaide.edu.au or

March 10 - 20 Workshop on CP Violation
Special Research Centre for the Subatomic Structure of Matter and the
National Institute for Theoretic Physics, University of Adelaide
Contact Dr He Xiao-Gang, email hexg@dirac.ph.unimelb.edu.au or
Antarctic Astronomy: Looking at the Beginning of the Universe From the End of the Earth

JOHN STOREY

The 1997 Pawsey Lecture was presented on the first of August at the University of Tasmania’s Stanley Burbury Theatre in Hobart. Several distinguished guests were present including Sir Guy Green, Governor of Tasmania, and members of the Pawsey family. The following is a brief summary of the lecture.

Why do Astronomy from Antarctica?

Much of astronomy concerns itself with understanding the origins of things:
- How did the sun and the solar system (including the earth) form?
- Where do galaxies come from?
- How did the Universe evolve from the structureless big bang to the present intricate web of galaxies, galaxy super-clusters, voids, etc?

Infrared and submillimeter astronomy represent two of the most effective tools for pursuing these studies. These longer wavelengths (compared to visible light) not only convey the bulk of the energy output from cooler "proto" objects, but also penetrate the dusty universe much better. In addition, at larger redshifts (z) the familiar visible and near-UV spectra are redshifted into the infrared. At a z of 2.5, for example, the important Hα line - so well studied by optical astronomers - appears at a wavelength of 2.3 microns. The cosmic microwave background radiation (CMBR) has a black-body spectrum that peaks at around one millimetre. A wealth of information can be gained from the subtle anisotropies in the spatial distribution of the CMBR, and from the departure from a pure Planckian spectrum in particular directions. Finally, the main "cooling" spectral lines that dominate the energy balance of collapsing molecular clouds are also to be found in the sub-millimetre.

The history of infrared and submillimeter astronomy has been one in which major advances in understanding have followed rapidly on the heels of technological progress. In order to dramatically increase our knowledge, let us therefore ask for an additional factor of ten in sensitivity over what can presently be achieved. Where is this "factor of ten" likely to come from? It might be achieved with:
- Better (larger) telescopes
- Better instruments
- Better sites

In the near- and mid-infrared, the largest telescopes in existence or under construction are 8 to 10 metres in diameter (e.g., Keck, Gemini, and Europe’s Very Large Telescope). The price tag for a single 10 metre telescope is around $100 million. With the cost of a telescope rising almost as the cube of its diameter, it is clear that the next "factor of ten" will not be coming from a simple increase in telescope size in the near future!

The quantum efficiency of near-infrared detectors now exceeds 80%, and arrays of 1024 x 1024 pixels are available. Even in the mid-IR, 256 x 256 arrays are available with quantum efficiencies exceeding 40%. Instrument losses can also be extremely small, especially if reflective optics are used. Small gains in sensitivity are foreseeable, but it is clear that existing instruments are close to achieving theoretical performance limits.

This leaves a better observing site as the only hope for a large improvement in our capabilities. Measurements we have carried out at the South Pole have shown that the near-IR sky background can be up to a factor of 100 lower than that at temperate sites. Here at last is our next "factor of ten". (With a background-limited detector, sensitivity goes as the square root of the background flux.) In addition, the incredible dryness of the atmosphere offers dramatically improved transmission at many wavebands, even opening up some regions of the spectrum that are otherwise totally inaccessible from the ground. This is particularly so in the sub-millimetre, a spectral region still barely exploited - largely because of the extreme difficulty of making observations from temperate sites.

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aircraft, and operates autonomously for 12 months at a time. The AASTO is currently undergoing shake-down tests at the South Pole, prior to its first remote deployment.

An important feature of the AASTO is its very low environmental impact. The antarctic plateau is a pristine wilderness, and we should only carry out research there if we can do so without damage to the environment. Astronomical research is a very good example of the kind of research that is largely passive – the measurements themselves create no environmental disturbance, only the infrastructure required to support the measurements. An important element of minimising the impact is therefore the use of uninhabited, robotic installations, that require on annual servicing.

A Look to the Future

As we move into the next millennium, a review of Australia’s approach to antarctic science is appropriate. Australia has an outstanding record of achievement in Antarctica, and we should all be proud of ANARE’s history and of our present Antarctic Division. However the heroic days of antarctic exploration are over, and what is important now is for Australia to do the best science it can with the available resources. By far the most valuable scientific resource we have in this country is the intellectual vigour of our people – the students, scientists and technical staff at our government institutes, CSIRO and the universities.

To properly make use of this intellectual resource it is essential that an air link be established between Australia and Antarctica. It is no longer necessary to be a hero to work in Antarctica, but you do need to be able to get to and from the continent quickly. The realities of current academic life are such that spending weeks on a ship each year is simply impossible for most researchers. Until an airlink is established, Antarctica will remain inaccessible to most of Australia’s scientists, including many who could make an enormous contribution to our research programs there.

It makes no difference whether this air link is established through international agreement, by leasing ski-equipped Hercules aircraft, or by building a rock runway at Davis. As the US Antarctic Program has shown, involvement of the “mainstream” scientific community in Antarctic research is a powerful stimulus to the attainment and maintenance of research excellence. This is even more important for a small country like Australia, as we cannot afford not to involve our top researchers in each particular field. An air capability might also be the most efficient way of servicing an inland base (although tractor-traverse offers a viable alternative). In this way the plateau can be opened up for scientific work – not just for astronomy but glaciology, climatology and meteorite research.

With all of the best potential astronomical sites lying within the Australian Antarctic Territory, a wonderful opportunity now exists for Australia in what will certainly become a major new research area. The development of an international astronomical observatory on the high antarctic plateau is likely to occur in the first few years of the new millennium. Australia is ideally placed to play a leading role in this exciting new development, building upon our traditional strengths in both astronomy and antarctic research.

Where are the Best Sites?

At the present time, the only comprehensive data we have on astronomical conditions in Antarctica are from the US Amundsen Scott Station at the South Pole. However, the South Pole is not a particularly special place as far as the topography of Antarctica is concerned. Higher, drier, colder sites lie further up the plateau. Locations of particular interest include Dome C, Vostok (a Russian base) and Dome A. None of these locations is currently occupied during the winter (in the case of Dome A, no-one has even been there!) In order to fully assess the potential of the Antarctic plateau for astronomy, the AASTO (Automated Astrophysical Site-Testing Observatory) has been developed (see article in Sept/Oct 1997 Australian & New Zealand Physicist). The AASTO can acquire detailed data over a wide wavelength range from any site, even those that are uninhabited. This “robot” observatory can be placed anywhere on the plateau by ski-equipped Hercules.
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