WHAT IS THE UNIVERSE MADE OF?

SCIENTIFIC TEACHING CONTROVERSIES

PHYSICS ENROLMENTS IN
AUSTRALIA AND NEW ZEALAND
RF GD-OES For Depth Profile Analysis
A new tool for more in-depth investigations

Example of white pre-painted steel sheet.
Organic coating/Cr Sr/Al Zn Si/Fe Matrix

INNOVATIONS in GD-OES ... for the benefit of the analyst:
- Unique RF source (MARCUS-type) for sputtering of conductive and non-conductive materials
- New mode of detection... HDD (High Dynamic range Detector)
- New software algorithms for Quantification with RF source
- Highest Quality Simultaneous (and Sequential) Spectrometers
- IMAGE: New electronics and software allowing a complete qualitative and semi-quantitative analysis of unknown samples in less than two minutes.

The New MARCUS-type RF Source:
The combination of DC and RF generators coupled on the classic GRIMM lamp previously available from JY permitted the application of GD-OES to the analysis of the non-conductive materials, although some modifications were necessary to change from conductive to non-conductive samples. The new MARCUS type RF source (without a DC generator) permits the analysis of conductive and non-conductive materials without any instrument modifications, increasing the versatility of the GD-OES technique.

LasTeK
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Minister Kemp has now released the 'White Paper', 'Knowledge and Innovation: A policy statement on research and research training', and so far the responses in the press have been less than favourable. I comment briefly on one of the five key dot points from section I.2 ['The Need for Reform'] which states, "Research in our universities is too often disconnected from the national innovation system". I hope that when I attend the National Innovation Summit on 10th and 11th of February someone will properly define what is meant by the 'national innovation system'. The 'White Paper' retains the hope expressed in the 'Green Paper' that somehow industry will provide the additional funds to bankroll research and development in Australia. The Institute's "Response to the 'Green Paper'" ['The Physicist' Vol 36, Sept-Oct 1999] cautioned whether that was in fact realistic. The bottom line is that by international standards, funding for basic research in the universities needs to be at least doubled in line with that promised to the NHMRC as recommended in our response to the Green Paper. Some have suggested that a fourfold increase is needed to make Australia truly competitive. The reform of the ARC is long overdue but, without an increase in funding in real terms referred to above, the changes proposed may not amount to much. The Institute, with help from the Science Policy Committee, must seek to understand the implications of this new government policy. The Melbourne 'Age' of 27th January quoted an interview with the Australian of the Year, Sir Gustav Nossal, which touches on the issues above and I give the following quotes. 'Yesterday he began his year-long quest to show Australians how this country could benefit from the work of its scientists. The 21st Century would be dominated by science and technology, he said, with biotechnology and information and communication technologies being hugely important... One of the issues dear to many scientists, and well-known to Sir Gustav, is the drop in funding for university research that scientists claim has threatened the future of basic research. "I definitely believe universities need more support," he said. "Australia, by cutting support and funding, is drastically shooting itself in the foot."... to force commercialisation on to scientists who excelled at basic research would be detrimental to Australia, he said, 'There will be some scientists of real excellence who will never move away from basic science, they will be the E = mc² type of people and that's the most valuable science of all.'".

FATS have just forwarded a report on a speech given on 21st January at Caltech by President Bill Clinton in which he stated that support of science and technology is an investment in America's future! Particularly noteworthy are the increases in two areas relevant to physics:- The National Nanotechnology Initiative will receive S$US497m while the NSF will receive a S$US275m increase, double the size of any previous increase. Translated to our smaller population base, these sums work out to S$50m and S$68m Australian dollars respectively. These facts give food for thought.

The Physics HODs meeting was held in Canberra on the 22nd and 23rd of November and was attended by about two thirds of the Heads of Physics Departments or Schools from around the country. A separate report will be published in 'The Physicist'. The underlying concern expressed more or less universally was the erosion of funding at the departmental/school level. Further reductions in physics academic staff in our universities will lead to restricted course offerings and further erode the capacity of Australia to respond intelligently to the technological challenges of the new Millennium.

It is without doubt that 2000 will be a difficult year for most departments or schools of physics in Australia. Recent publicity about the fall in applications for entry to BSc programs across the country is of great concern. Salary levels upon graduation, perceptions regarding job prospects and the lack of recognition generally of the contribution the basic sciences make to the wealth of the country are among the factors that have lead to the present situation. Furthermore, the Institute has long recognised the need for more well-trained and properly rewarded teachers in our secondary schools but so far we cannot claim any success in bringing that about.

At the November Executive Meeting, we welcomed the Australian Society for General Relativity and Gravitation (ASGRG) as a Cognate Society of the Institute. Dr David McClelland, President of ASGRG, was in attendance.

The Annual Council Meeting will be held in Melbourne on the 8th and 9th of February. Amongst issues to be discussed will be benefits to members. In particular we will consider the special membership offer from the IOP that would be open to any AIP member and which would provide web access to three of the IOP journals of one's choice and all other normal benefits of IOP membership.

I would be glad to hear from members regarding matters that should be taken up either by the Executive or the Science Policy Committee. Last year I invited members to suggest success stories from Australian physics that could form the basis of several publicity flyers we would like to prepare along the lines of those produced last year by the American Institute of Physics. I have about three such stories that could be used but about a dozen are required in order for us to have any real impact.

What about it?

John Pillrow
EDITORIAL

What’s your dream?

One of the most famous sayings of last century was Martin Luther King’s “I have a dream!”. These days I hear everyone telling of their special “dream”.

Physicists have their own particular brands of dream. Some are fairly modest - to finally provide an accepted theoretical explanation for some observed phenomenon. Some are grander. To solve the world’s energy problems through development of a feasible nuclear fusion device or to develop a quantum computer (just drawing on material in the last issue of the ‘Physicist’) Some people have a succession of dreams which get fulfilled as time progresses. I heard one scientist who said he made an exciting discovery about every six months (he was a chemist). For many of us there is a much longer time in between excitements. But the dream keeps us going. Some people’s dreams may never get fulfilled. Those searching for extraterrestrial intelligence may only ever get garbled noise in their receivers. But they have a big dream! So they press on. Some scientists’ dreams are fairly private: they labour quietly along in their labs and hardly anyone knows what they are doing or why they are doing it. Often funding agencies don’t appreciate their dream either - probably because they are unable to transmit their own vision into a grant application which will grab those assessing it. Others work in a group and cause colleagues to be fired by their dream and join in. Funding allows travel and other excitement. These are the lucky ones. But, even for them, sometimes the dream comes to a bad end as a fatal or expensive flaw is discovered, an impasse which their intellectual cleverness or funding is unable to bridge.

I wonder what dreams our government has for our science? One obsessive dream of this government seems to be that scientists should work for less and not belong to unions! But they would also like us to invent a magic wand which could be waved and millions of dollars would pour into the economy. I wonder how many of you are applying for funding for wand research? In one of DETYA’s recent papers, they listed various attributes which employers found lacking in science graduates. These included “flair and creativity”. I looked up “flair” in my dictionary: its primary meaning was given as “a sense of smell”. Other meanings included intuition and discernment so I guess it means the ability to sniff out the solution to some particular problem.

There has been only a little research on how to educate for creativity. The same concern was discussed in an editorial in *Nature* (Vol 403, No 6785, issue of 6 January 2000). The suggestion there is that undergraduates be encouraged to look for creative answers to questions and also to ask questions about what they encounter in their everyday environment. It is also said that “Targets of publication output and other productivity measures undermine creativity psychologically as well as inducing a short-term, problem-solving outlook.”

It may be that some of the suggested government priorities may be mutually contradictory. Other suggestions one can find for fostering creativity include practice in the use of brainstorming, teaching certain basic research skills and the use of creative reading. We may need to consider how more scope may be provided for such activities but, in my experience, physicists tend to look askance at a person who appears in front of them armed with a large piece of butcher’s paper and a texta. Maybe we should be more tolerant of these procedures. I think we do try to inculcate the research skill of formulating and testing hypotheses but we probably have little patience with students who spend time with what we would consider to be the wrong hypothesis to start with. Creative reading involves thinking as you read of ways that you can use the information in your own particular setting or circumstance which may be quite different from that which you are reading about. But I have allowed my Ed Psych book to cause me to wander from my dream topic (yet, I hope, in a creative fashion).

Meanwhile let us continue to “Climb every mountain, ford every stream, follow every rainbow, till we find our dream!”

Robert Stening
MORE SCIENCE HISTORY

In a previous letter (Science History, The Physicist, vol 36, pp 166-7, 1999), I commented favourably on the wealth of historical articles published in The Physicist (a short list of references was provided) and asked whether there was an index of these articles. Prof H.C. Bolton has kindly written to me to point out that he has published a 25 year index of historical articles published in 'Historical Records of Australian Science' (Bolton, 1992), a publication of the Australian Academy of Science. As he points out, this index could be used as a reading list on the history of Australian science. At this stage, he does not have a definite intention to produce a similar index for The Physicist and its predecessors.

Prof Bolton has written an article about the history of scientific instrument making in Victoria up to 1914 (Bolton and Williams, 1998) which also may be of interest. On the topic of science and technology in the years 1939-1945 (also mentioned in my earlier letter), Ross (1995) would be an excellent and stimulating introduction to the history of that period and the manufacturing boom of the war years.

I hope readers will find the topic of the history of Australian science and technology of general interest, in the context of science and technology policy, as well as of historical interest.

References


Dr M.Keenotk Department of Mechanical and Mechatronic Engineering, University of Sydney, 2006 NSW

RENEWABLE ENERGY

In the article, "The Sun and the Wind. Green and Grey Electricity", published in the July/August 1999 edition of The Physicist, Arthur Pryor asserts that solar and wind generation of electricity are not realistic alternatives to fossil fuels. The arguments put forward by Pryor to support this statement are largely based on economic grounds. Several problems with this article were suggested and discussed by Andrew Blakers in his letter to The Physicist, September/October 1999. I would like to make further comments regarding Pryor's article.

A shortcoming in Pryor's economic analysis is that an important cost has not been included: the cost to the environment. Blakers has mentioned, for example, that costs such as CO₂ and coal resource depletion are being externalised by the coal-fired Bayswater station, and that Pryor's 18% discount rate is 'not appropriate in the context of nuclear waste disposal...and climate change arising from burning fossil fuels'.

Marginal user cost (MUC) may be defined as the cost of using an additional unit of the environment rather than preserving it. When this is neglected, and thus driven to zero, we have market failure if the MUC is not actually zero. In this case, the optimal price of goods or services calculated without consideration of the MUC will be different to the price which is optimal to society. The actual cost of generating electricity by burning fossil fuels may therefore not be lower than the cost of using solar or wind sources. Rather, when the environmental costs of oil, coal and gas derived energy are taken into account, the cost of electricity generated from such energy sources is likely to be very much higher than Pryor suggests.

Before dismissing solar and wind power as unrealistic alternatives based on economic rationalism, perhaps we should also be questioning the economic system upon which this "rationalism" is based, and economic rationalism itself. There are many cases where decisions based solely on economic rationalism seem to run against human values, morals, and even common sense. Pryor ends his article by acknowledging that people place a value on "green" sources of energy: "passion for nature and the sun and the wind is part of our make-up". Is there a problem with the system if economic rationalism does not extend to inclusion of the non-material or intrinsic qualities that people value? There is certainly justification to raise this question when matters as important as environmental issues are neglected from the equation entirely. The fact that there are people willing to pay extra money for "green" electricity, as Pryor notes, suggests that traditional economic rationalism is not the only factor to consider.

Of relevance to physicists, are education and science research funding which are often targets of economic rationalism.

I agree with both Pryor and Blakers in that we should be conserving energy. I would like to take this further, and suggest that the problems we should be tackling are not only the way in which we generate our electricity, but the actual cause of our problems: namely society's usage of energy, society's lifestyle, and the attitudes of society towards the environment. The issue of the "energy crisis", as Pryor describes it, should be considered holistically, and not just as a problem with 'electricity generation and portable fuel'. We will not have successfully dealt with the problem until there are changes in the way society views and uses the environment.

In his article, Pryor also makes mention of current technical unfeasibility with respect to solar generated electricity. As with any problem, I am optimistic that unless there are fundamental limitations, a feasible solution would be found if sufficient resources, will, and effort were made available. Some points to note are that low-cost high-quality inverters that convert DC electricity to AC electricity are in fact available (http://www.pv.unsw.edu.au/info/gridcomm.html), and that solar cells exist which have efficiencies approaching 25%, not the 10-20% suggested by Pryor. More information on this may be found at the UNSW photovoltaics web site.

Anita Aditya
University of Western Australia

Footnote: I strongly support Pryor's idea of raising the price of petrol by '50% or more'.

WHITHER AIP?

You will have no idea who I am but I have been a member of AIP for about 25 years. I got to thinking after reading your editorial in the December issue. You raised a number of key issues about problem solving skills, the role & perception of physics etc.

I would like very much to share with you a bit about my career and the significant role that physics played in it. It may be useful to share with other colleagues and students.

Please keep in mind that I am no great academic. I am not dumb but I always had to get through by sheer determination & hard work.

Back in the early 70's I had the "misfortune" of attending an open day at UNSW. I had already enrolled & been accepted into medicine at Sydney Uni (I had my heart set on being a paediatrician). I met a wonderful person called Prof David Morton who had a dream of developing practical physics training for people to work in industry - I was hooked.

The reality hit me well into the course. One - I was certainly no rocket scientist and Two the chances of getting a decent job out there were slim.

By this stage I had met a lovely young lady
who was at college studying to be a preschool teacher. Well who else better equipped to cope
with me - a disoriented physics student! Needless to say I married her within months -
we have just had our 25th wedding anniversary - some people never learn.

Both of us obviously could not afford to be full time students so I found myself a job in the Biochemistry dept. of all places and entered into part time study. A godsend because now I was teamed up with mature students who had real jobs, families and had worked out the practical way to complete their physics training in the precious few spare hours they had!

Another significant lecturer who I admired was Hans Coster. I had always struggled with thermodynamics concepts. - I am still no expert. But Hans was able to help me along the road. There are two very important things that he helped get my head around & have greatly assisted my career. Namely- The concept that everything in life is a "system". It does not matter whether it be people, animals or industrial processes. But you have to understand the concepts of inputs, dynamics, feedback loops etc. The other was Entropy - this has been extremely important to me in managing multimillion 7 day 24 hour operations, as well as family.

My first real job was in the technical dept of a large aluminium manufacturer. I was thrown into getting a 2 colour infrared ratio pyrometer up and going. No one knew how it worked (let alone me) but it cost a lot of money and was still sitting on the shelf. That was just the start of being given projects that were in the too hard basket. Basically the company had no real idea of what to do with a "physicist" - it must have sounded good at the time to have one on your books.

Well after a couple of years we decided to buy a farm in Armidale & I worked as an assistant to Prof Neville Fletcher. Another great learning experience. He was able to kindle in me a deeper understanding of how you actually developed equations from scratch to explain phenomena - this had eluded me for years. This became extremely helpful when I found myself coaching students in many different disciplines & watched their eyes light up as the penny dropped and the mystique was gone.

At 29 I got a phone call to come back to Sydney and get back into industry. This was with Kimberly Clark. Reluctantly we packed up our kids and sold the farm. It was a very fruitful move(not to do with S) I found myself running a major part of the factory with new and old equipment and a lot of disenchanted employees. I rapidly had to utilise my technical skill and now go on a steep learning curve on managing people. It was a role that David Morton said I would finally find myself in - he was right - I was no outstanding academic - but I loved working with people and using my background in physics in a real down to earth manner on a daily basis.

I must have done something right. I got promoted and sent down to Albury (where we still live) and help set up and run a state of the art $40 million factory. We ended up having our colleagues in the US, UK & Korea coming out to learn our people and process techniques. Boy was I really putting into place the skills taught to me years ago in physics. Access to technical backup was difficult. I can assure you at 3am after 36 hours of no sleep and there is a very costly problem in your face you find yourself drawing on those skills you learnt in your Honours degree projects.

About 8 years ago I was asked by a number of key managers from other companies to leave my secure senior management job and jump into the recession (we had to have) and consult. It was hard leaving a team and working for myself - but basically it was a dream I wanted to fulfil and finally I thought I may have learnt just enough to help others.

During these years I have been actively involved in Quality Assurance, Strategic Planning, Food Safety, Organisational Change, Leadership & Management training - & finally got over most of my fear of public speaking - all my work comes by word of mouth. I work with a tight network of very qualified and experienced practical people. We love our job and the never ending challenges. So whither AIP? Whither physics? Never - My life would never be like it is without that wonderful background. Physics is still relevant - but we are not very good at marketing it. Used well it teaches people to question, know how get help from others, problem solve, conceptualise & be creative. It also helps us rationalise many complex issues that we are confronted with during our career. The only regret I have is that it has not helped me rationalise why our 2 year old son was killed when he fell asleep at the wheel when we moved out to our farm 2 years ago - I suppose not everything in life is logical.

I hope this story gives you guys some further hope about the future of Physics - It is not about half the stuff I cannot understand any more in the journal or the sometimes very esoteric topics I see for meetings. For 25 years I have fought a battle to make people from all walks of life understand the benefits of what Physics can contribute to. The best results I have achieved are by practical examples of its use and using very simple explanations while working through real live situations.

Anyway I have to go and teach our dog how to drive the tractor( suppose that's only fair as she taught me how to run sound after the cattle.

Ron Silk

The Physicist Volume 37, Number 1, January/February 2000

MILLENNIUM ISSUE

I can appreciate the feelings of an editor of 'The Physicist', doing an arduous unpaid job, faced with ungrateful readers. But my loyalties lie with the physicists of Australia and it seems to me that they were badly served by your millennial issue of Nov/Dec 1999. What is our editorial policy? Pretentious theory-worship and technophobia to judge from that issue.

There was an astruse article on 'the Baxter revolution'in statistical mechanics. Hands up those who have heard of Baxter. Hands up those who have specialised in statistical mechanics enough to read the article with profit and who also think that 'The Physicist' was an appropriate place to publish it. Do I see one or two hands? Or none at all? Then there was an article on 'Fusion in Australia'. Surely the fusion bandwagon has stalled and, for the last decade or so, simply everyone has agreed that the prospects of commercial fusion power via magnetic confinement are next door to zero and, via laser confinement, even less. But I guess it's great news that Australia is a world leader in the field. Next was an article on superheavy nuclei. Fascinating, to be sure, but one of the most supremely inapplicable fields of research known to physics. Then a survey of the history of the development of quark-lepton theory. Great stuff for those whose careers are given to that sort of thing, but opaque for that 99% of the profession engaged in down-to-earth matters.

Worst of all was the article by the geologist Professor Veevers rubbishing the 'Pangaea' proposals for the storage of radioactive waste at remote WA sites. This was presented to us by the Editor as the work of a physicist offering 'facts' that are 'correct and/or properly qualified'. I noted a silly cartoon but the only 'fact' was the claim that radioactive elements must be stored for 10 half-lives: plutonium-239 (half-life 24000 years) to be stored for 240000 years, and so on. What about uranium-238 (half-life 4.5 gigayears)? Presumably we should store it for 45 gigayears, but there it is, millions of tons of it, just lying around any old place, where God so carelessly left it when He made this earth 4 gigayears ago. The meaningful facts are the amount of radioactivity and its possible route of dispersal. It is not enough to claim, when discussing ocean transport, that 'one cargo unaccountably going down would irreversibly damage the biosphere'. On the contrary, experts would agree that, given that the material is contained to accepted standards, the deep ocean floor would be an appropriate and harmless place for a few cargoes.

As for the Pangaea repository, in order for the hazards to eventuate the radioactive material would have to diffuse out of the ceramic body,
penetrate the stainless steel or zircalloy can, ascend several hundred metres to the surface, travel several hundred kilometres, and insert itself into the food chain of its victims. Let’s have a scenario of how all that might happen. At the same time let us consider the obvious advantages of the proposal. First, that it would provide a service that many nations would eagerly use and so help to establish the one technology that can make, and has made, a huge contribution to non-polluting, multi-gigawatt electricity generation. Second, that it would earn a lot of money.

Put yourself in the place of an employer wondering whether or not to employ a physics graduate, or a student wondering whether or not to major in physics. What sort of impression would your issue give? It would suggest that physicists are pre-occupied with impractical theories and radical ideologies; that they are not at all interested in practical services and applications. Surely that is a disastrous impression to be giving.

Arthur Pryor
Visiting Fellow, Department of Physics
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Editor’s note:
In response to some of Arthur’s comments:
The article on “The Baxter Revolution” was included in honour of Rodney Baxter’s 60th birthday celebrations at the ANU in February, since Rodney is probably Australia’s most distinguished theoretical physicist. Barry McCoy’s article will have been too technical for many of our general readers, but will be recognized as a masterly overview by those in the field of statistical mechanics.

The article by John Veegers, who is actually a geologist, was included along with that of Alan Marks to try and present both sides of the debate on the nuclear waste issue. Readers can make up their own minds on the merit of the arguments.

For the rest: the articles we publish are a reflection of the work going on in physics departments around the country. They are contributed by or commissioned from members of those departments, by and large. Nevertheless, we would like to thank Arthur for keeping us on our toes.

C/JH

Satellite data tested over Australia

NASA’s latest satellite, the Earth Observing-1 satellite, set for launch in May, will contain the ‘Hyperion’ imaging equipment. This instrument will observe the Earth in 220 different spectral bands, ranging from the visible to the infra-red. This is a vast increase on the current satellites, such as LANDSAT, which observes in only seven bands.

The extra detail will enable studies such as the determination of the composition of rocks and soils, the types of algae or other pollutants in water or even the component types of tree in a forest. Even the water content of leaves or the level of stress in trees can be mapped.

CSIRO researchers, led by Dr David Jupp, are setting up five test sites to calibrate Hyperion using ground-based and airborne instruments. Australia has a wonderful variety of landscapes on which to perform these tests - ranging from Lake Argyle in WA, which looks dark from space, to the bright glare of the Strzelecki desert. These and other test sites used by CSIRO are indicated by dots on the map. The picture shows test instruments in place.

In future even more advanced satellites are envisaged. Among these will be the Australian Resource Information and Environment Satellite (ARIES).
Shaping Australia’s Future

This is the title of a paper prepared for the National Innovation Summit to be held in Melbourne on 10-11 February.

Among the points made in the paper are

- Our science and technology is still mainly oriented to agricultural and earth sciences and needs to be broadened.
- The average small size of Australian businesses inhibits their ability to compete in overseas markets and to innovate.
- Foreign-owned firms invest strongly in local R & D but they are less innovative and export-oriented than Australian firms.
- While our educational and research infrastructure and institutions have high standing internationally, “significant” investment in the coming years will be necessary to retain our present position.


Kangaroo in the Sky

University of New South Wales astronomers have been researching an area of the sky which includes the keyhole nebula and the spectacular star Eta Carina. Several clumps of gas are found in the region, which have been swept up by winds from Eta Carina. However, the heating expected to be associated with this is no longer observed, so it is supposed that the Eta Carina winds have turned off. Typically these clumps weigh more than ten solar masses and may one day themselves form into stars.

One of the clumps looks like a kangaroo. The picture was taken from infra-red emission from molecular hydrogen.

www.phys.unsw.edu.au

New CRC for Greenhouse Accounting at ANU

This new CRC is based at the Research School of Biological Sciences. Also participating are the CSIRO, the Bureau of Rural Sciences and state government agencies. The CRC aims to improve understanding of the terrestrial carbon cycle and its effect on global change. Professor Ian Noble, the Chief Executive Officer of the CRC, said that “In Australia, about 30% of human-derived greenhouse gas emissions come from the terrestrial carbon cycle through land-use practices such as agriculture, land clearing and forestry.”

Researchers at the CRC will work on describing and predicting the responses of biophysical systems to global change. Methods will be developed for measuring terrestrial ecological carbon fluxes, sources and sinks.

www.anu.edu.au

University of Canberra researchers exchange first Australian quantum key

A team of physicists and telecommunications engineers working at the University of Canberra's Centre for Advanced Telecommunications and Quantum Electronics Research (CATQER) have succeeded in exchanging and verifying a quantum cryptographic key using linearly polarised single photons as qubits. The 30 bit per second quantum key exchange was implemented using a laboratory based quantum key distribution test bed, believed to be the first in Australia, using the BB82 protocol devised by Charles Bennett at IBM. The quantum coded information carried by single photons cannot be covertly intercepted without introducing excess noise and so preserving the presence of an eavesdropper. Many believe quantum cryptography to be closer to practical realisation and application than other 21st century quantum information technologies such as quantum computing and quantum teleportation.

The random binary key was generated in the UC tested by Gallium Phosphide light emitters pulsed at 100 kHz. Non-orthogonally polarised pulses of weak collimated green light were attenuated to less than 0.1 photons per pulse on average in order to suppress pulses containing more than one photon. The UC team is currently investigating the feasibility of using optical low earth orbit satellites to distribute quantum keys worldwide with the assistance of Electro Optic Systems Pty Limited and the Australian Surveying and Land Information Group (AUSLIG). They are also currently working with colleagues at the ANU, Hamamatsu Photonics, and Stanford University to develop quiet lasers for use in quantum cryptography and other quantum physics based measurement and communication systems.

catqer@ozemail.com.au

Honours for Guy White

We congratulate Guy White, formerly of CSIRO in Sydney, for his well deserved recognition in the Australia Day honours list.

Pilbrow in International Resonance

AIP President, Professor John Pilbrow, was elected President of the International EPRI Society last October for a three year term. He is supported by a Vice-President in Japan, Secretary in Israel & a Treasurer in the USA. In January 2000 he was elected an Honorary Member of the "National Society of Magnetic Resonance" of India. Three foreign Honorary Members are elected each year.

XENA aids cement industry

A newly developed fast neutron and gamma ray technique is being used to control the raw mix composition of cement. The CSIRO X-ray belt analyser (XENA) is positioned directly on the conveyor belt transporting the raw material to the mill. It can accurately measure concentrations of calcium, silicon, aluminium, iron and minor elements independent of both horizontal and vertical segregation and independent of changes in belt loading.

A second analyser measures the composition and mineralogy of finished product cement in real time and on line. It is based on X-ray diffraction (XRD) techniques and Rietveld analytical methods. Data collections are very rapid as it detects the whole diffraction pattern simultaneously.

The work was performed by CSIRO in collaboration with Fuel and Combustion Technology Ltd for Adelaide Brighton Management Ltd.

HIFAR survives Y2K

The Australian Nuclear Science and Technology Organisation issued a news release on January Ist 2000 advising that their research nuclear reactor at Lucas Heights was operating normally, irradiating materials used to make nuclear medicine. Because it was built in 1958, it did not depend on computers for its operation.

Nevertheless the reactor was shut down from 11.50 pm until 12.30 am to confirm that external water, power and telecommunications services remained available. Normal operations were resumed at 12.30 am.

www.ansto.gov.au
WHAT IS THE UNIVERSE MADE OF?  
HOW OLD IS IT?

CHARLES H. LINEWEAVER  
University of New South Wales

For the past 15 years most astronomers have assumed that 95% of the Universe was in some mysterious form of cold dark matter. They also assumed that the cosmological constant, \( \Omega_{\Lambda} \), was Einstein's biggest blunder and could be ignored. However, recent measurements of the cosmic microwave background combined with other cosmological observations strongly suggest that 75% of the Universe is made of cosmological constant (vacuum energy), while only 20% is made of non-baryonic cold dark matter. Normal baryonic matter, the stuff most physicists study, makes up about 3% of the Universe. If these results are correct, an unknown 75% of the Universe has been identified. Estimates of the age of the Universe depend upon what it is made of. Thus, our new inventory gives us a new age for the Universe: 13.4 ± 1.6 Gyr.

"The history of cosmology shows us that in every age devout people believe that they have at last discovered the true nature of the Universe."

(E. Harrison in Cosmology: The Science of the Universe 1981)

Progress

A few decades ago cosmology was laughed at for being the only science with no data. Cosmology was theory-rich but data-poor. It attracted armchair enthusiasts spouting speculations without data to test them. It was the only science where the errors could be kept in the exponents — where you could set the speed of light to 1, not for dimensionless convenience, but because the observations were so poor that it didn't matter. The night sky was calculated to be as bright as the Sun and the Universe was younger than the Galaxy.

Times have changed. We have entered a new era of precision cosmology. Cosmologists are being flooded with high quality measurements from an army of new instruments. We are observing the Universe at new frequencies, with higher sensitivity, higher spectral resolution and higher spatial resolution.

1 COBE, ISO, IRAS, HIPPARCOS, HST, IUE, BeppoSax, Uhuru, ROSAT, Chandra, BATSE, VLA, ATCA, Arecibo, KAO, SOFA, SCUBA, BIMA, KECK, VLT, CFHT, MMT, UKIRT, AAT, CTIO, FLY'S EYE, JSO, JCMT, NTT, KPO, UKIRT, INT, JKT, WHT, Magellan, GTC, LBT, MAX, Kamiokande, Super Kamiokande, HOMESTAKE, VIRGO, LIGO, Gravity Probe-B, GINGA, ASTRO A, B, C, D, CERN, FERMILAB, STANFORD, DS1, MILAGRO, Gnn Sasso, SNO...

We have so much new data that state-of-the-art computers process and store them with difficulty. Cosmology papers now include error bars — often asymmetric and sometimes even with a distinction made between statistical and systematic error bars. This is progress.

The standard hot big bang model describes the evolution of the Universe. It is the dominant paradigm against which all new ideas are tested. It provides a consistent framework into which all the relevant cosmological data seem to fit. Progress has been made in working out the details of this hot big bang model — for it is the details which provide new, unprecedentedly precise answers to questions of cosmological importance: What is the Universe made of? How old is the Universe?

The CMB: cosmology's coolest new tool.

The cosmic microwave background (CMB) is the oldest fossil we have ever found. It is a bath of photons coming from every direction. These photons are the afterglow of the big bang. Their long journey toward us has lasted more than 99.99% of the age of the Universe and began when the Universe was one thousand times smaller than it is today. The CMB was emitted by the hot plasma of the Universe long before there were planets, stars or galaxies. The CMB is an isotropic field of electromagnetic radiation — the redshifted relic of the hot big bang. One of the most recent and most important advances in astronomy has been the discovery of hot and cold spots in the CMB based on data from the COBE satellite (Smoot et al. 1992). This discovery has been hailed as “Proof of the Big Bang” and the “Holy Grail of Cosmology” and elicited comments like: “If you're religious it's like looking at the face of God” (George Smoot) and “It's the greatest discovery of the century, if not of all time” (Stephen Hawking). As a graduate student analyzing COBE data at the time, I knew we had discovered something fundamental but its full import didn’t sink in until one night after a telephone interview for BBC radio. I asked the interviewer for a copy of the interview, and he told me that would be possible if I sent a request to the religious affairs department.
peaks at smaller angular scales are due to acoustic oscillations in the photon-baryon fluid in cold dark matter (CDM) gravitational potential wells. The detailed features of these peaks in the power spectrum are dependent on a large number of cosmological parameters including,

- $\Omega_m$, the density of matter (where $\Omega_m = \Omega_{\text{CDM}} + \Omega_\Lambda$)
- $\Omega_{\text{CDM}}$, the density of cold dark matter
- $\Omega_\Lambda$, the density of normal baryonic matter
- $\Omega_{\text{vac}}$, the density of vacuum energy (cosmological constant)
- $h$, the Hubble constant (giving the rate of expansion of the Universe)

The CMB comes from the surface of last scattering of the Universe. When you look into a fog, you are looking at a surface of last scattering. It is a surface defined by all the molecules of water which scattered a photon into your eye. On a foggy day you can see 100 meters, on really foggy days you can see 10 meters. If the fog is so dense that you cannot see your hand then the surface of last scattering is less than an arm's length away. Similarly, when you look at the surface of the Sun you are seeing photons last scattered by the hot plasma of the photosphere. The early Universe is as hot as the Sun and similarly the early Universe has a photosphere (the surface of last scattering) beyond which (in time and space) we cannot see (Fig. 1). As its name implies, the surface of last scattering is where the CMB photons were scattered for the last time before arriving in our detectors. The 'surface of last screaming' presented in Fig. 2 is a pedagogical analogue.

Since the COBE discovery of hot and cold spots in the CMB, anisotropy detections have been reported by more than a dozen groups with various instruments, at various frequencies and in various patches and swaths of the microwave sky. Fig. 3 is a compilation of recent measurements. The COBE measurements (on the left) are at large angular scales while most recent measurements are trying to constrain the angular scale and amplitude of the dominant first peak at $-1/2$ degree (the size of the full Moon). This dominant peak and the smaller amplitude

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*Figure 1. Our view of the Universe.*

In this spacetime diagram we are at the apex of our past light cone. All the photons we see come to us along the surface of this cone. One spatial dimension has been suppressed. When we look as far away as we can, we see the oldest observable photons — the CMB — coming from the wavy circle in the surface of last scattering (A, B and C are on the circle). The opaque surface of last scattering is the boundary between the current transparent universe and the hotter, denser, opaque, ionized universe. The figure gives the time, temperature and redshift of the big bang, the surface of last scattering and today. This is a comoving diagram, that is, the expansion of the Universe is not shown. We see the object C on the surface of last scattering as it was 13 Gyr ago. Today C has become C', but since the speed of light is not infinite, we cannot see C' now.

*Figure 2. The Surface of Last Screaming.*

Consider an infinite field full of people screaming. The circles are their heads. You are screaming too. Your head is the black dot. Now suppose everyone stops screaming at the same time. What will you hear? Sound travels at 330 m/s. After 1 second everyone stops screaming you will be able to hear the screams from a 'surface of last screaming' 330 meters away from you in all directions. After 3 seconds the faint screaming will be coming from 1 km away... etc. No matter how long you wait, faint screaming will always be coming from the surface of last scattering — a surface that is receding from you at the speed of sound ($v_{\text{sound}}$). This can be said of any observer — each is the center of a surface of last screaming. In particular, observers on your surface of last scattering are currently hearing you scream since you are on that surface of last scattering. The screams from the people closer to you than the surface of last scattering have passed you by — you hear nothing from them (grey heads). When we observe the CMB in every direction we are seeing photons from the surface of last scattering. We are seeing back to a time soon after the big bang when the entire Universe was opaque (screaming). If the Universe were not expanding, the surface of last scattering would be receding at the speed of light. The expansion of the Universe adds an additional recession velocity and makes the surface of last scattering recede at $-3c$. 
What is the Universe made of?

If we know what the Universe is made of, we know how it will behave and how it has behaved — we know its dynamics and shape and destiny — whether it will expand forever or collapse in a big crunch — whether it is spatially finite or infinite — whether it is 10 billion years old or 20. Many of these issues can be reduced to the question: Where does our Universe lie in the ($\Omega_m, \Omega_\Lambda$) plane? Observational constraints in this plane are then the crucial arbiters. Figure 4 can be used to translate $\Omega_m$ and $\Omega_\Lambda$ constraints into the words most commonly used to describe the Universe.

In cosmology we keep track of the components of the Universe by their densities: $\Omega_m$, $\Omega_{\text{CDM}}$, $\Omega_\Lambda$. These are all dimensionless densities expressed in units of the critical density, $10^{-29}$ g cm$^{-3}$ (9 orders of magnitude emptier than the best laboratory vacuums). If the Universe has the critical density ($\Omega_m = 1$), then its current rate of expansion is analogous to the escape velocity, that is, it will expand forever, asymptotically approaching no expansion as $t \to \infty$ (just as the velocity of an object with escape velocity asymptotically approaches 0). One can read from Fig. 4 that an ($\Omega_m, \Omega_\Lambda$) = (1.0, 0.0) universe is flat, decelerating and will expand forever.

Much Ado About Nothing

One of the most surprising recent advances in cosmology is that 75% of the Universe seems to be made out of nothing, i.e., the energy of the vacuum. I have assembled much of the observational evidence for this in Fig. 5. Recent CMB anisotropy measurements favour the elongated triangle in panel A of Fig. 5. This plot shows that if $\Omega_m = 0$ then $\Omega_\Lambda \sim 0.3$ is more than ~4$\sigma$ from the best fit and $\Omega_\Lambda \sim 0.1$ is more than ~7$\sigma$ away. The confidence levels in this diagram are very rough but the message is clear: if $\Omega_m = 0$, then low $\Omega_\Lambda$ models are strongly excluded by the CMB data. No other data set can exclude this region with such high confidence. The combination of CMB and supernovae constraints (Fig. 5B) provides strong evidence that $\Omega_m > 0$. If any $\Omega_m = 0$ model can squeak by the new supernovae constraints it is the very low $\Omega_m$ models. However these models are the ones most strongly excluded by the CMB data. The constraints shown in panels C, D and E support this result. Separately these data sets cannot determine unambiguously what the destiny of the Universe will be. However, together they form a powerful interlocking network of constraints yielding the most precise estimates of $\Omega_m$ and $\Omega_\Lambda$. The result is strong evidence and the best evidence to date that the Universe will expand forever, dominated by a 75% contribution from the vacuum.

I believe this result is robust because of a series of conservative choices made in the analysis and because it arises when the data sets are combined individually (as in panels B, C, D and E) or combined together (as in F). Systematic errors may compromise one or the other of the observations but are less likely to bias all of the observations in the same way.
The language used to describe the Universe, e.g. 'infinite/finite', 'open/flattened', 'accelerating/decelerating' and 'a universe which will expand forever and in a big crunch', can be confusing. However the boundaries between these various types of universe can be simply represented in the $(\Omega_m, \Omega_\Lambda)$ plane. For example, spatially open universes (3-D analog of the surface of a saddle, negative curvature) are in the lower left while spatially closed universes (3-D analog of the surface of a sphere, positive curvature) are in the upper right. Flat Euclidean universes are on the diagonal line between them. Flat and open models are spatially infinite; closed models are finite. Notice that one can have finite universes which expand forever and can be either accelerating or decelerating. One can also have infinite universes which collapse into a big crunch if $\Omega_\Lambda < 0$. A detail that is slightly ambiguous: if $\Omega_\Lambda = 0$ then $\Omega_m < 1$ universes expand forever while $\Omega_m > 1$ universes crunch. Observational constraints in this $(\Omega_m, \Omega_\Lambda)$ plane are given in Fig. 5; they favour accelerating, slightly open, but nearly flat universes with $\Omega_m = 0.3$ and $\Omega_\Lambda = 0.7$.

The $\Lambda$-CDM region of the $(\Omega_m, \Omega_\Lambda)$ plane fits the CMB, supernovae and other data sets and should be viewed as the new standard model of cosmology. Standard CDM with $\Omega_m = 1$ and $\Omega_\Lambda = 0$ is a simpler model, but circular planetary orbits are also simpler than ellipses. The results presented in Fig. 5F (Lineweaver 1999a) quantify the main components of the new standard $\Lambda$-CDM model. They are depicted in Fig. 6 and are as follows:

### Table of Contents of the Universe

- **75% Vacuum energy, cosmological constant**
  The vacuum of modern physics is not empty. It is seething with virtual particles coming in and out of existence. All this seething produces a vacuum energy (the zero point energy of quantum field theory) which has a negative pressure. Unlike normal mass which slows down the expansion of the Universe, vacuum energy speeds up the expansion. It's a bit like discovering compressed springs everywhere in the vacuum of space. These springs make the Universe expand. This mysterious stuff does not clump. It is the Lorentz invariant structure of the vacuum and its existence is probably most directly established by the Casimir effect and the Lamb shift. $\Omega_\Lambda = 0.65 \pm 0.13$ corresponding to $74 \pm 4\%$ of the Universe.

- **20% Cold Dark Matter (CDM)**
  Non-baryonic and non-relativistic, CDM density fluctuations collapse gravitationally. It clumps. Corresponding CDM potential wells (and hills) produce the hot and cold spots in the CMB and are the principal seeds for the formation of the large scale structure we see around us today (galaxies, great walls, voids etc). This non-baryonic stuff has never been detected directly. $\Omega_{cdm} = 0.19 \pm 0.09$ corresponding to $21 \pm 7\%$ of the Universe. Leading candidates for it are axions or neutralinos (see Turner 1999).

- **5% Normal baryonic matter**
  This is the normal stuff that stars and ourselves are made of. We breathe it, eat it and physicists study it. $\Omega_b = 0.04 \pm 0.02$, corresponding to $5 \pm 2\%$ of the Universe. This value comes from big bang nucleosynthesis calculations and deuterium measurements in quasar spectra. In terms of elemental composition this normal baryonic matter is 75% hydrogen, 23% helium, and 2% all other elements. In terms of phase (see Fukugita et al 1998, Cen & Ostriker 1998), it is 80% diffuse hot ionized gas, 17% stars and 3% neutral gas and dust.

The total density of the Universe is $\Omega_{total} = \Omega_m + \Omega_\Lambda = 0.88\pm0.05\%$ (Fig. 5F). The percentages listed above are based on $\Omega_{total} = 0.88$ (not $\Omega_{total} = 1$, most versions of inflation have $\Omega_{total} = 1$). The density from photons (from the CMB and from stars) is negligible: 0.006% of the Universe. I have left out one ingredient of the Universe because we don’t know whether it is important or not — neutrinos. We know their number density fairly accurately. It's the uncertainty in their mass which is responsible for our ignorance. Much effort is being put into measuring the masses of neutrinos. Potentially they could contribute more than all the baryons and probably as much as all the stars. A good guess might be $\Omega_\nu = 0.05\%$ where the upper limit comes from the tendency of relativistic particles to escape from small scale structures, i.e., if neutrinos formed more than 15% of the Universe, we would see much less small scale structure. The lower limit comes from the recent Super Kamiokande detection of a small but positive mass difference between two neutrino species (Fukuda et al 1998). They could be negligible at 0.3% of the Universe or they could be ~15% of the Universe (Turner 1999). A ~10% contribution would make $\Omega_{total} \sim 1$ as preferred by inflation and would reduce the contribution of $\Omega_m$ from 75% to 65%.

The values quoted above for the composition of the Universe are not universally accepted. A vocal minority of $\Lambda$-phobic cosmologists and particle theorists believe that any $\Omega_\Lambda > 0$ result has got to be wrong. Their reasoning goes something like
How old is the Universe?

In the big bang model, the age of the Universe, \( t_u \), is a function of three parameters: \( h \), \( \Omega_m \), and \( \Omega_{\Lambda} \). The dimensionless Hubble's constant, \( h \), tells us how fast the Universe is expanding. The matter density \( \Omega_m \) slows the expansion while the vacuum energy \( \Omega_{\Lambda} \) speeds up the expansion. Recently, large uncertainties in the measurements of \( h \), \( \Omega_m \), and \( \Omega_{\Lambda} \) made efforts to determine \( t_u(h, \Omega_m, \Omega_{\Lambda}) \) unreliable. Theoretical preferences were, and still are, often used to remedy these observational uncertainties. One assumed the standard model (\( \Omega_m = 1, \Omega_{\Lambda} = 0 \)), dat-

What could be wrong?

Doubts about some of the observations used here are discussed in Dekel et al (1998). The contribution of neutrinos (or another form of hot dark matter) to \( \Omega_m \) remains a wild card. It is possible that supernovae are not as uniformly bright as we believe. It is possible that the well-motivated assumptions used in the CMB analysis (gaussian adiabatic fluctuations, structure for-
A compilation of recent age estimates for the Universe and for the oldest objects in our Galaxy. Estimates of the age of the Universe are based on estimates of \( \Omega_\Lambda \), \( \Omega_m \) and \( h \). Galactic age estimates are direct in the sense that they do not depend on cosmology. Averages of the estimates of the age of the Galactic halo and Galactic disk are shaded grey. The absence of any single age estimate more than \( \sim 2\sigma \) from the average adds plausibility to the possibly overdetermined procedure of computing the variance-weighted averages. The age of the Sun is accurately known and is included for reference. The largest dot at 13.4 \( \pm \) 1.6 Ga (billion years) is the main result of the Lineweaver (1999) paper. This age range is shaded grey on the x-axis of the Fig. 8. Comfortingly, the Universe is older than the objects in it. This has not always been the case in cosmology and its absence has been a leading cause of cosmology bashing.

There has been some speculation recently that the evidence for \( \Omega_\Lambda \) is really evidence for some form of stranger dark energy (dubbed ‘quintessence’) that we have been incorrectly interpreting as \( \Omega_m \). Several workers have tested this idea. The evidence so far indicates that the cosmological constant interpretation fits the data as well as or better than an explanation based on more mysterious dark energy (Perlmutter et al. 1999a, Garnavich et al. 1998, Perlmutter et al. 1999b).

The Future

As the quality and quantity of cosmological data improve, the questions: What is the Universe made of? How old is the Universe? will get increasingly precise answers from an ever-tightening network of constraints. An army of instruments is coming on line. Better CMB detectors are being built; long duration balloons will fly; sensitive new high resolution interferometers will soon be on line and we all have high expectations for the two CMB satellites MAP and Planck. In the near future, new CMB measurements will reduce the error bars in Fig. 4 by a factor of \( \sim 5 \) and... if some inconsistency is found, force us to change our basic understanding of the Universe. Maybe inflation is wrong, maybe CDM doesn’t exist or we live in an eternally inflating multiverse.

The biggest prize of all may be something unexpected. We know that our model of the Universe is incomplete at the largest scales and that it breaks down as we get closer and closer to the big bang. It seems very probable that our model is wrong in some unexpectedly fundamental way. It may contain some crucial conceptual blunder (as has happened so many times in the past). Some unexpected quirk in the data may point us in a new direction and revolutionize our view of the Universe on the largest scales. Surely this is the golden age of cosmology.

What does this all mean for the physicists in the street? We should devote more effort to studying nothing — the vacuum. We should improve on measurements of the Casimir effect. Maybe one of us will invent a heat engine based not on a phase transition of water but on a phase transition of the vacuum. In
the past, on the few occasions where general relativity and quantum theory intersected (Ω, is a quantum term in a classical equation) exciting new things have emerged: Hawking radiation, entropy calculations of black holes and maybe soon a theoretical calculation of Ω, which will lead to a plausible theory of quantum gravity.

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AIP2000 CONGRESS

14th National Congress of the Australian Institute of Physics
Adelaide: 10 - 15 December 2000

The AIP2000 Congress, to be held at The University of Adelaide from Sunday 10th December to Friday 15 December, incorporates the following conferences:

- Computers in Physics Education (OzCuPE)
- Women in Physics (WIP)
- Solar, Terrestrial and Space Physics (STSP)
- 7th Vacuum Society of Australia Congress (VSA)
- Atomic and Molecular Physics and Quantum Chemistry (AMPOC)
- Condensed Matter Physics (CMP)
- 18th AINSE Nuclear and Particle Physics Conference (AINSE/NUPP)
- Australian Conference for Teachers of Physics (SASTA)
- AOS2000 - 13th Conference of the Australian Optical Society (AOS)
- Australian General Relativity Workshop - Australasian Society for General Relativity and Gravitation (ASGRG)
- Plasma2000 - 23rd AINSE Plasma Science and Technology Conference (AINSE)
- Astronomy and Astrophysics Conference - Astronomical Society of Australia (ASA)

The Congress will commence with a Welcome Reception on Sunday evening, 10 December and the Official Opening of the formal program will be held on Monday 11 December in Bonython Hall at the University of Adelaide. Apart from the technical program, the Congress will include a public lecture by Paul Davies, an exhibition, poster displays, Congress dinner and optional tours.

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PHYSICS ENROLMENTS IN AUSTRALIAN AND NEW ZEALAND UNIVERSITIES 1994 - 1999

JOHN DE LAETER, PHILLIP JENNINGS AND GRAEME PUTT

This is the eleventh of a series of triennial surveys of physics enrolments in Australian and New Zealand Universities.

This project began in 1974 with surveys by de Laeter [1] and Watson-Munro [2] for physics enrolments at Australian Colleges of Advanced Education and Universities respectively in the period 1963 to 1973. The original aim of the surveys was to collect data for planning purposes and to study the effects of Government policy on the physics profession.

In 1975 de Laeter and Watson-Munro [3] produced the first of these combined surveys for all Australian tertiary educational institutions covering the period 1965-1975. They repeated the exercise in 1979 [4]. Following the retirement of Professor Watson-Munro in 1979, Philip Jennings and John de Laeter combined to continue the surveys at triennial intervals through the eighties [5,6,7,8]. In 1993 the survey was expanded to include New Zealand universities and Graeme Putt joined the team [9,10].

We now have a consistent set of data covering the period 1968 to 1999 for Australian universities and from 1991 to 1999 for New Zealand universities. Originally, the surveys focussed on numbers of third and fourth year physics students. These were easier to identify than graduates in physics as some of them do double majors and are difficult to keep track of, while others graduate at mid-year. Although it is easier today to collect the data on physics graduates because it is required by the federal government, we have continued to count third and fourth year physics majors for consistency. They also represent a more realistic estimate of the enrolments in physics rather than the output of physics departments.

Beginning with the 1982 survey, we began to collect the total number of postgraduate students in physics and we now have a complete data set covering the years 1979-1999 for Australian universities (1991-1999 for New Zealand universities). Here again we chose to count the total number of postgraduate students to gain an indication of the size of the postgraduate effort. In earlier surveys we also estimated the number of pass, honours and postgraduate graduates each year.

Beginning in 1991, we also began to address gender issues because of the perceived low level of participation by females in physics. Initially there was some difficulty in obtaining these data but we now have sufficient data to draw conclusions and as time goes by, we will be able to study trends in participation rates.

The 1996 survey by Jennings, de Laeter and Putt [10] was undertaken in the midst of unprecedented anxiety about the future of physics in Australia and New Zealand due to the severe budget cuts in tertiary education. The situation has not improved over the intervening period of time.

Two of us presented a paper at the Thirteenth National Congress of the Australian Institute of Physics, addressing the problems faced by Australian universities in terms of student enrolments, the loss of service teaching and the reduction in public funding. Preliminary physics enrolment statistics for the years 1997 and 1998 were presented and an undertaking was given that this data, supplemented by the 1999 statistics would be published in the "Physicist" as soon as practicable.

This paper is the outcome of this undertaking. It not only provides the enrolment data for 1994-1999 in detail, but also presents, in graphical form, the data for Australian universities from 1968-1999 for third and fourth years, and for postgraduate students from 1986-1999. The New Zealand data is presented from 1991 - 1999. An attempt has also been made to report significant changes which may have occurred in the structure and offerings of Physics Departments over the past few years.

These data were obtained from the Heads of the various physics departments in Australia and New Zealand. We have tried to ensure that the data are consistent and accurate by circulating the tables to Heads for checking. However, there are certain to be minor errors due to the difficulty of uniquely identifying physics majors. We encourage physicists to correct the data as necessary.

Third Year Enrolments

Table 1 contains the data on third year physics enrolments for the period 1994 - 1999. Institutions are grouped by State together with a group for the New Zealand universities. A few of the numbers differ slightly from those in our previous survey by Jennings, de Laeter and Putt [10] due to retrospective corrections notified by Departmental Heads during the course of this survey. In Figure 1 we have plotted these enrolments over the period 1968 to 1999.

The total number of Australian Third year students has decreased slightly over the past six years. The average number of third year students was 607 over the previous three-year period 1994-1996 as compared to an average of 552 students over the 1997-1999 period. Over the same time periods, the
New Zealand Third year numbers have increased from an average of 114 from 1994 - 1996 to 131 in the past three years.

Over the longer term it is clear that growth has occurred from around 400 third year students in the late 1960's to around 550 in the late 1990's. This is a very modest growth rate and it is superimposed on a fluctuating background where variations of up to 100 students can occur from one year to the next. Over this same period the Australian University population has increased by a factor greater than three, so physics has clearly failed to share in most of the growth which has occurred in the tertiary education sector.

It should be noted that a number of universities listed in Table 1 no longer offer a physics program. In Victoria three universities are in this category - Ballarat, Deakin and Swinburne. Thus the Victorian numbers have been reduced from an average of 245 students in 1994 - 1996 to an average of 187 in 1997 - 1999, almost a 25% decline.

There has also been a significant decline in South Australia, which has partly been caused by the situation at the University of South Australia. However, USA is confident that the situation will improve in future years. Enrolments in third year physics have remained stable in Queensland and NSW and have increased in the ACT and WA, as have the New Zealand numbers. A minor artifact in the increases at third year in the last three years concerns the contribution from Auckland, the most populous of NZ's six universities. The Faculty of Science altered its BSc regulations in 1996, endorsing bachelor degrees for the first time with an actual subject major. Accordingly the more stringent criterion previously used to define a third year Physics major at Auckland has been significantly relaxed from an effective 37% to 19% third year Physics loading content of its overall BSc degree.

The Australian participation rate at a third year level in physics is now approximately 29 per million people as determined by the third year statistics, which is now slightly lower than New Zealand. The participation rate in Queensland in the late eighties and early nineties was close to the Australian average but has declined significantly since then. In NSW the physics participation rate has always been lower than the Australian average and it has remained that way. The reasons for these anomalies are not known.

The female participation rate in physics has averaged 22% over the past three years at third year level in Australia as compared with 15% in 1991. The proportion of female numbers seems to be growing despite the decline in male numbers over the past few years. In New Zealand, the female numbers are significantly lower (around 16%) but have increased over the present three-year period, although with such small numbers the proportion of females fluctuates considerably. The female proportion of the enrolments is remarkably similar in all Australian States despite the large differences in the overall participation rate.
Fourth Year Enrolments

The data for fourth year enrolments for 1994-1999 are presented in Table 2 and the trends in these enrolments from 1968 to 1999 are plotted in Figure 2. The fourth year numbers include honours, diploma and masters preliminary students. These numbers have followed a similar fluctuating pattern to the third year enrolments. Over the thirty years, from the mid sixties to the mid nineties, the number of fourth year students in Australian universities has doubled, from about 120 to 240, while the third year numbers have only increased by 50% over this period.

This can be explained by an increase in the retention rate from third year to fourth year from 30% in 1968 to 40% in 1996. The New Zealand figures indicate a higher participation rate in fourth year (~16.5 per million) than in Australia (~14 per million). This appears to be due to a higher retention rate from third year to fourth year in New Zealand (~15% above that in Australia) over the period 1992 to 1996, which may be the result of marginally better employment prospects for Australian pass graduates.

Whilst this was the situation up to 1996, the situation over the past three years has altered drastically. The average number of 4th year students over the period 1994 - 1996 was 246 whereas in the 1997 - 1999 period, it has slumped to 177 - a decline of 28%. This is in part due to the smaller numbers in 3rd year physics in 1996, 1997 and 1998 together with a decline in retentivity from 3rd to 4th year. On the other hand, the New Zealand situation is the reverse, moving from an average of 58 over 1994 - 1996 to 68 from 1997 - 1999.

The proportion of females undertaking a 4th year in Australian universities has increased from 16% in 1991 to 25% in 1999 which correlates with the gender balance situation at third year. The proportion of females in 4th year physics courses in New Zealand is approximately 15% over the period 1997-1999, which, as expected, correlates with the female situation in 3rd year.

Postgraduate Enrolments

The data on Masters and PhD enrolments are presented in Table 3. These figures are the number of students currently enrolled for a higher degree at an Australian or New Zealand university. The trends are plotted in Figure 3 for the period 1979 - 1999.

The data in Figure 3 reveal that after 15 years of steady growth, post-graduate numbers stabilised at about 950 from 1994 - 1996. However, in a similar pattern to the 4th year enrolments, the average number of postgraduate students has declined to an average of 825 per year over the past three years, a decline of approximately 13% with respect to the previous three-year period. The New Zealand figures have continued to rise to an all-time maximum of 175 in 1999. The reasons for this contrasting behaviour are probably related to the introduction of fees for higher education in Australia in 1990 and the restrictions on postgraduate scholarships, especially for overseas stu-
udents. It is now very difficult for overseas students from developing countries to undertake higher degrees in Australia unless they are sponsored by an international aid agency.

The participation rate in higher degree studies in physics is similar to all Australian States and New Zealand. The only exception is the ACT where the Research School of Physical Sciences and Engineering has a dominant role and attracts students from all States and overseas. However the number of students at ANU has declined over the period 1997 - 1999.

The proportion of females undertaking higher degree studies in physics continues to increase steadily, from 12% in 1991 to 19% in 1999. A similar trend is occurring in New Zealand with the proportion of females in postgraduate studies averaging 17% over the past three years.

### Administrative Changes

In the course of conducting this survey, Heads of Departments were asked to comment on any significant changes that may have occurred to the administration of physics in their university. The following is a summary of their responses, first those from Australian HOD's then those from NZ HOD's:

- James Cook University: Physics is now in the School of Computer Science, Mathematics and Physics.
- Queensland University of Technology: Physics is now in the School of Physical Sciences (with Chemistry).
- Central Queensland University: Physics is now in the School of Engineering and Physical Systems.
- University of New England: Physics is now in the School of Physical Science and Engineering (although the Bachelor of Engineering is to be phased out).
- University of Western Sydney: a number of structural changes are taking place.
- University of Wollongong: Physics is now a Department of Engineering Physics in the Faculty of Engineering.
- University of Canberra: Physics has, for some time, been part of the School of Electronic Engineering and Applied Physics.
- La Trobe University: Physics is a Department within the School of Engineering.
- Victoria University: Physics is now in the School of Communications and Information.
- University of Tasmania: Physics is now in the School of Mathematics and Physics.
- Flinders University: Physics is now part of the School of Chemistry, Physics and Earth Sciences.
- University of South Australia: Physics has been merged with the Department of Electronic Engineering.
- Murdoch University: Physics is now part of the Department of Physics and Energy Studies.

Other comments made by Heads of Departments with respect to their courses reflect that many double degree courses have been introduced in recent years - particularly with Engineering, and these have lifted enrolments and established good cross-disciplinary relationships. Some physics courses have had to be reduced to a basic core, and in Western Australia there is a cooperative teaching program between Curtin and Murdoch Universities at the 2nd, 3rd and 4th year levels. Macquarie University has introduced a successful BSc in Astronomy and Astrophysics, and many other Departments have introduced astronomy as an elective unit. The University of Western

### Table 3

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### Figure 3

Disciplinary studies. Some physics courses have had to be reduced to a basic core, and in Western Australia there is a cooperative teaching program between Curtin and Murdoch Universities at the 2nd, 3rd and 4th year levels. Macquarie University has introduced a successful BSc in Astronomy and Astrophysics, and many other Departments have introduced astronomy as an elective unit. The University of Western

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Australia now offers a degree in Medical Physics in tandem with their Physics major, whilst Flinders has introduced new degrees in nanotechnology and computational modelling. Many Universities have restructured their physics courses to make them more flexible and attractive to students.

**New Zealand**

Mergers of Physics with other departments have occurred at two of the six universities: in 1997 Victoria University of Wellington merged Physics with Chemistry into the School of Chemical and Physical Sciences and in 1998, Massey University merged Physics & Biophysics with Chemistry and Mathematics into the Institute of Fundamental Sciences.

Other comments from HOD's reflect significant structural changes in courses. Both Auckland and Canterbury are collaborating in a leading way with Engineering Schools in four year B.Tech programmes. Wellington is doing likewise with appropriate Crown Research Institutes (formerly DSIR) and Massey is contributing several electronics/electromagnetism papers to B.Tech programmes led by Computer Engineering and Consumer Technology sections. All universities have restructured their Physics courses to make them more accessible and alluring to students with funding in the tertiary sector continuing to be dominated by quantity rather than quality considerations.

**Conclusions**

The results of this survey show that physics is experiencing a difficult time in Australia. Third year, fourth year and postgraduate numbers have all declined in the three-year period 1997 - 1999 as compared to the previous three year period. This does not create a position of strength in times of financial stringencies where student numbers are an essential factor in determining Departmental budgets. A number of Physics Departments have, in fact, been closed down, and others have been amalgamated. The loss of Physics staff (both academic and technical) has exacerbated the situation and smaller Departments are sometimes hard pressed to cover the range of subject matter required in a good undergraduate course. Some Physics Departments have, in fact, joined forces to cover the teaching requirements of their courses.

The present study reveals a much better picture in New Zealand universities than their Australian counterparts. Third year, 4th year and postgraduate enrolments have all increased over the past three year period, and the number of third year physics students (1338) now represents 25% of the total Australian third year enrolments in 1999. It is interesting to note that Physics in New Zealand is also enjoying increased participation at the secondary school level. Enrolments in Physics that have traditionally lagged those in Chemistry now exceed them. It is tempting to link gains in both gender participation (enhancement of NZ statistics for women by summing participation at all three levels of third, fourth and post-graduate levels reveals a genuine increase from 12% to 15% over the past two triennia) and overall tertiary participation to changes that have occurred in the national school curriculum and examination style in Physics at the Universities Bursary (matriculation) level over the past half-decade. The rigour of both has been softened by demands for relevance and context in secondary science curricula much to the concern, if not chagrin, of academic staff wrestling with the deficiencies in university entry level background of contemporary students. Indeed the two larger universities at Auckland and Canterbury now have basic courses in their offerings that provide for a three-semester introductory sequence for significant numbers of students rather than the standard two-semester sequence able students still undertake. (Massey also offers a foundation course on a summer school basis but it responds to blanks in entry level rather than remedial needs). Nevertheless, the fact remains that while the secondary preparation of students had been significantly watered down, the subject has enjoyed increased popularity as an area of study at both senior secondary and all tertiary levels in New Zealand. The degree to which the two are causally linked is a matter for interesting debate in another forum. However, its mention here at least provides some food for thought to national bodies concerned with overall trends in Physics.

Another pleasing feature of this survey has been the increasing proportion of females comprising the various physics cohorts in both Australian and New Zealand universities. Although the increases have been small, they are nevertheless important for the future of physics in these two countries.

Yet draconian decreases in funding levels to the Australian tertiary sector which have resulted in savage staff reductions, deterioration of equipment and other facilities, and difficulties in sustaining research endeavours of international quality, are replicated to some extent in the decline in student numbers which, in turn, could trigger further decreases in staff etc. The Federal Government's recent Green Paper on research does not provide any comfort that the situation with respect to research will improve. Ridd and Heron [11] addressed the difficulties faced by Australian Physics Departments and related the decrease in enrolments to the decline in Secondary School physics enrolments.

This is not just a problem, which is of concern to the Physics community, but one which the Federal Government through the Prime Ministers Science, Engineering and Technology Council, should be addressing as a matter of urgency. The problem is not confined to Physics, but applies equally to Chemistry and Mathematics.

Evans [12], Dean of Research, School of Chemistry at the Australian National University has recently stated that:

"No modern society is possible in the absence of university schools somewhere in the nation, that are capable of teaching the broad, fundamental curriculum of chemistry, mathematics and physics. Tertiary education and research is in crisis across this nation."

Physics enrolments in the United States shows a similar pattern to Australia, in that the number of students graduating with a bachelor's degree in 1997 was the lowest for 40 years (Chodos, [13]. Chodos [13] argues that the lesson to be learned from the recent suspected Chinese spy case at Los Alamos National
Laboratory is that more American graduate students are required to enable the US National Laboratories to be able to recruit US nationals rather than have to rely on foreign-born scientists. Schwartz [14] has addressed some of the myths with respect to Physics Departments, students and employment in the United States. It is pertinent to remark that the US universities can at least recruit overseas students, whereas in Australia the Government policy on fees and overseas students has made this a much more difficult undertaking. This pattern has not occurred in New Zealand where Government policies are different.

It is important to conclude that this survey has shown that, although some decreases in student numbers in physics have occurred in Australian universities, the long term trends are encouraging, whilst in New Zealand the situation with respect to physics enrolments has never been better. It is also pleasing to note that the difficulties confronting physics departments have invariably been addressed in a positive and constructive way, with some innovative solutions emerging which should serve the profession well in the future. In fact there is reason to believe that the discipline of physics will emerge from the vicissitudes of the present time stronger than before.

Acknowledgments

The authors are indebted to our colleagues in the various universities of Australia and New Zealand who have supplied us with the data and checked the tables for us. We would also like to thank Mrs Sue Shephard of Curtin University who prepared the manuscript for publication.

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INTRODUCTION

"What is science?" This question is not necessarily an abstract one to preoccupy a handful of scholars. It is a very practical question parents ask when hearing that their children—high school graduates—want to go into "science". "Does my boy or girl have the qualities to succeed in science? Is science a profession a diligent student can learn, or a special gift is required to study science, such as is required for singing, for instance? Perhaps he or she had better go to study law or medicine?"

The work of a lawyer or a physician is visible to public, and there is a sense of understanding what these professionals do. Not so about scientists. The word "science" usually flashes in people's minds only when a controversial issue related to science is raised in the media, such as building a space station or genetic engineering. When hearing arguments for and against such a project people ask themselves how much in this debate is science and how much is special groups' interests. When big money is involved, or there are concerns with health, the environment, or even survival of the human species, it is difficult to separate scientific arguments from social, political, religious and other ones.

A historian of science would suggest that it is easier to understand the nature of science or the work of scientists, if we turn to scientific debates of the past: it is easier to judge the arguments when one understands the subject matter.

Normally, individual scientists' arguments for and against each theory remain unknown to but a few, but once in a while some scientists decide to take them out into a public forum. These cases are precious, because they offer an opportunity to learn how scientists make their judgements, what criteria they use, and the like.

I will discuss today two examples of such scientific controversies, the debate on the "animal" electricity and the debate on the nature of the volcanic pile. Both are associated with the name of Alessandro Volta and, in particular, with his discovery of the electric battery, the bicentennial of which is being celebrated this year around the world.

The "animal" electricity

This controversy began in 1792, after publication of the discovery by Luigi Galvani (1737-1798), Professor of Anatomy and Obstetrics at the University of Bologna. For more than 10 years, Galvani studied electrical stimulation of animal organs, especially a frog's preparation of hind legs and part of the vertebra (Fig. 1). It had been known for quite a while that a muscle twitched if one pricks the corresponding nerve with a sharp needle, or places a grain of salt on it, or touches the nerve with a hot object. Then it was found that touching the nerve with a conductor carrying static electricity produced even more powerful contractions, and several physiologists began to study electrical stimulation systematically. The view of that time was that muscles move when an agent called "nervous fluid" flows from the brain to the muscle through a nerve. According to one of the theories, shared by Galvani, this fluid was of an electrical nature. The facts in favour of this hypothesis were: 1) the high speed of the muscular reaction; 2) the existence of electric fish and 3) the possibility of electric stimulation of animals. Once Galvani observed contractions when a scalpel touched a frog at the same time as an electrical machine unconnected to it produced a spark. Galvani thought that if electrical stimulation can take place at a distance, then atmos...
pheric electricity can do it too. Indeed, he observed that a frog's preparation placed outside twitched during a thunderstorm. When he hung the preparation on the grill by means of a hook attached to the vertebra, the legs twitched even in serene weather. A closer inspection showed that the convulsions occurred only when the legs touched the grill. To eliminate atmospheric electricity, Galvani brought the frog inside his room and touched both the nerve and the muscle with an iron arc: the contractions resumed.

To prove that the stimulation was not mechanical, he laid down the nerve and the muscle on two metal plates and brought the arc in touch with these plates rather than with the tissues: the contractions continued. The stimulation appeared to be electrical in nature, because if the connecting arc included a piece of non-conducting material, such as glass, there was no twitching. To eliminate static electricity coming from his body or the table, Galvani provided the arc with a glass handle and made the support for the frog from a conducting material. Galvani concluded that since the stimulating agent was electricity and it was neither static nor atmospheric electricity, it had to be a new kind of electricity, and probably it was "animal" electricity.

To explain the new phenomena, which became known as "galvanic", Galvani argued that due to life processes a disbalance of electricity is created between a nerve and a corresponding muscle, as in a Leyden jar. When the two are connected by a good conductor, a "discharge" occurs, and the flow of electricity stimulates contractions. According to Galvani, this experiment (and some others) proved that animal electricity is not limited to certain fish but exists in every animal body.

The "contact" electricity

Galvani's theory immediately prompted several objections. One was that since both muscles and nerves are conductors, they cannot make a Leyden jar. To counter this, Galvani invented an oily substance that supposedly insulated the sciatic nerve from the muscle. Another objection was that convulsions were much stronger when the arc consisted of two different metals rather than a single one. This circumstance appeared crucial to Alessandro Volta (1745-1827), Professor of Physics at the University of Pavia. Volta agreed that the phenomenon was electrical but he assumed the main source of electricity to be outside, in the contact of different metals, and the frog was merely a conductor.

Being unable to explain convulsions produced with a single metal, Volta maintained for a while the "animal" electricity together with his "contact" electricity. Then in 1794 he discovered experimentally that a difference in temperature or polish at the ends of a wire was sufficient to excite contractions. Thus, he concluded, since a single heterogeneous wire could be treated as two different metals, the contact electricity alone could explain all phenomena.

Giovanni Aldini (1762-1834), Professor of Physics at the University of Bologna and Galvani's nephew, countered this argument with a new experiment. He showed that mercury free of the heterogeneity described by Volta did produce contractions. Another strong blow to Volta's theory came from Galvani's and Aldini's experiment in which contractions occurred when a nerve directly touched the muscle without any intermediaries (the so-called "all-animal" circuit) (Fig.2)

First, Volta tried to find a flaw in the opponents' experiments, such as mechanical pressure or a chemical difference at the ends of the connecting arc, but eventually he decided to modify his own theory. According to the new more general theory, electricity can be moved by a contact of any two different substances. The greatest electromotive force is created by a contact of different metals and some other solid bodies; a less vigorous effect was produced by a contact of a metal with a liquid or a wet substance; and the weakest of all was a contact of two liquids or wet substances.

Although Volta's new theory explained all galvanic phenomena, this generality was a sign of weakness rather than strength. Indeed, his statement that any three conductors of the second class created galvanic electricity could not be independently verified, for the only experiment supporting it - the "all-animal circuit" - was the one that the hypothesis was created to account for. Besides, Volta had a difficulty in combining this generality with the fact that the contractions produced by two different metals and a liquid were much stronger than the rest. Actually, he opened a path for returning to his original theory that weakest contractions may result from internal animal electricity while the stronger ones came from external electricity. At the time, no one utilised this opportunity, but fifty years later this theory began to gain strength.

By 1795, Volta realised that he could not fully establish the existence of the "contact" electricity without eliminating the "animal electricity". The main difficulty with this was that the frog's preparation was the only available sensitive detector of galvanic electricity: one could always say that electricity
responsible for the contractions came from the frog itself rather than from the external part of the circuit. Thus Volta decided to replace the frog with an electrometer provided with a multiplier (either a condenser or a doubler).

He soldered copper and zinc rods to one another. Holding its zinc end in his hand he brought the copper end in touch with a copper disk of a condenser; the electrometer showed a negative charge. To Volta, this proved that a contact of zinc and copper makes copper negative with respect to zinc, or that electricity moves across the contact from copper to zinc. However, when he reversed the bi-metal, touching the condenser with zinc, the electrometer showed no charge instead of the expected positive one. Volta explained the result by an interference of another contact, between the condenser plate and the zinc rod: two copper objects adjacent to zinc pushed electricity in the opposite directions, and so electricity did not move. To prove this, he placed a piece of wet cardboard between zinc and condenser: now the electrometer was charged positively. According to Volta, water eliminated the effect of the second copper-zinc contact without creating an electromotive force of its own at its contact with a metal. Since the electrometer showed the same magnitude of tension with water and without, Volta concluded that water does not play any significant role in creating electricity. Although he had no means to prove this, this statement was accepted without any challenge.

Volta's hope that the electrometer experiment would provide the decisive proof of his theory did not materialize, in part because the electricity produced by a contact was so weak that it could have been confused with "spontaneous" electricity produced by multipliers during their operation. Volta however remained convinced of the truth of his theory, which led him in December 1799 to one of the greatest discoveries of the nineteenth century: an electric pile.

The Pile

In March 1800 Volta described it in a letter sent to the Royal Society of London, where it was read on June 26. The apparatus consisted of many similar components—"couples"—consisting of two different metals such as silver and zinc or copper and zinc (originally they used coins) and a wet cardboard. In one form of this apparatus (a "pile") all these components ("couples") made up a column arranged from the bottom up, for instance, as follows: copper, zinc, cloth, copper, zinc, cloth, etc. Another version of this apparatus, called a "chain of cups", consisted of a number of non-metal cups filled with salt water, each having a zinc and a copper plate immersed in water. The cups were arranged so that the zinc of one cup was connected to the copper of another cup, and so on (Fig. 3).

Volta observed that when the number of couples was sufficiently high, the pile produced a shock similar to that of a Leyden jar. In addition to shock, the apparatus could affect an electrometer and produce an electric spark, although these actions were less pronounced than the shock. For these reasons, Volta compared his apparatus to a battery of Leyden jars, "weakly charged" but of an "immense capacity". However, he emphasises two important differences between them: 1) the pile acts continuously, providing repeated shocks without being recharged by any external electricity; and 2) it consists solely of conductors of electricity. Volta drew from this difference two consequences. One was that he discovered the first "perpetual" source of electricity. Another one, less known, was that he found an explanation of the electric torpedo.

While Volta was convinced of having refuted animal electricity as a general feature of animal life, he could not challenge the existence of electricity in a few species of fish, such as the torpedo. In this case instead of denying the electricity of the torpedo, he wanted to explain it by physical factors. Being a reductionist, Volta aimed at explaining life phenomena by physical processes without bringing in any mysterious "vital forces".

Volta began with a critique of William Nicholson's theory of the electric organ of the torpedo, which compared it to a battery of Leyden jars. In Volta's view, since all membranes making up the columns of the electric organ are filled with fluids, they are comparatively good conductors. Since a Leyden jar cannot be made without an insulator, Volta concluded that electricity produced by the torpedo and some other fish cannot be static electricity. On the other hand, his pile consisted solely of conductors, and this, Volta supposed, could be the necessary model: the electricity of fish is galvanic, being produced by contact of organic substances of different nature. He indicates that shocks produced by a pile are comparable in strength to those of a languid torpedo, and that it can give repeating shocks. He even calls his apparatus an "artificial electric organ". This name, as well as the initial shape of the apparatus - a column - show that his preoccupation with imitating the electric organ of the torpedo was an essential element of his research program.

To convince his readers, Volta wanted them to succeed in repeating his experiments. Thus, he explains in detail how to build the apparatus and how to use it. In particular, he recommends to increase the number of couples and wet the fingers touching a pile, or, better still, to immerse a part of the hand in water that is connected to the pile. These tips are more
than empirical findings, they are closely correlated with his theory. Volta maintains that only a junction of two metals is an "electric motor", while the liquid itself is merely a conductor. Since one of the two metals attracts electricity more strongly than the other, each couple moves electricity in a certain direction, e.g. from zinc to copper. Thus, if several couples have the same orientation, their efforts combine, and the electricity moves faster: the more couples, the better. As to wetting the hand touching to the pile, it is to reduce its resistance. Using the whole hand instead of fingers serves the same purpose by increasing the area of its contact with the liquid. This idea provides a fine opportunity for physics teachers to expand their teaching of resistance to non-metal conductors.

Although Volta insisted that he had proven his theory of contact electricity earlier, it was the pile that made many scientists turn to Volta's theory from that of Galvani. Apparently, they reasoned as follows: 1) the actions of the pile are electrical; 2) since its effect is nothing but a multiplied effect of a single couple, therefore a contact of two different metals creates electricity; and 3) the electricity created by a bimetal is the same whether it is detected by an electrometer or by a frog, thus Galvani's experiments were due to the "contact electricity" rather than "animal electricity". In fact, the last conclusion was not logical, since a circuit with a frog could have had both sources of electricity, but this detail went unnoticed. Yet, while securing the victory of contact electricity over animal electricity, the pile brought to life another powerful rival: the chemical theory.

The chicken-and-egg problem

The first objections came from England. Having seen the first part of Volta's paper before it was read in full at the Royal Society, several scientists constructed voltaic piles and began experimenting with them. In addition to the effects described by Volta, they found that a pile can produce various chemical phenomena. As the result, William Hyde Wollaston (1766-1828) and Humphrey Davy (1778-1829) suggested that, contrary to Volta's opinion, liquids play an active role in galvanic phenomena, and chemical reactions may be the cause of electricity rather than its consequence. Actually, some sort of a chemical theory was initiated by Giovanni Fabbri in 1792, who saw the primary cause of galvanic phenomena in chemical reactions rather than electricity. However, after 1800, the meaning of the theory changed. To show the active role of the liquid, Davy performed the following experiment (Davy, 1800). In an iron-copper pile with water, iron is charged positively, but if water is replaced with sulfate of potassium it changes its charge to negative. He also created a pile of a single metal but of two different liquids: metal, cloth wetted with nitric acid, cloth with water, cloth with sulfate of potassium, same metal, nitric acid, etc. The acid and the alkaline at the ends of the pile were connected by paper strips moistened with water.

In his first responses to this criticism, Volta insisted that he had already proved in 1797 that a contact of different metals is an "electric motor". Soon Volta changed his tactics, claiming that the objections to his theory actually support it, including Davy's experiment with one metal and two liquids. In particular, he said, since a contact of any two different substances produces tension, and since the metal is positive relative to one liquid and negative relative to the other, both tensions move electricity in the same direction. As to the role of chemical reactions, since adding salt to pure water does not change the tension or polarity, chemical reactions are of no consequence to producing electricity. Volta agrees however to give chemical reactions a role in improving the conductivity of the pile: when an acid, for instance, attacks a metal surface, it adheres closer to it than water and thus diminishes the resistance of this contact.

The inconsistency of these two arguments is caused by Volta's usage of different detectors of electricity in the two cases. If the main criterion of the pile's power is tension vs measured by an electrometer, then, indeed, different liquids produce about the same effect. However, when the power of a pile is measured by a shock or the rate of a chemical reaction, both of which are derivatives of current, changing the liquid does change the outcome. In fact, Volta himself confirms this by noting that adding salt to water made the shock much stronger.

His second argument would have been unsayable, if he could provide independent evidence that the conductivity of a liquid depends on the substance dissolved, its concentration, the area of contact, etc. However, for static electricity, such measurements were limited to comparing distilled water with sea water. As to galvanic electricity, no such data existed at all. In fact, eventually it became clear that the only way to compare the conductivity of two piles made of the same number of couples was by comparing an effect that depends on current, such as a shock received by the same person. Thus, Volta had no ground to assume that, given the same number of couples, the pile made of copper and zinc immersed in weak sulfuric acid acts more strongly than the one made of silver and zinc immersed in saline water, because the former pile has a greater conductivity than the latter.

Volta's theory of the pile dominated until the late 1830s, when the chemical theory began to gain ground. Interestingly, after 1802, Volta himself no longer participated in the debate.

Debating in science

What lessons can one draw from these debates? Perhaps the first impression would be that they do not fit the image people may have of a "scientific discussion", where the participants are attentive to the views of one another, passionless, and pursue no other goal than finding the truth.

In particular, one is struck by the rigid, uncompromising attitude of the participants, where each side claims to have the whole truth and insists on it until death. For instance, although there was some evidence that both "animal" and "contact" electricity exist, neither Galvani and Aldini, nor Volta were interested in a compromise.

Also, one may find it dishonest when scientists hide the shortcomings of the theory they favour (as Galvani with his Leyden
jar model) or emphasise only those aspects of an experiment that supports this theory. For instance, Volta preferred to measure the "power" of a voltaic pile by its tension, because he had found tension to be independent of the chemical activity of a liquid. Davy, on the other hand, chose for that purpose the amount of gas released by the pile, because it depends on the liquid, which supported his theory of the active role of a liquid.

One may be surprised by logical inconsistencies in scientists' reasoning, such as rejecting "animal electricity" on the basis of experiments with a pile, or Volta's conclusion that zinc-copper couples produced the same electricity whether they have water between them or not.

Moreover, one may find some conclusions lacking any proof, such as Volta's statements that contacts of metals with liquids or of two liquids can move electricity. And bearing in mind that the latter statement was created with the sole purpose of explaining the "all-animal circuit", this should leave Volta's refutation of the frog's electricity hanging in the air.

All these circumstances can lead one to a conclusion that perhaps a scientific debate is not so different from a family dispute or a court trial where people try to win an argument rather than to establish the truth. Are scientists subjected to human passions when talking science? Apparently, yes, as one can see from the examples given above. However, before making the final decision that scientists very much resemble other human beings it makes sense to check whether an appearance of personal features does hide behind it objective (impersonal) factors. That impersonal factors exist follows from the fact that a similar pattern of behavior can be seen among scientists from different countries who argued about different matters.

One of them explains the simultaneous appearance of different theories. We have seen that the very nature of galvanic phenomena, where bio-potentials and electrochemical potentials coexist, allowed for either a physiological or a physical interpretation. Likewise, functioning of the pile was consistent with either a physical theory or a chemical one, for one could have attributed the origin of electricity to a mere contact of two different substances or to a chemical interaction between them.

Another reason accounts for scientists' stubbornness in adhering to a certain theory. When all competing theories are internally consistent and sufficiently supported by experiment, as those discussed above, selecting one of them is a personal matter. When neither theory explains everything, the choice of one is affected by various metaphysical beliefs, thus it cannot appear convincing to all. This means that clinging to one theory for a long time is no less "legitimate" than vacillating between the rival theories with each new experiment. Since some defects of each theory were obvious from its inception, apparently its partisans made their choice on the basis of the theory's positive contribution, with the hope that future research will resolve its difficulties. The same belief in the future appears to be behind the questionable methods of debating: the idea that presenting a theory only at its best may attract talented people who will develop the theory further and free it of its shortcomings.

Still another factor may explain a shortage of compromises. One type of compromise involves recognising more than one cause of a phenomenon. This was rather unusual for the 19th century when scientists frequently relied on the "Occam's razor", or the principle of reducing the number of possible causes to a minimum. Sometimes, they succeeded in this, but in other cases they failed. Volta, for instance, was out of luck, for having initially admitted both "animal" and "contact" electrics, eventually he decided to drop the former. Another type of compromises involves creating a "compound" theory, which can be illustrated by the debate on the nature of voltaic electricity around 1850.

Finally, sometimes a failure of scientists to reach a consensus reflects the fact that necessary concepts had been not yet developed. For example, an uncertainty of arguments in the debate on voltaic electricity resulted from a lack of understanding of the role of the contact of two substances in their chemical interaction.

If a teacher is keen on investigative experimentation, this story supported by students' experiments may have practical consequences in teaching students how to go about creating a theory explaining their own investigative experiments. In particular, they learn that as long as a theory is internally consistent and explains several experiments, it has a right to exist even if it cannot account for other experiments. Here the concept of the "partial truth" is very useful: within the given range of phenomena studied and time spent the "partial truth" is the truth, and if future research modifies it, the original conclusion still preserves its validity within the original range. Although both Galvani and Volta believed they had discovered the whole truth, since their theories did not cover all known phenomena, they come under the above stated definition of the "partial truth". And if something was satisfactory (in the modern view) for Galvani and Volta, it must be satisfactory for students too. This means that in their investigations students should not fear to invent a false theory, provided they take care to make their conclusions sufficiently consistent and based on a sufficient number of experiments.

Naturally, students will soon discover the ambiguity of the word "sufficient": one cannot know in advance how many times to repeat each experiment and how many times to modify it in order to arrive at a "partial truth". Having learned this from their own experience students may become more critical of the certainty of the results of historical experiments and their validity as arguments in a theoretical debate.

Conclusion

Studying scientific controversies is one of the best ways for understanding of how scientists defend a new theory or choose between two theories. And historical cases are more suitable for this purpose than the modern one: a distance in time is important to separate essential from non-essential factors.

While the role of "human factors" in a scientific debate deserves special study, its absence should not preclude people from discussing the impersonal factors, which should come first, because it is they that make science different from other human enterprises.
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THE HARRIE MASSEY MEDAL

The Australian Institute of Physics, on behalf of the Institute of Physics, UK, seeks nominations for the 2000 Harrie Massey Medal, to be presented by the President of the IOP at the AIP Congress in Adelaide in December 2000.

Background: The Massey Medal was proposed at the AIP Congress in 1988 and established in 1990 as a gift of the Institute of Physics, UK, to mark the 25th anniversary of the founding of the AIP as a separate institution in 1963.

Sir Harrie Massey, born near Melbourne in 1908, had a distinguished career in the UK and in 1931, with Edward Bullard, published the first experimental evidence for electron diffraction in gases. He saw the potential of using direct rocket probes of the atmosphere layers and eventually, as Chairman of the British National Committee for Space Research he guided the entire UK space research programme. From 1960-64 he was President of the European Preparatory Commission for Space research. He was knighted in 1960.

Conditions: The prize is awarded every two years for contributions to physics or its applications made by an Australian physicist working anywhere in the world, or by a non-Australian resident in, and for work carried out in, Australia. A lecture on the work for which the Medal is awarded is presented at Congress in the year of the award, and an article published in the Physicist. The recipient must be a member of the Australian Institute of Physics or the IOP.

Previous winners have been:

1990 Professor R Dalitz
1992 Professor D H Briggs
1994 Professor R Baxter, ANU
1995 Professor A D Buckingham, University of Cambridge
1996 Professor A Snyder, ANU
1997 Professor D Pegge, Griffith University
1998 Professor D Melrose, University of Sydney

Nominations as hard copy must reach Moira Welch, Honorary Secretary of the Institute, PO Box 283 Richmond NSW 2753, or as a Word 6, rtf file email attachment (m.welch@uws.edu.au) by Wednesday April 28th, 2000, accompanied by the following: A citation of not more than 300 words, written for a scientifically literate lay person (the citation is a crucial factor in the selection of the recipient); A short curriculum vitae for the Nominee: a full publication list is not required; 10 of the Nominee's most significant papers should be listed; A list, with dates, of the Nominee's most significant contributions to their chosen field; Names and contact details of 3 referees.

Further details may be obtained from the Secretary, Ph 02 4578 4328.

Moira Welch,
Honorary Secretary,
Australian Institute of Physics
Ph (02) 4578 4328
Mailing address: PO Box 283 Richmond NSW 2753
Zygo appoints Coherent Scientific

Zygo Corporation is a technology leader well known for accurate measurement, process monitoring, and automation solutions in precision manufacturing environments. With over 100 patents granted/pending and numerous industry-related awards, Zygo Corporation leads the precision non-contact measurement industry with innovative solutions in five distinct market segments: data storage, research, semiconductor, OEM, and other high-technology industries.

Products available from Zygo Corporation include:

- The New View 5000 3D optical (non-contact) surface structure analyzer. Primarily a Z-axis tool, the New View 5000 combines the critical technologies of microscopes and surface profilometers to provide surface texture measurements to angstrom level. Built for production floor capabilities, it is extremely gauge capable and repeatable. In conjunction with the Zygo Automation group, it is finding new applications in many industries (semiconductor, disk drive, and automotive) that need metrology capabilities for yield improvement and higher levels of quality control.

- The MESA flatness measuring tool provides the flatness measurements that are required on an increasing number of surfaces. The MESA provides the feedback to grinding, honing, polishing, lapping and super-finishing processes that permit these machines to produce more consistent and reliable parts. The MESA provides accurate, repeatable, fast, cost-effective, and safe flatness measurements for a wide range of surface roughness and departures.

- The GPI optical interferometer - the industry standard. Protected by excellent intellectual property patents, combined with state-of-the-art software, these tools are used in hundreds of different applications. They are most suited and primarily designed for science institutes; research laboratories; optical shops; defense electronics; consumer electronic component manufacturers. In fact the GPI is suited to virtually any industry that requires a high degree of the measurement resolution of the surface quality and shape of: mirrors, prisms, lenses and other reflecting, non-glass precision parts.

- The ZMI, displacement measuring interferometer, product line is primarily sold on an OEM basis. A key market area is high-end photolithography stepper manufacturers, who require precision motion to obtain the 0.18 micron accuracy needed when etching micro circuits onto silicon wafers. Non-OEM uses include scientific and R&D end users requiring a high degree of precision.

For more information please contact:
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Coherent Laser Group Mira Ultrafast Laser

The Coherent Mira 900F femtosecond Ti:S laser, when optically pumped by the output of the Verdi solid-state laser, produces transform limited 100fs pulses in the wavelength range 500nm to 1000nm.

The Mira 900F operates on the principle of Kerr lens modelocking. The cavity is designed to make use of changes in the spatial profile of the modelocked beam produced by self-focussing in the Ti:S crystal (the Kerr lens effect). An adjustable slit placed near the focus acts as a discriminator against CW operation, for optimal modelocking performance.

The Optima control system distinguishes the Coherent Mira 900F from other modelocked Ti:S lasers. The integrated diagnostic system continuously monitors the laser's performance, measuring quantities such as laser power, CW breakthrough, timing and relative humidity. These results are continuously displayed on a LCD screen and ensure the Mira 900F is operating to the highest level of performance.

The Optima system ensures optimum operation of the Ti:S laser without the need for external diagnostic equipment.

The Coherent Verdi and Mira 900F Ti:S laser system provides a complete solution for applications such as multi-photon excitation, non-linear spectroscopy and pump-probe spectroscopy.

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Air-Cooled Argon-Ion Lasers from JDS Uniphase

The 2010 series of Air-Cooled Argon-Ion Laser systems from JDS Uniphase (California) are the lasers of choice for a wide range of scientific and OEM applications.

The 2010 series features higher efficiency, an active filter technology for ultra-low noise operation and can be remotely controlled by the 2500 series interface controller. They are available in rectangular or cylindrical packages with low and high output power models.

There are many different versions available in the 2010 series. These include:

- Single line: 488nm (blue), 515nm (green), 458nm (violet)
- Multiline blue: (458nm, 476nm, 488nm, and 497nm)
- Multiline blue/green: (458nm, 476nm, 488nm, 497nm, 502nm and 515nm)
- Multiline, multimode: (458nm, 476nm, 488nm, 497nm, 502nm, and 515nm)

All are linearly polarised except the multimode versions, which are randomly polarised.

The benefits of the 2010 series include:

- High power specifications, maximum output power 300mW (for multiline, multimode)
- Higher efficiency
- Ultra-low noise operation as a result of active filter technology
- Compact dimensions
- Versatile operation, can be operated in either light or current regulation control modes
- Fast warm-up time
- Hands-free operation

Air-cooled argon-ion lasers can be used in a wide range of applications including flow cytometry, DNA sequencing, and semiconductor inspection.

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A message from the incoming president

At midnight on November 23, Peter Cullen's two year term as President of FASTS concluded. The success of "Science meets Parliament" Day was a fitting conclusion to his splendid term as President, and our office is still coping with requests for follow-up information. The FASTS' Board has decided to run a similar event in 2000, and this will clearly be a priority for me as I begin my two year term as President.

Participating scientists and technologists came from nearly all 45 Member Societies, with over 30 from the Institute of Physics. As a matter of policy we declined the registrations of several scientists who were not members of Societies affiliated to FASTS. The Board decided this event was a benefit of membership.

Three quarters of participants rated the meetings with Parliamentarians as "very positive" or "very encouraging", and the overall event was given an average score of eight and a half out of ten. The participants made three clear observations on Parliamentarians in their feedback sheets:

- MPs were fascinated by accounts of research being undertaken by scientists, so that most 30 minute meetings extended to an hour.
- MPs want to maintain contact and be kept informed on issues, particularly electorate issues.
- They urged scientists to communicate better with people in the electorate, both directly and through the media, as a means of maintaining pressure on MPs.

It was a great opportunity to promote the value of Australia investing in research. One highlight was the reception at Parliament House for 300 scientists and MPs hosted by the President of the Senate, the Speaker and the Minister. Another was meeting with key Parliamentarians such as Deputy Prime Minister John Anderson, Education Minister David Kemp, Communication Minister Richard Alston; ALP spokespeople Bob McMullan and Michael Lee; and Deputy Leader of the Democrats Natasha Stott Despoja. Two thirds of all MPs and Senators met with a scientist that day, an outstanding commitment in their busy schedules.

Fifty-one Parliamentarians were asked the direct question "how is science doing?". Forty-two said science has problems, with the most common reasons being that it needs more funding or that it needs to raise public awareness.

Our new Policy Document was launched at Parliament House on November 24. Minister Nick Minchin said at the launch that he and his Department found FASTS' contributions to the policy debate very useful. The Document has been completely revamped into 14 issue-based sections to make it easier to read policy on specific subjects. My thanks to Ken Baldwin for an excellent job in chairing the Policy Committee, and to the scientists who helped with comments on early drafts.

The Board is determined to increase membership of FASTS so the cost of providing a better service can be spread over more Members. We would like the opportunity to meet with as many Member Societies as possible, and invitations to your meetings and conferences would be most welcome.

Our new Board and Executive has members in Adelaide, Brisbane, Canberra, Melbourne and Sydney. A list of these people and their contact points is attached. If you have issues you would like to raise, please contact the Board Member representing your cluster or any member of the Executive or the Executive Director.

I will conclude by thanking Peter Cullen for the excellent condition in which he handed FASTS over to me. He has built upon the work of his predecessors Graham Johnston and Joe Baker to establish FASTS firmly in the role of policy formulation. In particular he has played a wonderfully constructive role in the Prime Minister's Science, Engineering and Innovation Council. FASTS is widely regarded as punching well above its weight in policy circles, with the SmP Day underlining what can be done even on a slim budget.

I look forward to your support over the next two years.

Sue Serjeantson

PRESIDENT'S REPORT

Peter Cullen
Council Meeting 23rd November, 1999

1. Introduction
As I come to the end of my term as president of FASTS it is a time both to celebrate our achievements and to reflect on how and what we might have done better. Celebrating might strike you as strange when we see the sustained attack on our Universities taking a heavy toll on science, and the general lack of funding support from Government is a grave concern for the future of our country. But FASTS does have plenty to celebrate: we are now a mainstream player in science policy issues and we have consolidated our reputation as a serious and well-respected voice for science.

In my view we have had another successful year. We have excellent access to Ministers and the Government, and an exceptionally good media profile. This was however achieved by a relatively small number of people making major contributions, and is getting harder given the stress in most academic and science organisations today. In my view, FASTS must continue to become more professional as a lobby group. This requires more funding. We must also become more inclusive so we better involve members in policy development, the drafting of submissions and the many other activities such as Forums and Occasional Papers which are all critical elements in our work.

2. Membership and Finance
There are two ways we can increase our resource base. We can and should seek to increase our membership. This will provide revenue. It will also provide energy and ideas if we can organise ourselves to utilise the skills and talents within our Member Societies.

Our membership drive over the last year has brought us some new societies, but we are also losing a few who obviously do not see they get value for money from FASTS. It is clear we need to do more to keep societies and their members aware of what FASTS is doing, and we need to do more to find out what they think FASTS should provide. In communicating with our membership we need to assess the relative importance of:

- Media coverage in both the scientific press and the general media
- Bi-monthly circulars to Presidents
- Phoning around by sector representatives
- Direct contact with the Executive Director
- Members of the Executive addressing meetings of Member Societies and prospective members

We are re-thinking our different classes of membership and what each group get in return for their subscription. How much in the loop should we keep groups that have similar interests, but choose not to pay any subscriptions to FASTS? These are important strategic issues for FASTS that I hope we will be able to address.

We also need to increase our subscription rate, and you will have the opportunity to comment on the Board's decision on that matter in the meeting. I believe we need an annual income of around $150,000 a year to do the things we need to have done. Some of this will be to pay
professionals to help us develop our positions and analyses of situations.

3. The Role of FASTS

FASTS is consulted on a range of science issues. I thank my predecessors Joe Baker and Graham Johnston for creating this foundation. The Executive and Executive Director, Toss Gascoigne, have made critical contributions to achieving this position.

Prime Minister's Science Engineering and Innovation Council (PMSEIC) The Prime Minister's Science, Engineering and Innovation Council is now a key source of advice to government, as the only forum that allows a whole-of-Government approach to be developed on science issues. Incoming President Sue Serjeantson now becomes the FASTS' ex officio position as a member of PMSEIC and will attend her first meeting on Friday. PMSEIC has a Standing Committee of the non-Ministerial members who meet from time to time and identify issues that might be developed for presentation to PMSEIC.

This provides an opportunity for FASTS to raise issues. I raised the issue of the development of antibiotic resistance in bacteria as a result of inappropriate use of antibiotics as growth stimulants in livestock. This was an issue brought to us some time ago by the Australian Society of Microbiology. The Society provided useful documentation which I tabled and I believe PMSEIC is likely to establish a working group on this issue.

During my term on PMSEIC I co-chaired the working group on Dryland Salinity which reported to the Council in November last year. At the invitation of the Chief Scientist and Ministers concerned, I have been involved with the development of the Government's response to the Salinity report which is due to be tabled at the coming meeting. This has been a challenging issue for the agencies involved since it is a difficult, cross-disciplinary and cross-jurisdictional problem.

4. Occasional Papers

The issuing of occasional papers on matters of importance is a new step for FASTS. Our biotechnology paper by Peter French helped build the pressures for a successful budget outcome in this area. The second occasional paper by Toss and Jenny Metcalfe ("Scientists commercialising their Research") has been well received and I will have the opportunity next week to present it to the PMSEIC. It will be a useful building block to the Innovation Summit early next year.

Other sectors of FASTS should think about mobilising their energy and thinking to develop Occasional Papers on matters of concern to them. It is a useful way of consolidating thinking on an issue, and provides a rich resource of material for submissions. It is my view that this Government, like most Governments, is interested in good ideas; they just get tired of being told to send more cash without the new ideas.

5. Press Club Forums

Over the last two years, FASTS has developed its innovative and influential Forums at the National Press Club in Canberra. These give us incredible exposure and let us not only present our ideas, but to develop alliances with other organisations that seek to influence Government. I acknowledge the efforts of Jan Thomas as a tower of strength in making these events work. The fact that powerful lobby groups like the Business Council of Australia and the Australian Chamber of Commerce and Industry are prepared to work with us is a clear signal that business sees the need for Government support for research.

The nationally televised Press Club speeches by Ian Lowe, Tim Besley and John Nitand have helped shape the agenda and keep our issues before Government.

6. Submissions

During the year we have made a number of submissions. These include:
- The Higher Education Research Green Paper
- Inquiry into Impacts of Reforms in Government on R&D
- Review of Science & Technology Awareness Program

7. Meetings with Ministers

I have had a number of meetings with the Minister for Industry, Science and Resources Senator Nick Minchin; Minister for Environment Senator Robert Hill; and Ministers for Agriculture, Fisheries and Forestry, Mark Vaile and Warren Truss. The PMSEIC meetings have brought me into regular contact with the Prime Minister and a number of Cabinet ministers on both a formal and informal basis.

8. "Science meets Parliament" Day

Today marks another new initiative for FASTS with the "Science meets Parliament" Day. This has been championed by Ken Baldwin and I and Sue Serjeantson (with Toss and the FASTS' staff) have put in a huge effort in planning it. The response from our Member Societies has been fantastic with over 170 scientists registering. We have had to turn more away, either because they registered late or because they were members of societies not affiliated with FASTS. The "SitM" Day is a benefit of membership.

Even more fantastic is the support we have had from Parliament. Speaker Neil Andrews and the Chair of Industry, Science and Resources Senator Nick Minchin have given strong support, and this has been replicated by the spokespeople for science in both the Opposition and the Democrats. That we have 140 parliamentarians agreeing to meet with scientists is a remarkably positive response.

9. The Science Scene in Australia

The vaunted funding of the Universities continues with the failure to provide salary supplementation, and a number of expensive science courses are in serious difficulties. Australia is starting to lose scientific capacity. More and more university staff are now submitting the decline in quality of what we offer students. A number of our major universities have made serious cutbacks in science faculties during the year. We have not yet succeeded in getting the Government to treat this issue seriously.

I think the Government is aware of the problem, but believe the solution is to shift the costs of higher education from the taxpayer to the people they see as the immediate beneficiaries: the students and their parents. The issue is not just one of persuading the Government that there are major economic returns from investing in science, but it is necessary to establish this case in the way the Wills Report did for medical research.

The key to changing the Government's behaviour is to argue the case for public investment and demonstrate the need for an appropriate cost-sharing. In the past, equity arguments have helped but they are less persuasive to this Government.

The Deans of Science commissioned a professional study into science enrolments that shows how misleading the sorts of statistics being collected by Government are. The effect of these statistics is to mask important enrolment trends. The quite dramatic collapse in enrolments in basic sciences is being disguised in the official statistics by increases in related application areas. Rather than wringing our hands about the workings of the employment market, we need to be clear as to the long-term impacts and to develop market solutions to address the problem. HECS charging rates are an obvious lever available to Government.

The collapse of Business Expenditure on R&D continues with a further 7% reduction announced in the last budget papers. (You will find this referred to as "Business Investment on R&D" - BIRD - in our new Policy Document, as a more appropriate description.) The impacts of the drop in the tax deduction for research is now obvious, and in my view serious. It is clear that the START program is not effective in stimulating R&D, and that supplementary approaches are needed. The Government's response is that Government expenditure in this area is very small. This may be true in relative terms, but these figures are based on built-in assumptions about how much of the higher education budget is spent on
research. The assumptions need revisiting, given the contraction of university funding.

The Government's cutbacks to R&D are all the more perplexing when seen in the international context. Most of our major competitors are increasing their support for research.

The Government is interested in innovation where it can convert good ideas into industry, wealth and employment. We need to establish the point that a strong basic and applied research sector is the fundamental driver to innovation; and that it is necessary, although not sufficient, for us to become a knowledge economy. It is important that we have a level playing field so that new start-up companies can grow and prosper in Australia. It is for this reason that I have strongly supported the changes to the capital gains tax regime to bring it more in line with the US and UK. We also need to ensure our company takeover rules do not mitigate against Australian companies growing in Australia. The Government has been listening to these issues and has proposed changes.

I have taken the view during my Presidency that this Government is interested in stimulating the economy, and so the way forward is to push the role of R&D in underpinning the new knowledge economy. There is no one arguing against this: the problem is the lack of good ideas to carry it forward. In particular the innovation process that links good science to economic outcome is poorly developed and poorly understood. Arguing that basic science is the fundamental building block for the knowledge economy is all very well, but when our own study of commercialising research shows people do not know how to commercialise or are not very interested in commercialising, it is hard to argue that this is a smart investment.

We need to build stronger links with business and industry to get their support for our lobbying for science. One way to achieve this is to use our undoubted media skills to target the financial press.

10. The Emerging Role for FASTS

It is apparent that to influence policy we need two things:
- The ability to analyse situations to help clarify issues and possible solutions;
- The ability to deliver those options to Government and the politicians.

In my view our delivery mechanisms, both direct and through the media, are presently outstripping our analytical capacity. It is for this reason that I argue we need more funds to hire professional skills not within our memberships, and to mobilise more of the intellectual firepower of our members.

The Biotechnology paper is an example of what we can do; and the Wills report and its impact on medical research funding shows what can be achieved by high level analysis showing the returns on investment in research.

The days of being that science is great and that all Governments need to do is send cash are over. If we want financial support we need to demonstrate the financial, social and environmental benefits to Australia. This requires greater analytical skills in economics than we have so far been able to muster.

We do need to develop some small task forces to track specific areas and to help develop sharper positions that we can take to Government.

11. In Conclusion

In my view the need for an organisation like FASTS has never been more clear. There is no other voice speaking for science as a whole. Individual societies advocating science can be picked off as being nothing more than special pleading. Many of our societies would like to learn more about influencing policy, and FASTS is assisting in this area.

It is an exciting and rewarding opportunity to be President of FASTS and I have enjoyed it all, despite the difficult times we find ourselves in. It would be nice if one could do the job full-time, but even then it would not be enough to do all the things that we should be doing to advance the cause of science.

It is time to thank all of you for your support of FASTS, and the personal support and encouragement so many of you have given me, even as you have helped me understand the breadth and diversity of issues of concern to FASTS' members.

During my term I have had wonderful support and encouragement from Past-president Joe Baker and President-elect Sue Serjeantson. As Vice-president Jan Thomas has put in a sterling effort, as have Ken Baldwin as Chair of our Policy Committee and other members of the Executive. You are all aware of the contributions made by Toss Gascoigne as Executive Director. Toss provides the critical communications between our members, between FASTS and other related bodies and with Government. He is responsible for the strong media position of FASTS, which is a critical foundation to our being taken seriously by Government. It has also been a great pleasure to have the opportunity to work with him.

Peter Cullen

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TOP TEN FOR 2000

Australia's peak council for scientists and technologists called for a proper analysis of Government figures to assess the extent of the "brain drain" of Australian scientists, when it released its 'Ten Top Issues' for 2000. Professor Sue Serjeantson, President of FASTS, says the brain drain is an indication that research science is tottering on a see-saw in Australia, and scientists are voting with their feet to escape to a better world.

"Our 'Ten Top Issues' for 2000 is a wish-list for scientists," she says. "If these issues were rectified, we'd have booming new high-technology industries, and top-level scientists and technologists from overseas clamouring to join Australia's vigorous research effort.

Australia will continue its gentle slide into mediocrity."

She says the issues boil down to three key factors unless we change our complacent attitude to science as an investment, Australia will continue its gentle slide into mediocrity:
- greater Government investment in public good science
- increased investment by industry in research to generate the products of tomorrow
- a shared determination by Australians to seek a future based on satisfying, well-paid jobs in high-technology industries

"Anecdotal evidence about the draining away of talented Australian scientists is mounting. Every Australian scientist has farewell friends and colleagues to better jobs overseas," she says. "Conditions are better, research funds are more available, job security is better.

"Australian scientists working overseas say they'd love to be able to return, but they can't afford the career insecurity, difficulty gaining research funds and the crumbling infrastructure."
We want Australians to go overseas to broaden their experience and gain new contacts. But we need a way to encourage them to bring their new skills back to Australia, so they return at least for extended periods of research."

Professor Serjeantson says there is no evidence to support claims the brain drain is being matched by a flow of talent into Australia.

"There is a suspicion that Australia is losing potential Einsteins, but gaining tradespeople in return," she says. "The statistics available to the public are very unreliable, and may well cover up the true picture."

"There is a natural tendency by people wishing to move to Australia to inflate their qualifications."

Professor Serjeantson says she is calling on the Government to undertake an analysis of highly qualified people moving into and out of the country. This should include a close examination of the confidential records of immigrants, including a careful assessment of their qualifications.

Only the Government has access to these confidential records and the resources to analyse them.

FASTS "Ten Top Issues" for 2000

1. INVEST IN THE FUTURE

Australian scientists are starved of research money, and the Government's White Paper contains no new funding. Government funding for research should be increased in the same way funding for medical research was boosted in 1999.

2. SCIENCE FOR THE BUSH

Coordinate Australian science to create jobs, improve existing industries, solve environmental problems and improve digital communication in regional and rural Australia.

3. MORE SCIENCE AND MATHS TEACHERS

Science and mathematics teachers take home less money than teachers because they have a higher HECS debt to repay. Removing the inequity would help overcome the shortfall of qualified science and mathematics teachers.

4. BRAIN DRAIN BECOMES EXPRESS TRAIN

Job insecurity, lack of career paths and low salaries are driving good young scientists away from jobs in research. Australia is in danger of losing a generation of scientists and technologists, to jobs overseas or to other professions.

5. KEEPING AUSTRALIA IN TOUCH

Australia is losing touch with international science as the price of scientific journals rise and libraries cancel subscriptions. We need a national arrangement to buy electronic academic publications, to enable all Australian researchers access to the latest scientific ideas.

6. ESTABLISH THE FUTURE OF THE CRC PROGRAM

Cooperative Research Centres help industry and researchers work more closely on key national issues. The CRC Program should be on a regular footing, with an annual schedule to consider proposals for funding new centres.

7. BRINGING THE BOYS (AND GIRLS) BACK HOME

Introduce a scheme of fellowships and stipends to enable Australian scientists working overseas to return for short and medium-term research activities, to bring their knowledge back and take Australian ideas overseas.

8. A NATIONAL MAP AND COMPASS

Does Australia know where it is going in a rapidly-changing world? Setting national goals and national priorities, and identifying where S&T fit in is a key job for the Prime Minister's Science Council. Mechanisms to coordinate science and promote a whole-of-Government approach need strengthening.

9. REVERSING THE DECLINE:

INDUSTRY INVESTMENT IN R&D

Industry investment in research continues to slump. Australia needs a range of incentives to encourage investment in R&D, including tax deductibility at internationally-competitive rates and a tax credit system.

The Ralph Review reforms are just a start.

10. CHANGING THE CULTURE THROUGH SCIENCE AWARENESS

Australians are proud of their science, but know little about its value. A vigorous program of science and mathematics awareness targeted at the business community would help the nation appreciate the central role S&T play in invigorating existing businesses and generating new industries.

ACADEMY OF SCIENCE

RESPONSE TO WHITE PAPER

Too late - too simplistic

- Following is a preliminary response by the Academy to the White Paper on Higher Education Research, "New Knowledge and Innovation" released on 21 December 1999.

- The strengthening of the Australian Research Council with the provision of its own Act, as well as the arrangements for its governance and operation, is a long overdue move.

- There is virtually no new money offered. The paper regrettably uses outdated figures purporting to show how generously higher education research is funded by the Government. It neglects to mention that cuts of 12% (as a percentage of GDP) have since been applied to Australia's university research funding (Source: OECD).

- The proposal to use simplistic formulae as a surrogate quality measure to decide the allocation of large sums of money is intrinsically flawed; the Academy believes that a research assessment exercise is required, to assure due rewards for excellent outcomes.

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Science Policy, Secretary.

COMMERCIALISING SCIENCE,
AND DR KEMP'S WHITE PAPER

Australia's peak body for scientists and technologists expressed surprise at remarks made by Education Minister David Kemp on the ABC Radio program AM.

The Minister criticised Australian scientists for a lack of entrepreneurial attitude, and for failing to generate the jobs and the industries the Government is seeking.

President Professor Sue Serjeantson, President of FASTS said that a study carried out by FASTS earlier this year found many scientists were keenly interested in commercialising their work (see below).

"We found they were not given much encouragement by their research organisations, industry, or Government support schemes, which were sometimes criticised as being poorly targeted.

"The Government's recent changes to the tax system are a tacit recognition that all was not well.

"It's not just scientists that have to change if we are to make good use of our research. Industry, research organisations and government all need to take a more commercial focus," she said.

Professor Serjeantson said the new ideas in the White Paper on Higher Education could distort the system, simply because scientists are so desperate for funding.

Commercialisation is important, but we must maintain our national effort in basic research because this generates the ideas of tomorrow.

"The Government has missed an opportunity. The White Paper deals with relatively minor issues, instead of the enormous problems which scientists face daily in research and research training.

"But we welcome, for instance, a new independence for the Australian Research Council (ARC) and an extension of PhD scholarships up to four years. This Paper is a significant
improvement over the earlier version, and shows the Minister has been listening to his constituency,” she said. Professor Serjeantson was sharply critical of the Government’s failure to inject new funding into a sector which has been staggering under the weight of successive budget cuts. She estimated the total cuts amounted to nearly 20 per cent over the last four years.

“This Government really needs to inject fresh funds into the system. The smarter countries overseas (USA, UK, Japan, Germany) are all investing heavily in research,” she said.

“The Government seems intent on running a bargain basement university system. We will continue to lose our best scientists overseas, attracted by higher salaries and better research conditions.”

MEDIA SKILLS WORKSHOPS & PRESENTATION SKILLS WORKSHOPS

PRESENTATION SKILLS WORKSHOP:
(For scientists and others involved in science.)

- ‘Learn how to make a talk work for you and the audience’ - structuring and preparing an effective presentation - overcoming nerves, and handling questions - making best use of audio-visual aids

2000 Dates: Melbourne: February 21-22; Sydney: April 10-11; Canberra: June 19-20; Perth: July 31-August 1; Brisbane: September 4-5; Hobart: October 9-10

MEDIA SKILLS WORKSHOP:

- ‘Learn how to make the media work for you’
- work with the media with confidence - practice your interview technique with working journalists - get your message out as accurately as possible

2000 Dates: Adelaide: March 6-7; Sydney: April 13-14; Melbourne: May 1-2; Canberra: June 22-23; Perth: August 3-4; Brisbane: September 7-8; Hobart: October 12-13

Presenters Toss Gascoigne and Jenni Metcalfe have backgrounds in journalism, science communication and education. They work in daily contact with scientists and journalists, and have been running Workshops for seven years.

Cost: $595 per participant (plus GST after June 30) per workshop. Numbers are limited to 10 participants each, and special workshops can be arranged if the above dates and locations do not suit.

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**AROUND THE TRAPS**

Greenhouse Sea Levels Exaggerated

Scientists from the Antarctic Cooperative Research Centre are predicting that oceans around the world will only rise about 90 cm a century. This is in contrast to the popular belief that warming of 2 to 3 degrees will cause sea levels to rise by 120 metres as happened in the last ice age.

They found that melting ice in both Antarctica and Greenland will cause some increase in sea levels but most of the rise will come from melting non-polar glaciers and from thermal expansion of the ocean.

Antarctica is unlikely to melt with an increase of 2-3° because temperatures in most of Antarctica are well below the melting point of ice. However, if Antarctica were to melt, it contains enough frozen water to raise the sea level by 55 meters.

In the short term an increase in Antarctic ice is predicted as warmer oceans cause greater evaporation and more snow falling.

Professor Garth Paltridge said that, for really catastrophic events to occur, both the Greenland and the Antarctic ice would have to melt and that is believed to be unlikely.

www.abc.net.au
William Boundy, Honorary Fellow of the Australian Institute of Physics, died on 10 October 1999 after a short illness.

Bill, as he was universally known, was born in Adelaide of Cornish stock and spent most of his early life in Peterborough, a town in the mid-north of South Australia. He attended Peterborough State Schools until coming to the city for his final year of secondary education at Adelaide High School. He was a proud South Australian.

In the 1930s and early 40s, tertiary education was financially impossible for many young people unless they were sufficiently able to be accepted for employment by the Education Department. Entry to the Department was through appointment as a junior teacher; if they proved themselves they gained entry to the Teachers’ College. Those chosen as future secondary teachers were then permitted to attend the University of Adelaide and enrol for either an Arts or a Science Degree.

Whilst in training Bill was a prominent member of the Student Union and distinguished himself in many College activities. He was a good comic actor and, so the story goes, played a hilarious part in Gilbert and Sullivan’s Pirates of Penzance. The part required that he sang - but Bill was not a great singer, so he mouthed the words as they were sung by the College’s Director of Music.

At school Bill had been good at both maths and the sciences, and he certainly loved physics. In his early days at the University of Adelaide he came under the influence of Dr R S Burdon, then Reader in Physics. The “Doc” was internationally known for his work on surface tension, and Bill assisted him with some of his experiments.

Due to a war-time teacher shortage Bill began teaching in May 1944 without the opportunity to complete his degree. As a consequence it was not until 1950 that his BSc was finally awarded to him. In May 1945 he married Betsy Prosser, a fellow student. They started their married life in Port Lincoln but later returned to Adelaide where Bill taught at Unley High School. As a teacher, Bill’s enthusiasm for transmitting knowledge - he taught a variety of subjects including maths, physics, chemistry, English and general science - ensured that he was respected by staff and appreciated by his students. Contributing to the high regard in which he was held was his concern for the welfare of others, and his sense of justice. And who could forget his quirky sense of humour?

Bill left school-teaching in 1958 and became a lecturer in the joint Maths/Physics Department of the SA School of Mines, later to become the SA Institute of Technology (SAIT) and, later still, part of the University of South Australia. In due course he was promoted to a Senior and later a Principal Lectureship. As a member, and later President, of the SAIT Staff Association, Bill played a significant part in the development of the Institute/University as a centre of learning and professional expertise within the State. He was an innovative and inspirational lecturer, and he designed and oversaw the construction of some unique and fascinating laboratory experiments. He was always generous with his time, and many outside his own department benefited from his advice - advice that came from a physicist with very catholic interests and a broad range of experience.

Bill particular interests were in electromagnetic theory, optics, solid state electronics and the physics of ionised gases. A few lines in a letter from Mr C G Wilson, one of his former Heads of School, give an indication of Bill’s worth.

Bill’s free time was filled with a quest for understanding the problems that arose from his daily work in teaching physics. He was a real scientist whose mind, like that of a musician, or other artist, was always alert to some new thought that gripped the imagination. He was not only a physicist, but a first class mathematician.

In the 1960s very little research was possible in the SAIT. Bill took a leading role in the introduction of the Diploma of Technology, later the Bachelor's degree in Applied Physics. Many of his early students did not come directly from school, but were mature-aged students, studying part-time. Many were not born in Australia; nevertheless they were determined to achieve professional status even though some had originally trained as apprentices. Many of the lectures were in the evenings, often from 6.00 to 9.30 pm. Working late was the norm for most staff; many taught either two or three evenings each week during term. It was common that lecturers taught two hours each week, often with six or more in the evenings, yet each morning saw them at their desks by 9.00 am. The reason for minimal research is obvious. Despite this, Bill gained his MSc from the University of Adelaide in 1968, based on work done at the Royal Military College of Science, Shrivenham, while on study leave.

Bill Boundy’s outside activities were many and varied. For a number of years he was State Secretary of the Water Foundation, a Council Member of Murray Park CAE, a member of the Anglican Social Welfare Committee, and Chairman of the Archway Rehabilitation Centre in Port Adelaide, a refuge for alcoholics and drug addicts. He was always an active member of congregation of St. David’s Anglican Church in Burnside, the suburb in which he spent most of his life. He was also a gifted artist and poet.

Bill was one of the initial members of the Australian Institute of Physics (AIP) and was an active participant in Institute affairs, attending his last SA Branch Meeting only about a month before his death. He was on that Committee for many years, being Chairman from 1974 to 1978. He initiated the series of National Physics Conferences, chairing the organizing committee of the first conference which was held in Adelaide in 1974. In 1976, he became Editor of the Australian Physicist and held this position for five years. It was in recognition of his contributions to the AIP that he was made an Honorary Fellow on 2 February 1990.

Bill’s family was central to him. He and Betsy had four children, three girls and a boy, and he was a much loved father and eventually grandfather. However, several events caused the family great sorrow. In 1970 their house was completely destroyed by fire, and Bill lost most of his personal papers and books. He started again, building on the same block of land. A few years later his daughter Helen, a dental therapist, died of leukaemia when only in her early 20s. Sadly, in 1981, Bill suffered a massive stroke from which he never totally recovered and which caused his early retirement.

Bill did not give up. He started life anew. He did some teaching at the SAIT and took prac-
tical classes at Flinders University; he also continued some research on biopolymers at the SAIT School of Chemical Technology. But he did not have access to a laboratory, and so turned his mind to mathematical problems.

For details of some of Bill’s mathematical interests and contributions in his final years, I am grateful to Professor H C Bolton who has given me the following material.

Bill was interested in Euclidean Geometry, particularly in problems involving circles. Discussions of the packing of circles in a plane and the similar packing of spheres in three dimensions, are all connected with the description of solid state physics problems.

An example of the packing of circles is the classic analysis of the geography of farms in Northern Europe, which surrounded a walled, fortified city. This was started by a German geographer, J H von Thuenen (1806 - 1850), and the mathematics was developed by the Swiss Mathematician Jacob Steiner (1796-1863). Bill interested Professor Bolton in this problem and a brisk correspondence between them led to a joint article: Bert Bolton and Bill Boundy, Chains of Circles: an analysis of the problem of the historical geography of towns and farms, published in Function 18(5) (1974) 130. This journal is produced by staff of the Department of Mathematics at Monash University and is addressed principally to upper secondary students.

Bill’s keenness in encouraging students of physics and mathematics to use Euclidean Geometry caused him to turn to another classic problem concerning the relationships between the radii of four mutually tangent circles. This has a long history dating from Descartes in 1643, to an Englishman Philip Beecroft in 1842, then to Frederick Sadd, who had worked with Rutherford, in 1936. Sadd described the Four Circle relationship in verse (F Sadd, The Kiss Precise, Nature, 137 (1936) 1021 and Nature 139 (1937) 62). Bill spent many hours attempting to solve these relationships using Euclidean Geometry, and he was working, until his death, on a related problem.

Bill showed delight in music, literature and science. He was a man of humanity and intense friendly warmth which, with his kindly sense of humour, made him loved by his family, friends and colleagues. We are all saddened by his loss.

Compiled by Barbara Possingham with help from Professor H C Bolton, Mr C G Wilson, Dr Stewart Martin, Bill’s wife Betsy and many friends.

OBITUARY

JOHN ROBERT PHILIP
1927 - 1999

John Robert Philip, AGU Fellow, and winner of the Horton Award and the Horton Medal, was killed in a traffic accident in Amsterdam on June 26, 1999. He had just spent 2 weeks at the Mathematics Institute there after a visit to Israel, and was on route to the United States to meet with colleagues.

Officially he retired 7 years ago but remained an (unpaid) full-time researcher (starting at 7 a.m. rather than his previous 5 a.m.) at Commonwealth Scientific and Industrial Research Organisation (CSIRO), Land and Water, in Canberra, Australia, producing a substantial body of new work each year. He won the Horton Award with Dan de Vries in 1957 and the medal in 1982.

John Philip was a pioneering figure in soil physics and micrometeorology. His early studies on sunken irrigation flows in the physical description of advection. His more than 300 papers, primarily in the fluid Earth sciences, were skillfully crafted and were models of brevity and precision. In some, the gap between two equations represented 2 weeks of work. He had little tolerance for editors and reviewers who recommended changes. Those who could not follow his mathematics were beyond the pale.

Born on January 18, 1927, in Ballarat in rural Victoria, Australia, Philip acquired a lifelong love of learning from his schoolteacher mother. His passion for Australian Rules football and cricket he got from his father. He was a child prodigy, and a scholarship to the elite Scotch College (high school) in Melbourne was his ticket out of the depression era rural poverty. He flourished in the highly competitive and intellectually stimulating environment. (Two of his classmates later became Fellows of the Royal Society). He was encouraged to write poetry and this remained a lifelong passion; his work appeared in numerous literary publications as well as the standard collection of Australian verse.

Graduating from Scotch College at 13, Philip spent another 2 years at school before being deemed old enough at 16 to study civil engineering at the University of Melbourne. Plainly bored by the demanding engineering course, which he described scornfully as merely “learning which handbook to look up,” he spent much of his time reading, writing poetry, and socializing and earned his B.C.E degree at age 19, the youngest-ever engineering graduate. Purely by luck he was offered a research assistantship by the University of Melbourne and was immediately sent to the Council for Industrial and Scientific Research (renamed CSIRO in 1949) research station at Griffith to work on problems of furrow irrigation. It was a revelation to him that not all questions were solved and that people wrestled with finding answers to them.

Philip flourished in this environment. His fellowship ended after a year and he left to work as an engineer in Queensland. He had acquired a passion for research and made an impression on the management of CSIRO; 2 years later he was asked to join the CSIRO Division of Plant Industry at Deniliquen, in New South Wales. He took up this position in 1951, living for some time with his wife Frances in a tent beside the Edwards River because of a housing shortage.

Otto Frankel (in later years Sir Otto) became John’s boss. Frankel, a distinguished plant geneticist, was charged with revitalizing the then somewhat moribund division.

He consulted with John Jaeger and Pat Moran, two world-renowned scientists and mathematicians at the Australian National University, who reported positively on John’s proposed research plans in agricultural physics, and gave him freedom to proceed.

John focused on the vadose zone: for much of Australia evaporation is the dominant hydrologic process with only about 15% of the precipitation reaching the groundwater.
Understanding vadose zone water movement was John’s central concern. He moved rapidly from particular studies of the hydraulics of furrow irrigation to the general formulation of unsaturated infiltration and soil-water movement. He produced in a very short time the set of papers containing the so-called “Philip” equation for water infiltrating into partially saturated soil. He formulated the thermodynamic continuum concept as a way of describing water transport through the soil-plant atmosphere system. At age 26, John proposed to the CSIRO Executive in 1953 a comprehensive and unique program of integrated land and water research. It is only in recent years that his farsighted program in scientific hydrology has been partially implemented.

John Philip moved in 1964 from Deniliquen to Canberra to head the Agricultural Physics section of the Division of Plant Industry (headed by Frankel). A bequest to CSIRO provided the funds to build a laboratory to house the team of researchers John had assembled to work on fluid mechanics of porous media, micrometeorology, plant physical ecology, and soil physics.

John and his wife Frances, a notable Australian painter, had a deep appreciation of art and architecture. Together with the architect Ken Woolley, they created the F. C. Pye Laboratory. Thirty years later, it remains a paradigm of good laboratory design; its fragile elegance fosters scientific interaction and accommodates a multiplicity of functions.

In the 1970s John turned his attention to the rigorous formulation of flow in swelling media. He took on additional administrative responsibilities as director of the CSIRO Institute of Physical Sciences. John was also a robust defender of scientific autonomy. A report he drafted for the Royal Commission on Australian Government Administration was a highly readable and persuasive description of the necessary environment for effective and creative scientific research. It is now a minor classic in the field.

John thoroughly explored the problem of unsaturated flows around underground cavities and identified the optimum shape to ensure minimal water entry—a result of relevance to designing safe underground nuclear storage cavities. More recent work included an engineering analysis of the meteorological consequences of small-scale heterogeneity at the Earth’s surface, and how this heterogeneity may be incorporated into larger scale models.

John wrote the definitive reviews at the time on mathematical/physical analysis of infiltration (1958) and of the theory of flow and volume change in swelling soils (1995), and he was in demand as a book reviewer. While confident and proud of his own achievements, he honored the pioneers of hydrology. He gave a memorable talk at the Soil Science Society of America’s meeting marking his own formal retirement on his adventures to visit the grave of Henry Darcy in Dijon, where “nobody knows who Darcy was, and nobody cares.”

John traveled extensively throughout the world to lecture, meet with colleagues, and serve on research advisory boards. During the last 15 years he gave generously of his time on these trips. He particularly enjoyed his discussions with graduate students who had developed “healthy scepticism.” All of us who spent time with him sharpened our thinking.

John was primarily self-taught. He was awarded a higher doctorate in physics from Melbourne University in 1960 for his pioneering work on the physics of flow in unsaturated soil and subsequently an honorary D.Eng. He was a fellow of the Australian Academy of Science, the Royal Society of London, the Royal Meteorological Society, and the Soil Science Society of America. He was a foreign member of the All-Union (now Russian) Academy of Agricultural Sciences, and the second Australian foreign associate of the U.S. National Academy of Engineering. He was the recipient of the 1995 International Hydrology Prize. He was made an officer of the Order of Australia in 1998 for “services to the science of hydrology.” One prize he appreciated enormously was the Jaeger Medal of the Australian Academy of Science, awarded to him in April 1999. He commented to us that John Jaeger influenced him enormously.

John Philip is survived by his wife, best friend, and sharpest critic, Frances, and their adult children, sons Perigrine and Julian, and daughter Candida.

Authors

Stephen J. Burgess, Department of Civil and Environmental Engineering, University of Washington, Seattle, USA; Phillip W. Ford, CSIRO Land and Water, Canberra, Australia; and Ian White, Centre for Resource and Environmental Studies, Australian National University, Canberra. Reprinted by permission from EOS, Transactions of the American Geophysical Union (AGU), issue of November 30, 1999.

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**AIP BRANCH NEWS**

**Tasmanian teachers seminar - December 1999**

The 1999 AIP/RACI seminar for Tasmanian year 11/12 chemistry and physics teachers was held at the University of Tasmania in Launceston on Monday 6 December and at a sequence of agrochemical industrial companies along the Tasmanian north coast on Tuesday 7 December. We were pleased to be able to associate with the University’s teacher professional development programme organised by David Russell on the Tuesday.

Here is a brief report of the physics component, which was on the Monday. The session began with two talks of current physics interest. Dr Gary Burns, Australian Antarctic Division, gave a colourfully illustrated talk on Aurora time! The sunspot cycle maximum, expected in 2000, should bring energetic particules of the solar wind, funnelled by the earth’s magnetosphere, into the atmosphere above Tasmania. Gary Burns advised us to look south on a moonless, clear night, with the best display expected around midnight.

Dr Peter Jarvis, University of Tasmania, gave us a simplified version of the highly complicated theory underlying the quantum Hall effect, which shows how changes in conductors can manifest fractional electronic charge values. At the start of his talk, a dramatic split occurred in the group about the sign of the classical Hall effect! In the true spirit of scientific dialogue however, we eventually developed agreement on what should be expected.

For the Great Balloon Challenge, teachers and AIP members alike, calibrated helium-filled balloons for rise time against payload and, in most cases, succeeded in getting their balloon to rise to the ceiling in the specified time of 2.7 seconds. The Challenge was felt to be a possible way of introducing a physics course at year 11, using a science-inquiry approach.

Bevis Yaxley, Principal Education Officer (Science) Education Department, presented results of the SPIRT project on student perceptions of science in year 11.

Elizabeth Cherkowska, for the AIP, reviewed the 1999 AIP Quiz for year 11/12 students in Tasmania. As an encouragement for schools and colleges to send teams, we have placed the 1999 questions on the AIP Tasmanian Branch Web site (www.phys.utas.edu.au/physics/AIP_TasBranch/Quiz/1999_Quiz/index.html).

The Monday programme concluded with a wide-ranging discussion of a number of curriculum issues and of some resources available.

Ian Newman
Prompt Critical

One of the Greatest

Recently, in a millennium poll, over 250 of the world’s leading physicists voted Ernest Rutherford, discoverer of the atomic nucleus, among the top ten physicists of all time. Arguably he could rate as the greatest scientist ever born south of the equator. Second son in a family of twelve of a New Zealand farmer, Ernest Rutherford rose from humble beginnings to attain the pinnacle of physics and a richly deserved Nobel Prize. News of Rutherford’s early death brought tears to the eyes of Niels Bohr and other Nobel physicists who held him in the highest regard. His ashes were interred in Westminster Abbey near Newton’s grave.

The story of Rutherford’s life is authoritatively presented in a painstakingly researched biography by John Campbell, a physics lecturer at Rutherford’s alma mater, Canterbury College in New Zealand. “Rutherford - Scientist Supreme” is the product of more than two decades’ investigation which can never be repeated because so many of John’s sources have passed on. Now, as a result of his efforts, we have a splendid, richly illustrated, fact-filled volume that will serve as a goldmine for historians of science. John was driven to research Rutherford’s life and times by New Zealand’s shocking disregard for the brilliant career of her greatest son. None of the Rutherford family dwellings have been preserved and it took heroic fund-raising efforts by John to have a fitting memorial constructed near Rutherford’s birthplace not far from Nelson. By way of contrast, England honoured him in his lifetime by creating a life barony: he became Lord Rutherford of Nelson.

The reason for New Zealand’s neglect of Rutherford’s memory stems from the strong anti-nuclear feeling in that country over several decades. Such activist sentiments savagely denoted the father of nuclear physics to obscurity in his home country. John Campbell has performed an inestimable service to physics and history by producing, and publishing himself, a most rewarding biography of the great man. This excellently bound volume of more than 500 pages suffers only a minor defect: the standard of proofreading falls below the excellence of the whole. None of the errors are critical but when one encounters them they do rather detract from the otherwise smooth flow of

John’s writing. A smoothness, I might add, that is enhanced by John’s liberal dry humour and occasional drollery. This is no stodgy academic tome. Too bad there are pedants who will disapprove of John’s liberal use of Rutherford’s nickname. He was affectionately known as En to those closest to him. However Australian readers will appreciate the candour of John Campbell’s approach.

“Rutherford - Scientist Supreme” deserves a place on the bookshelf of any physicist interested in the history of the subject, in every high school library as an inspiration to future scientists, and in every public library as an honest portrayal of one the world’s great achievers. This priceless volume may be obtained directly from AAS Publications, P O Box 31-035, Christchurch, New Zealand. An Australian cheque for $60 (Australian currency) will cover the cost, packing and economy-air postage. It bears the ISBN 0-473-05700-X but this might confuse your friendly local book supplier so go straight to the source for this wonderful book.

Colin Keay
Reviews Editor

Reviews

Introduction to Energy (2nd ed.)
E S Cassedy and P Z Grossman
x + 427 pp., AS$44.95 (paperback)
ISBN 0-521-63767-8

Memories of oil crises and reactor accidents may have dimmed but energy considerations such as gas explosions, uranium mines, radioactive waste dumps, greenhouse gases and climate change are currently in our papers. Each physicist should be informed about the advantages, costs and risks of all major energy technologies.

This book is well written. Its main thrust is ethical and social but physics aspects of competing technologies are interestingly summarised. It contains three major sections: energy demand, current technology, and the future. The first of these has necessarily the smallest physics content. The topics discussed do concern us. Some examples: “Do you have to be a scientist to usefully understand energy matters?” “Must increased energy consumption be required for economic growth?” “Can you change demand in a free society?”

Ethical considerations are summarised as lifestyle ethics (being self contained) or space-ship ethics (sharing). As a physicist I found the current technology of the middle section the most readable. Some comments: After the reactor accidents of the last 20 years the authors feel that the fear of nuclear accidents can no longer be considered irrational and has essentially destroyed the promise of nuclear power. There is no clear cut answer to the best technology. The economics of scale of large power stations versus smaller ones have been misleading. Smaller stations may be more reliable and suitable for fluctuating demand.

The third section on the future has considerable physics relevance. Fusion research should still concentrate on the underlying physics. It is too early for investigating the technology. Final conclusions prefer self-restraint to economic growth. Certainly this book should be in every physics library and be used as a reference for our energy courses.

G G Shute
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University of Melbourne

The Philosopher’s Tree:
A Selection of Michael Faraday’s Writings
P Day (ed.)
IOP Publishing, Bristol 1999
xv + 211 pp., UK£16.00 (paperback)
ISBN 0-7503-0571-1

Michael Faraday’s life was surprisingly simple but extraordinarily productive. From humble beginnings, he spent his entire working life at the Royal Institution in London, where he changed the face of science and its public profile. He declined university chairs, Royal Society office, student supervision, and most social and scientific invitations. He was the quintessential experimenter and public lecturer, from a wide scientific menu.

Faraday’s life and work have been the subject of detailed historical study, so why another limited selection of his writings? Largely because the historical works are rather forbidding to present-day scientists and laymen; but will a disjoined if tatty selection satisfy? Only with patience, I think, for this book needs to be savoured at leisure. Polite English society did not permit Faraday to expose his inner thoughts except on rare occasions. Thus, of science and scientists: he desired when young “to enter the service of Science, which I imagined made its pursuers amiable and liberal”; while later he considered giving it up “for it frequently presents to him
who pursues it, quite as much that is degraded and base.

There is useful advice on lectures and lecturing, although the examples, including the famous ‘Chemical History of a Candle’, now seem dated. His modest self for lecturing successfully to the young was surely “I claim the privilege of speaking to juveniles as a juvenile myself”. He wrote with feeling about his distrust of the paranorm, the need to clean up the Thames, and the need to incorporate science into general education.

As to Faraday’s science itself, there are quotations from his writings on magnetism, induction, the dynamo, the Faraday cage, lines of force and much else. He coined the terms diamagnetism and paramagnetism. But to me the tastiest morsel of this selection is Faraday’s search for unity in science: thus, regarding gravity, magnetism, cohesion, chemical affinity and electrical attraction “we must try and comprehend what relation they bear to each other, and how these powers may be changed one into the others”. It is a search as old and as modern as Aristotle, Newton and “a theory of everything”.

John Jenkin
School of Philosophy
La Trobe University

Measuring the Universe
Stephen Webb
Springer-Praxis, Chichester UK 1999
xvi + 342 pp., DM 69 (paperback)

If there were a single good way of measuring distances in the universe, this would be a short book. In reality, the whole arsenal of our knowledge of astrophysics is deployed for the purpose of determining distances, and so this book serves as a complete introduction to stellar and galactic astronomy. Directed at those taking a first or second course in astronomy, the book communicates well with those possessed of a high school or freshman knowledge of physics.

In general, the effort to reduce matters to the lowest level of physics possible has worked well, although sometimes this has been overdone. Equations 10.4 through 10.6 on the Hubble expansion are dimensionally inconsistent. On the other hand, sometimes the simplification has gone far enough. Equation 3.10 is intended to be an easy form of Kepler’s third law.

However this form:

\[(1 + m) T^{2} \text{ (years)} = a^{2} \text{ (AU)}\]

would be simpler, where \(T\) is the period, \(m\) is the mass of a planet in solar units, and \(a\) is the minor axis of the orbit.

There are also a number of naive statements, e.g., “Hubble missed C D galaxies from his classification scheme for the very good reason that he never saw one.” And “the physical mechanism behind the Faber-Jackson relation is even more mysterious than that behind the Tully-Fisher relation.” In fact, the author devotes a section to each of these distance indicators, leaving little room for mystery. And a third example: “When radiation from stars passes through the cooler gaseous regions in a galaxy, it is selectively absorbed at the Ca II H and K wavelengths before leaving the galaxy.” Although this is a physical possibility in galactic halos for these resonance lines, the absorption (not “absorption”, doesn’t the publisher have a spell checker?) arises in the photospheres of the galaxy’s stars.

These are small problems, of course. On the whole the book is didactically a good one, both in its scope and its level. The publisher’s price will not help it in this, but it will find a market. It is an entry level university astronomy course (or a final year high school reading course) ready to be taught.

Jeremy Mould
Research School of Astronomy
Australian National University

Atomic Physics with Heavy Ions
H F Beyer and V P Shevelko (eds)
Springer, Berlin 1999
xi + 396 pp., AS175 (hardcover)
ISBN 3-540-64875-5

This volume is a collection of articles covering the physics that can be studied using the highly charged positive ions coming from storage rings. To quote: “virtually any element can now be obtained in any charged state”. Topics include experimental aspects of storage rings, high field quantum electrodynamics (QED), the physics of ion-atom (and electron-ion) collisions and exotic such as hollow atoms (ions with their innermost electrons removed).

The general reader will probably find the several articles on strong-field QED most interesting. It is gratifying to know the theoretical ground-state Lamb shift for \(U^{114}\) of 465.5 eV is in good accord with the experimental value. However its merit as a description of the status of QED is diminished by the omission of material discussing QED tests for atomic hydrogen and helium.

An application to fundamental physics was the precise measurement of the transverse Doppler shift for Li ion. The storage ring version of the Ives-Stilwell experiment reproduces the expected relativistic time-dilation factor to better than one part in a million.

Storage ring experiments on hyperfine spectra beta decay of heavy ions are at the interface with atomic and nuclear physics. Hyperfine line splittings at optical wavelengths (for \(Ho^{+}\)) have both nuclear and QED contributions. High charge states (the normal state of affairs for stellar nucleosynthesis) can change nuclear beta process decay rates by many orders of magnitude (the half-life of \(Re^{187}\) is a billion times shorter than for neutral Re).

Some of the articles make only minor concessions to the general reader and the volume would have been better if the articles were fewer (but longer). Also, the articles on ion-atom collisions do not sit well with those discussing more fundamental aspects of physics. In addition, there was some poor production work. One table caption did not state what the units were, or even what was being tabulated.

To summarise, this volume is most valuable to an experimental physicist working directly with storage ring technology. While anyone reading the volume will find some of the articles interesting, the jumble of topics, and uneven quality make it only modest value for money.

Jim Mitroy
Faculty of Science
Northern Territory University

Turbulent Flows: Models and Physics
Jean Piquet
Springer-Verlag, Berlin 1999
x + 371 pp., DM 298 (hardcover)
ISBN 3-540-65411-9

The book by Jean Piquet “Turbulent Flows - Models and Physics” is an exposition on contemporary turbulence physics. This work should be highly beneficial for graduate students and researchers in the field of turbulence. However, the book also seems like a good reference for engineers and scholars in other branches of fluid mechanics.

The first two chapters are classical. Here the governing equations of motion for a Newtonian fluid and the well-known closure problem of turbulence are introduced. Chapter one includes a discussion of the vorticity equation and topological methods of analysing turbulent flows. In chapter two different averaging methods for studying turbulence, frame invariance and a discussion of small scales in turbulent flows are presented. Chapter three deals with the results of homogeneous and homogeneous isotropic turbulence and presents a discussion of rapid distortion theory. In chapter four turbulence modelling including Reynolds stress modelling, non-linear models for the Reynolds stress tensor, algebraic Reynolds stress models and intermittency modelling are presented and discussed. The most interesting chapters are five and six covering the physics of canonical inhomogeneous turbulent flows.
Much of the classical, modern experimental and DNS research of turbulent free shear flows (including jets, wakes and mixing layers) and turbulent wall bounded flows (such as channel flow, pipe flow and turbulent boundary layer flow) is discussed in some detail in chapter five. In chapter six additional complexities are introduced into these turbulent flows such as the effect of adverse pressure gradients on turbulent boundary layers, turbulent separation and rotation effects to mention a few.

In conclusion, I would like to congratulate the author on providing a well compiled book on some of the most relevant areas of turbulence research, including many appropriate references to the available literature. However, I must also note that the book requires a number of typographical corrections.

Julio Soria
Department of Mechanical Engineering
Monash University

Exploring Chaos: Theory and Experiment
Brian Davies
Perseus Books, Reading MA 1999 xiii + 237pp., US$45 (hardcover)

The book is not (and nor does it claim to be) a comprehensive text on chaotic dynamics. It contains little in the way of dynamical systems theory, and it does not cover homoclinic and heteroclinic tangling, Melnikov's method, Hamitonian dynamics and KAM theory, and multi-fractals among other topics. However the omission of advanced topics such as these makes the subject of chaos more accessible to students across a broad range of disciplines seeking an introductory understanding. Indeed by judiciously concentrating for the most part on first order and second order nonlinear maps Brian Davies has delivered a carefully composed book together with immediately accessible computer software that provides an excellent first introduction to the mathematical basis of chaotic dynamics.

The great strength of this book and accompanying software is the simplicity of presentation which succinctly guides the user through potentially complex topics such as universal scaling exponents, fractals, numerical shadowing, ergodicity, feedback control and Lyapunov exponents. It is clear that the material has been presented by a skilled teacher adept at providing a proper mathematical understanding with minimal mathematical effort. The book is also packed with pedagogical student exercises.

The software is provided in cross-platform format as JAVA class files which are freely available for download from http://sunsite.anu.edu.au/education/chaos. With almost no startup preparation the user will quickly be able to explore period doubling bifurcations, intermittency and strange attractors, and be able to evaluate Fourier spectra, Lyapunov exponents and box counting dimensions.

I highly recommend this book and the accompanying software as an ideal starting point for undergraduates wanting to learn about the mathematics of chaotic dynamical systems.

B I Henry
Department of Applied Mathematics
University of New South Wales

Radiation Protection Dosimetry:
Solid State Dosimetry
A Delgado and J M Gómez Ros (eds)
Nuclear Technology Publishing Ashford UK, 1999 Vol 84: xx + 568 pp; Vol 85: xiv + 536 pp., UK£110 the set (hardcover)

This two volume set covers an immense amount of ground. It reflects a continuing and growing need to measure the effects of ionising radiation. Appropriate to radiation protection, there is an emphasis on the need to quantify the doses received by individuals, either occupationally or from the environment. The search for the ideal dosimeter is as varied as the conditions in which people find themselves being exposed deliberately or accidentally. Solid state devices are perhaps seen as being best able to satisfy the diverse demands of those conditions.

Here the papers presented at an international conference in Spain in 1998 have been collected into seven categories, moving from basic processes through materials and instrumentation to a range of areas of application. There is overlap however and placement of a paper may owe more to the degree of emphasis.

Thermoluminescence techniques dominate the field. Widely used materials such as LiF:Mg,Ti are subjected to greater scrutiny and newer materials are investigated for greater sensitivity, linearity and dynamic range. The complexity of thermoluminescent processes is recognised but it surprises that there is still much to be learned. The usefulness of TLD for personal monitoring is undoubted. Dosimetry for therapy proton beams and for synchrotron radiation is encouraging.

Mixed fields are more complex and neuron and heavy charged particle dosimetry pose problems that are resolved by other techniques. Diode, etched track, superheated drop and bubble damage detectors are described and finding interesting applications in space radiation. I wanted more on ESR and the use of amino acids as dosimetric materials. The ESR response of L-tryptophan is one of only a few methods that are applicable to doses of the order of 10-100 kGy needed for sterilisation processes.

As someone once said, if you can't go to the conference the next best thing is a good set of proceedings.

David Webb
Medical Physics Group
Australian Radiation Protection & Nuclear Safety Agency
Practical Digital Imaging and PACS AAPM Medical Physics Monograph 25.

J Seibert, I Filipow and K Andriole (eds.)
Medical Physics Publishing, Madison WI 1999
vi + 577 pages, US $105 (hardcover)
ISBN 0-944838-20-0

We live in a digital world (in the sense that most things can be handled, stored and processed by a computer). Medical images are no exception and Picture Archiving and Communication System or PACS for short is the description for the computer network that handles transfer, display, processing and storage of the images. PACS offers many theoretical advantages: the images themselves are cheap and easy to transfer, they can be displayed in many locations at the same time and computer images suit modalities such as computed tomography and MRI that already produce images in digital format. However, the introduction of PACS and the ‘film-less radiology department’ has been much slower than anticipated. This is at least partially due to the lack of software that accommodates current clinical practice, missing interconnectivity with other information systems (pretty pictures alone are not sufficient for clinical evaluation) and the high cost of specialized hardware.

The present publication tries to bridge this gap between expectations and reality. It is a compilation of 24 papers from distinguished authors who presented the material at the 1999 summer school of the American Association of Physicists in Medicine. The fact that the material originated in a teaching context is evident in many contributions: they are easy to read and well illustrated. In its entirety the papers cover a wide field ranging from description of basic imaging tools (eg. ‘Nuclear Medicine Imaging Technology’ or an ‘Update on Computed Tomography’) to image quality and the discussion of image formats (two chapters specifically on DICOM).

As such, ‘Practical Digital Imaging and PACS’ is an excellent text to accompany and update a text book on radiological physics - a subject index would have been useful. It is a valuable resource for medical physicists, hospital based computer scientists and radiologists.

Tomasz Kron
Medical Physics
Newcastle Mater Hospital

Slicing Pizzas, Racing Turtles: and Further Adventures in Applied Mathematics

Robert B. Banks
Princeton University Press, Princeton NJ 1999
xi + 286 pp., US $24.95 (hardcover)
ISBN 0-691-05947-0

In this book, a sequel to the highly acclaimed “Towing Icebergs, Falling Dominoes and Other Adventures in Applied Mathematics” (reviewed in The Physicist, 1999, 36), Robert Banks continues his high spirited sleuth-like approach to solving real world problems with junior level undergraduate mathematics.

Problems range from practical problems; determining the optimal speed to go from A to B in steady rain in order to remain as dry as possible, how to get the most pieces of pizza from the least number of cuts; through to curiosities, mathematical calculations of by how many the dead outnumber the living, and of the length of a baseball seam.

In this book and its predecessor, Banks has developed an exciting new genre that lies between textbook style writing and popular science writing. This new genre involves the reader as an active participant and it is irresistible to a scientifically educated mind. Again, like its predecessor, the book carefully sets out the problems in mathematical terms and it provides numerous follow up references.

I have no doubt that readers of this column would find such a book most enjoyable, whether they delve into it for the sheer pleasure of mathematically understanding real world problems for themselves or whether they borrow from the style and content as inspiration in teaching “problem solving” subjects.

B J Henry
Department of Applied Mathematics
University of New South Wales

Total Eclipse

Pierre Guillaumier & Serge Kouchchny
Springer-Praxis, Chichester UK 1999
xivii + 247 pp., DM 59.00 (paperback)
ISBN 1-85233-160-7

In June 1973 Serge Kouchchny, one of the authors of this book, observed a total eclipse for an unprecedented 74 minutes onboard a Concorde aircraft. The book gives a good description of the flight and its results. While the book’s subtitle is Science, Observations, Myths and Legends, the emphasis is on the first two of the topics. Even the long historical chapter mostly concentrates on the scientific results of 20th century eclipse expeditions.

There is a wide variation in the level of the material included in the book. This is not surprising as it is a collaboration between an amateur and a professional astronomer. The content ranges from basic information on what exposure times to use during a total solar eclipse to a professional level article on what we know about the physics of the corona. A few errors mar the book: on page 58 the 18.6 year recession period of the moon’s line of nodes is confused with the 18 year 11 day Saros cycle. And an incorrect formula is given and used on page 76 to calculate the moon’s distance from eclipse timings.

Total Eclipse is not as easy to read as Duncan Steel’s Eclipse, a book that was recently reviewed in these pages. However, the focus in this book is very different. It also has some excellent photographs, including a wonderful colour picture of the corona from a 1995 Indian eclipse. The book could be read profitably by highly motivated amateur astronomers interested in the Sun. As well, it could be of relevance to astronomers and physicists if they are curious about the science carried out during those rare and precious minutes when the moon completely blocks the Sun.

Nick Lamb
Sydney Observatory
Powerhouse Museum

Spinors in Physics

Jean Hladik (translated from French by J.M. Cole)
Springer, New York NY 1999
xi + 226 pp., DM 89 (hardcover)

Spinors were first introduced into physics by Pauli in 1927 in order to provide a mathematical description for the spinning electron. Subsequently Dirac discovered a relativistic theory of four-componented spinors which subsumed Pauli’s theory in the slow motion limit. Spinors were, however, first discovered by Elie Cartan in 1913 and have a rich mathematical theory involving Clifford algebras and the representation theory of rotation groups in all dimensions. This attractive little book makes no attempt at giving the full story, but it does give a detailed picture of those aspects of spinors which appear in the most common physical applications.

Hladik’s approach is firstly to describe spinors geometrically, as Cartan did, by ascribing pairs of complex numbers to points of the sphere. Succeeding chapters develop the representation theories of SU(2), SO(3) and the Lorentz group. The final chapter gives a glimpse of what is on offer in higher dimensions. Given the specialized nature of the topic, I would have expected some discussion of covering groups, whereby rotations through 360° do not return spinors to their original value but change their sign. However this intriguing feature is barely touched upon.

Although this book is easy to read I am left wondering exactly what readership it is aimed at. The general impression is that of a text
Black Holes Wormholes and Time Machines
Jim Al-Khalili
IOP Publishing, Bristol UK 1999
xxii + 265 pp., UK£ 9.99 (softcover)
ISBN 0-7503-0560-6
Jim Al-Khalili has written a splendid popular book. It begins where it must, with geometry, curved space and all that. At first I thought "been there, done that" because the arguments were so similar to those I used with Geoff McNamara in our popular book Ripples on a Cosmic Sea. But Al-Khalili does not want to tell the story of gravity waves, but rather the modern developments in cosmology, black hole physics and worm holes. In its preface Al-Khalili calls his book "edutainment". That made me wary - it sounded like something out of Hollywood carrying the warning "this product is oversimplified and inaccurate and may damage your intellect". To my relief this is incorrect. The book is authoritative and yet reasonably simple. It contains some excellent insights and analogies, but always warns you of the limits to the analogies.

The book would be an excellent resource for school teachers in both Maths and Physics to enrich their teaching, and to enthuse their students. I especially liked the story of the hotel with an infinity of rooms, and the procedures for accommodating further infinities of guests. Finally the book delves into time and time travel and the debate on whether time travel is theoretically possible. This brings into focus the contradictions between quantum physics and general relativity. The reader is left well aware of what we do know and most importantly, what we don't know, and the exciting theoretical challenges ahead.

Many physicists will enjoy this easy to read book, but they will have to be patient with many of the easy bits. I highly recommend it for teenagers with an interest in science and for non-scientists interested in the deep questions of our universe.

David G Blair
Department of Physics
University of Western Australia

Millennium Science
J A Nicholls and R E Collins
Science Foundation for Physics
University of Sydney, 1999
xiii + 146 pp., A$36 (softcover)
This series of articles based on lectures to the 30th Harry Messel International Science School is a worthy introduction to up-to-the-minute science for almost anyone. The standard of presentation and difficulty is that of Scientific American articles, plus the benefits of being written for Australian readers by leading Australian scientists. Topcs range from the human genome project, through quantum communication to space exploration and far out astronomy. All are well illustrated on high quality paper, making for a handsome product well worth its cost.

"Millennium Science" does not avoid contentious issues, its treatment of nuclear power production for example is very well balanced. For all of the above reasons this book deserves a wide readership from politicians to school children. Every secondary school library should have an ample number on its shelves and the book should be an auxiliary text for years nine through eleven. Public libraries too should make available this excellent overview of modern science. An order form is available on the web at www.physics.usyd.edu.au/millennium_science/.
April 26-27
4th Australian Geomagnetism Workshop
Australian National University, Canberra
Contact: Heather McCreadie (Heather.McCreadie@ogso.gov.au)

April 27-29
Workshop on the Applications of Radio Science
La Trobe University - Beechworth Campus
Contact: Dr. Elizabeth Essex, e.essex@latrobe.edu.au

May 14-19
Conference on Precision Electromagnetic Measurements (CPEM2000), Sydney

May 23-26
8th International Conference on Ground Penetrating Radar (GPR '2000)
Gold Coast
Dr. David Noon, Dept of Computer Science & Elec.Eng., University of Qld., QLD 4072
Tel: (07) 3365 3693 Fax: (07) 3365 3684
Email: noon@csee.uq.edu.au

May 29-31
25th Annual Conference of the Australian Radiation Protection Society (ARPS25)
Millennium Hotel, Kings Cross, Sydney
Contact: ARPS 25 Conference Secretariat, c/o Dr Ron Cameron,
ARPS 25 Convenor, Safety Division, ANSTO, Private Mail Bag 1, Menai NSW 2234
Fax: (03) 9347 4547 Email: arps@vicnet.com.au

July 2-7
CONASTA 2000
Perth
Rob Jamieson, Convenor,
PO Box 1099, Osborne Park WA 6916

July 3-7
11th International Semiconducting and Insulating Materials Conference SIMC-XI 2000
Canberra
Contact: Dr C. Jagadish, RSPhysSE, ANU, Canberra ACT 0200
Ph: 61-2-6249-0363 Fax: 61-2-6249-0511 Email: simc2000@anu.edu.au

July 7-9
Mathematical Physics Winter Workshop
Greenmount Resort, Coolangatta
http://AusMWS2000.maths.uq.edu.au

Oct 1-6
International Symposium on Metal-Hydrogen Systems Fundamentals and Applications
Noosa, Queensland
Contact: A/Prof Evan Gray, Griffith University, Ph:
(07) 3875 7240, Fax: (07) 3875 7656, email: E.Grey@sct.gu.edu.au, or
A/Prof Colin Sholl, University of New England, Ph:
(02) 67 732 387 Fax: (02) 67 733 413, email: csholl@metz.une.edu.au

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

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

Dec 10-15
AIP 2000 CONGRESS
University of Adelaide
Contact: Stafford Conference Management
128 Fullarton Road, Norwood SA 5067
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email: enquiries@stafford.on.net
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