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The Physicist Volume 38, Number 1, January/February 2001
January/February 2001

Volume 38, Number 1

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Cronulla Printing Co. Pty. Ltd.
16 Cronulla Plaza, Cronulla 2230
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Published 6 times a year, on behalf of
The Australian Institute of Physics
by Cronulla Printing Co. Pty Ltd.
Copyright 2000 Pub. No. PP 224960 / 00008 ISSN 1036-3831

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The Physicist do not necessarily reflect the views
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or Committees.
If you had asked me what one thing caused me most anxiety in accepting the opportunity to become President of the AIP my response would be the pressure to come up with a president's column for each issue of the Physicist. Now I am facing that anxiety. The next problem is to ensure that in this first column I capture your interest sufficiently that you will read this in the future - or write so badly that I will be sure that no-one will read any subsequent contributions!

I love to come at a problem in a round-about way which is a bit like creeping up on it from behind, but that is because I am cautious, not scared. So walk with me for a moment so that I can show you where I am coming from, where I am going to and why.

I recall a simple model proposed, I think, by David Suzuki in which he considered a test tube of nutrient which only contained one microbe. This microbe has some intelligence and perception, plus it divides every minute so therefore the population of microbes doubles every minute. Clearly this rate of growth cannot be sustained indefinitely but for the first 30 minutes there is no great problem. At this stage some of the "intelligent microbes" would be sounding a word of warning but the "politician microbes" and others would be saying "don't worry we are only using 1% of the currently available resources". A further 3.5 minutes later they would be up to the 10% level and a significant part of the population (but perhaps not a majority) would be expressing concern. Now the "politicians" and others would be declaring that they would look into the matter and consider taking action. Little do they realise that they only have 3.5 minutes left!

So what is the point of this story? Well it was originally told to point out what a constant rate of growth implies for the human race. The question is, are we at the 1% or 10% level? How much longer do we have to act on environmental issues? At a different level of interpretation, there are the farsighted individuals who saw the problem coming and urged action when all seemed OK to the remainder. When many or most see the problem is it too late?

Rather than consider the big issue of the environment, how does this relate to science in Australia? We have seen serious issues raised in the Batterham report and there is much rhetoric circulating around the capital. We heard at the AIP congress that there have been several great developments in science support in the UK and we can only hope that the Australian government will follow suit. Such drastic action would not have been needed if the problem had been addressed earlier when the first warning signs were seen.

Can the concept be carried over to the state of the AIP? Do we have to wait too late before we take action to change the direction of the society? The longer you leave action, the more drastic the correction has to be and the more risky the outcome.

In the case of the AIP I believe we have not gone far too, but we do need to address serious issues concerning the future of the society and we need the members to work together. In talking to many members there is no one solution on which they all agree. The executive will have to determine the optimal solution and seek the support of the membership to bring about that change for the ultimate good of the AIP. In the long term it is in all our best interests. In this issue we seek your response to the issue related to the future of the Physicist. We are not seeking to make change for our benefit, we are trying to make it for the members and we can do that most representatively if we have your feedback.

Stay tuned for further developments. We have many issues that we need your advice on and we will ask again for you to participate.

I am encouraged by the confidence my colleagues have shown in me, and the support they have offered. I am grateful for that and look forward to making a significant change.

Oh, and did you want to know what happened to the test tube of microbes? It got too hot to handle and the first year science student dropped it when it had 3 minutes to go! The microbe equivalent of a 10km meteor into the earth!

John O'Connor
AIP Congress

The AIP Congress in Adelaide was a resounding success. Some 650 people registered, putting the Congress in the black, and a very pleasant time was had by all. Congratulations to the organizers, Tony Williams and all his helpers.

The plenary lectures were very impressive. I noticed that everyone seems to be using Powerpoint nowadays, which adds a professional gloss to the presentation. Particularly impressive was the talk by young Ping Koy Lam, the Bragg Medal winner, on quantum teleportation and squeezed states of light. Further notes on the Congress appear later in this issue.

I was interested also in a talk by John Boldeman on BOOMERANG, the proposed new synchrotron light source for Australia. Apparently there is keen competition between Victoria and Queensland to host the facility, if it goes ahead. Victoria would like to place it on a site near Monash University; while in Queensland, Premier Peter Beattie has taken a personal interest, and even paid a visit to the laboratory at Tsukuba in Japan.

2000 in Review

This is our usual time to review the past year of physics in Australia, as reflected in the pages of the Physicist. Perhaps we should be reviewing the past millennium as well, but that can wait awhile!

On the teaching side, the number of physics students still seems to be declining, and physics departments are still shrinking — see ‘Around The Traps’. We can only hope that the government’s new science and technology initiatives will arrest the slide. Ken Baldwin told us about the ACT’s innovative outreach program, ‘Adopt-a-Physicist’, which might help.

Employment prospects have stabilized, according to John Prescott. In some areas of new technology, such as photonics, there is an insatiable demand for qualified graduates.

The picture is somewhat brighter as regards research facilities. We have heard about ‘TIGER’, the new ionospheric radar system for research into space weather processes, and the plans for a new Gravitational Wave Research Facility at the ANU. A substantial injection of funds has gone into the new Centre for Quantum Computing. A National Computer Facility for Lattice Gauge Theory has been installed at Adelaide. A contract for construction of the new reactor at ANSTO has been awarded to the Argentinian company INVAP. Proposals have been made for a new Australian synchrotron, BOOMERANG, as mentioned above; and Australia is still in the running to host the Square Kilometre Array, a huge new international project in radio astronomy.

We have heard about NMR studies of complex fluids from Paul Callaghan on the other side of the Tasman. Yuri Kivshar and Serge Mingaleev have reviewed the theory of ‘photonic crystals’, or semiconductors for light waves. In this issue, Tony Murphy of CSIRO Telecommunications and Industrial Physics discusses his work on plasmas, leading to a new incineration system for hazardous chemical wastes, which won him the Pawsley Medal.

French, Burns, Greet et al have outlined their observation of rare ‘noctilucent clouds’ in the Antarctic; and Sue Burrell has sketched Australia’s role in the Kyoto climate change negotiations.

Finally, the end of the century has marked the passing of two giants of Australian physics, in Mark Oliphant and John Ward, together with other well-known and distinguished figures in Bert Bolton, Trevor Ophel, and David Robertson. They will be sadly missed.

New AIP President

John Pilbrow has recently handed over the reins as AIP President. We owe him thanks for his sterling efforts as an energetic and conscientious President, particularly active in forging new links with overseas societies, and involving the AIP in science policy via FASTS and the ‘Science meets Parliament’ days. We wish him well in his retirement, and offer good wishes to the incoming President, John O’Connor of Newcastle.

Chris Hamer
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Rutherford Slurred

In his recent book E = mc², David Bodanis makes an outrageous claim (p. 176) about Ernest Rutherford, that "with women he was bluff and pretty much a thug." This is a preposterous claim, which is nowhere near the truth, if not libellous, and it is so easily disproved.

Rutherford had an ex-schoolteacher mother, and he had six sisters all of whom received a good education in New Zealand. Four of the 10 Junior University Scholarships awarded in 1899 were won by women. As a student at the University of New Zealand's Canterbury College (1890-1894), he was brought up with women students having the same rights as men and coached at least one female student. The college had fully accepted women as equals from the day it opened in 1871. Professor Bickerton, who taught him physical science, was a well-known champion of women.

Mary Newton, Rutherford's landlady and future mother-in-law, was one of the stalwarts who ensured that New Zealand was the first country in the world to allow women the vote, in 1893 the year that he too first appeared on the electoral roll. His wife marched with the suffragettes in Britain before they belatedly won the vote.

His first research student was a woman, Harriet Brooks (McGill University 1898). They remained lifelong friends, they had great respect for each other and Rutherford wrote her obituary for the international science magazine *Nature* (17 June 1933). The mutual respect between him and Marie Curie is also a matter of record. Rutherford had several other women students or colleagues including Fanny Gates, May Leslie and Elizabeth Karamichailova.

There are several examples of Rutherford's vocal support for women's rights, including the 1920 letter to The Times, in which Rutherford and the professor of chemistry encouraged their fellow academics to give full rights to women at Cambridge University. Their letter concluded: "For our part, we welcome the presence of women in our laboratories on the ground that residence in this University is intended to fit the rising generation to its proper place in the outside world, where, to an ever-increasing extent, men and women are being called upon to work harmoniously side by side in every department of human affairs. For better or for worse, women are often endowed with such a degree of intelligence as enables them to contribute substantially to progress in the various branches of learning; at the present stage in the world's affairs we can afford less than ever before to neglect the training and cultivation of all the young intelligence available. For this reason, no less than for those of elementary justice and of expediency, we consider that women should be admitted to degrees and to representation in our University, and should be invited to maintain Cambridge in close contact with every aspect of human affairs.

Our friends among the opposition seem to forget that every broadening of the University interests and the abolition of the disabilities of Nonconformists and of the restrictions concerning the marriage of College Fellows, the provision of teaching and research facilities in science – has been the turning point for rapid extensions in the usefulness of the University.

We write these few lines in the hope of inducing some, so dazzled by the glories of Cambridge that they foresee no future grander than the past, to reflect that there is a great world outside for whose needs we have to cater, and to join with the supporters of Report A in their determination to minister to those needs in greater measure than before. We cannot afford to retain the women seen but not recognized in this University nor to leave them at the mercy of another university which is not yet planned."

The pity is that once an error is in a book it lurches there, awaiting "discovery" by decades of future readers. As a different example, last year a booklet on Rutherford reproduced a photograph of two people, labelled Rutherford's parents, in spite of the fact that I had pointed out a decade ago that those two people were not Rutherford's parents.

Bodanis has used only the reminiscences of Cecilia Payne, the only woman in an advanced physics class at Cambridge, who took offence not only at having to sit in the front row by herself (as the decorum of the day had dictated at Canterbury College as well) but also by Rutherford opening each lecture with "Ladies and Gentlemen". It seems certain that Payne misinterpreted a supportive gesture by Rutherford. At the time, lecturers at Cambridge commonly addressed their classes as "Gentlemen" even when, as was often the case during the First World War, the class was exclusively female. Thus to commence his lectures with "Ladies and Gentlemen" can be seen as a deliberate provocative stance in support of the presence of women in the classroom.

It is regrettable that Bodanis, in seeking a catchy comment, maligned a person who in fact championed women in science and higher education. His claim was exaggerated even further by a newspaper in New Zealand (NZ Herald 6th Jan 2001) which had as a front page headline "Scientist Hero a Sextist Thug".

I will do what I can to correct this terrible slor on Ernest Rutherford. I am not alone. Marlene and Geoffrey Rayner-Canham, Canadian biographers of Harriet Brooks, together with two prominent biographers of Rutherford, Lawrence Badash of the USA (the author of Rutherford's entry in the UK's Dictionary of National Biography) and Jeff Hughes of the UK, have joined me in repudiating Bodanis's slanderous claim.

John Campbell
author of "Rutherford Scientist Supreme"
University of Canterbury, New Zealand
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Physicist questionnaire

The AIP executive is seeking input from its membership on the future of The Physicist. While it is an important method of keeping in touch with our membership and it is valued by a large cross section of the AIP, it remains a major fraction of our budget and it is impeding our ability to develop new strategies and benefits for the AIP. It is our clear intention to keep The Physicist, however we need to know in what form you would like it to appear. Outlined below are three options to which we would like your response. You can easily respond by sending an email to me with your vote in the subject line of the email. It is easy, quick and effective. If you feel there are alternatives we have not canvassed in these three options then you can elect Option D and include in the text of the message your proposal.

This is a vital issue to the society so please participate – we need your advice.

Email to John.OConnor@Newcastle.edu.au with the option of your choice in the subject line. There is no need for message content unless you select Option D.

Option A: current form of Physicist bimonthly (no potential reduction in membership fees)

Option B: a Web based form of the Physicist monthly with email notification when it is available. Members who do not have access to the web or who prefer a printed version will receive that bimonthly. Estimated saving on membership fee typically $5-$10 per year.

Option C: a newsletter monthly on plain paper. Estimated saving on membership fee $10-$15 per year.

Option D: tell us about your solution.

If you don't have access to email then post your response to:

A/Prof John O'Connor
Physics, University of Newcastle, Callaghan NSW 2308

The Physicist Volume 38, Number 1, January/February 2001
Innovation Statement

The Prime Minister made his long-awaited statement on innovation policy on January 29th. The program amounts to a $2.9 billion package over five years. Some features of the policy include:

- $995 million for a HECS-style loan scheme for fee-paying postgraduate students;
- 23 Federation Fellowships for top researchers, worth $225,000 per year for five years;
- $460 million for a premium tax concession for companies doing additional R&D;
- $355 million R&D Start program for small start-up companies;
- $736 million increase in funding for the ARC;
- $583 million for research equipment, libraries and laboratories;
- $227 million for new Co-operative Research Centres;
- $176 million for centres of excellence in biotechnology and IT;
- $155 million for major national research facilities;
- $151 million for 21,000 new full-time university places in maths, science and IT;
- $130 million to foster science, maths and technical skills in government schools.

The Opposition spokesman, Carmen Lawrence, branded the policy "too little, too late". Only a small fraction of the package is due for expenditure in the next financial year.

["Sydney Morning Herald", 24 November 2000]

Stellar Nursery Discovered

Australian astronomers have made a stunning discovery using the Hubble Space Telescope. They have spotted a distant galaxy in the most intense throes of star formation ever seen. Dr. Brian Boyle of the AAO said the so-called "stellar nursery" was 100 times more active than any other comparable galaxy. It lies between 5 and 11 billion light-years from Earth, in a patch of sky called Hubble Deep Field South. It is very faint in visible light, but quite bright at radio wavelengths, according to Professor Ray Norris of the CSIRO.

The Anglo-Australian Telescope also recently discovered two planets orbiting stars 150 light years away. These are said to be the first planets to be discovered by Australians.

["The Age"]

Bush Science

The new US President, George W. Bush, is expected to make some significant changes in science policy. He is enthusiastic about the "National Missile Defense" scheme, and has stated his willingness to break the Anti-Ballistic Missile (ABM) Treaty of 1972 in order to achieve it. "We will offer Russia the necessary amendments to the treaty", he said. "If Russia refuses the changes we propose, we will give prompt notice under the provisions of the treaty that we can no longer be a party to it." On the other hand, President Bush has indicated his readiness to trim the American nuclear stockpile further, and to take the weapons off hair-trigger alert. Defence R&D will receive a big boost, of order $20 billion up to 2006.

The Bush administration will also take a more sceptical line on global warming, and is likely to take a far more market-oriented attitude towards energy and environmental issues. It has indicated that it will allow oil drilling in the Arctic National Wildlife Refuge in Alaska.

["Physics World", January 2001]

Physics at Monash

On 1 January this year, Monash University established the School of Physics and Materials Engineering. This cross-faculty school was formed from the Departments of Physics and Materials Engineering. This is an exciting development, appropriate in the Monash context, since both these former departments have had long-standing collaborative teaching and research interests in materials science.

Monash Physics commenced in 1961 with research strengths in condensed matter physics. In 1990 the department was merged with the Department of Applied Physics at the Chisholm Institute of Technology. In the last 10 years the department has broadly maintained its student base, but a contraction in staff numbers has made it difficult to maintain the level of research activity and establish initiatives in research. The formation of the new school provides the opportunity to continue with the teaching programs of physics, materials engineering and materials science while at the same time expanding the research activities in x-ray and synchrotron physics, materials characterisation and nanotechnology. A number of physics staff have taken early retirement but have arranged to continue their active research programs.

Monash University has signalled a clear commitment to support physics teaching and research, and the new school looks forward to vigorous growth with a Chair in X-ray and Synchrotron Physics currently being advertised, and with a number of related appointments envisaged in the coming 12 months. Further information on the School of Physics and Materials Engineering can be obtained from the Head of School, Professor Barry Muddle, on (61 3) 9905 4908 or barry.muddle@eng.monash.edu.au

Black Hole in Science Teaching

Australia is not alone finding difficulty in recruiting science graduates into teaching. In the UK, the number of science graduates entering teacher training has dropped by 60% since 1993. This is despite incentives including a hefty lump sum after one year on the job, fast track promotion, a free laptop computer, and double the normal pay increases.

The effect is compounded by a large number of expected retirements of experienced teachers over the next decade. Many physics teachers are already aged over 50. Increasing paperwork, growing class sizes, low morale and increasing stress have been cited as reasons for qualified teachers quitting the classroom.

Efforts are being made to fill the gap by targeting older, mature applicants for teacher training.

["Physics World", January 2001]

Saturnine moons

Four more moons have been discovered orbiting Saturn, bringing the known total to 22. The moons are only 10-50 kilometres across, just right for a holiday home in the Outer Solar System. They have irregular orbits, and may have been captured by the planet after forming elsewhere. The discovery was announced by Matt Holman of the Harvard-Smithsonian Center for Astrophysics, at a meeting of the American Astronomical Society.

["New Scientist", 4 November 2000]

Australian Journal of Physics

It emerged at the AIP Congress that due to financial exigencies the CSIRO has withdrawn all subsides from the Australian Journal of Physics. The journal will be closed down unless it can start making a profit within a year. It is currently losing of order $10-20 thousand per annum.
DIFFUSION, DEMIXING AND DESTRUCTION IN THERMAL PLASMAS

TONY MURPHY
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Introduction

Thermal plasmas are just one of many different types of plasmas that find application in industrial processes and products. These include (to name just a few examples) the low-pressure glow discharges used in reactors for etching of semiconductors, the dark discharges used in Geiger counters, the corona discharges used in electrostatic precipitators, and the dielectric barrier discharges used in ozone generators.

Thermal plasmas typically operate at around atmospheric pressure or greater, and can be excited by dc, ac, rf or microwave fields. The electrons are directly heated by the field, and in most plasmas, the electron temperature is significantly greater than the ion temperature. In thermal plasmas, the relatively high pressure means that the collision rate between electrons and ions is sufficiently high to maintain an ion temperature close to the electron temperature. Typical temperatures are in the range 10 000 K to 25 000 K, and electron number densities are of order $10^9$ m$^{-3}$.

Thermal plasmas are used widely in industry. Applications include arc welding, circuit breakers and switch gear used to interrupt large electrical currents, arc furnaces used to process minerals, arc lamps for lighting, and arc torches, or plasma torches, used for plasma cutting, plasma spraying and waste destruction. A feature of most of these applications is that mixtures of different gases are used. For example, in tungsten-inert-gas (TIG) welding, helium or hydrogen is often added to the argon plasma gas. In metal-inert-gas (MIG) welding, carbon dioxide or oxygen is added to argon. In circuit breakers, sulfur hexafluoride is usually used, and ablated polymer or ceramic vapours form part of the mixture. In plasma spraying, nitrogen, helium or hydrogen is typically added to argon. In many applications, metal evaporated from electrodes can ‘contaminate’ the gas mixture. In mineral processing and waste destruction, very complex gas mixtures are present.

Despite the ubiquity of gas mixtures in thermal plasma applications, scientific investigations, both experimental and theoretical, have tended to concentrate on plasmas in pure, homonuclear gases; i.e., plasmas containing only a single chemical element. This has been mainly for reasons of simplicity: the presence of more than one chemical element complicates both the measurement and calculation of the properties of thermal plasmas. The major difficulty in the theoretical study of mixed-gas thermal plasmas is the treatment of diffusion in the presence of many species. In this article, I will outline the problem, and present an elegant solution with wide applicability. I will then examine the phenomenon of demixing, which leads to the separation of the different gases in a mixed-gas plasma. I will demonstrate the importance of demixing in determining the properties of welding arcs. Further, I will show how understanding diffusion allows physical insights into the processes that drive demixing. Finally, I will look at a ‘real-world’ application of thermal plasmas in which complex gas mixtures are present, plasma waste destruction. I will show how an understanding of the physics and chemistry of mixed-gas plasmas has contributed to the development of a successful industrial process.

Diffusion

The high collisionality of thermal plasmas means that fluid dynamic equations can be applied in calculating their properties, with appropriate modifications to take into account plasma phenomena such as the flow of charge and the emission of radiation. The equations that are used are those describing the conservation of mass, momentum, energy, charge, and of each species present. Thermodynamic properties such as density, specific heat and enthalpy; radiative emission coefficients; and the transport coefficients viscosity, thermal conductivity, electrical conductivity and diffusion coefficients appear in the equations. The equation of state is included implicitly through the dependence of the transport and thermodynamic properties on the temperature and composition of the plasma.

An assumption that is usually made in the study of thermal plasmas is that local thermodynamic equilibrium (LTE) exists. Under this assumption, the translational, excitation and reaction temperatures of all species in the plasma are equal. The assumption requires that reaction times are small compared to transport times, which is usually justified except close to the electrodes and in the fringes of the plasma. The assumption of LTE has the consequence that the local composition of the plasma and the corresponding thermodynamic and transport properties are fully defined by the local temperature and the mole fractions of the chemical elements present.

Tony Murphy received the BSc (Hons) and PhD degrees from the University of Sydney in 1981 and 1987 respectively. From 1987 to 1989, he worked as a Post-Doctoral Scientist at the Max Planck Institute for Plasma Physics in Garching, Germany, in the field of radio-frequency heating of fusion plasmas. Since then, he has been with CSIRO Telecommunications and Industrial Physics (formerly CSIRO Division of Applied Physics), where he is a Senior Principal Research Scientist. His work on thermal plasmas, some of which is described in this article, has been recognised by the award of the Fawsey Medal by the Australian Academy of Sciences and the Edgeworth David Medal by the Royal Society of New South Wales.
If only a single chemical element is present, species conservation equations and diffusion coefficients can be dispensed with, greatly simplifying the treatment of the plasma. If, however, more than one chemical element is present, species conservation equations and diffusion coefficients have to be considered. The steady-state equation of mass continuity for a species $i$ is

$$\nabla \cdot (\rho \mathbf{u}_{Y_i}) + \nabla \cdot \mathbf{J}_i = r_i,$$

(1)

where $Y_i$ is the mass fraction of species $i$, $\rho$ is the density and $\mathbf{u}$ is the mass-averaged velocity. The three terms describe respectively convection, diffusion and the net rate of production of species $i$ due to chemical reactions. $J_i$ is the diffusive mass flux of species $i$, and is given by

$$J_i = \frac{n_i^2 m_i}{\rho} \sum_j m_j \left[ D_{ij}^d \nabla x_j - D_{ij}^d \frac{e_j}{k_B T} \left( e_j x_j \right) - D_{ij}^m \nabla \ln T \right],$$

(2)

where $x_j, m_j$ and $Z_j$ are respectively the mole fraction, mass and charge number of species $j$, $T$ is the temperature, $E$ is the applied electric field, and $e$ and $k_B$ are the electronic charge and Boltzmann's constant, respectively. The $D_{ij}$ are ordinary diffusion coefficients and the $D_{ij}^d$ and $D_{ij}^m$ are respectively ordinary and thermal diffusion coefficients modified to take into account ambipolar effects. Ambipolar effects arise because electrons diffuse more rapidly than ions, setting up an 'ambipolar' electric field that slows the diffusion of electrons and speeds that of ions.

It can be appreciated from equations (1) and (2) that the need to treat diffusion and species conservation greatly complicates the study of thermal plasmas. In a plasma containing $q$ species, a total of $q(q-1)/2$ species conservation equations have to be solved. This requires the calculation of $(q^2-q)/2$ linearly-independent ordinary diffusion coefficients and $q-1$ linearly-independent thermal diffusion coefficients for each temperature and composition. In a mixed-gas plasma (a plasma containing more than one chemical element), $q$ is typically large; in an argon-nitrogen plasma for example, 11 species, i.e., $\text{Ar}, \text{Ar}^+, \text{Ar}^{2+}, \text{Ar}^{3+}, \text{N}_2, \text{N}, \text{N}^+, \text{N}^{2+}, \text{N}^{3+}$ and the electron, would usually be present. Hence 10 species conservation equations would have to be solved, and 65 diffusion coefficients would have to be calculated for each temperature and composition.

In a single-gas plasma, in contrast, no species conservation equations are required, and diffusion coefficients can be dispensed with. Because of the large increase in complexity arising through the introduction of an additional gas, mixed-gas plasmas are often treated as single-gas plasmas by assuming that the gases are fully mixed. Unfortunately, the occurrence of demixing processes means that this assumption is usually not justified; such processes will be considered further in the next section.

A development that greatly simplified the treatment of mixed-gas plasmas was the introduction of the combined diffusion coefficient formulation [1]. Under this formulation, the plasma is treated in terms of gases (or chemical elements) rather than species. For example, in an argon-nitrogen arc, the species $\text{Ar}$, $\text{Ar}^+$, $\text{Ar}^{2+}$ and the electrons arising from the ionisation of argon species are assigned to argon gas, and the species $\text{N}_2$, $\text{N}$, $\text{N}^+$, $\text{N}^{2+}$, $\text{N}^{3+}$ and the electrons arising from the ionisation of nitrogen species are assigned to nitrogen gas. Such a treatment is possible if the plasma is in LTE, or at least in local chemical equilibrium (LCE), and if the chemical elements present do not react with each other.

Let us consider such a plasma, containing two gases, A and B. The $q-1$ species conservation equations [1] are replaced by a single conservation equation for gas A:

$$\nabla \cdot (\rho \mathbf{u}_{\overline{Y}_A}) + \nabla \cdot \mathbf{J}_A = 0,$$

(3)

where $\overline{Y}_A$ and $\mathbf{J}_A$ are respectively the mass fraction and mass flux of gas A, defined respectively as the sum of the mass fractions and mass fluxes of its constituent species.

The combined diffusion coefficients are defined by writing an expression for $J_A$ with a form equivalent to equation (2) for a two-species gas:

$$J_A = \frac{n_A^2 m_A}{\rho} (\overline{m}_A \overline{m}_B \overline{D}_{\overline{AB}}^d \nabla x_B + \overline{D}_{\overline{AB}}^m E) - \overline{D}_{\overline{AB}}^m \nabla \ln T,$$

(4)

where $\overline{m}_A$ and $\overline{m}_B$ are respectively the average masses of the heavy species of gases A and B and $x_B$ is the sum of the mole fractions of the species of gas B.

The parameters $\overline{D}_{\overline{AB}}^d$, $\overline{D}_{\overline{AB}}^m$ and $\overline{D}_{\overline{AB}}^r$ are respectively the combined ordinary diffusion coefficient, the combined electric field diffusion coefficient, and the combined temperature diffusion coefficient. They are linear combinations of the ordinary and thermal diffusion coefficients $D_{ij}^d$ and $D_{ij}^m$. The diffusive mixing of two gases due to concentration gradients, external electric fields and temperature gradients can be fully described by these three parameters. For an argon-nitrogen plasma containing 11 species, 10 species conservation equations and 65 diffusion coefficients have been replaced by one gas conservation equation and three combined diffusion coefficients. This represents a major simplification, without any loss of accuracy if the assumption of local chemical equilibrium, used in the calculation of the combined diffusion coefficients, is valid.

Figure 1 shows the temperature dependence of the combined ordinary diffusion coefficient $D_{\overline{AB}}^d$ for an argon-nitrogen plasma. $D_{\overline{AB}}^d$ is a linear combination of the ambipolar ordinary diffusion coefficients $D_{ij}^d$ of the pairs of species present, of which some are shown in the figure. At low temperature, for which Ar and N are the only species present, $D_{\overline{AB}}^d = D_{\text{ArN}}^d$. At temperatures around 9000 K, for which Ar and N are the dominant species present, $D_{\overline{AB}}^d = D_{\text{ArN}}^d$. We see that $D_{\overline{AB}}^d$ increases with temperature up to temperatures at which significant ionisation occurs; at higher temperatures, it falls rapidly, owing to the lower values of $D_{ij}^d$ for ionised species. These lower values are due to the strength of the Coulomb interaction, which leads to larger collision cross-sections and hence lower diffusion rates. At all temperatures, $D_{\overline{AB}}^d$, represents a weighted average of the ambipolar ordinary diffusion coefficients of the pairs of species present. Similar relations can be demonstrated for the other combined diffusion coefficients.
Demixing in Welding Arcs

Demixing is a process driven by diffusion that leads to the partial separation of the chemical elements that are present in the arc [2, 3]. It occurs in the presence of temperature gradients, or of certain external forces such as those due to electric fields. The processes that lead to demixing can be divided into a number of categories: demixing due to mole fraction (or partial pressure) gradients, due to frictional forces, due to thermal diffusion, and cataphoresis, or demixing due to electric fields.

Figure 2 shows the mole fractions of the species present in a mixture of argon and helium as a function of temperature if demixing is neglected. It thus represents the composition that would be seen if the gas mixture were heated in the absence of temperature gradients or external forces. At low temperature, only atoms are present. As the temperature increases above 10 000 K, argon begins to ionise, and each argon atom is replaced by an ion and an electron. Hence the total argon mole fraction, \( \overline{x}_{\text{Ar}} \), increases and, since the sum of mole fractions is one, the total helium mole fraction, \( \overline{x}_{\text{He}} \), decreases. This continues until a temperature of around 17 000 K, at which the helium atoms begin to ionise, is reached. Note that despite the changes in mole fraction with temperature, the mass fractions of the gases remain constant if demixing does not occur.

If we now consider the more realistic situation in which a temperature gradient is present, then the increase in \( \overline{x}_{\text{Ar}} \), and the decrease in \( \overline{x}_{\text{He}} \), result in mole fraction gradients. Let us for the moment consider only the first term in (4), so that the diffusive mass flux of argon is given by

\[
\dot{J}_A = \frac{n_A}{p} \overline{m}_{\text{Ar}} \overline{m}_{\text{He}} \nabla \overline{x}_{\text{He}} \cdot \nabla x_{\text{He}} \tag{5}
\]

Equation (5) and its equivalent for the mass flux of helium, \( \dot{J}_{\text{He}} \), indicate that the mole fraction gradients drive diffusion of argon and helium, which will continue until the mole fraction gradients disappear. This effect is known as demixing due to mole fraction gradients, and in this case leads to an increase in the mass fraction of helium in the high temperature region, and an increase in the mass fraction of argon in the low temperature region. In general, demixing due to mole fraction gradients leads to an increase in the mass fraction of the chemical element with the higher ionisation energy in the high temperature region.

Let us now consider the effect of the collisional interactions between the species on the demixing process, returning again to the example of argon and helium. We see from Figure 1 that at temperatures between around 8000 and 17 000 K, argon is partially ionised so that the species Ar, Ar\(^+\), and e\(^-\) are present, while helium is present almost solely as atomic helium. The mole fraction gradients of the respective species will drive a flux of argon atoms towards the region at higher temperature, and a flux of argon ions and electrons towards the region at lower temperature. These fluxes in themselves do not alter the composition if local chemical equilibrium can be assumed, since ionisation and recombination reactions then occur sufficiently rapidly to balance the fluxes. However, helium atoms also collide with the argon species; the collisions with argon atoms drive the helium towards the higher temperature regions, and the collisions with the argon ions and electrons drive the helium in the opposite direction. The net effect of the collisional interactions is to increase the mass fraction of helium in
the regions at higher temperature. This effect is known as demixing due to frictional forces, and usually leads to an increase in the mass fraction of the lighter chemical element in the regions at higher temperature. The effect tends to be greater when the mass difference between the elements is large.

Thermal diffusion also leads to demixing whenever a temperature gradient is present. As with frictional forces, thermal diffusion usually causes a flux of the lighter chemical element to regions at higher temperature.

Applied electric fields, such as that between the electrodes in an arc, lead to cataphoresis, or demixing due to electric fields, in which the more easily ionised chemical element is concentrated near the cathode.

Equation (3) can, by splitting the combined temperature diffusion coefficient $D_{\text{th}}$ into two parts, respectively linear combinations of ambipolar ordinary and thermal diffusion coefficients, be written so that each term contains one combined diffusion coefficient. It can then be shown that each diffusion coefficient corresponds to a separate demixing process.

To investigate the effect of demixing, the fluid dynamic equations, incorporating the combined diffusion coefficient formulation, were applied to arcs typical of those used in TIG welding. Such arcs have a conical tungsten anode and a flat anode (the metal to be welded) separated by a few millimetres, and operate typically at atmospheric pressure in an inert gas environment. Figure 3 shows the helium mass fraction and the temperature in an arc in a mixture of 10% helium and 90% argon by mass. The composition in the cool edge regions is that of the input mixture. As temperature increases, demixing leads to an increase in the helium concentration, with the helium mass fraction in the hottest regions reaching 25%. Even larger changes in concentration can occur in argon-hydrogen arcs, but when the mass difference between the gases is smaller, such as in argon-nitrogen arcs, the effects of demixing are less marked.

Since the different demixing processes correspond to different diffusion coefficients, it is possible to isolate the influence of the different processes on the change in arc composition in the calculation. An example is given in figure 4, which shows the radial dependence of the helium mass fraction at two axial positions, 2 mm and 4 mm below the cathode, in a 5 mm long arc. Three demixing processes lead to the concentration of helium near the arc axis. Demixing due to mole fraction gradients has only a relatively small effect, causing an increase in the helium mass fraction of about 30%.

The most important effect is demixing due to frictional forces, which causes the helium mass fraction to increase from a radius of around 2 mm right up to the arc axis. Demixing due to thermal diffusion also has a significant effect, particularly close to the arc axis.

Cataphoresis has little effect close to the cathode. However, as shown in figure 4(b), cataphoresis leads to a significant increase in the helium mass fraction close to the anode. Hence cataphoresis is found to concentrate the less-easily ionised chemical element near the anode.

![Figure 3: (a) Helium mass fraction contours and (b) temperature contours, labelled in units of 1000 K; calculated for a 200 A 5 mm arc with a 10 L min⁻¹ input flow composed of 10% helium and 90% argon by mass.](image)

![Figure 4: Calculated radial dependence of the mass fraction of helium at axial positions (a) 2 mm and (b) 4 mm below the cathode for the conditions of figure 3, with the effects of the different demixing processes shown.](image)

While demixing usually has a large effect on the composition of a free-burning arc, particularly when the mass difference between the chemical elements present is large, it generally has a relatively small effect on arc properties such as temperature and flow velocity. However, demixing can significantly alter the thermal transport to the anode. This is an important parameter in many applications of free-burning arcs, such as TIG welding, plasma cutting, and mineral processing, in which the role of the arc is to transfer a concentrated flux of heat to the anode. The heat flux is the sum of a thermal conduction term and a direct electron heating term.

Figure 5 shows the heat flux to the anode, calculated including and neglecting the influence of demixing, for an argon-hydrogen arc. In this case, demixing has a very large influence, increasing the heat flux on axis by the order of 50%. The increases are mainly in the conductive component, and may be explained by the increased thermal conductivity of the gas mixture for the range of temperatures, from about 5000 K to 10 000 K, present close to the anode. This is due to the increase in the concentration of the molecular gas caused by demixing; molecular gases have greater thermal conductivities than argon in this temperature range.

The predictions of the fluid-dynamic modelling generally agree well with spectroscopic measurements of arc temperature and composition [2, 4]. An example is given in figure 6, in
which the predicted helium mass fraction on the axis of argon-helium arcs is compared to optical and mass spectroscopy measurements. Both calculation and experiment show a significant concentration of helium on the axis due to demixing.

![Graph showing anode heat flux](image)

**Figure 5:** Radial dependence of the heat flux to the anode in a 200 A 5 mm arc with a 10 L min⁻¹ input flow composed of 5% hydrogen and 93% argon by mass. The contributions due to conduction and electron heating are shown separately. The dotted lines show values calculated neglecting demixing, while the other line types show values calculated including the effects of demixing.

![Diagram of PLASCON waste destruction process](image)

**Figure 7:** Schematic of the PLASCON waste destruction process.

### Waste Destruction

Thermal plasmas are increasingly being used for the destruction of hazardous wastes. A major advantage of plasma-based systems over conventional high-temperature incinerators is the higher temperatures and energy densities, which allows shorter residence times and the possibility of large throughputs in small reactors. Such small reactors are easily integrated into manufacturing processes, allowing on-site destruction. The main restriction to the wider application of thermal plasmas to waste destruction is cost; however, there are many applications, in particular those involving the destruction of concentrated wastes, in which plasma systems are economically viable.

CSIRO and Siddons Ramset Pty Ltd have developed PLASCON™ [5, 6], a thermal plasma process for the destruction of liquid and gaseous wastes. A schematic diagram of the process is given in Figure 7. An argon plasma jet is produced using a 150 kW de plasma torch. The waste is injected, together with an oxidising gas to prevent soot formation, through an injection manifold towards the end of the plasma torch. The resulting hot gas mixture passes through a reaction tube, which ensures residence times are sufficient for thorough destruction of the waste. The mixture is then rapidly quenched using a liquid spray, and is passed through a caustic soda scrubber to remove acid gases and halogens. The exhaust typically contains argon, carbon dioxide and water vapour.

Four PLASCON systems now operate in Australia. Two are used by Nufarm Ltd, a manufacturer of agricultural chemicals, to destroy on-line the waste liquid from the manufacture of 2,4 D, a selective herbicide. The liquid contains dichlorophenols, dioxins and other organic species. A third PLASCON plant is operated under contract to the Australian Government to destroy Australia's stockpile of ozone-depleting substances, in particular halons, or bromochlorofluorocarbons, and CFCs, or chlorofluorocarbons. The fourth plant is run by BCD Technologies to destroy PCB-contaminated oils.
most conditions, CF\textsubscript{3}Cl was the dominant ozone-depleting substance in the exhaust gas.

A further problem shown in figure 8 is the production of CF\textsubscript{4} at concentrations of up to 10\%. While not an ozone-depleting substance, CF\textsubscript{4} is a very strong greenhouse gas (6500 times worse than \text{CO}_2 per molecule), so its release to the atmosphere in high concentrations is undesirable. Chemical kinetic simulations, performed by Trevor McAllister of CSIRO Manufacturing Science and Technology, indicated that using steam rather than oxygen as the oxidizing gas would eliminate CF\textsubscript{4} from the exhaust gas. The fluorine atoms were predicted to react preferentially with the hydrogen atoms from the steam to form hydrogen fluoride. This theoretical prediction was confirmed in tests on the research reactor, and the ozone-depleting substance destruction process was subsequently redesigned to use steam rather than oxygen as the oxidizing gas. This constitutes a major success of the PLASCON theoretical programme.

The use of steam as the oxidising gas also significantly reduced the level of CF\textsubscript{3}Cl in the exhaust gas; nevertheless, the formation of CF\textsubscript{3}Cl remains the major limiting factor on the rate at which the ozone-depleting substances can be destroyed in the PLASCON process. To investigate this and other phenomena, a two-dimensional fluid dynamic model was developed \cite{6}. The model takes into account the electromagnetic, fluid dynamic and chemical kinetics phenomena occurring in the plasma torch, injection manifold and reaction tube regions. A two-stage procedure is used. In the first, the fluid dynamic and electromagnetic equations are solved to give temperature and flow fields. It is assumed in this stage that the composition can be calculated by invoking local chemical equilibrium, except that a one-step chemical kinetic scheme is used to model the initial dissociation of the CF\textsubscript{3}Cl. A modified version of the combined diffusion coefficient formulation is used to treat the diffusive mixing of the CF\textsubscript{3}Cl, the argon plasma gas, and the products of destruction. In the second stage, an extended chemical kinetic scheme, involving 23 species and 42 reactions \cite{5} is solved to give concentration fields of all species considered.

Figure 9 shows temperatures, streamlines and concentrations of CF\textsubscript{2}Cl\textsubscript{2} and CF\textsubscript{3}Cl calculated by the model. Inside the plasma torch, the temperature of the argon plasma gas reaches 27 \text{000 K}. At the point at which the plasma torch joins the injection manifold, the temperature has fallen to around 13 \text{000 K} on axis. The influx of cold gas (CF\textsubscript{3}Cl mixed with O\textsubscript{2}) from the injection manifold leads to rapid cooling. The temperature is between 1000 K and 2000 K in most of the reaction tube, falling to close to 300 K at the walls. The streamlines show the presence of a large recirculation region in the reaction tube. This has both positive and negative effects on the destruction process. The direction of flow near the injection manifold ensures that the injected gas is forced into the vicinity of the axis of the reaction tube, where the temperature is higher, promoting thorough destruction. However, the recirculating flow also carries cold gas into the region in which the injected gas mixes with the plasma, hence cooling this region and slowing
Concluding Remarks

I have discussed here three diverse topics relating to thermal plasmas in gas mixtures; the microscopic and somewhat esoteric process of diffusion, the more macroscopic and observable phenomenon of demixing, and the real-world industrial-scale application of plasma waste destruction. I have attempted, in my discussion, to demonstrate the relationships between the topics. The combined diffusion coefficient formulation was used to great effect in modelling demixing (and indeed has been applied to many other thermal plasma processes, including heat transfer to metal beads, and rf and dc plasma torches operating in gas mixtures). More generally, an understanding of the microscopic chemical and physical processes was essential in the successful development of the PLASCON process for the destruction of hazardous chemicals. If there is a conclusion to be drawn, it is that the development of new technologies is greatly assisted by a thorough scientific understanding of the processes and phenomena on which the technology is based.

References

PRESIDENT'S REPORT, COUNCIL MEETING, OCTOBER 31 2000

FASTS has made considerable progress in putting the matter of research and development on the national agenda for the next federal election.

Increasingly, the broader community is becoming convinced that private and public support for R&D is an investment in the nation's future prosperity.

Of course, for any lobby group or peak body, it is impossible to demonstrate a direct relationship between the effort and the outcome. That said, we are seeing increased interest in our views by the popular press and by influential radio interviewers, such as Graham Richardson and Alan Jones, as well as by our traditional outlets such as the ABC and The Australian. The issue of investment in R&D is getting the attention of esteemed economists and the cartoonists; next, talkback radio!

Our main task now is to maintain the momentum behind the Chief Scientist's report, "Chance for Change". We have seen many such reports, including the West report on higher education, sink without trace. Budget 2001 is the nation's last chance to change and we cannot let this opportunity be lost.

Maintaining the momentum without antagonising the policy makers of today and of tomorrow is an interesting challenge.

I have watched other organisations, such as the Australian Medical Association (AMA), undergo serious divisions on the matter of style. The AMA is divided between those who prefer a cosy relationship with the Minister and those who think it is more effective to beat from the side-lines.

During my Presidency I have attempted to steer the middle course, continuing the non-partisan record of FASTS that I inherited from my predecessors, Peter Cullen, Joe Baker and Graham Johnston. The Minister may not have ordered three bottles of champagne for us in the early hours of the morning, as did Dr Wooldridge for the former AMA team, but we have had the occasional quiet beer or breakfast with members of parliament and officers of ISR. This has not prevented our public comment on issues of importance to FASTS. FASTS is perceived, by one Cabinet Minister at least, as a 'good player'.

The first shock to the President of FASTS is to fully appreciate how limited the resources truly are. Following an increase in fees this year, individual members pay a maximum of $5.00 per year plus 50 cents GST, tax deductible. While the individual subscriptions are modest, the total fee for any individual society can be substantial. I would urge societies to list the FASTS contribution as a separate item on personal subscription invoices. The subscriptions support an Executive Director and one part-time office manager. So we are dependent, in the most vulnerable way, on volunteer scientists in the area of policy development, on our sponsors, and on our membership societies, for sustainability.

When I looked at this situation, I decided that the immediate strategy had to be one of increasing the standing of FASTS. That is, our volunteers need to gain professional recognition for their contributions to the Federation and sponsors need to be assured that they are supporting a highly professional organisation deserving of their respect. Our members need to know that they are getting value for money and are proud to be associated with FASTS.

I cannot pretend that this is an easy or short-term task and it has been an ongoing one for my predecessors. Some of our most talented volunteers have not been given the recognition that they deserve in terms of their professional development, and this is of great concern to me. I want association with FASTS, whether as office bearers, as board members, or as member societies, to be keenly sought and also to be valued by those outside the organisation.

One indicator of progress in promoting the profile of FASTS is that sponsorship of FASTS' activities has increased significantly. Generous support of our events has been given willingly, and for that I thank our traditional and new supporters. Another indicator is increasing requests for private briefings to government officers on draft policy papers or to journalists on science-related media stories.

One other indicator, and the most important element for FASTS, is society membership. Essentially, over the past twelve months the membership status quo has been maintained, with two societies giving notice of withdrawal and CAPA joining. I'm truly delighted to have our young scientists join us and to have their fresh ideas put forward at Board meetings. We have made some progress in forging relationships with other organisations, such as the CRC Association, the Institution of Engineers, Australia; and the Australian Society for Medical Research. But we need to do more to recruit new corporate member societies.

Our achievements speak for themselves and I direct people to the list of Year 2000 activities undertaken by FASTS listed on our website. Other useful contributions, in terms of science policy and in promoting science, have been made through FASTS' ex officio membership of the Prime Minister's Science, Engineering and Innovation Council, PMSEIC. The non-ministerial members have responsibility for developing agenda items for PMSEIC. I chaired the item Science and Technology in Fighting and Preventing Crime for the June 2000 meeting and am deputy chair of an item on Molecular Medicine for the November 2000 meeting of PMSEIC. In 1999, Peter Cullen co-chaired a PMSEIC working group on Salinity, and that work has continued to make important contributions to federal and state government policy on this issue.

The highlights for FASTS this year have been our two high-profile events, the Forum "Science & Technology in the Boardroom" and our second "Science meets Parliament Day". The success of these events is due to the stellar contributions of Toss Gascoigne and Robyn Easton. In addition, Toss is responsible for the strong media position of FASTS, working hard to maintain personal contacts, submit press releases in a timely way and ensure the ready availability of commentators.

I would like to thank the members of the Board, the Executive and of the Policy Committee for your terrific support during the year and to say that it is a privilege to be your President. I hope the next twelve months, and the election budget, realise some returns for our efforts.

Sue Sergeantson AO PhD.

"SCIENCE meets PARLIAMENT" DAY

Three quarters of all federal Parliamentarians had individual appointments with scientists on November 1, in the second "Science meets Parliament" Day. Feedback from participants has been positive, with the event scoring eight and a half out of ten overall. The address by Dr Neal Lane, Bill Clinton's science adviser, was a highlight, as were briefings by Parliamentarians and parliamentary staffers.

The event had a clear and immediate impact, with over 30 speeches and questions in the House and the Senate on November 1. TV showed up the number of MPs wearing the blue "SmP" badges.

Media coverage was good, and included ABC News, Radio National Breakfast, the PM program, ABC TV News; as well as articles in the Sydney Morning Herald, Australian, Adelaide Advertiser, Hobart Mercury, Aust Financial Review, and West Australian.

FASTS is now suggesting that scientists everywhere should invite their local MP or Senator out to inspect an experimental site or
3. HELP PARLIAMENTARIANS TACKLE THE ISSUES
Science needs a stronger presence in Parliament to assist MPs make decisions on highly technical areas like greenhouse, IT and gene technology. Appoint young scientists as interns to MPs.

4. SCIENCE AND THE BOARDROOM
Adopt a "Science and the Boardroom" program, to bring science and industry together at the highest levels to assist in the transfer of technology and good ideas.

5. SELLING AUSTRALIAN SCIENCE OVERSEAS
Australia is an attractive place to do science business, but our international profile is low. Each major overseas embassy should have a science attaché to sell our science expertise, and to stimulate collaborative research and development activity.

6. PROVIDING A START: SCIENCE AND TEACHERS OF SCIENCE
Science can inspire, but only when it is taught by highly trained, well-qualified teachers working in modern laboratories with good textbooks. We need HECS relief and a vigorous national program to recruit and train science graduates, with refresher programs to keep their science up to date.

7. COHERENT POLICY ON MAJOR NATIONAL RESEARCH FACILITIES
Australia should work out the best way to run big science infrastructure.

Establishing large national and international facilities requires regular funding and a systematic approach.

8. 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.

9. BRAIN DRAIN BECOMES EXPRESS TRAIN
Australia is in danger of losing a generation of scientists and technologists overseas. Invest more in higher salaries, better career paths, and improved research funding to retain our best and brightest.

10. BENCHMARKING FOR BUSINESS
Australia must be more agile in attracting overseas companies to base R&D operations here, by offering competitive incentives and moving quickly to adjust our regulations and incentive schemes.

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Around the Traps

ABC cuts

Sue Serjeantson, outgoing president of FASTS, has sent an open letter to Jonathan Shier, head of the ABC, to protest the abandonment of its in-house science programming. "Clearly the ABC has a major role to play, as an authoritative, nation-wide source of information and a critical investigator on science matters", she said. "For 16 years Quantum has made a valuable contribution. We regret the decision of the ABC to bring this successful program to an end. We seek your assurance that the ABC will continue to produce high-quality science programs for television".

[FASTS newsletter]

Louis Néel

Louis Néel, the French Nobel prize-winner, died on 17 November 2000. He is famous for his discovery of antiferromagnetism in 1932, and the transition temperature at which the antiferromagnetic state disappears is named after him. He shared the 1970 Nobel Prize with Hannes Alfven.

["Physics World", January 2001]

Superquant was set up only three months ago to provide quantitative risk analysis to the global finance industry. It was founded by Dr Peter Jones, who was also the founding chief executive of ac3, and is seeking $1 million in venture capital.

The Securities Industry Research Centre of the Asia-Pacific (SIRCA) is an organization that "scrubs" or checks financial data. They are a key member of the new Co-operative Research Centre for Technology Enabled Capital Markets, which will receive $14.2 million in government funding over seven years.

Animated Biomedical Productions is the only one of the three 'customers which is revenue positive. They specialize in 3D animation for the medical industry, and earn 75% of their revenue from exports. They will use ac3 for storage and distribution of their huge library of animated images, provided a broadband network can be put in place. Ac3 is also talking to companies in film post-production.

["Sydney Morning Herald", 24 November 2000]
On 14 December 1900 Max Planck delivered an epoch-making address to the Physical Society in Berlin where he presented for the first time his complete formula describing the spectrum of black body radiation. In particular he introduced quanta of energy through his famous formula $\varepsilon = h \nu$ where, what is now called Planck's constant $h$ appears for the first time. We shall in this historical overview trace the pertinent steps which led, in the last few decades of the 19th century to the birth of quantum theory right at the turn of the 20th century.

**Physics at the end of the 19th century**

Over the last few decades of the 19th century the foundations of physics seemed to be firmly established and what, with hindsight, we now call "classical" physics was considered by many physicists a complete framework for all physical phenomena, present and forthcoming.

Mechanics, the first and second law of thermodynamics with, in particular, the concept of entropy, together with Maxwell’s equations of electrodynamics, so beautifully validated by Hertz’s experimental demonstration of the equivalence of electromagnetic waves and light, were well understood and expected to account for all known physical phenomena. Only details would have to be worked out. Some experimental observations as yet not fully explained would sooner or later yield and be incorporated into the general framework outlined above.

A young aspiring student, Max Planck, in 1874 was even discouraged by his physics professor in Munich, Philipp von Jolly, from studying physics because no exciting new and fundamental developments could be expected and only the filling in of details would be left to future generations of physicists. Similar beliefs were shared by other eminent physicists of the time, e.g. the famous Emil Du Bois-Reymond in Berlin. Max Planck, fortunately undeterred by von Jolly’s verdict, studied physics and, having contributed important work clarifying the second law of thermodynamics and the concept of entropy, eventually rose to the most prestigious chair of theoretical physics in Germany, the one at the Friedrich-Wilhelm University in Berlin. In his own words “in an act of desperation” he would introduce the concept of quanta and a new fundamental constant of nature which now bears his name-Planck’s constant $h$. In doing so he would prove von Jolly and the other conservative physicists of his time wrong and open the way to a fundamentally new understanding of nature: the quantum theory whose 100th anniversary was celebrated in Berlin on 14 December, 2000 [1].

**The road to quantum theory**

Among the many fundamental unresolved problems which occupied the greatest minds in physics at the end of the 19th century were the spectrum of black body radiation, the discrete spectral lines of gases and the inability to experimentally detect an ether. These and some other unexplained experimental observations would eventually be solved over the first few decades of the 20th century giving rise to what we now call “modern” physics: quantum theory and the theories of relativity. However it was the unexplained spectrum of black body radiation which forced Max Planck to introduce in 1900 discrete quanta of energy and his new fundamental constant $h$.

From purely classical arguments, using only the first law of thermodynamics and Maxwell’s equations, it was known that the total energy radiated by a black body over all wavelengths is proportional to the fourth power of the ambient temperature, the Stefan-Boltzmann law

$$I = \sigma T^4$$  \hspace{1cm} (1)

It is interesting to note that the Stefan-Boltzmann law was only validated experimentally to high precision by Lümmen and Pringsheim in 1897. The spectrum of black body radiation was also poorly known experimentally, but some important theoretical work had been published in 1894 by Wien. Wien’s displacement law was derived again from a combination of thermodynamics and electrodynamics. The wavelength of radiation when adiabatically expanded changes inversely with temperature

$$\lambda \cdot T = \text{constant}.$$  \hspace{1cm} (2)

This displacement of the wavelength with temperature especially holds for the maximum of the radiation spectrum as was confirmed experimentally.

Combining the Stefan-Boltzmann law and his displacement law, Wien derived the general expression for the energy density
per wavelength interval $u(\lambda)$

$$u(\lambda)\lambda^4 = \text{constant}. \tag{2}$$

Moreover, since $\lambda T = \text{constant}$, this can be written in the form

$$u(\lambda)d\lambda = \lambda^{-4}f(\lambda T)d\lambda. \tag{6}$$

with a function $f$ only involving the product $\lambda T$. Or, in terms of frequencies rather than wavelengths

$$u(v)dv = v^3f(vT)dv. \tag{7}$$

These results were all new when Planck, in 1894, became interested in the problem of the spectrum of black body radiation. Let us now turn to Planck's huge and decisive contribution to the understanding of black body radiation and hence the beginning of quantum theory.

**Planck's contribution to black body radiation**

In 1894, most likely motivated by Wien's investigations culminating in the displacement law, Planck turned his attention to the problem of the spectrum of thermal or black body radiation. In 1895 he published his first preliminary results on the resonant scattering of plane electromagnetic waves off an oscillating dipole, a paper which he regarded as a first step towards an understanding of the full problem of the black body radiation spectrum. His goal was to study an oscillator or a set of oscillators in an enclosed cavity radiating and interacting with each other and the walls of the cavity via the radiation emitted. After sufficiently long time the system of oscillators and radiation would be in thermal equilibrium, so that then the laws of equilibrium thermodynamics could be applied to black body radiation and hence its spectrum understood. An important aspect of the problem, pointed out in the paper of 1895, was that the oscillator loses energy by sending out electromagnetic waves rather than heat. Planck considered the relation between the average energy of an oscillator and its radiation in thermal equilibrium. To do this he needed to calculate first the radiation sent out by an accelerated charged particle and compare this result with the radiation damping of the oscillator or the set of oscillators. The final and very remarkable answer for the spectral energy density is

$$u(v) = (8\pi v^3/c^3)E \tag{8}$$

where $E$ is the energy of the oscillator or the average energy of the set of oscillators considered. This result was published by Planck in a paper in June 1899.

One would now be tempted to use the equipartition theorem of Maxwell and Boltzmann and write

$$E = kT, \tag{9}$$

since the oscillator has 2 degrees of freedom, each of which, according to the equipartition theorem carries $kT/2$ of energy. Planck, however, didn't do this because he still rejected the statistical basis from which this result was derived. He only believed in "classical" thermodynamics as opposed to the "statistical" thermodynamics whose proponents were Boltzmann and Maxwell.

Although Planck later was forced to adopt the statistical viewpoint it is, with hindsight, fortunate that he didn't do so at this point. Lord Rayleigh, however, did not hesitate to insert (7) into (6) to arrive at an expression which is now called the Rayleigh-Jeans law. Earlier Wien had suggested

$$u(v) = (8\pi v^3/c^3)\alpha v e^{\beta v}. \tag{10}$$

with constants $\alpha$ and $\beta$. According to Rayleigh this could only be viewed as "little more than a conjecture". From the measurements which became available with better and better accuracy due to Rubens and Kurlbaum, it became clear that neither Wien's nor Rayleigh-Jeans' law described the black body spectrum correctly, the one being incorrect at low frequencies, the other at high frequencies.

Hence, it was apparent to Planck that what was needed was a relation between $E$, the energy of the oscillator or the average energy of the set of oscillators, the temperature $T$ and the frequency $v$.

Planck's next step was guided by the detailed measurements Rubens and Kurlbaum published in October 1900, which showed conclusively that Wien's law was inadequate to explain the distribution of black body radiation at low frequencies and high temperatures, i.e. when the relevant variable $vT$ is small. Rubens and Kurlbaum told Planck about their results before their official presentation and asked him for comments. These comments were published in a paper entitled "An Improvement of the Wien Distribution". It was in this paper that Planck's famous formula appears for the first time in its primitive form. His arguments were called again from thermodynamics. Later he would comment that he was prepared to sacrifice all of his physical convictions except the first and second law of thermodynamics in order to explain the black body spectrum which he considered the most important problem of the time.

His arguments amount to an interpolation between low and high values of the variable $vT$, i.e. the only variable which appears in all the known results for the black body spectrum. In other words he interpolated between the Rayleigh-Jeans and the Wien law.

From the first law of thermodynamics he obtained

$$dS/dE = 1/T. \tag{11}$$

For low frequencies, i.e. where the Rayleigh-Jeans law is good, he obtained

$$u(v) \propto E \propto T \tag{12}$$

and therefore

$$dS/dE \propto 1/E \tag{13}$$

and

$$dS/dE \propto 1/vE. \tag{14}$$

From Wien's law, on the other hand, Planck concluded that

$$dS/dE \propto 1/E, \tag{15}$$

which is good for large values of $vT$. Thus Planck only needed to interpolate between (14) and (15) and furthermore, to satisfy the second law of thermodynamics, demand that the entropy is
maximal and hence \( \frac{dS}{dE^2} \) is negative. The interpolation can be achieved by the following expression

\[
\frac{dS}{dE^2} = \frac{a}{E(b+E)}.
\]

(16)

Now Planck’s formula in its primitive form follows

\[
E = b(e^{h\nu}-1),
\]

(17)

or, for the radiation spectrum

\[
u(\nu) = \frac{(8\pi \nu^3 c^3)}{E} = \frac{(8\pi \nu^3 c)}{b(e^{h\nu}-1)}.
\]

(18)

Comparing again with Wien’s formula, shows that \( b \propto \nu \) and thus

\[
u(\nu) = A \nu^4 (e^{h\nu}-1).
\]

(19)

This was the status of understanding of the black body radiation spectrum in October 1900. Although Eq. (19) described the measurements of Rubens and Kurlbaum best among the competing formulae, its understanding was of course still poor.

To understand the formula (19) Planck had to give up his opposition to the statistical methods of Boltzmann and Maxwell in thermodynamics. He introduced small energy elements \( \epsilon \) for the individual oscillator and calculated the probability with which a fixed amount of energy \( E \), subdivided into energy packets or quanta \( \epsilon \), is distributed amongst the set of oscillators.

Although Planck did not do that quite in the spirit of Boltzmann and Maxwell, he nevertheless got the answer right. Only through the work of Bose in 1924 did the correct way of deriving Planck’s result become fully apparent. Planck found in his analysis that the energy quanta had to be chosen proportional to the frequency of the oscillator \( \epsilon = h\nu \) and he immediately saw that the proportionality factor \( h \) was a new fundamental constant of nature.

Of course, this was not the usual procedure in statistical thermodynamics where the energy elements \( \epsilon \) were only a formal device and \( \epsilon \to 0 \) was taken at the end of the day. This limit was no longer possible for Planck in his final analysis which he presented to the Physical Society in Berlin on 14 December 1900 and which gave the result for the black body radiation spectrum

\[
u(\nu) = \frac{(8\pi h \nu^3 c^3)}{E(b-1)}
\]

(20)

where another fundamental constant of nature also appears, Boltzmann’s constant \( k \).

This concludes this short history of Planck’s famous result for the black body radiation spectrum which marks the start of quantum theory.

References

1. See http://www.dmg-physik.de/kalender/qt100/qt100e.htm for a detailed programme of the celebrations in Berlin.
2. For a more detailed exposition of the physics leading to Planck’s discovery along historical lines, see: M. S. Longair Theoretical concepts in physics (Cambridge University Press, Cambridge, 1984).
3. For a complete history of quantum theory, see e.g. Friedrich Hund The history of quantum theory (Harrap, London, 1974).
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PIFOC Piezoelectric Positioners
Physik Instrumente (PI) offers a complete line of PIFOC piezoelectric positioners to remotely position microscope objectives with subnanometer resolution. These fast and compact drive units can be mounted on almost any microscope and offer travel ranges of 100, 200 and 350 μm.

Integrated linear variable differentiation transformer or capacitive sensors are optional. The new Power PIFOC (the POF/FOC) was designed to position the microscope turret with multiple objectives.

These and other integrated systems from PI are available from WARSASH Scientific on (02) 9319 0122 or at sales@warsash.com.au.

New NanoAutomation Digital Controller
Physik Instrumente (PI) of Germany has developed a new NanoAutomation digital controller. The E-750.CP controller has an optional integrated Mach through-put co-processor that can increase the speed of settling structures by up to three orders of magnitude.

Stage calibration is stored in EEPROM in the cable connector, for plug-and-play compatibility with PI’s motion devices. The device also features 21-bit precision (0.7 Å for a 15um stage) and fourth-order dynamic linearisation.

Communications options include an analog input and RS-232 and optical fiber input/outputs. The E-750.CP is suitable for OEM integration where tooling must be swapped for process changes.

Further details are available from WARSASH Scientific on (02) 9319 0122 or at sales@warsash.com.au.
1st Asian Physics Olympiad - Jakarta, Indonesia

April 2000 saw the successful commencement of a new regional physics competition. The First Asian Physics Olympiad was hosted by Jakarta, Indonesia and was attended by five of Australia’s finest and most promising Year 12 Physics students:

Andrew Hill - Silver Medal - Knox Grammar School, NSW
Clancy James - Honourable Mention - Westminster School, SA
Belinda Leong - Methodist Ladies College, NSW
Garth Pearce - Honourable Mention - Penrith High School, NSW
Chi Yeun (Kenneth) Tsui - Honourable Mention - Bossley Park High School, NSW

The opening and closing ceremonies were spectacular displays of many attractions that Indonesia and 2001’s host country (Chinese Taipei) have to offer. An extensive cultural program organised by the Australian Embassy in Jakarta and the APhO Organising Committee left our students overwhelmed by the diverse experiences offered by our closest neighbouring country.

Cultural events included: tour of Taman Mini Indonesia Indah Park (Beautiful Indonesia in Miniature); dinner at the Australian Ambassador’s residence; tour of the Bataan research reactor facility at Serpong; tour of a safari garden; visit to a tea plantation at Panek Pass; tour of a Batik factory; and visits to Borobudur and Prambanan temples. The Aussie competitors were left exhausted, but excited about returning to Indonesia at some later stage for a more extended trip.

Added to this, the overall experience of meeting, competing with and talking to many talented Physics students from the Asian region was a wonderful educational opportunity.

The results from the competition and the maturity demonstrated by the Australian contingent is to be greatly admired - particularly in the face of many challenges associated with an unfamiliar climate and and surroundings together with unexpected attention from the Indonesian media.

The Asian Physics Olympiad is now an annual event on the RTASO Physics Program calendar and we are looking forward to APhO 2001 in April. Candidates for this year’s team to Chinese Taipei are already past the first two stages in the selection process and currently in the midst of a strenuous programme of private study ahead of the final team selection exam.

The RTASO Programs are always on the lookout for anyone who shares our goal of encouraging the best secondary school students to get involved in science. If you’re interested, please contact us via our website: http://www.rtaso.org.au/.

As a challenge, take a look at the following problem from the APhO 2000 competition. The solution is included below. This problem comprised approximately one third of the marks in the five hour theoretical competition.

**Problem:**

**Stewart-Tolman Effect**

In 1917, Stewart and Tolman discovered a flow of current through a coil wound around a cylinder rotated axially with certain angular acceleration.

Consider a great number of rings, with the radius $r$ each, made of a thin metallic wire with resistance $R$. The rings have been arranged in a uniform way on very long glass cylinder, which has a vacuum inside. Their positions on the cylinder are fixed by gluing the rings to the cylinder. The number of rings per unit length along the symmetry axis is $n$. The planes containing the rings are perpendicular to the symmetry axis of the cylinder.

At some moment the cylinder starts a rotational movement around its symmetry axis with acceleration $\alpha$. Find the value of the magnetic field $B$ at the center of the cylinder after equilibrium is reached. We assume that the electric charge $e$ of an electron, and the electron mass $m$ are known.

**Solution:**

Consider a single ring first: let us take into account a small part of the ring and introduce a reference system in which this part is at rest. The ring is moving with a certain angular acceleration $\alpha$. Thus, our reference system is not an inertial one and there exists a certain linear acceleration. The radial component of this acceleration may be neglected as the ring is very thin and no radial effects should be observed. The tangential component of the linear acceleration along the considered part of the ring is $\alpha r$. In the frame of reference we have defined, the positive ions forming the crystal lattice of the metal are at rest and an inertial force acts on the electrons. This force has the value $m\alpha r$ and acts in the opposite direction to the acceleration mentioned above.
The interaction between the electrons and the crystal lattice does not allow the electrons to increase their velocity without limitation. This interaction, according to Ohm's law, increases with the velocity of the electrons relative to the crystal lattice. After some time, equilibrium between the inertial force and the force due to the interaction with the lattice is reached. When this equilibrium is reached, the positive ions and the negative electrons are moving with respect to each other and an electric current is flowing.

The inertial force is constant and at each point is tangent to the ring. Its action on the electrons can be imagined as equivalent to a (fictitious) electric field, $E$, tangent to the ring at each point. The force due to the field should be equal to the inertial force, thus:

$$eE = mra$$

Therefore:

$$E = \frac{mra}{e}$$

In the ring (at rest) with resistance $R$, the field would generate a current:

$$I = \frac{2\pi r E}{R}$$

Thus, the current in the ring would be:

$$I = \frac{2\pi r a}{eR}$$

The field $E$ is a fictitious electric field, but it describes a real action of the inertial force on the electrons, and the consequent flow of current is certainly real!

We can now treat the overall system as a very long solenoid consisting of $\pi$ loops per unit length (along the symmetry axis), in which the current $I$ is flowing. The magnitude of the field $B$ inside such a solenoid (neglecting end effects) is homogenous and given by:

$$B = \mu_0 \eta I$$

where $\mu_0$ denotes the permeability of free space. Thus, since the point at the axis is not rotating, it is at rest both in the non-inertial and in the laboratory frame, and the magnetic field at the center of the axis in the laboratory frame is

$$B = \frac{2\pi \mu_0 \eta m r a}{eR}$$

---

**Choosing a career? Thinking of a career change?**

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Medical physics is a growing and rewarding field offering the scientific challenges of meeting the ever increasing demands for accuracy and precision in treatment and diagnosis as well as the satisfaction of a key role in the care of patients.

CancerCare Manitoba offers training positions with annual salaries of up to CDN$62,000 for M.Sc. or Ph.D. level physicists entering the fields of radiotherapy physics or diagnostic imaging physics. Positions are also available for dedicated, fully qualified medical physicists, who can earn up to CDN$125,000 per year.

The Department of Medical Physics at CancerCare Manitoba has university and teaching hospital affiliations with state-of-the-art clinical facilities and an active research and teaching program. Our research activities include exciting development work in virtual-reality-guided brachytherapy, theoretical and experimental studies of dosimetry using electronic portal imaging devices, and development of a radioactive-source-based CT-imaging system. The department is supported by strong electronics, mechanical and information technology staff and facilities.

CancerCare Manitoba is located in Winnipeg, a medium-sized city which offers excellent cultural and sporting activities, a strong education system at all levels and a very competitive cost of living. CancerCare Manitoba acknowledges all forms of human diversity and respects the rights, dignity, pride and privacy of all persons. We provide a smoke free working environment.

Please send requests for further information about Medical Physics at CancerCare Manitoba and applications for regular or training positions (which should include a detailed current resume) to Dr David A. Wiggins at the address below as soon as possible. Additional information about Winnipeg and Manitoba, and general information about medical physics may be found at the following websites: www.CancerCare.mb.ca, www.city.winnipeg.mb.ca, www.manitoba.worldweb.com, www.gov.mb.ca/index.shtml, www.umanitoba.ca, www.medphys.ca, aapm.org

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Chairman’s Report

The 14th National Congress of the Australian Institute of Physics (AIP2000) was held at Adelaide University from Sunday 10 to Friday 15 December, 2000. It attracted 658 registered participants and twelve Associated Conferences. The Congress began with a brief introduction and welcome by John Pilbrow (AIP President) and Neil Byrnes (DSTO, Principal Sponsor) and was officially opened by His Excellency, Sir Eric Neal, Governor of South Australia.

The unifying backbone of the Congress was a series of excellent and varied plenary talks on a wide variety of physics issues from the origin of the universe to developments in science/physics policy and funding in the United Kingdom. The plenary speakers and their talks were:

John Barrow (ASGGR) - "The Origin of the Universe";
Mike Kelley (STSP) - "Exciting New Discoveries in ionospheric Science";
Sir Gareth Roberts FRS, President IOP - "Sagacity and Significant Stretch for Survival";
Michael Hough (SASTA) - "Physics Education in a Globalizing Economy where Knowledge & Information are Competitive Advantages";
Alun Jones, Chief Executive, IOP - "Developments in Science/Physics Policy & Funding in the UK";
Dean Zollman (OxCUPE) - "Teaching Quantum Mechanics to Everyone: Can it be done with Technology?";
Phillip Stiles (CMP) - "Condensed matter Physics: The last 50 years and future directions";
Victor Ninov (AINSE/NUPP) - "Production and Structure of Super-heavy Elements";
Janet Conrad (WIP) - "Navigating the World of Neutrino Oscillations";
Sajeev John (AOS) - "Photonic Band Gap Materials: A New Frontier in Quantum and Nonlinear Optics";
Jeffrey Harris (Plasma2000/AINSE) - "Plasma Physics: Innovation in Energy and Industrial Technology";
Roger Horn (VSA) - "Surfaces Cover Everything";
Chris Greene (AMPQC) - "Photoionization of Light Atoms and Molecules: A Window into Few-body and Many-body Dynamics".

(Where a plenary speaker was associated with and recommended by one of the Associated Conferences, this is indicated in parentheses.)

The plenary talks were uniformly aimed at a general physics audience and set an excellent tone for the Congress. Roger Horn deserves special mention for being courageous enough to perform an experiment involving an overhead projector, surfactants, water, and mica during his plenary talk.

The Associated Conferences were run in parallel, mostly in the afternoons, and formed the main body of the Congress. There was a significant level of cross-fertilization and cooperation between some of these where it was mutually advantageous. While no single person could attend even a small fraction of the talks in these Conferences all the feedback received indicates that each of them was very well organized with a series of stimulating talks and posters. The Associated Conferences and their Convenors were:

Australasian Society for General Relativity and Gravitation (ASGGR), David Wiltshire; Atomic and Molecular Physics and Quantum Chemistry (AMPQC), Igor Bray and Michael Brunger;
7th Vacuum Society of Australian Congress (VSA), John O’Connor;
Australian Conference on University Physics Education (OxCUPE), Judith Pollard;
18th AINSE Nuclear and Particle Physics Conference (AINSE/NUPP), Andrew Stuchbery and Dennis Mather;
Women in Physics (WIP), Margaret Law;
Australian Optical Society (AOS), Murray Hamilton;
Condensed Matter Physics (CMP), Stephen Colloct and Joan Oltman;
Solar, Terrestrial and Space Physics (STSP), Dick Thomas;
23rd AINSE Plasma Science and Technology Conference (Plasma2000), Robin Storer and Dennis Mather;
Australian Conference for Teachers of Physics (organized in part by the South Australian Science Teachers Association, SASTA), Alan Pepper, Barbara Possingham, and Susan Cockshell;
Medical Physics (MP), Eva Bezak and Tim van Doorn.

The Convenors of the Associated Conferences spent much time and effort putting together their Conference programs and the Congress Organizing Committee is very grateful for all of their hard work.

The Massey Medal winner, Tony Thomas, gave a well-attended and very clear award presentation on his work in theoretical strong interaction physics in a talk entitled "Probing the Heart of Matter" on Monday evening. On Tuesday evening Paul Davies gave a public lecture on "Time-travel fact or fiction" to a capacity crowd of over 900 people in Boynthon Hall. The Organizing Committee is extremely grateful to Paul for donating his time to the Congress in this way and in so doing helping to raise the profile of our Congress in the eyes of the general public. On Wednesday morning the Bragg Medal winner, Ping Koy Lam, gave an excellent presentation on his award-winning Ph.D. thesis work entitled "Applications of quantum electro-optic control and squeezed light".

The last session on Wednesday morning was an AIP General Meeting and the afternoon was left free for optional tours, including wineries, wildlife and beaches. Murray Hamilton deserves special thanks for organizing the "Physics-based industry in Adelaide" tours which were also available Wednesday afternoon and were very well attended.

The Congress dinner was held at the Hyatt Regency and was attended by 420 registrants and guests. The food and wine appeared to be enjoyed by all as was the jazz quartet.

The Congress ran smoothly with things happening at the right time with a minimum of fuss and, as much as we on the Organizing Committee might like to take the credit, this was in reality due to the outstanding staff at Staffords Conference Management. Special thanks go to Ann Ewer and Maria Stuart for all they did during the Congress and in the 15 months of preparation leading up to it. The Organizing Committee consisted of Reg Cahill, Margaret Law, Derek Leinweber, Ian McCarthy, Jesper Munch, Tony Thomas, Alan Pepper, Barbara Possingham, John Thomas, and Robert Vincent. I sincerely thank them for their invaluable efforts and support during the lengthy preparation period. The skills of Stewart Wright in setting up and maintaining the Congress web page are much appreciated.

We are also grateful for the support of all of the exhibitors and sponsors and in particular acknowledge the support of DSTO as Principal Sponsor of the Congress.

The Institute of Physics (UK) provided the welcome reception on Sunday evening following the opening of Registration. I am sure that all AIP members would join with me in extending our sincere thanks to Sir Gareth Roberts and Alan Jones of the IOP for this reception, for their talks, and for taking the time to attend AIP2000.

For the curious the web page is still available and includes a full program detailing all of the plenary talks and the parallel Conference talks and posters (http://www.physics.adelaide.edu.au/aip-sa/aip2000/).

I am pleased to report that the Congress budget was balanced. While there were many factors which contributed to this (sponsors, exhibitors, the public lecture, etc.), in the end...

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it was simply a matter of numbers of registrants. A strong attendance at the Congress helps to mitigate the fixed costs (as opposed to the per registrant costs) and in so doing allows us to keep the registration costs to a minimum. Putting on an international quality Congress while minimizing registration costs is a delicate balance indeed and the more people that attend the Congresses the lower will be the cost of registration.

In closing, I would like to thank all participants of AIP2000 for supporting their AIP and their Congress. I look forward to joining all AIP members in actively supporting and attending the next Congress in New South Wales in 2002!

Anthony G. Williams
Chair, AIP2000 Organizing Committee

Reports from Group Convenors

STSP GROUP

The meeting of the Solar Terrestrial and Space Physics (STSP) Group at AIP2000 featured 35 oral and 10 poster presentations, with approximately 50 of the 120 nominal group members in attendance. Our Plenary Speaker, Prof Michael Kelley from Cornell University USA, spoke about new optical techniques for exploration of the ionosphere, including lidar and all-sky airglow cameras operating at various wavelengths to examine such phenomena as long-lived meteor trails, noctilucent clouds, red sprites and travelling ionospheric disturbances. Prof Kelley intends to install an air-glamer in northern Australia as part of DARWEX (Darwin Area Wave Experiment), a project aiming to investigate atmospheric and ionospheric effects related to tropical thunderstorms, and which will be led by the University of Adelaide.

Research papers, both oral and poster, were contributed in the areas of ionospheric and magnetospheric physics, HF propagation, high latitude phenomena, plasmaspheric modelling and the effects of ionisation irregularities. In addition, for the first time at any Congress (a first for the STSP Group, at least), we enjoyed a joint session convened between the STSP and Plasma Groups. This initiative of Prof Brian Fraser (University of Newcastle) succeeded admirably in bringing together laboratory plasma physicists and space physicists into a single forum to discuss plasmas in the space environment. An entire session was also devoted to papers from the recently commissioned Tasman International Geospace Environment Radar (TIGER), an auroral HF radar located in Tasmania and developed by an Australian consortium of universities, government departments and industry, overseen by La Trobe University. TIGER is part of the expanding international Super Dual Auroral Radar Network (SuperDARN) to study the high latitude ionosphere in each hemisphere. One of the main features of SuperDARN is the ability to map ionospheric convection, an important space weather system that plays a dominating role in the high latitude ionosphere.

At the STSP Business Meeting, Dr P Wilkinson was elected Convenor for the next AIP Congress at Sydney in 2002. Other agenda items included web publication of STSP presentations, the future of Antarctic physics and plans for the DARWEX experiment. It was also decided not to hold a special meeting in 2001 (between Congresses) due to the unusually large number of related meetings also taking place around the same time.

Dr R M Thomas,
Convenor of STSP Group at AIP2000

CMP Program

Condensed Matter Physics was a significant part of the AIP2000 Congress, with well attended sessions extending over the five days. Some 85 papers were presented, with 21 orals and the remainder, posters.

The convenors, Stephen Collocoott and myself, decided to follow a format in which most of the oral presentations were 35 minute invited talks. These were chosen to cover most of the major areas of the field and as many as possible of the major Australian research groups. Speakers were asked to make at least the first part of their talk of an overview nature, and we were pleased at how well this request was adopted.

The various sessions were arranged around themes. The first session was in the general area of complex materials and was led off by Michele Parrinello, Director of the Max Planck Institute for Solid State Research in Stuttgart, famous for the Carr-Parrinello model of ab-initio molecular dynamics. David McKenzie from Sydney University spoke on materials for biotechnology and John Dobson on calculation of dispersion forces in complex systems. The second session was, in the main, aimed at neutron scattering. Robert Robinson spoke on the new reactor project and on some of the physics planned for the facility and Oscar Mose, Modena, spoke on using neutron scattering to determine structures and interactions in novel magnetic materials. The session concluded with an update on the Australian Light Source proposal from John Boldeman. The Tuesday morning session was devoted to magnetism and superconductivity with talks from Trevor Hicks, Roger Lewis and Emma Mitchell. The afternoon session again turned to materials, with talks by David Williams on DNA (as an example of "soft condensed matter"), Paul McCormick on nanopowders and Craig Buckley on metal-hydrogen systems.

Thursday was devoted largely to semiconductors and nanostructures. Jim Williams overviewed the work of his group and indicated how novel semiconductor devices have led to a new start-up company in Canberra. Steven Prater told us about wide band gap materials and the development of blue lasers while Phil Smith described calculations of chemisorption on silicon surfaces. In the afternoon Bob Clark described the program of his new Special Research Centre to develop a silicon based quantum computer, Bob Stamps spoke about "spin electronics" and He-Bi Sun discussed a theoretical approach to probe electron states of a prototype qubit device. Friday morning featured a joint session with the Australian Vacuum Society, in surface physics, with talks from Steven Thurgate, Rob Ebelland and Matthew Fewell.

The sessions and the poster presentations provided a comprehensive showcase of the excellent and exciting research being carried out in many groups across the country and augurs well for the continuing vitality of Condensed Matter Physics in Australia.

Jaen Ottinoa,
CMP Convenor

AMPQC Program

The Atomic and Molecular Physics and Quantum Chemistry meeting presented recent progress in unusually diverse areas. These ranged from the claimed solution of the fundamental e-H Coulomb three-body problem that made the front cover of Science, through to the application of atomic physics and quantum chemistry in the fields of nanotechnology, quantum computing and explosives. Australia's historical strength in the area of atomic collision physics, in both theory and experiment, looks to continue long into the future following presentations from the ANU, Flinders, Griffith, Murdoch and UWA groups. In all, around 35 speakers gave presentations, a large proportion by students. The quality of the student presentations was particularly outstanding suggesting that sometimes "Do as I say and not as I do" does occasionally work.

More specifically, the plenary speaker was Chris Greene from the University of Boulder Colorado. He spoke of various fundamental Coulomb three-body problems. These include electron-impact ionisation of atomic hydrogen, and double photoionisation of helium or the H-minus ion. While these have no practical application they are fundamental to the understanding of the treatment of collisions involving more practical but complicated targets where the underlying interactions are also governed by the long-range Coulomb potentials.
Many other invited speakers spoke on closely related subjects. Birgit Lohmann of Griffith University discussed experiments involving formation of heavy rare gases. Bill MacGillivray, also of Griffith, presented progress in the field of laser assisted electron-atom collisions. This was also the main theme of the talk by Victor Karangan of Flinders University, and that of Maarten Hoogerland from the ANU. Peter Hammond, UWA, talked of experiments where more complicated collisions involving two target electrons are performed. Progress in the theory of fundamental Coulomb three-body problems was discussed by Andris Steibovics of Murdoch University and Anatoli Khinefs of the ANU. Harry Quency of the University of Melbourne showed the importance of using relativistic theory in the treatment of heavy atoms and molecules.

It was particularly interesting to see the application of atomic physics to check if the fundamental constants of nature change with time, as discussed by Victor Flambeau of UNSW. Gerard Milburn covered recent progress in the emerging field of Quantum Computing, and Jamai Berndt, Hall University, Germany, showed how fundamental atomic collision theory has applications in describing Quantum Dots. Helen Dorsett, DSTO, described quantum chemistry calculations used to understand the performance of explosives.

Additionally, 23 contributed talks and 17 posters were presented. We won't attempt to cover them all, but for those interested the program will be available at http://yin.ph.flinders.edu.au/ampqc/ for a few months after the publication of this article.

The AMPQC organisers would like to thank the AMPQC participants and the organisers of the Congress for ensuring that everything progressed very smoothly.

Michael Brungar and Igor Bray.

ASRG Workshop

The workshop consisted of two afternoons of talks, one experimental and one theoretical. In the experimental session Dr David McClelland gave an fascinating overview of the present worldwide effort to detect gravitational waves with the network of laser interferometer observatories. He explained why he believed that gravitational waves would be detected within the next 10 years, discussed the technical challenges involved, and gave a glimpse on the new field of gravitational wave astronomy which will emerge once the technology becomes a reality.

In the remaining talks we were presented with more detailed discussions of particular experimental projects, as well as the immense effort in data reduction which will be required.

The theoretical sessions were wide ranging, covering all aspects of gravitational physics, from mathematical relativity to cosmology and to string theory. Dr Peter Bouwknegt presented an overview of recent results in string theory, while Dr David Wiltshire presented an overview of the new popular "brane world" scenario, in which extra spatial dimensions are either compact but larger than had been previously considered to be the case, or possibly infinite. The more technical talks covered topics including the evidence for a vacuum energy in the universe - "quintessence" - and possible models to explain it, cosmic strings, solutions of Einstein's equations on null characteristics, and mathematical properties of abstract boundary conditions, both in Einstein's theory and generalisations which include fields from string theory. Though small, the meeting was a great success, and we look forward in July, 2001 to both the "6th Edoardo Amaldi Conference on Gravitational Waves" in Perth http://www.gravity.uwa.edu.au/amaldi/amaldi.htm and the "Third Australasian Conference on General Relativity and Gravitation" http://www.physics.adelaide.edu.au/ASGRC/ACGRG3/ which is being held this time as a satellite meeting to the international Amaldi conference.

David Wiltshire

Australian Conference for Teachers of Physics (Secondary)

[The SASTA (South Australian Science Teachers Association) Strand of the AIP Physics Congress 2000]

This was the first opportunity for secondary physics teachers to participate as a strand of an AIP National Conference. They welcomed and supported the concept with over 80 participants.

Conferences came from every state.

All of the parallel sessions in the secondary teaching strand were held in the Rennie Lecture Theatre. The conference provided the teachers with the opportunity to hear world-class physicists present their Plenary Lectures to the assembled Congress in the Bonnym Hall, and with many opportunities to discuss matters including physics education with physics educators from the tertiary sector.

Prof. Michael Hough and Prof. Dean Zollman presented a secondary physics context view in their very interesting and relevant plenary presentations. These stimulated much discussion with Prof. Zollman demonstrating the brilliance of University of Kansas' interactive Web site. This allows high school students to access the concepts of Quantum Mechanics and by manipulating variables and performing demonstration experiments come to a better understanding of the part that Quantum Mechanics plays in our everyday lives.

The Information Sessions were held on the Monday afternoon and a smorgasbord of ideas was presented:

A Rayner: "Teaching Problem Solving to Young Scientists" The University of Queensland, QLD rayner@physics.uq.edu.au

Dan O’Keeffe "Participation in Secondary Physics across Australia" Camberwell Grammar School dok@egs.vic.edu.au

Anne Fernandez: "Web-based resources and Resources for Secondary Science." physiC@vmail.usyd.edu.au

Dr Pal Fekete University of NSW "High School Physics Resources on the WEB" fekete@physics.usyd.edu.au


Prof John Prescott "Careers in Physics – Current Prospects"

The Tuesday program provided conferences with a perspective of Computer interfacing devices. We were pleased to sample the directions, development and applications of Tony Papatschew, Intelecta (Aust.), Steve Howard TAINLab (Aust) and Russell Armstrong EasySense (Data Harvest, UK). Each gave inspirational presentations demonstrating where we are and glimpses of future directions for the integration of this technology into the classroom.

The last session, "Physics Courses in Australia", enabled presentations from: Rosemary Hafner, Board of Studies in NSW; Neil Champion, VCE in Victoria; Cliff Rothenberg and Alan Pepper, SSASA in SA; and Trevor Portlock, The Baccalaureate Physics Program. This comprehensive delivery enabled the conferences to see the range of physics curricula and the different manner in which each is assessed thus providing not only a better understanding of Physics Education but other useful assessment strategies.

The evaluation from our delegates was very positive and they were generous with their praise for the contributors. It was a very worthwhile event and has great significance as a professional development activity.

My thanks to sub committee members Barb Possingham and Susan Cockshill for their energy, perception and support.

Alan Pepper

(Further group reports will appear in the following issue.)
AN EXPERIMENT TO MEASURE THERMAL PROPERTIES OF KANGAROO AND KOALA FUR, AND BOX JELLYFISH TISSUE

R.E. ROBSON, R.H. HINRICHSEN AND A.K. KROCKENBERGER,
Faculty of Science and Engineering,
James Cook University, Cairns 4870, Australia

This paper describes a simple experiment to measure the thermal conductivity and convective heat transfer coefficient of samples of mammal fur, specifically the red kangaroo and koala of the Australian bush. We discuss the ways in which such thermal properties are related to survival strategies of these animals in their harsh environment.

We also report results of measurement of the thermal properties of another unique Australian animal, the deadly box jellyfish.

1. Introduction

Environmental physics is that branch of physics involving the study of the interaction between living organisms and their environment, and the physics of the environment itself. It is left to the biological sciences to study the physiological properties of the organisms, but an analysis of physical processes is essential to provide a complete understanding of these living things. In particular, organisms exchange heat with their environment through processes involving radiation, convection, conduction and evaporation/condensation, all of which are described by fundamental laws of physics.

Understanding energy flow (and energy transformation from one form to another) is critical to evaluating the response of organisms to their environment. Endotherms, such as mammals or birds, generally maintain a relatively high and stable body temperature through endogenous metabolic processes. Because of this requirement of thermoregulation, they may be subject to thermal stresses in environmental extremes, having to either enhance metabolic action, or to dissipate excess metabolic loads in conditions of low or high temperature respectively. To help buffer the body against such extremes, mammals have evolved insulation in the form of fur, and birds have acquired feathers. Obviously different habitats have different thermal extremes, and naturally the insulative quality of fur of different species of mammals living in different environments is variable [1]. Thermal regimes also change seasonally, and a mammal’s requirements for insulation will change correspondingly. The Australian climate can be harsh, with large seasonal and diurnal fluctuations in temperature, and our mammals have had to develop appropriate thermal survival strategies. These mammals therefore make very interesting subjects for study in an environmental physics course. This paper reports on an undergraduate laboratory investigation of the thermal properties of different types of fur from two well-known, unique Australian animals: the red kangaroo (Macropus rufus) and the koala (Phascolarctos cinereus). We also investigate another less well known and less attractive Australian creature, Chironex fleckeri, the deadly box jellyfish that plagued northern tropical waters in the summer months.

Specifically, we measure the thermal conductivity and convective heat transfer coefficients of a number of specimens, using a methodology originally developed by Professor T.J. Dawson of the University of New South Wales, Sydney more for examining physiological consequences rather than elucidating basic physical properties per se. In this interdisciplinary work, it is of some interest to note that ecologists and physicists attach similar significance to the same quantities, but use them in different ways, and use different terminology. In the present paper, we wish to think like physicists, and therefore attach more importance to the concepts rather than details, at the same time using short arguments and simple mathematics to achieve our goals. In addition, we stress that this is not a comprehensive discussion of the effect of microclimate on living
organisms, and we have only a little to say about the radiative environment and nothing about moisture and latent heat transfer. There are several excellent texts, which could however be consulted for this purpose [2,3]. Note also that this is not an attempt to empirically describe the thermal characteristics of the fur of these species. More detailed descriptions may be found in the literature [4,5].

Before describing the experiment, we briefly review the theory.

2. Theory

Consider a uniform layer of material, of thickness Δx, with thermal conductivity coefficient k, as shown in Figure 1.

Heat is produced within the body by metabolism, and eventually reaches the skin, whence it flows through the fur by the mechanism of conduction. (NB At high wind speeds the turbulence of the boundary layer also disturbs the fur, so there is also some convection within the fur.) Thus, by Fourier’s law, assuming a linear temperature profile through the fur, we have for the heat flux

$$H = k \frac{(T_s - T'_s)}{\Delta x}$$

(1)

From the surface of the fur, heat flows to the surrounding environment through both convection and radiation transfer, but the latter will not be considered explicitly here. Thus, by Newton’s law of convective cooling,

$$H = h_c (T_s - T')$$

(2)

In these equations, $T_s$, $T'_s$, and $T'$ denote respectively skin, fur surface and air temperature respectively.

It is important to note that the conductive heat flux within the fur is equal to the convective heat flux away from the top of the fur in a steady state. If $T'_s$ is eliminated between (1) and (2), we obtain

$$H = (T_s - T_a)/R$$

(3)

where

$$R = \frac{\Delta x}{k} + \frac{1}{h_c}$$

(4)

is the “resistance” to heat transfer from the skin to the environment. The units are m$^2$ °C/W. For textiles, a convenient measure is the tog, where

$$1\text{ tog} = 0.1\text{ m}^2\text{ °C}/\text{W}.$$  

(5)

For example, a typical woolen sweater has a thermal resistance of around 1 tog [6].

Note that there are two contributions on the right hand side of (4) to the total resistance $R$, and that what interests us primarily is the thermal resistance of the fur layer only, viz,

$$r = \frac{\Delta x}{k}$$

(6)

= $(T_s - T'_s)/H$

(7)

the last equation following directly from (1). The other contribution in (4) to the total resistance $R$ is the “boundary layer resistance” $1/h_c$.

With measurements of temperature and heat flux, these equations can be applied to estimate $k$ and $h_c$. Note that the latter generally increases significantly with wind speed $v$.

3. Experimental details

a) Specimens

Thermal conductivity was measured in 3 fur samples on loan from the University of New South Wales (UNSW) Zoology teaching collection. All the samples were originally collected in the early 1970s as part of other studies.

The red kangaroo furs were from 2 individuals sampled in summer and winter respectively at the UNSW Fowler’s Gap Field Station north of Broken Hill in western NSW and the koala fur from a road-killed specimen on the New England Tablelands of northern NSW. All the fur samples were taken from the back of the animal.

The jellyfish tissue was from a Chironex fleckeri Cubozoaan medusa sampled at Weipa in far northern Queensland.

b) Apparatus

The basic features of the apparatus are shown in Figure 2. Samples were placed on top of an aluminium mounting block heated to 36°C by water circulated by a thermostatic water heater through internal channels. They were fixed in position by an annular mounting ring that prevented convection under the surface.

A heat-flow transducer (HFT-I, Thermotechnics Corporation) was fitted into a recess in the top of the mounting block so it was in contact with the under side of the fur and top of the block. This heat flow transducer was calibrated to give a voltage output proportional to the heat flow through the system.

Temperatures were measured with thermocouples (Type T, copper-constantan) placed at the base of the fur (via a needle hole from under the skin), at the fur-tip and at a position approximately 5 cm above the fur.
Voltage from the heat-flow transducer and thermocouples were measured every second by a datalogger (Data Electronics DT500) and downloaded to a PC computer.

Air was blown over the experimental set up using a desk fan with two settings placed approximately 30 cm away. The wind speed at the specimen was measured using a Rimco miniature anemometer.

c) Procedure

Specimens were placed onto the mounting block and temperatures allowed to stabilise for at least 15 minutes (fur samples) and 30 minutes for the jellyfish.

After the stabilisation period the temperatures and heat flow were measured every second, and averaged over 15 second periods.

These measurements were made in still air, at 3.4 m/s (Speed 1) and at 4.0 m/s (Speed 2).

4. Results, sample calculation and discussion

The results of the experiment are summarised in Table 1. Also shown are the values of thermal conductivity \( k \), convective heat transfer coefficient \( h_c \), and thermal resistance \( r \) of the fur derived from the experimental data. The unit of resistance is the tog, defined by equation (5).

(i) Sample calculation - kangaroo in summer

We illustrate the nature of the calculations for the case of a Kangaroo in summer, firstly at zero wind speed. That is, we use the first four rows of data from column 4 of Table 1.

To find the value of resistance of the specimen, we use equation (7):

\[
\begin{align*}
    r &= (35.3 - 27.3)/74.4 = 0.108 \, \text{m}^2 \, \text{K} / \text{W} = 1.08 \, \text{tog} \\
    \end{align*}
\]

and then by (6) we have

\[
\begin{align*}
    k &= \Delta x / r = 0.004/0.108 = 0.037 \, \text{W/m/} \text{K} \\
\end{align*}
\]

The convective heat transfer coefficient can be calculated most simply from (2):

\[
\begin{align*}
    h_c = H / (T_f^{'} - T_s) = 74.4 / (27.3 - 23.4) = 19.1 \, \text{W/m}^2 \, \text{K}. \\
\end{align*}
\]

These numbers have been rounded up one digit in the table and error estimates included.

Not shown in the table is the total resistance to heat transfer, \( R \), as given by (4), which is the sum of fur and boundary layer resistances. For still air, we therefore find

\[
\begin{align*}
    R &= r + 1/h_c \\
        &= 0.108 + 0.052 \\
        &= 0.160 \, \text{m}^2 \, \text{K} / \text{W} \\
\end{align*}
\]

The boundary layer resistance \( 1/h_c \) becomes much smaller as the wind speed \( v \) increases, as can be deduced from Table 1. Thus in all cases \( R \to r \) for large enough wind speeds.

<table>
<thead>
<tr>
<th>Still air ( v = 0 , \text{m/sec} )</th>
<th>Koala</th>
<th>Kangaroo (Winter)</th>
<th>Kangaroo (Summer)</th>
<th>Box jellyfish</th>
</tr>
</thead>
<tbody>
<tr>
<td>( H ) (W/m(^2))</td>
<td>42.2</td>
<td>40.2</td>
<td>74.4</td>
<td>220.11</td>
</tr>
<tr>
<td>( T_f ) (C)</td>
<td>21.9</td>
<td>23.5</td>
<td>23.4</td>
<td>22.9</td>
</tr>
<tr>
<td>( T_s ) (C)</td>
<td>36.7</td>
<td>35.8</td>
<td>35.3</td>
<td>35.4</td>
</tr>
<tr>
<td>( T_f^{'} ) (C)</td>
<td>25.2</td>
<td>27.4</td>
<td>27.3</td>
<td>29.4</td>
</tr>
<tr>
<td>( r ) (tog)</td>
<td>2.7 (±0.2)</td>
<td>2.1 (±0.2)</td>
<td>1.1 (±0.1)</td>
<td>0.27 (±0.03)</td>
</tr>
<tr>
<td>( k ) (W/m(^2)/C)</td>
<td>0.07 (±0.01)</td>
<td>0.07 (±0.01)</td>
<td>0.04 (±0.01)</td>
<td>0.41 (±0.09)</td>
</tr>
<tr>
<td>( h_c ) (W/m(^2)/C)</td>
<td>12 (±2)</td>
<td>10 (±1)</td>
<td>19 (±3)</td>
<td>33 (±5)</td>
</tr>
</tbody>
</table>

| \( v = 3.4 \, \text{m/sec} \)        |       |                   |                   |              |
| \( H \) (W/m\(^2\))                 | 54.2  | 41.2              | 86.4              | 365.18       |
| \( T_f \) (C)                        | 23.9  | 23.9              | 24.5              | 23.6         |
| \( T_s \) (C)                        | 35.4  | 35.4              | 34.7              | 33.6         |
| \( T_f^{'} \) (C)                    | 25.7  | 25.7              | 25.9              | 23.9         |
| \( r \) (tog)                        | 1.8 (±0.2) | 2.4 (±0.2) | 1.1 (±0.1) | 0.27 (±0.02) |
| \( k \) (W/m\(^2\)/C)               | 0.1 (±0.01) | 0.06 (±0.01) | 0.04 (±0.01) | 0.41 (±0.07) |
| \( h_c \) (W/m\(^2\)/C)             | 30 (±5) | 22 (±3)           | 63 (±8)           | 1700 (±200)  |

| \( v = 4.0 \, \text{m/sec} \)        |       |                   |                   |              |
| \( H \) (W/m\(^2\))                 | 56.2  | 42.2              | 86.4              | 369.18       |
| \( T_f \) (C)                        | 23.1  | 23.9              | 24.2              | 23.6         |
| \( T_s \) (C)                        | 35.6  | 35.3              | 34.7              | 33.5         |
| \( T_f^{'} \) (C)                    | 24.2  | 25.8              | 25.1              | 23.6         |
| \( r \) (tog)                        | 2.0 (±0.2) | 2.3 (±0.2) | 1.1 (±0.1) | 0.27 (±0.02) |
| \( k \) (W/m\(^2\)/C)               | 0.09 (±0.01) | 0.07 (±0.01) | 0.04 (±0.01) | 0.41 (±0.07) |
| \( h_c \) (W/m\(^2\)/C)             | 51 (±6) | 22 (±3)           | 100 (±13)         | 9000 (±1000) |

Table 1. Measurements of heat flux \( H \), and air, fur tip and skin temperatures \( T_f, T_s, \) and \( T_f^{'} \) respectively, for four different samples, and three different air flow speeds \( v \). Also shown are thermal properties deduced from these data. The unit of resistance tog is defined in equation (5).

(ii) Variability of \( k \) and \( r \) with wind speed

Ideally, for a solid material layer, both \( k \) and \( r \) should be independent of \( v \). This is clearly the case for the Box jellyfish, as shown in column 5 of Table 1. However, as the Table shows, for the koala and kangaroo in winter, both \( k \) and \( r \) vary with wind speed \( v \). This is because the moving air ventilates the fur and thus alters its effective thickness and thermal properties.
The non-uniform nature of the air-flow generated by the fan is thought to be responsible for the non-systematic variation in k and r.

(iii) Kangaroos

The thermal resistances for red kangaroos change markedly between summer and winter, with both the fur and boundary layer resistances being significantly lower in summer. The habitat of the red kangaroo, the Australian arid and semi-arid zone, exhibits extremes in ambient temperatures, ranging from sub-freezing nighttime conditions in winter to values in excess of 40°C in summer [7]. The clear skies in both summer and winter mean that in both seasons nighttime radiative heat loss can be high, whereas in summer daytime radiation heat loads can reach around 1000 W/m². The seasonally varying thermal properties of kangaroo fur reflects the need for the animal to change its thermal contact with its environment, to alternately conserve and dispose of its metabolically generated heat. Extrapolation of the results for h₉ reported in Table 1 to these higher values suggests that the boundary layer resistance in summer is all but negligible, again favouring improved thermal contact with the environment, and the shedding of metabolically generated heat.

(iv) Koala

Like the kangaroo, the koala must have a capacity to survive under extremes in environmental conditions. Unlike the kangaroo, it generally inhabits the heights in trees, where it is generally subject to higher winds than at the surface, and therefore it must cope with a higher value of h₉ and a lower boundary layer resistance [5].

(v) The Box jellyfish

Table I shows that the thermal conductivity of the Box jellyfish tissue is many times that of the mammal fur, while the convective heat transfer coefficient is several orders of magnitude greater. Of course, this is an aquatic animal, and it would be more relevant to measure h₉ in water, rather than air. We are not aware of any such experiments being reported in the literature. All we wish to point out here is that the Box jellyfish is in excellent thermal contact with its surroundings, and that ambient temperature is therefore a crucial factor in the life cycle of this organism. This may be one causal factor in the markedly seasonal occurrence of this medusa.

5. Concluding Remarks

We have described an experiment adapted from animal physiology for the measurement of thermal conductivities and resistances of layered materials, and have reported results for koala and kangaroo fur, and for a sample of Box jellyfish tissue. The results have been analysed in conjunction with elementary physical theory based upon Fourier’s law of heat conduction and Newton’s law of cooling. The role of air flow has been discussed in particular. We have related the measured physical properties to the survival strategies of these organisms in their respective environments.

It is our belief that this experiment offers an excellent example of the way in which two disciplines can benefit from a conjunction of ideas, for which the final goals may be different, but the basic science is the same.

6. Acknowledgments

We thank Charles Hatcher for technical assistance and Lucas Talbot for assisting with collection of the data. Professor T.J. Dawson kindly provided the fur samples and the design for the initial experimental set-up, and Dr Jamie Seymour provided the Chironex fleckeri specimen.

References

No Easy Road to Space

These days space launches, even manned missions, gain only brief attention by the news media. This creates the impression that spaceflight has become routine. But when something goes wrong the world's media go into hyperdrive, scratching for every morsel of comment from experts real and self-appointed alike. As with aircraft accidents the stories aired at the time leave the real questions hanging. Only after the ensuing inquiry produces its report will real cause be known, and lessons for the future learned. Even then it is often hard to find the facts.

This is where David Shayler's book "Disasters and Accidents in Manned Spaceflight" is most welcome. It includes much detail of the Soviet incidents which were for many years highly mysterious. There is material that I have not seen elsewhere.

The book contains excitement, suspense and frequently conveys a sense of involvement. It covers incidents from the earliest days of manned spaceflight right up to December 1999. This is not to imply a chronological presentation, and here is where I disagree with the organisation of its content. Similar incidents, such as launch failures or landing accidents, are grouped together albeit in a time sequence. But that makes it hard to see the big picture. I feel that a strictly chronological treatment would have kept the race to space in better focus and enhanced the tensions.

This 478-page book is well illustrated and generally well written, except for the early sections which are sloppy. The publisher, Springer-Verlag in Great Britain, has produced a nice though bulky paperback priced at 19 UK pounds which represents good value even at the current exchange rate. I recommend "Disasters and Accidents in Manned Spaceflight" to anyone with an interest in the subject and for libraries as an excellent supplement to whatever other resources they may have on space activities. Order it through its ISBN 1-85233-225-5.

Colin Keay
Reviews Editor.


H S Green
Springer-Verlag, Berlin
2000 ix + 244 pp., DM139 (hard cover)
ISBN 3-540-66517-X

This book gives a strong impression that the author has had a lucid vision of how some of the most fundamental concepts of physics may be brought together in a simple but rigorous way. This includes all aspects of quantum mechanics from the theory of atomic spectra to all types of quantum field theories including string theories and quantum gravity and the issues related to measurement. The "conscious process" of the title is, as common usage would suggest, a matter of awareness and volition. The technical meaning given to the latter two here is that of acquisition and creation of new information. The information itself is defined via a generalisation of the Shannon's expression in terms of qubits. The mathematics used here is based on simple matrix algebra which itself is explained in an appendix!

Certain statements are marked with an asterisk and suggested as exercises. There is a list of references at the end but items in it are not mentioned in the text and there is no index. The list nevertheless does provide some indication of the context in which the work is to be placed.

As noted in his obituary (The Physicist, Vol. 36, 72, 1999) Professor Green completed this work "in a final heroic effort" towards the end of his life and it deserves serious attention from experts in the field. Actually, the arguments are simple enough for it to be accessible to non-experts but at the present time all the topics mentioned above are being investigated in many specialised ways and various usages and concepts are being tried. To arrive at a meaningful understanding the reader will have to resolve many matters concerning the appropriate context and interpretation of the material presented here.

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Prescribing, Recording and Reporting Photon Beam Therapy. ICRU Report 62

International Commission on Radiation Units and Measurements, Bethesda, MD 1999
ix + 52 pages, US$85.00 (softcover)
ISBN 0-8155-4654-1

Have you ever wondered what the script your doctor gave you really meant?

This is a question the International Commission on Radiation Units and Measurements (ICRU) tries to address in this report in the case of radiotherapy of cancer patients. The prescription must be concise and complete and the accompanying documentation must be intelligible by other practitioners in years to come: such as when re-treatment for recurrence may be necessary. As modern radiotherapy techniques can be quite complicated, guidelines such as the present ICRU report are very important - in particular if the patient is part of a clinical study where the results are to be reported widely.

What has this to do with The Physicist? In the case of radiotherapy, physicists are intimately involved in the treatment process and one of their major responsibilities is to make sure that the prescription of a clinician is followed and the process verified. As such they will be amongst the main users of the present report and nearly half of the members of the Report Committee are physicists. The present report is subtitled "Supplement to ICRU Report 50" which was published 6 years ago. However, it can be read on its own and expands significantly on the concepts introduced in Report 50. ICRU Report 62 is particularly relevant for advanced X-ray treatment delivery techniques such as conformal radiotherapy and it introduces guidelines for reporting dose to healthy 'organs at risk' which limit the dose that can be delivered to the tumor. ICRU Report 62 is important for radiotherapy physicists and physicists are important for the report - they will largely be responsible to help its implementation.

Tomas Kron
Medical Physics
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Laser Plasma Physics

Heinrich Hora
SPIE Press, Bellingham WA 2000
xi + 217 pp., US$66.00 (hardcover)
ISBN 0-8194-3599-0

The author is one of the pioneers in the field of laser-matter interaction and laser induced fusion. He witnessed the developments in the field during almost four decades, being the active member of the laser plasma international community, and an ardent...
advocate for the imminent importance of the non-linear forces involved.

It is very difficult to define the genre of this book: it is not a comprehensive textbook on laser-matter interaction or laser plasma, nor is it a historical review of the research in this field, and it is not a book of essays. It is rather a mixture of all these genres in one! It is also a controversial and a very personal book.

It presents the recent status and topics of laser plasma research only partially, mainly reflecting the ideas and results of the author with emphasis placed on the importance of the pondersomme (non linear in respect to the amplitude of the applied electric field) forces. The author introduces a questionable "non-linearity principle" claiming that nonlinear interactions in general can be inexhaustible sources of the new physical effects, in contrast to the views of some prominent scientists (Stephen Hawking and Richard Feynman) on the approaching "end of theoretical physics".

I would not recommend this book as textbook in laser plasma physics for students, because it does not present the topic self-consistently, always sending a reader to the numerous (but incomplete) references. This book is for an advanced reader, who could assess the authors' controversial ideas.

Eugene Ganany
Department of Applied Mathematics
Australian National University

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**Henry Norris Russell:**
**Dean of American Astronomers**

David H DeVorkin
Princeton University Press, Princeton 2000

David H DeVorkin
Princeton University Press, Princeton 2000
xix + 499 pp., US$49.50 (hardcover)
ISBN 0-691-04918-1

Known to today's astronomy and astrophysics students for the Hertzsprung-Russell diagram, Henry Norris Russell is credited as one of the prime driving forces behind turning American astronomy from an observational discipline to a science solidly founded on universal physical principles.

This tome is the first full-length biography of Russell and will undoubtedly help readers grasp the profundity of historical acclaim for his subject. It is written more by theme than as a strict chronology; the principal themes are religion, education, the Princeton professor, stellar spectral classification, physical aspects of spectra, stellar evolution and the Russell influence.

Personal life and social interaction are drawn mostly from indirect sources, as all personal records were destroyed by his family.

However, the author emphasises two successful propensities that recur throughout Russell's professional life - the use of physical and mathematical approximations, and the marshalling of other worker's data for analysis.

In essence the volume is a detailed technical history describing the major works of Russell, showing how his ideas interacted with, modified and moulded contemporary astronomical thought. As a reference work, it should be of interest to astronomers, students of astronomical history and the anthropologist interested in the processes of disciplinary change. It contains copious notes on source material, an extensive bibliography with 5 pages of selected works by Russell, a comprehensive index, and a central insert of 14 photographic plates.

John A Keenwell
Learnmonth Solar Observatory
IPS Radio and Space Services

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**The Physics of Quantum Information**

D Bouwmeester, A Ekert and A Zeilinger (eds)
Springer-Verlag, Berlin 2000
xi + 314 pp., DM 98 (Hardcover)
ISBN 3-540-66774-8

This volume covers Quantum Cryptography, Quantum Teleportation and Quantum Computation. The book presents clearly the fundamental concepts, amply illustrated with theoretical calculations and descriptions of experimental work. Consequently, the first is a class primer, pitched at a level suitable for honours students or above.

The first section, dealing with Quantum Cryptography, discusses the possibility of secure exchange of key material via entangled states in quantum channels. The presentation makes it clear that quantum key exchange, using quantum indeterminacy to test for an eavesdropper, offers genuine security. The discussion of experimental realizations suggests that this will be a practical technology in the not too distant future.

The next chapter is on Quantum "teleportation", the transfer of a quantum state to an entangled system at another location. This chapter includes a discussion of a number of elegant experiments.

Much of the book is devoted to Quantum Computing. An introduction introduces the qubit (quantum bit) and quantum logic gates, followed by a very clear exposition of quantum algorithms, and their speed advantages over classical algorithms. The presentation then moves to the practicalities of building a quantum computer. Decoherence, a formidable challenge, is covered at length. There is a tendency in some writings to understate the difficulties that decoherence might present, but here the discussion is clear and balanced. The authors then move to potential solutions; quantum error correction and entanglement purification.

Finally, this book has a very good index and an extensive bibliography. Unreservedly recommended, and deserving of a place in any Physics library.

Andrew Davies
Department of Defence
Canberra ACT

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**Rare Earth - why Complex Life is Uncommon in the Universe**

P D Ward and D Brownlee
Springer-Verlag, New York NY 2000
ISBN 0-387-98701-0

The central thesis in this book is that, while microscopic life may be very common on planets around other stars, intelligent civilisations like ours are very rare. It does so by listing the many coincidences that had to occur for us to be here as we are now, and saying: "If it hadn't happened just so, then we would not have evolved as we did". Hmm.

Perhaps.

But perhaps our particular evolutionary path to civilisation is not the only one. For example, it is argued that the tremendous stability of the earth's climate has been the key to our successful evolution. Elsewhere it is shown that diversity needs near-catastrophic accidents, such as the asteroid which wiped out the dinosaurs 65 million years ago. It argues that if the heavy elements in the solar nebula were 10% rarer, the Earth would be too small to retain a rich atmosphere. But of course these same changes would have rendered currently inhospitable planets suitable for life. So this is a fascinating yet frustrating book to read.

Although I had some problems with the hypothesis being sold here, I have to say to the authors' credit that they refer to "testing a hypothesis", rather than "proving a fact", which is the trap encountered by some science popularisers. Above all, whether or not you agree with their hypothesis, it is a fascinating account of the rocky path from RNA to civilisation, and of the factors that go into determining whether a planet is habitable or not. Physicists in other fields will find the book entertaining and illuminating - and often sometimes frustrating.

Ray P Norris
Australia Telescope
Epping, N S W

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The Physicist Volume 38, Number 1, January/February 2001
The Physics of Quantum Fields
Michael Stone
Springer-Verlag, New York 2000
xii + 270 pp., A$75 (hardcover)
ISBN 0-387-98909-9
This is an interesting and useful introductory text on quantum field theory (QFT). The author gives a good pedagogical presentation of basic techniques and places a significant emphasis on giving a clear presentation of the more difficult concepts. If a subtle point in QFT proves elusive, you may well find the answer here.

One of the unique features of the text is that it does not immediately specialize into either relativistic QFT, relevant for particle physics, or into nonrelativistic QFT, relevant for condensed matter physics. It provides a useful introduction to both and shows their relation clearly. On the particle physics side the reader is taken carefully from the very basics through to the Feynman diagram expansion of quantum electrodynamics and to considerations of the unitarity and analyticity of the scattering matrix. On the condensed matter physics side we see discussions of Bose-Einstein condensation, superconductivity, superfluidity, and finite temperature field theory. There are also useful introductions to the renormalization group, lattice field theory, and dimensional regularization. There are just a few quirks of presentation, such as occasionally quoting Latin literature (in Latin and with no English translation), no exercises are included, and there are some now outdated remarks on chiral fermions on the lattice. These minor shortcomings are far outweighed by the book's strengths.

If I was teaching either a condensed matter QFT course or a particle physics QFT course I would probably choose a more specialized text. However, I strongly recommend this book as a reference text to anyone with an interest in quantum field theory.

It could serve as a textbook for a broad introduction to the subject and would be an invaluable addition to the recommended reading list for more specialized courses.

Anthony G. Williams
Department of Physics
and Mathematical Physics
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Integrated Silicon Opto-electronics
Horst Zimmermann
Springer-Verlag, Berlin 2000
xvi + 329 pp., DM149 (hardcover)
ISBN 3-540-66662-1
Photonic devices which generate, detect or manipulate light are increasingly common in a very wide range of consumer products. As well as the myriad of systems containing some form of display, devices such as CV or DVD players also contain lasers and optical detectors as part of their on-board opto-electronics. Whilst in high end applications, III/V semiconductors providing very high speed and efficient light emission can be employed, at the consumer end of the market cost becomes the dominant issue and devices based on relatively low cost silicon technology are the only viable choice.

This excellent book Integrated Silicon Opto-Electronics by Horst Zimmermann provides a comprehensive overview of the impact of silicon in a wide range of such optical devices. It covers a good range of topics. Whilst most readers will be quite familiar with the role of silicon in visible and near infra-red detectors, which is covered quite extensively, many will be less familiar with silicon as an optical emitter or as a material for the fabrication of optical waveguides. Such applications are likely to become increasingly important as they increase the functionality of silicon-based opto-electronics and form the subject of briefer review chapters in the book. In addition the basics are not omitted with tutorial coverage of optical effects in semiconductors, for example, proving some background for those new to the field. As a result this book can appeal to a wide readership: whilst not really being an undergraduate text, postgraduates will no doubt find it a useful introduction to this important area of technology and it can also be recommended to researchers as a comprehensive overview of the field.

Barry Luther-Davies
Photonics C R C
Australian National University

The Expanded Quotable Einstein
Alice Calaprice
Princeton University Press, Princeton 2000
xxx + 407 pp., US$18.95 (hardcover)
ISBN 0-691-07021-0
This addition to the seemingly never-ending stream of literature devoted to the life and work of Einstein answers, for me, one question. Why was Einstein the greatest physicist, bar Newton perhaps, that ever lived? Answer: because he had so many interesting things to say about things that are not physics. Only about 10% of this collection of Einstein "pears" has to do with science at all. The rest is all about sex, love, death, people, Germans, Americans, Jews, music, pacifism, God, ... He was quirky, full of contradictions, not at all politically correct, and a disaster in his personal relations - in other words, totally human.

Ever-present in Einstein's writings is his dedication, above all, to the sanctity of life. Yet despite this serious undertone there is often a deliciously impossible sense of humour which comes out at times in Zen-like descriptions of himself by oxymorons such as "militant pacifist" and "religious nonbeliever". You will find serious humour, playful humour and some pure nonsense in this book. Sometimes it is the context itself which is funny. Even physics should not be taken too seriously since its main source is the "playful drive of the tinkering researcher". As early as 1919 we are informed that ultimately "the truth of a theory can never be proved" - foreshadowing Popper (c. 1959)! This collection is better than any autobiography Einstein might have attempted, because what it provides is a picture of the person as a whole. I loved it.
P Zeckeser
Mathematical Physics
University of Adelaide

Quantum Mechanics
Karl T Hecht
Springer-Verlag, New York 2000
xix + 760 pp., AS173.00 (hardcover)
ISBN 0-387-98199-6
This book has apparently been motivated by an extensive teaching practice of the author and provides everything basic and essential in quantum mechanics: from the duality of nature to many body and relativistic quantum mechanics. Many topics are covered with some introductory notes before the mathematical formalism is extensively used and illustrated by use of many examples from atomic, molecular and nuclear physics. The extended inter-chapters references help in moving from topic to topic without losing the focus, and the list of problems attached to each part of the book is very helpful as solutions of the most demanding and challenging questions are also provided. So, the broad selection of topics and the way they are discussed nicely defines quantum mechanics. And that is what makes this book really useful. The reader will quickly realise, however, that the text is not fully self-contained and each discussed topic is clearly the tip of an iceberg. While the trade off between the extended content and the depth of treatment is obvious and acceptable, the problem is that the reader will very occasionally know where to go beyond the book - no attempt was made to give a complete list of references. Also, a relatively short Index at the end of the book is of little practical use.

According to the editor, the text is "intended for a first year graduate course in quantum mechanics, provides a through introduction to the subject" and, as "self-contained, can be used by students without a previous course in quantum mechanics". I would be more careful. The book certainly represents a very valuable resource for students but some prerequisite knowledge is essential. I would thus recommend this text for lecturers, and dedicated, interested students.

M W Radin
School of Mathematical and Physical Sciences
University of Newcastle
The Science and Applications of Acoustics
Daniel R Raichel
xv + 598 pp., AS147.26 (hardcover)

Acoustics is a wide-ranging subject, and this book attempts the ambitious task of giving an account, not just of the basic theory, but also of most of its major applications. The target readership is at advanced undergraduate or early graduate level, and the pedagogical aims are reinforced by inclusion of an occasional worked example and a dozen or so problems at the end of each chapter. The problems are, however, not intrusive, and the book can also be regarded as a useful information source.

The basic theory -- strings, rods, plates, waves, tubes, etc. -- is disposed of in a capable fashion in the first third of the book and provides a suitable background for the applications that follow. These span a wide range -- acoustic measurement, human hearing, architectural acoustics, noise control, underwater acoustics, ultrasound, music, and vibration control -- each of these topics getting a single chapter, except for architecture and noise control, each of which gets two. Individual chapters could usefully be read by someone with adequate general background and would provide a good introduction to the particular application discussed.

As might be expected in such a large and diverse book, there are some things with which a reviewer will not agree. I found a few minor errors of fact, and rather too many instances of poor English expression or grammatical errors. The book uses a mixture of metric and Imperial units, which is confusing (can you guess what dB/kgyd means?) but does provide a two-page conversion table.

For anyone who wants a broad and up-to-date introduction to the many applied aspects of acoustics, I can recommend this book. It would also be a good text for a graduate-level survey course.

Neville Fletcher
R S Phys E
Australian National University

Frontiers in Magnetism
Y Miyako, H Takayama and S Miyashita (eds.)
Physical Society of Japan, Tokyo 105 Japan
vi + 416 pp., Yen 12,800 (A4 hardcover).

This physically large book is a Supplement (A) to the Journal of the Physical Society of Japan. It contains fifty nine papers covering the topics of metallic magnetism, glassy magnetism and quantum magnetism.

It purports to be a summary of the international cooperative research projects on magnetism between Japan, Germany, France, Netherlands and the USA. Most of the papers were received at the beginning of the year 2000 so it is an up to date compilation by many prominent workers in the field. Why it has been published as a separate volume is not clear. The papers are a addition to the original literature, what J. M. Ziman termed in the preface to his classic textbook 'Principles of the Theory of Solids' as 'those copious, if muddy, sources'. Many of the papers in the book will be of interest to those working in the field of modern quantum magnetism but science librarians would be advised to purchase a copy only if their customers specifically request one.

Andrew Stewart
Department of Applied Mathematics
Australian National University

GEMA: Birthplace of German Radar and Sonar
Harry von Kroge
Translated and edited by Louis Brown
I o P Publishing, Bristol 2000
x + 206 pp., UK £45.00 (hardcover)
ISBN 0-7503-0732-3

This is the story of GEMA (Gesellschaft für Elektroakustische und Mechanische Apparate), a company founded by two young engineers in 1934. Already they had developed contacts with the German naval research laboratories that had a great interest in sonar equipment. One of the navy scientists realised that sonar principles could be applied to radar. GEMA played the major role in developing German radar although other firms such as Siemens and Telefunken also made valuable contributions. The story continued during the war with Hitler making his contribution by forbidding further research. This did not deter GEMA who continued to devise new models until the Russians were knocking at the gates of Berlin.

The most interesting chapter is the last one by the translator. Louis Brown compares German, American and British efforts. Germany and the US developments went closely parallel due to the corporate structures and secrecy between firms and between services. In Britain ionospheric physicists were the leading lights and, of interest to the AIP, the early work was done almost entirely by physicists since it was felt that engineers would be too narrow.

The book suffers from being mostly about one firm written by an ardent admirer of that firm, from lack of detail about the effect of the inventions on the conduct of the war and from the Victorian flavour of the English such as:

"The circumstance that the tube had suffered no damage and still functioned after having been in the water and surrounded by drifting ice brought happiness to the champions of the CRT."

Indeed.
J D Whitehead
Consultant
Brisbane

Permanent Magnetism
Ralph Skomski and J M D Coey
Institute of Physics Publishing, Bristol 1999
xi + 404 pp., UK £110 (hardcover)

In our hurried lifestyle we tend to take for granted the benefits we obtain from modern permanent magnets. Permanent magnets are an integral part of domestic appliances, from washing machines to microwaves, and many tens of magnets are to be found in the modern automobile. This book brings together magnetism in its entirety by showing how the applications connect with physics, metallurgy, materials processing and the role of the materials microstructure in producing technologically useful magnetic properties. This inevitably leads to discussions of different types of magnetic materials, and the processing methods used to optimise magnetic properties in these materials. A wide range of magnet types are discussed including, the hard ferrites, ALNICO, metallic 3d magnets, rare-earth magnets (with limited discussions on new phases such as the 1:12s and 2:17s), and a brief review of some soft magnetic materials. The book concludes with a chapter on Applications, which includes both dynamic and static applications. Sections are found on motors, magnetic separation, magnetic recording etc.

The attempt to 'cover everything' in one book is both a strength and weakness.

At one level it does it very well, I applaud the authors, but inevitably some topics receive only scant attention. However Coey's complementary book 'Rare-Earth Iron Permanent Magnets' focuses on rare-earth iron magnets and is ideal to consult when more detail is required about them.

'Permanent Magnetism' is a first class work, with its subject matter presented in a very accessible manner. It deserves and it will find wide appeal with physicists, materials scientists and engineers. It was already on my bookshelf before I was asked to review it.

S J Collacott
Telecommunications and Industrial Physics
CSIRO Lindfield

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CONFERENCES & MEETINGS

2001

Mar 26 – Apr 6  
Workshop on Lepton Scattering, Hadrons and QCD  
CSSM, University of Adelaide  
Contact: Mrs. Sharon Johnson, CSSM, U. of Adelaide, SA 5005,  
lepsct01@physics.adelaide.edu.au,  
or Andreas Schreiber, aschreiber@physics.adelaide.edu.au

July 9 – 18  
Workshop on Lattice Hadron Physics,  
Rhiga Colonial Club Resort, Cairns  
Contact: Mrs. Sharon Johnson, CSSM, University of Adelaide,  
Adelaide SA 5005. Email: LHP2001@physics.adelaide.edu.au

July 15-20  
15th International Conference on Ion Beam Analysis (IBA-15)  
(Incorporating 12th AINSE Conference on Nuclear Techniques of Analysis)  
Cairns  
Contact: Rob Elliman, ANU  
Fax: (02) 6251 0672; Email: iba2001@anu.edu.au  

Nov 25 – Dec 2  
ISES 2001 Solar World Congress  
Adelaide  
Contact: Hartley Management Group Pty Ltd  
PO Box 20 Kent Town SA 5071  
Ph: (61)-8-8363-4399 Fax: (61)-8-8363-43577  
Email: ises2001@hartleymgmt.com.au

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