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Published 11 times a year, on behalf of the Australian Institute of Physics and the New Zealand Institute of Physics by Impress Studios.

This month’s cover picture shows the Collider Detector at the Fermilab (CDF) experiment, with some of the physicists who helped to build it. CDF have recently published evidence that the top quark has been discovered. See David Blair’s article on page 144. The detector is shown in the “open” position which allows access for maintenance. It would be closed when collecting data. Photo from CDF.
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School Science Revisited

Over the last year or two education issues have been given special attention in the Institute’s Science Policy committee meetings. Last week’s meeting was no exception, and hopefully it marked an important step forward in addressing the concerns which many physicists, chemists and mathematicians have expressed concerning the controversial Science (and Mathematics) Statements and Profiles that were released (although not universally agreed to) by the Commonwealth and state Ministers of Education.

The committee agreed some time ago that the Institute should concentrate, initially at least, on physics education at Years 11 and 12 since the Statements and Profiles appear to allow more flexibility in curriculum development for these years. By good fortune, I met Ms Ann Semple, the recently elected President of the Australian Science Teachers’ Association, and invited her to meet the committee at its next meeting. Also invited were two of our members, one from South Australia and one from Victoria, who are currently teaching physics at the senior secondary level but have also had experience teaching in universities. The RACI also expressed their wish to have a representative at that meeting; the Chairman of their Chemical Education Division also joined us. It was not a meeting to propose solutions, but rather one to see more clearly where problems lie and to find a method of addressing them.

There was much common ground and many of the problems facing teachers were already known to us. Apart from the changing demands in curriculum development of finding a proper balance between course content and the more general educational aim of teaching students how to learn, our guests stressed once again the grossly inadequate funding available for the professional development of teachers, including provision for relief teachers for those on in service training courses, the escalating crisis due to the low numbers of people currently being trained as secondary school physics teachers, and the perennial problem of progressing anything nationally when school education is primarily a state responsibility.

"...But the federal government faces big problems in attempting to upgrade a schools system that is managed and financed at the local, county, level..."

Only the second last word in this quotation gives the clue to the fact that this article does not refer to Australia but to the US, where attempts are being made by the National Science Foundation to do in that country what seems so necessary to be done here also. In the Nature article from which this quotation is taken, headed “US makes boldest effort in years to boost school science teaching” the writer describes an NSF initiative to address a situation “which, American universities contend, leaves a typical 18-year-old high-school graduate 18 months behind his or her counterpart in Europe or Japan”. That, of course, is also the fear of our university lecturers.

The dilemma is how, on the one hand, to provide a general education in the physical sciences, (whether or not it is provided in the traditional way as separate chemistry and physics courses) to those who require some knowledge to function effectively in a society increasingly dependent on technology, while on the other to cater adequately for those who will require scientific knowledge in greater depth as a basis for further education in the profession of their choice. The dilemma would be less if an additional year could be added to university courses, but no one thought that such a proposal would be likely to attract much Government enthusiasm!

In attempting to make progress we face the difficulty of knowing what is actually done in each state at Years 11 and 12 as distinct from what can be gleaned from some of the official government rhetoric, federal or state. Representatives will therefore have little here agreed to serve who will gather as quickly as possible information on the following: curriculum content, structure of examination boards and / or the system of assessment, hours per week.

Continued on page 128
EDITORIAL

GRAVITY AND PERSONALITY

A piece of university built equipment which takes seventeen years to become operational and, even when it is working, may not have anything turn up to be measured for further years, sounds like the sort of thing that sends PhD supervisors prematurely grey and drives experimentalists to drink. Fortunately Western Australia provides some splendid wines for just such an emergency. This drawn out saga deserves a happy ending and you will see that such is the case by reading the article on the Perth gravity wave antenna on page 134 of this issue. It is written by David Blair and features a cast of thousands. They have overcome enormous difficulties to produce the lowest noise temperature ever recorded in such a device and on the way made significant contributions to a number of other areas mentioned in the article.

Those of us outside the field have, over the years, heard rumours, and occasional facts, of what was going on in Perth and admired their persistence. Through the eighties, when so many people were jumping up and down shouting “What do we want?” “Everything!” “When do we want it?” “Now!” It was nice to know that a really worthwhile project with a much longer time scale than was fashionable was still moving forward.

There is obviously a good book in this. I hope someone is recording oral history from the many involved and preserving the details. One must particularly admire those capable of persuading a University Investment Committee to lend the money for 1.5 tonnes of pure niobium, a metal they had probably never heard of. This achievement is all the more noteworthy at a time when several Perth entrepreneurs were offering what looked like much more rewarding investments. Surely a classic example of investment in physics paying off, or at the very least avoiding a serious financial loss. Let us hope that the University remains prosperous enough not to need its niobium back, at least not before significant gravitational waves have passed through Perth.

There is a boom in books and courses on how to measure your motivations, penetrate the mysteries of your personality and embark on a voyage of self-discovery, all in the interests of winning and being more successful. Perhaps it is the uncertain times in which we live. It is even happening to physicists, as we mentioned last month. Results of psychometric testing of UK physicists for the Institute of Physics have just been published (G.D. Wilson & C.J. Jackson Personality & Individual Differences, 16 [1994] 187-89). They had 240 members of the IOP fill out questionnaires of the Eysenck Personality Profile type which detects introversion, adventurism and emotionalism. Is there a shadow of political correctness in their assertion “...that there are no good or bad aspects of personality, either at the individual or group level of analysis.” (Chris Jackson Physics World April 94 101-103). I would have thought that a personality trait that leads someone to go around killing people with an axe is unambiguously bad aspect of personality at the individual level. Perhaps I am generalising invalidly and the remark was meant to apply only to those aspects of personality tested in this study, in spite of the generality of its wording.

They found, amongst other things, that their sample of physicists were introverted, hid their feelings, were more prone to follow than to lead and were less ambitious and confrontational than the average. They were however intelligent and aesthetically sensitive and felt less guilt when things went wrong. They ticked the “Can’t decide” box more often than average, which was interpreted as being indecisive and not aware of their personalities. Rubbish! If you are not relaxed about living with uncertainty you shouldn’t be doing physics, or indeed research in any science. The admission of ignorance is the beginning of wisdom. As Einstein remarked “Imagination is more important than knowledge” How do physicists from the Asian Pacific area, including us, compare with the above unflattering profiles? Come to BrisPhys next month and find out.

Jak Kelly
spent on physics (in classroom and laboratory) and availability of teacher support material and support personnel. When collated this material will provide the basis for the Institute to make recommendations to federal and state education authorities on an issue that has been of major concern to this Institute and other professional societies.

Whatever these recommendations might exist: that of providing teachers with adequate support to carry out their vital role. The Institute has already joined the RACI in writing in support of ASTA’s submission for a grant for an extensive program of professional development for teachers through the National Professional Development Program. Meanwhile those of us who can do so should lobby vigorously at the state level to ensure adequate resources are made available to enable teachers to be released to take advantage of this program, and that they receive appropriate recognition of their having done so.

Bob Crompton

STATPHYS 19
XIAMIN, CHINA
July 31 - August 4
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Check Out Miss Steaks

Dear Editor,

I am enjoying reading your editorials these days. So, in reading your latest prose last night the following came to mind which I thought you would appreciate. It is currently doing the “email rounds” in the US.

Author unknown.

I have a spelling checker
It came with my PC
It prints red marks four my revue
Miss steaks aye can knot sea.

Eye ran this poem throw it,
Your sure reel glad two no.
Its vary polished in’ts weigh
My checker tolled me sew.

A checker is a bless sing,
It freeze yew lodes of thyme.
It helps me right awl stiles two reed,
And ailes me when aye rime.

Each frays come posed up on my screen
Eye trusted too bee a joule
The checker pour o’er every word
To cheque some spelling rule.

Be fore a veiling checkers
Hour spelling mite decline,
And if were lacks or have a laps,
We would be maid to write.

Butt now bee cause my spelling
Is checked with such grate flare,
Their are know faults with in my site,
Of non eye am a wear.

Now spelling does not phase me
It does knot bring a tier.
My pay purrs awl due glad den
With wrapped words fare as hear.

To rite with care is quite a feet
Of which won should be proud.
And wee mussed dew the best wee can,
Sew flaws are not aloud.

Sow ewe can sea why aye dew prays
Such soft ware four pee seas.
And why I brake in two averse
By righting want too pleas.

Jan Brown
Lawrence Berkeley Laboratory
email ibrown@Csa3.LBL.Gov

The spelling “complimentarity” rather than complementarity in the heading on page 110 and the running headings on pages 111-114 of the May issue were typos put in by us and were not the author’s mistake. The failure to detect it we naturally blame on the spelling checker.

Local Press

Dear Editor,

I read with interest the President’s Column in the March Physicist, in which Bob Crompton did admirably in encouraging all to become involved in taking our science to the public via the media. A little addendum. The core of Crompton’s piece concerned the publicity following the publication of a paper in Nature by Mike Hawkins of the Royal Observatory, Edinburgh. The coverage seems to have been rampant in the U.K., but very muted here in the antipodes. Experience has shown that the Australian (and, presumably, New Zealand) media take the hook more easily if it is baited with some local connection; and quite right too.

Perhaps what would have happened with Hawkins’ discovery had the local media been made aware that all of his data were collected in Australia. The staff of the U.K. Schmidt Telescope (now operated as part of the Anglo-Australian Observatory) were responsible, diligently obtaining photographic plates over many years.

Duncan Steel
Anglo-Australian Observatory
& University of Adelaide

Make Up Your Own Mind

Dear Editor,

I have followed closely and with deepening disquiet the continuing series of articles, letters, and editorials criticising the National Science profile and statement over the past year. Is this really the level of analysis we bring as professional physicists to problems that confront us?

Let me state my views at the outset.

a Science education in primary and secondary schools should be just that - education, not solely training.

b We should hope to produce a generation of students who feel the excitement that scientific endeavour brings, and are able to use, when they need to, methods of science to deal with the problems that confront them in their own lives. They should be able to understand how science works in the world around them and learn some facts too. Training the 5% or so of students who will become professional scientists is a different matter. I see that as one task which we should be able to accomplish in 4 years of university life. If we can’t, then maybe it is our deficiency, not that of the students and their high school training.

b It is becoming increasingly apparent that the major problems confronting our world - the problems which science can play some part in solving - cannot be separated into neat boxes called physics and chemistry, etc. It is time we addressed that reality in our own working lives. If we do not, the continuing squeeze on traditional science department funding will force us to in any case.

As to the National science profile and statements, I have some serious reservations with what might happen to the whole concept. It is clear that the major multinational companies which H.H. Bolton quotes so approvingly are very strong supporters of national curricula. I suspect that they are only interested in doing so in order to, as the phrase goes, make a buck out of us.

Science which would serve the community without necessarily making a profit, is not really part of their agenda. Surely we need national curricula which go well beyond a narrow focus on basic literacy and numeracy.

Reading over the now completed draft profile and statement. I feel a great sense of excitement. Here is proposed a sort of education which can open up the minds of children to the wonders and mystery of the world, and set them on a path of attempting to unravel these mysteries. Surely that is the very essence of what good science is all about. Those who rail against the “anti-science bias” of the statement and profile need to go and read them again - I feel they have missed something important in them.

There are three criticisms which invite response:

1 The statement and profile are criticised as “a pseudo-arts curriculum”, with science seen as a “jumble of disconnected facts...”, and with the ideas and theories of science “provisional and uncertain...”

The plain answer to these criticisms is - rubbish. The documents contain a wealth of discussion of the history of scientific ideas, the way science develops, from very general ideas to the very specific. For example the assertion that astrology...
fundamentalism etc are given equal validity with careful investigative science is not supported by the documents - in fact a critical analysis of these ideas is recommended.

2 The documents are criticised for containing none of the “concise and well established elementary ideas” which we need to impart in school science curricula. Well for a start it is made abundantly clear that these documents are a “framework for curriculum development... a reference for the design of curricula.” They are not meant to be curriculum documents. The detailed curriculum design is how to include those “facts” which we all want imparted. Secondly the documents are aimed at grades 1 - 10, not 11 and 12... this is also made quite clear. More specific concentration on disciplines such as physics is expected to be the preserve of years 11 and 12. Even so, the short discussion of the science for these noncompulsory years (Band D, pages 37-38) makes some suggestions which seem both significant and fundamental to me - “investigation of quantities under different conditions.” “Scientific explanations evaluated against such principles as objectivity, falsifiability, reliability, internal consistency and validity.” “Concept of force field.” “Quantitative analyses to model behaviour of physical systems.” “Exploring and comparing the particle and wave models for explaining light.” “Examining energy conversions.” When this is fleshed out in a fully detailed curriculum, I think we can expect a good grounding in the basics of physics.

3 The documents are criticised for their inclusion of discussion of women’s role in science, the influence of other cultures - in particular the Aboriginal people’s culture - to scientific understanding of the world, and the discussion of the social role and context of science. Some people may be critical of including such issues in a science curriculum. I am not. I welcome it, and I suspect I am far from alone. Let’s make it clear where we all stand. We “politically correct” scientists are not the only ones to have a political stance - those who criticise us are often not aware that their attitudes towards the teaching and practice of science are just as political.

I would like finally to suggest to the members of the AIP who have not yet done so - get a copy of the documents yourself and make up your own mind. Don’t let the “scientifically correct”, who presume to speak for all of us, do it for you.

Ross Gwyther
Physics Department
University of Queensland

Fish Basin & Standing Waves
Dear Editor,

Fish basin standing waves (see article on page 76 of the April 94 Physicist) and Chladni plates are interesting experimental systems but are not readily available for students. A quite dramatic example of stationary waves bursting forth a spray of droplets from a fluid surface can be generated by sliding a styrofoam cup partly filled with coffee along a ‘laminex’ table. Unfortunately the stationary waves produced are much more chaotic than the fish bowl or Chladni plates so that the classical modes shown in the article do not often appear.

Martin Harris
Optiscan Pty Ltd
Dandenong Vic

Read For Yourself
Dear Editor,

In regard to the recent mixed review of Dye Laser Principles written by P. Drummond (ANZP, November 1993) the following comments are in order:

1 Less than 1% of the book is devoted to the Maxwell-Bloch equations that caused such much irritation to the reviewer.

2 Neither Hillman nor Diels (the authors of Chapters 2 and 3, respectively) are responsible for the Maxwell-Bloch equations.

3 It is well known, and indeed stated in Chapter 2, that a comprehensive treatment of the dynamics of dye lasers still needs to be developed. Here, I refer specifically to a theory that would account for the dynamics in the transient regime, that would incorporate multipass effects in amplifiers, and accurately predict measured laser linewidths. This remains an area of opportunity.

4 The field of dye lasers is essentially an experimental science. The history of dye lasers has been made in the laboratory. Only in noted exceptions theory has led the experiment. Hence, the style of the book is justified.

5 I was encouraged by the optimism of the reviewer reflected in the hope of a future and improved book on the principles of dye lasers. This book may have to wait due to the recent event of narrow linewidth solid-state dye laser oscillators that may demand yet even more improvements in the theory of dynamics.

Finally, in addition to the fact that the book has sold quite well, proof of its value is that it satisfies a major criterion of J.S. Bell for a good book 2: it has been reported stolen from several libraries.

References

F.J. Duarte
Rochester USA

Course in Temperature Measurement

The CSIRO Division of Applied Physics is again offering its intensive short course in the theory and practice of temperature measurement this year. The five day course will be given at the Division’s headquarters in Sydney from October 10th to 14th.

The course content has been updated, and a new comprehensive three-volume manual will be provided to participants. Generous allocation of time will be made for consultation and discussion on the participants own problems.

The fee for the Sydney course will be $950 and details can be obtained from: Robin Bentley, PO Box 218, Lindfield NSW 2070. Tel (02) 413 7211, email robin@dap.csiro.au
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Photometrics Supplies X-ray Detector to Siemens Analytical

Photometrics Ltd. (Tucson, AZ) announces the completion of a joint development program with the Analytical Instrumentation Business Unit of Siemens Industrial Automation (Madison, WI). This development project produced a fiber-optic coupled CCD detector which provides high spatial resolution, high sensitivity and conversion efficiency for the short molybdenum X-ray wavelengths. This new detector reduces X-ray crystallography data collection times from days to hours while maintaining the accuracy of the collected data.

Siemens introduced a new product, the SMART System, based on this CCD technology at the 1994 Pittsburgh conference in Chicago. Robert Stevenson, President of Photometrics, says, “This volume commitment from Siemens is the culmination of Photometrics’ recent focus on OEM development. We are now able to deliver high performance cameras in volume at very attractive prices. This now enables OEM instrument manufacturers to deliver cost effective, high quality product solutions to their customers.”

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For more information from Australia’s agents, please contact Graeme Jones at Lastek’s Canberra office.

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New 1994 Newport Catalogue & Price List

Newport has just released its new 1994 precision laboratory product catalogue and price list.

The new catalogue features products from Newport and Klinger/Micro Controle. Many new products also feature in the catalogue along with comprehensive technical specifications and application notes.

The new literature will be available by early in July.

For a free catalogue and price list, please contact: Mr Neil McMahon at Coherent Scientific Pty Ltd, 116 Burbridge Road, Hilton SA 5033. Tel 08-352-1111, fax 08-352-2020.

Air-cooled Argon Ion Lasers From Uniphase

Coherent Scientific has recently been appointed the exclusive Australian and New Zealand distributor for Uniphase, a Californian-based manufacturer of air-cooled argon ion laser systems.

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For further details, please contact: Dr Narrelle Murphy at Coherent Scientific Pty Ltd, 116 Burbridge Road, Hilton SA 5033. Tel 08-352-1111, fax 08-352-2020.

Data Acquisition Under Windows

Windows is everywhere in the PC marketplace, and with good reason. It provides the point-and-click convenience of the Mac with an industry standard hardware platform that can accept innovative hardware solutions for the research community offered by many vendors.

There is a catch, however. Windows uses up a lot of computer power, and any time it grabs the CPU it holds on to it for as long as it needs to. In a normal office environment this doesn’t matter. In a lab, however, this can be a major drawback. For example, in a measuring or controlling a real-time process it is critically important that computing power is available when it is needed.

If Windows is here to stay, then also here is an approach to PC-based Data Acquisition that puts intelligence right on the board where it can deal up front with the critical aspects of any application — the parts that run in real-time. MicroStar Laboratories has taken this approach further than any other company. The on-board processor of a Data Acquisition Processor greatly simplifies data acquisition under Windows. A Data Acquisition Processor can handle all the realtime data acquisition and processing, leaving the Windows application free for graphics and the user interaction.

Every Data Acquisition Processor in their range, from the entry level DAP 800 up to the 486 based DAP 3200, runs DAPL, the on-board multi-tasking real-time operating system that communicates with Windows on the PC platform. Simple command lists are sent from Windows to DAPL completely define how the system is to behave in any data acquisition application. And these command lists are simple. Most of the examples in the Applications manual use fewer than a dozen commands out of the hundred or more that are available.

The following is a list of common problems with data acquisition under Windows, and the corresponding solutions that the Data Acquisition Processor provides.

1 Long interrupt latencies can cause data to be lost. Interrupt latency is the time from when a data acquisition boards asserts an interrupt signal until Windows responds to that signal. Interrupts are often used to send a signal to the PC to prepare for data transfer (DMA). If the PC does not respond in time, data will be lost. Windows interrupt latencies are large and are growing larger!

Solution: Data Acquisition Processor interrupts are not time critical. A data Acquisition Processor buffers acquired data until a Windows application receives control and is ready to read data.

2 Unpredictable real-time response under Windows multi-tasking makes it impossible to know when a Windows application will receive control, and how long it will have control.

Solution: The Data Acquisition Processor can respond to events locally without needing to be monitored by the Windows application. For example, a Data Acquisition Processor PID process control loop runs completely on a Data Acquisition Processor. The Windows application needs only to configure the Data Acquisition Processor and start the process running.  

Details of the OEM Camera Siemens SMART System are available from Lastek.

Acquisition under Windows. A Data Acquisition Processor can handle all the realtime data acquisition and processing, leaving the Windows application free for graphics and the user interaction.

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Details of the OEM Camera Siemens SMART System are available from Lastek.
3 Data acquisition interfaces for Windows are complex.

Solution: The Microstar Laboratories Dynamic Link Library (DLL) provides a simple way to create Data acquisition applications. An application typically requires only five DLL calls to implement a complete system. DLLs are language independent, so the same Data Acquisition Processor DLL can be used by any Windows programming language or for applications that can make DLL calls.

4 PC bus and CPU speeds can limit acquisition speeds to far less than the speed of the data acquisition hardware itself.

Solution: The Data Acquisition Processor’s onboard processor handles the data acquisition, buffering, triggering, and real-time computation. This ensures that the Data Acquisition Processor can acquire data at full speed. Processing data on the Data Acquisition Processor frees the PC’s processor to work on operations such as graphing and user interaction.

5 PC hardware is virtualized under Windows. Furthermore, Direct Memory Access (DMA) is a limited hardware resource on PC’s and not all DMA modes are supported by Windows.

Solution: Communication with the Data Acquisition Processor does not require any DMA resources in the PC.

6 Windows Memory allocation and virtual-to-physical address translation are complex.

Solution: The Data Acquisition Processor performs local data buffering, and the Data Acquisition Processor DLL manages the transfer of data to the application’s memory space. There is no need for complex memory management routines.

7 Hardware Resources used by the data acquisition cards create limitations on developing large applications.

Solution: A Data Acquisition Processor has an intelligent PC interface which enables only a single interrupt line. A range of I/O addresses can be used to create a multi-DAP system. Up to seven Data Acquisition Processors can run in parallel on a single PC without using any DMA units.

The research community knows what it needs. Sooner or later every data acquisition board vendor is going to have to face up to this and deliver what the market is calling for: on-board intelligence that allows a user to develop and run high performance realtime data acquisition systems under Windows.

For more information, contact Con Saponis at Scitech Pty Ltd on Tel 03-438-4999, fax 03-416-9959.

New Open-source Vacuum System Controller

UTI Instruments (San Jose, California) is pleased to announce a new vacuum system controller for open-source QMA (quadrupole mass analyzer) process monitoring at high vacuum. The traditional closed-source vacuum system controller provides isolation, protection, vacuum system integration, and automation for QMA monitoring of process systems at higher pressure. Now, these same vacuum system controller capabilities are needed for the pumping systems and valves associated with QMAS monitoring high-vacuum applications where isolation is critical and the extra sensitivity of an open source is desired. Applications include open-source monitoring in high-vacuum process systems, loadlocks, and transfer chambers in cluster tools.

Vacuum system controllers tie the automatic opening and closing of valves associated with a QMA vacuum system to pressure levels, events, or time. QMA process monitoring plays a key role in improving the quality and repeatability of thin film processing; an open-source AMA is used for high-vacuum applications.

The open-source vacuum system controller consists of an automatic isolation valve, probe housing with side port, two liter/second ion pump and controller, heating mantle, and 25’ control cables.

UTI Instruments is a technology leader in the design and manufacture of advanced trace gas analysis instruments for vacuum system maintenance, process monitoring and laboratory analysis applications. UTI maintains an Application Sciences Department to provide its customers with expert applications support.

Technical contact: Tom Strahl, UTI Instruments. Fax USA 001-1-408-428-0823. Air-cooled Argon Ion Laser Systems manufactured by Uniphase, are now available from Coherent Scientific.
The Southern Hemisphere Gravitational Wave Antenna

DAVID BLAIR

Introduction

In 1969, Joseph Weber had announced the detection of gravitational waves. Weber's claim was based on the observed coincident excitation of vibration in two widely spaced bars of aluminium. His results created enormous excitement. Gravity wave antennas sprang up like mushrooms: Moscow, Rome, Munich, Paris, Glasgow, Oxford, Bell Telephone Labs, IBM.... Significant improvements were made, but all the newcomers were disappointed. Like cold fusion, the gravity wave signals went away. Except in a few peculiar and unreproduced circumstances, nobody other than Weber ever again saw the huge numbers of apparent gravity wave signals inferred from his published observations. The consensus formed that gravity waves had not been detected. However, this view is still hotly disputed by Weber.

Anyhow, Weber's observations were highly unsatisfactory, in that they were only inferred statistically. All signals were buried amongst a mass of accidental coincidences, so that it was impossible to identify a source direction for any individual event. Astrophysically Weber's observations were incredible, because they required the conversion of thousands of solar masses per year into gravity waves in our galaxy. At this rate the entire galaxy would have been converted to gravitational waves in $10^8$ years.1

Just before Weber's results became widely known, Bill Fairbank and Bill Hamilton who were both low temperature physicists at Stanford, began to consider the possibility of building cryogenic gravitational wave antennas. Fairbank was renowned for his bold vision and boyish enthusiasm. His rule was "any experiment can be done better if it is done at low temperatures". He applied his rule to superconducting particle accelerators, to the search for fractional charge, to tests of general relativity, and in this case, to gravitational wave detectors. For gravity wave detection he proposed building huge cryostats in which massive metal bars would be cooled to millikelvin temperatures. Superconducting vibration sensors would then be used to search for the infinitesimal vibrations induced by gravitational waves.

After years of painstaking efforts and never-ending problems, Hamilton added a lemma to Fairbank's rule: "it may be better, but it is always much harder".

This article describes the development of a cryogenic resonant bar gravitational wave antenna in Perth. For many years all we could prove was Hamilton's lemma! But today we can triumphantly claim also to have proved Fairbanks rule. In doing so we have proved the feasibility of a detection scheme originally outlined by Hamilton, along with a range of beautiful technology developed entirely in Australia.

Cryogenic Resonant Bars

The concept of a cryogenic resonant bar gravitational wave antenna is simple. Gravitational waves are waves of tidal force. A gravity wave pulse will cause a transient excitation of the longitudinal resonance of a bar. A supernova in our galaxy, or any other comparable gravitational collapse will produce a short broad band burst of gravitational waves in the audio frequency regime. The expected strain amplitude, denoted $h$, is about $10^{-18}$, corresponding to a change in length of a 3m long antenna of $\sim 3 \times 10^{-18}$ metres. Thus the problem of detecting gravitational waves becomes one of measuring such small amplitude changes in a metal bar.

This motion is much smaller than an atomic nucleus. It is also much smaller than the Brownian motion of the antenna itself. How can such small motions be detected? By ensuring that the system to be measured (the massive bar) and the system which measures it (the vibration transducer) both have a noise level less than the expected signal. The fluctuation-dissipation theorem specifies the requirements of both systems. The best known example of this is the Nyquist noise formula for a resistor: $V_n^2 = 4kTRB$. The voltage noise squared is proportional to temperature, resistance and bandwidth. In general the noise of both mechanical and electrical systems will reduce as the temperature is decreased and as the resistance is reduced. Fortuitously both electrical losses and mechanical losses (acoustic loss) can be enormously reduced at low temperatures, so cryogenic techniques allow one to win twice over, greatly reducing the overall noise level.2

D. G. Blair is in the Department of Physics at the University of Western Australia WA.
Finally, one must also ask, what is the quantum limit for a resonant bar? What limit does the uncertainty principle set on the measurement of displacement? The answer is simple, but surprisingly it was not recognised or understood until cryogenic resonant bars had been under development for several years. The limit is the amplitude equivalent to the photon energy $\hbar \omega$, where $\omega$, is the angular frequency of the antenna. Numerically, for a typical antenna it has an energy of $6 \times 10^{-31}$J, and a strain amplitude $h \sim 10^{-21}$. Interestingly, this limit can be overcome using quantum non-demolition techniques which are an exciting spin-off from gravity wave research.

Figure 1 Principles of a parametric transducer. (a) Schematic diagram and (b) the practical implementations using a re-entrant cavity on the UWA antenna.
The Perth Antenna

In 1976 three antennas were under development at Stanford, Louisiana and Rome. There was a clear need for a fourth antenna in the southern hemisphere, to allow maximum baselines for coincidence experiments, and for measuring the propagation time delay (~40 ms) for trigonometric direction finding for sources. The northern hemisphere detectors were aluminium bars of several tonnes. They were planned to be magnetically levitated, for vibration isolation, and cooled to millikelvin temperatures.

From the Nyquist noise formula it is clear that both loss (e.g. resistance and acoustic loss) and temperature are variables. If losses can be reduced sufficiently one need not cool so much. The experimentalist has a choice of optimisation methods.

The Perth project began under Roy Rand in 1976. When he left a couple of years later Michael Buckingham and Cyril Edwards saved the project. From the start I proposed that we focus on niobium as an antenna material because experiments by Paik at Stanford, and then by myself at Louisiana, had shown that it had acoustic losses perhaps 100 times less than aluminium. Besides, niobium was dense, so that a smaller cryostat was needed, and superconducting, making it ideal for magnetic levitation and superconducting vibration sensing.

John Ferreira from Perth embarked on a very detailed study of the acoustic losses in niobium. He discovered how to anneal niobium to obtain minimum losses, and gave us confidence to specify the ingot quality for the largest piece of niobium money could buy (1.5 tonnes). This was purchased by the University of Western Australia Investment Committee, and much to our delight, showed the lowest acoustic loss ever observed in a metal. Only silicon and sapphire are better. The quality factor was 230 million; the rate of dissipation was so low that for some time it appeared that there was an artificial signal source present and it took many hours to register a barely detectable reduction in amplitude.

This was one of the few high points in 15 years of struggle during which time we proved Hamilton’s lemma time and time again.

Another high point had occurred a few years earlier. Tony Mann had begun on a project to develop a small prototype antenna with a parametric transducer. The transducer followed Hamilton’s original proposal, combined with an idea of Vladimir Braginsky at Moscow: the idea was to place near to the end of a magnetically levitated bar, a servo controlled levitated microwave cavity, which would have its frequency modulated by the vibration of the bar. The principal of this type of parametric transducer is illustrated in Figure 1. A pump oscillator excites the cavity: phase variations are registered which correspond to the motion of the bar. Tony Mann’s system was a technological tour de force. It combined magnetic levitation, superconducting cavities, SQUID sensors, cryogenic microwave devices and cryogenic radiofrequency sensors. It worked very well, and proved the suitability of such transducers, but also showed that a superb microwave frequency source was required, since microwave phase noise was indistinguishable from vibration in the antenna.

Next came the stage of integration of a complete antenna. This was Peter Veitch’s task. By this time we knew from John Ferreira’s work that magnetic flux penetration made it impossible to levitate bars greater than 20 cm diameter. Reluctantly we decided that a bigger bar was better than a levitated bar. We supported the bar on a “catherine wheel” spring of our design. To save money, we had used a dewar design which had only one inner experimental chamber. For essential heat conduction purposes we used fine copper wires (about a quarter of a million of them hanging in loose bundles like shiny wigs). These were not supposed to conduct vibration, but they turned out to be our downfall.

Peter Veitch, later joined by Nick Linthorne, struggled from one problem to another. Big cryostats can be ugly temperamental beasts, plagued by leaks and thermo-
Figure 3: Side view of the niobium antenna at UWA. Note that there is no mechanical contact between the antenna and the cryostat except via the long vibration isolation path.
Figure 4  End view of the niobium antenna at UWA.
acoustic oscillations. An experimental run is a 3 month undertaking: one month pumping, one month cooling, and one month warming up. In each run we would discover a new noise source. In the first run where all systems worked, the noise temperature was 10⁶ degrees Kelvin. (It should have been 10⁻² K.) Ten runs later we had beaten it down to 100 K.

Meanwhile Peter Veitch, Nick Linthorne and Mike Tobar used these runs to explore the fascinating physics of the parametric transducer. The device is vastly more complex than Figure 1 implies. It is best considered as a device to promote scattering of microwave photons with acoustic phonons, as illustrated in Figure 2. Two processes take place, one which extracts phonons from the bar, another which injects phonons. Clearly the latter can lead to instabilities. It requires only simple frequency tuning to modify the balance between the two processes. In the first case the transducer acts like optical molasses, it sucks energy from the bar and cold dampens the antenna. Whereas optical molasses cools individual atoms, our microwave molasses can cool the normal mode of 1.5 tonnes of niobium to less than half a degree Kelvin! ▶

Figure 5  The 1.5 tonne niobium bar antenna.
By 1988 we knew that excess environmental noise was entering our system. The only solution was a major cryostat redesign, and a major effort in better vibration isolation. The problem is that cryostats are awful vibration environments. Boiling nitrogen and helium create broad spectrum noise, and complex tanks and pipes create resonances that are almost impossible to model. The best solution would be to totally decouple the cryostat from the apparatus inside it and to provide additional cryogenic stages of vibration isolation as well. This means supporting about 2.5 tonnes with a direct connection to the hot (300K) outside world. A cryogenic engineer would tell you that this is almost impossible; a recipe for thermal disaster due to the heat leak down the suspension rod.

In 1991 and 1992 we found solutions to all these problems. The University of Western Ontario Physics workshop engineered a superb new cryogenic vessel. Ju Li, following initial experiments by Adrienne Fairhall, developed a new type of vibration isolator without rubber components, that was able to operate in a cryogenic environment. To allow external support of the apparatus, Peter Turner developed a radiative thermal ground: this was a copper finned structure that used enhanced radiation to sink the incoming heat load down a titanium suspension rod before it reached the experimental chamber. Eugene Ivanov developed a pair of miniature microwave antennas that enabled the microwave transducer signal to be radiated directly to and from the transducer, thus eliminating the last possible vibration link to the antenna. This also involves a complex frequency tracking servo system, which must track the frequency variations of the transducer cavity as the bar slowly rocks on its suspension, plus the variations in distance between the microwave antennas due to the same motion. Superconducting microwave phase shifters and attenuators invented in our laboratory make this possible. These devices were developed by Laurie Mann. The entire transducer is pumped by a low sweep noise oscillator developed as part of our sapphire clock project.

Peter Turner and Eugene Ivanov integrated all these elements into the complete antenna in early 1993. The system is illustrated in Figure 3, 4 and 5. Following some 160 difficulties, the system came into full operation at the end of July 1993.

The antenna is monitored continuously using an elegant software package developed by Frank Van Kann and a second LabView based system developed by Nick Hamilton. All the data is transferred to hard disk and then is stored on magnetic tape. Figure 6 shows a typical system monitor screen dump. The top box is a chart recording showing the raw antenna amplitude: this fluctuates slowly in typical Brownian motion. The right hand box shows this in phase space, where the slow meandering of the antenna creates a Gaussian blob. The left and central boxes show the antenna energy statistics, antenna energy or effective energy on the horizontal axis, and log N on the vertical axis. Linear plots demonstrate good Gaussian noise performance.

A threshold is set corresponding to a few hundred events per day. Amongst these there could be a gravity wave signal. This restricted set of events is compared with data from antennas at Rome and Louisiana. Accidental coincidences should occur less than once per year. Thus any three-way coincidence is worth investigating as a candidate gravity wave signal.

Investigation can include correlation with neutrino detectors and an internal consistency check based on amplitude information. Is there a unique direction on the sky consistent with the observed amplitude in each detector? The Perth antenna is quite different from any other antennas in the world. It is the only niobium bar, the only successfully operated antenna with a parametric transducer and the only antenna utilizing a non-contacting readout. In recent years referees, while applauding our perseverance have said we should abandon our caustic activated catherine wheel, abandon the parametric transducer and abandon the non-contacting coupling. However, without these features, we might as well have abandoned the niobium bar itself and gone over to a lower Q aluminium bar. Now our perseverance has been vindicated. We have achieved the lowest noise temperature ever recorded in a gravity wave antenna and with a few simple external modifications, and without interruption of observations, we expect to achieve additional substantial improvements. We are continuously monitoring the Milky Way, and hoping for a gravitational collapse!

Performance of the Perth Antenna

As with radio telescopes, resonant bar antenna performance is measured by noise temperature, $T_n$. Proof of performance involves testing the noise distribution - is it Gaussian? - and measuring environmental immunity. The Perth antenna has a noise temperature typically a few millikelvin. This means that a signal depositing $kT_n$ of energy - a few x $10^{-26}$ Joules - can be detected. This is the energy of a single hydrogen atom travelling at less than 10 metres per second.

These energy limits relate to the change in state of the antenna - change in phase and/or amplitude - from measurement to measurement. Its actual amplitude would correspond to the $4.2K$ bath temperature except for the transducer cold damping which cools the fundamental mode to $0.5K$.

Late in this decade large scale laser interferometer gravitational wave observatories will probably supersede resonant bars. With broad bandwidth and greater sensitivity they should make gravitational wave astronomy a reality. In the meantime the bars have a modest chance of making the first detection of a gravity wave.

Acknowledgements

It is impossible to adequately acknowledge all the participants in this project. Besides those mentioned in the text, I wish to acknowledge the contributions of my colleagues, especially Michael Buckingham and Cyril
Edwards, and the University of Western Australia Physics Workshop staff, especially Arthur Woods, John Moore, Ron Bowers, John Devlin, Graham Warburton, Derek Newman, Mike Cull, Jack Budge, John Cryer, Alan Goreham, Dick Jones and Ian Russell. Essential to the project has been the work of the sapphire clock team: Steve Jones, Jesse Scaris, Andre Luiten, Tony Mann, Marco Costa and Adrian Giles. Past students Laurie Mann and Ralph James and Nigel Prestage also made important contributions. When faced with nothing but leaks and thermal oscillations Bernard Candy's pulsar project and Andrew William's supernova project kept up our spirits.

The University of Western Australia has consistently supported this research. The Australian Research Council has supported this work almost as consistently, and I wish to particularly acknowledge their recognition of the value of this long term and difficult enterprise which, at times, must have seemed never-ending. Special thanks also to Roger Clay for providing cosmic ray shower detectors for our environmental monitoring system and to Paul Davies for his moral support and enthusiasm.

References

1 In the 1980's Weber developed a new theory of the interaction of resonant bars with gravity waves implying a vastly increased sensitivity, therefore making his results astrophysically more plausible. Unfortunately this too is generally considered invalid.

2 Some years later a high Magnesium/Al alloy, 5056, was discovered to have losses at least 10 times less than more commonly used material. ♦

Figure 6 Screen dump from the antenna system monitor showing the phase space motion of the antenna, and the mode temperature and effective temperature statistics.

Atomic and Electron Fluids
The Microscopic Structure of Quantum and Classical Fluids

FOURTH GORDON GODFREY WORKSHOP ON CONDENSED MATTER PHYSICS
SEPTEMBER 26 - 28, 1994
University of New South Wales, Sydney

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As part of the Exchange Program between the Australian Academy of Science and Japan Society for the Promotion of Science, I was able to attend this year's Annual Meeting of the Japan Physical Society (JPS). Since the JPS has reciprocal rights with the AIP, I was able to attend the conference on the same basis as a local Japanese physicist.

Arriving at the conference venue, a new private University about 15 kms from the city centre, the first and lasting impression of the meeting was its size (approximately 3,000 attendees). As all the sessions were on one site, lunch queues became quite large and as all the conference delegates travelled by train, extra staff were drafted in by Japanese Railways at the local station at the end of each day to sell tickets.

Within the general field of Condensed Matter Physics, there were two abstract books each of approximately 500 pages (2 abstracts per page). My collaborator and main reason for visiting Japan is Professor Ichimiya of Nagoya University, with whom I have common interests in the characterisation of surfaces and growth processes by electron reflection, chiefly RHEED.

There were 5 half day sessions on solid state diffraction physics techniques. However, on growth processes studied by various techniques, there were fourteen half day sessions (i.e. 7 double parallel sessions) of 128 oral presentations, together with a poster session of 38 papers. Any report can accordingly only be highly selective.

Of interest was the varying standard of the talks, almost all of which were 15 minutes. There were most impressive talks from various world class experimental groups, for example, Yagi's group at Tokyo Institute of Technology on developments in Reflection Electron Microscopy (4 presentations). There were approximately 20 presentations involving STM/STS work, often combined with other techniques, for instance, there was work by my host on combined STM/RHEED. There were also very interesting STM theory papers by, for example, Sawamura, Tsukada and Aono together with Hirose and Tsukada (chiefly from Tokyo University). Other interesting theoretical work was on the absorption of C60 on Si(111)7x7 surfaces by Yamaguchi and Fujima of Hiroshima University, who also mentioned afterwards about their additional results for C70 (the rugby ball does not "sit down" as does the soccer ball but "sits up" and spins).

On the other hand, there were graduate students giving outlines of their projects, sometimes what they had achieved in their first year of study, as the Japanese University Year starts on 1st April. Some of these were of the standard of preliminary 4th Year's Honours Project Talks given at the beginning of the year in Australian Universities. It was very interesting to see the seriousness with which such presentations were also given, with appropriate simple questions by world authorities by others.

In conclusion, the link between the JPS and the AIP means that AIP members can attend such conferences, meeting up with acquaintances in the normal way. Even though over 90% of the oral presentations are in Japanese, this can still be a more efficient way of catching up with new research results than exchanging email etc. As many of the overheads are in English and many of the technical terms e.g. STM, Si(111)7x7 are expressed directly in English rather than translating into Japanese, it is fairly easy to follow a talk especially if it is close to one's own field of interest, even if ones Japanese is fairly limited. Detailed questioning can of course take place in English afterwards.

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*Australian & New Zealand Physicist Volume 31, Number 6, June 1994*
The Tenth Geoffrey Frew Lecture was presented by Professor Claude Cohen-Tannoudji on "Manipulating Atoms with Photons" at the University of Melbourne on 6 December, 1993. The Lecture marked the opening of the Australian Conference on Optics, Lasers and Spectroscopy and was attended by more than three hundred Australian and overseas delegates.

The Frew Fellowship was established by the Academy from funds donated by the late Mr Geoffrey Frew, Chairman of Techtron Pty Ltd, to enable distinguished overseas scientists to participate in the Australian Spectroscopy Conferences and to visit scientific centres around Australia. Techtron Pty Ltd, now Varian Australia Pty Ltd, manufactured the first commercial atomic absorption instruments for chemical analysis. The Lecture was attended by Mr Frew's daughter, Ms Adelle Palmer, and members of her family.

Professor Cohen-Tannoudji is Professor of Atomic and Molecular Physics at the College de France and Laboratoire de Spectroscopie Hertzienne de l'Ecole Normale Superieure in Paris. He is distinguished for his pioneering work on optical pumping and light shifts in atoms; on the theory of atom-photon interactions including the interaction of atoms with coherent laser fields; and most recently on theoretical and experimental investigations in the new field of laser cooling and trapping of atoms.

Professor Cohen-Tannoudji commenced his lecture by pointing out that atom-photon interactions can be used not only to investigate the structure of atoms, as in spectroscopy, but also as a means of manipulating atoms. In particular the action of quasi-resonant laser light can be used to manipulate the polarisation of an atomic sample (as in optical pumping), the energy of the atomic levels (as in light shifts), the atomic velocities (as in laser cooling), and the position of the atoms (as in laser trapping). He went on to describe a series of very elegant experiments, currently in progress in his laboratory in Paris, in which these various processes are being exploited to enable samples of atoms to be cooled down to temperatures in the microkelvin range, and below.

Professor Cohen-Tannoudji then described some fascinating applications of laser-cooled ultra-cold atoms. The first was the observation of quantisation of atomic motion in an optical potential well produced by light shifts, in which most of the atoms occupy the lowest potential energy state and the vibrational lines exhibit extremely narrow widths on account of the localisation of the atoms (Lamb-Dicke narrowing). By using a number of light fields with appropriate geometry, spatially ordered hexagonal and body-centred-cubic lattices of atoms having "antiferromagnetic" ordering have been observed - a new state of matter? The second application was the development of a gravitational cavity for ultra-cold atoms, in which a parabolic evanescent light field represents the first mirror of the cavity and gravity plays the role of the second mirror. Up to ten bounces of ultra-cold caesium atoms have recently been observed on such an "atomic trampoline".

The next stage is to develop a multiple-beam Fabry-Perot interferometer for atomic de Broglie waves, in which several atoms occupy the same quantum mode. The third application was the development of an atomic clock based on a metre-high "atomic fountain", in which ultra-cold caesium atoms are launched against gravity and spend about one second in free flight, which defines the effective atom interaction time of the system. This arrangement is expected to lead to an hundred-fold improvement in accuracy over the best existing atomic clocks. Further improvements should be possible by operating the atomic fountain in a microgravity environment, such as in an aircraft making parabolic flights (presently under investigation) or in an orbiting satellite.

In the final part of his lecture, Professor Cohen-Tannoudji reported some very recent results in which a sample of metastable helium atoms had been cooled down to a temperature of just 200 nanokelvins, using a method based on "velocity-selective coherent population trapping" in which the atoms are cooled by counterpropagating laser beams in a nonabsorbing linear superposition of two states of opposite linear momentum. This temperature corresponds to a kinetic energy which is a factor of twenty below the recoil energy associated with the emission or absorption of a single photon and corresponds to an atomic de Broglie wavelength of 4.5 km, which is a factor of four longer than the wavelength of the laser light used to cool the atoms.

Professor Cohen-Tannoudji concluded his lecture by demonstrating that there should be no fundamental lower limit, other than the atom-laser interaction time, to the temperature which can ultimately be achieved by laser cooling.

Peter Hannaford
CSIRO Division of Materials Science & Technology

This report was published in the January-March issue of the Australian Academy of Science Newsletter whose permission to reprint is acknowledged.

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HAVE WE REACHED THE TOP?

STUART TOVEY

A paper presenting evidence for the top quark has been submitted to Physical Review D and has led to numerous newspaper articles. This article reviews, from a historical viewpoint, why the top is needed by the Standard Model of Particle Physics, and evaluates the new data.

Introduction

The possible discovery of the top quark by the CDF collaboration (for Collider Detector at Fermilab to whom we are indebted for this month's cover picture) rated articles in most major newspapers in Australia, and I would expect worldwide. With, of course, the obligatory quotes from Nobel laureates saying how important the discovery was. The headline of the 'New York Times' article, at least as reprinted in the Melbourne 'Age' was in my opinion especially misleading: it read 'Scientists close in on final secret of matter'.

My aim in this article is not to belittle the discovery. Having spent many years searching for the top quark in the UA2 experiment at CERN, I would have been delighted to write a paper similar to the CDF one. But I will attempt to put the discovery into perspective.

Fermions in the Standard Model

The table below shows the twelve Fermions which are required by the 'Standard Model'. Evidence for the tau neutrino is compelling but indirect. Together with their antiparticles, and the Bosons (photons, gluons, W^±, Z^0 and gravitons) which transmit the forces between particles, they constitute the known members of the 'Particle Zoo'. They are grouped into three families with a strong quark/lepton symmetry.

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<tr>
<td>c</td>
<td>+2/3</td>
<td>v_µ</td>
<td>0</td>
</tr>
<tr>
<td>s</td>
<td>-1/3</td>
<td>µ^-</td>
<td>-1</td>
</tr>
<tr>
<td>t</td>
<td>+2/3</td>
<td>v_τ</td>
<td>0</td>
</tr>
<tr>
<td>b</td>
<td>-1/3</td>
<td>τ^-</td>
<td>-1</td>
</tr>
</tbody>
</table>

Each pair of quarks and leptons forms a doublet of weak isospin, not to be confused with the strong isospin of Heisenberg and nuclear physics, except they do have in common the group SU(2).

Once there were three quarks (u,d,s) and four leptons and, in a seminal paper, Glashow, Iliopoulos and Maiani postulated a fourth quark (c). They were not the first to do that. Several theorists had realized that the quark-lepton symmetry was the key to removing certain theoretical anomalies. But the GIM mechanism, as it quickly became known, achieved much more. It was designed to 'charm' away flavour changing neutral currents in which, for example, an s-quark could transform into a d-quark. Experimentally such processes were not observed but they were allowed by existing theories.

The GIM trio were completing a theory proposed by Cabibbo a decade before, which indicated that the weak eigenstates of quarks, which form the doublets of the Standard Model, are not the strong, or mass, eigenstates which build particles such as mesons and baryons. The weak and mass eigenstates are related through the Cabibbo angle (θc):

\[
\begin{vmatrix}
  s_w \\
  d_w
\end{vmatrix}
= \begin{vmatrix}
  \cos \theta_c \\
  -\sin \theta_c
\end{vmatrix}
\begin{vmatrix}
  s \\
  d
\end{vmatrix}
\]

The charm quark was duly discovered in 1973, 'simultaneously' at SLAC and Brookhaven, and a nice simple picture of nature emerged. However that was soon to change.

In another remarkable paper, written even before the observation of the c-quark, Kobayashi and Maskawa predicted the need for a third family of quarks. They added the family (t,b), and extended the Cabibbo mixing matrix to:

Dr Stuart Tovey is the Director of the Research Centre for High Energy Physics, School of Physics, University of Melbourne, Parkville, Victoria 3102.
The nine elements of the unitary Cabibbo-Kobayashi-Maskawa (CKM) matrix U are not independent, but can be written in terms of three angles and a complex phase. Why introduce this complication? The complex phase allowed CP-violation to occur ‘naturally’ in the model. CP-violation had been discovered a decade before and, according to Sakharov, was a necessary ingredient of any mechanism seeking to introduce a baryon-antibaryon asymmetry into a symmetrically created universe.

And, at about the same time that the physicists at SLAC found evidence for the c-quark, a team there led by Martin Perl also found the charged τ-leptons, and so the (t, b) doublet was also needed to restore quark-lepton symmetry.

To create a heavy particle requires a lot of energy. For nearly a decade searches for the t-quark were best made at CERN’s pp collider by the UA1 and UA2 experiments. They studied the head-on collisions of protons and antiprotons, each with an energy of 315 GeV. From about 1990 we could no longer compete with Fermilab near Chicago, with their beams of 900 GeV p and p.

The signature for the observation of t-quarks is far from simple. In order to preserve their ‘topness’, the quantum number which makes a top quark different from a lighter quark, top-quarks will be produced in tt pairs at the Fermilab collider. Massive t-quarks decay via the channel t → b + W⁺ (or the charge conjugate for the t) and the W⁺ then decay via no less than five decay channels. Those decays happen almost instantaneously, in less than 10⁻²⁰ s, but the b and b̄ are long lived. Mesons containing b-quarks survive for about a pico-second and, thanks to Lorentz boosts, travel typically one millimetre before decaying. One of the tricks used is to tag tt decays using displaced vertices from the b and b̄ decays. Figure 1 from the CDF paper shows a simplified view of such an event, and is included only to illustrate the complexity of the search.

There are two experiments in the pp ring at Fermilab: CDF and D0. Prior to the recent CDF paper both experiments were saying that the mass of the top was, with 95% confidence, about 140 GeV. To many that indicated that the discovery of top was not far away. The top mass may be estimated indirectly by what theorists call radiative corrections. These are loops in Feynman diagrams, one of which is shown in figure 2. Many such calculations have...

---

**Why the t-quark ‘Must’ Exist and How to Find it**

Experiments at the Large Electron Positron collider (LEP) at CERN produce copious numbers of Z⁰-particles which decay into fermion-antifermion pairs including bb. The strength of the coupling of fermions to the Z⁰ depends on the value of the third component (t₃) of their weak isospins. The LEP experiments have measured t₃ for the b-quark and the answer is t₃ = -0.012. Consequently, the b-quark is part of a weak-isospin doublet t₃ = -1/2 and a partner, the t-quark with t₃ = +1/2, should exist.

**Figure 1** An indication of the method used by CDF to find displaced vertices, thereby tagging top decays via the associated long lived b-quarks.

Jet Axis

Secondary Vertex

Primary Vertex

Lxy

---

_Australian & New Zealand Physicist_ Volume 31, Number 6, June 1994
Figure 2  The Feynman diagram for a typical radiative correction. The loop involving the t- and b-quarks modifies the mass of the W+ particle, a well measured quantity.

Summary

As must be clear from the previous sections, either the top quark has been found, or it should be found soon. And at Fermilab. Some of my colleagues consider the CDF paper to be premature, others agree with me that they were correct to go public.

My main problem is with the headline "Scientists close in on final secret of matter", which the newspapers do not attribute to any of the Nobel laureates or to CDF physicists. Possibly it was generated by a sub-editor; in any case it is quite wrong.

In the Standard Model the Higgs mechanism allows particles to have mass but does not predict masses, no reliable theory does. And there is one new particle, the Higgs Boson whose mass is completely free, although there are good reasons to believe that it is less than 1 TeV.

In order to find the Higgs Particle, or to check if the Higgs mechanism is indeed correct, we need the next generation of accelerators. Following the axing of the SSC in the USA that leaves the field open for CERN's Large Hadron Collider (LHC).

We do not know why the proton is about 2,000 times heavier than the electron, why the neutrinos are either very light or perhaps massless, why the t-quark is as massive as a Gold nucleus.

When we know why particles have masses, and can predict them, then maybe we can claim to be close to the 'final secret of matter'. My hope is that headlines like this one will not make politicians and policy makers think that the next generation of accelerators are not needed; they are!

Acknowledgements

This article could not have been written on the time scale demanded by the editor, "by yesterday", without invaluable help from Dr Iain Bertram, recently from this university and currently a post-doc on the D0 experiment at Fermilab. I would also like to thank Dr Ray Volkas for critically reading the article, in particular for theoretical errors.

References

Figure 3  A recent fit to all radiative corrections. The curves show $\chi^2$ vs. the mass of the $t$-quark for many processes. (From Ellis).
Entries are invited for the 1994 Michael Daley Awards for excellence in science, technology and engineering journalism, sponsored by the Science & Technology Awareness Program of the Department of Industry, Science and Technology, and the Institution of Engineers, Australia.

The awards are named in memory of the late Michael Daley, inaugural Executive Director of TV Science for the ABC, who was highly influential in promoting the value of science and technology journalism.

The awards will be presented to the Australian journalists and communicators whose work during the 1993-94 is assessed as having most effectively communicated scientific, technological and/or engineering issues to the public.

'Scientific, technological and/or engineering issues' includes the natural, physical or applied sciences (including agricultural sciences), all branches of engineering, information technology, technological innovation, design and development, the environment and health science issues, as well as work that presents the social and/or economic consequences of science, technology and engineering. Other areas may also be appropriate, particularly if not already covered by other journalism awards.

It is expected that the category winners will be announced in late 1994. A presentation ceremony will be held in Canberra in early 1995, at which the Best Entry Overall will be announced.

Entries close on 30 September 1994.

Judging criteria and technical requirements: Richard Scherer Phone (06) 276 1839.
Entry forms and other enquiries: Phone (06) 276 2463.
Prompt Critical

A Happy Reviewer is a Good Reviewer

Matching a book to a suitable reviewer is a continuing challenge. In processing over one hundred books a year, it would be lost without my database of over 600 Australasian scientists in physics and related disciplines. Given the very broad spectrum of books sent to us by their publishers, I am often obliged to despatch a volume to a potential reviewer with some trepidation, hoping that I have chosen the right person for the task.

So it is a very happy Reviews Editor when the incoming mail brings back promptly a good review, written by someone who has clearly enjoyed reading and evaluating the book (or software, video, or whatever). Usually the sentiments are not as explicit as the very welcome comment introducing Michael Box’s excellent and most readable review which follows. However one can often read between the lines the reviewer’s satisfaction.

The numbers given earlier imply that a scientist or engineer on our database can expect to receive a book for review about once every five years. That is much too simplistic. Regular readers of this section will have noted that some reviewers’ names crop up much more often. The reason is simple enough: they are the good reviewers, who have a history of producing a worthwhile review within the set deadline.

Tardy reviewers, whose late responses are registered in the database, rarely get a second try unless they happen to be in a very specialist field where I have no alternative. About ten percent of reviewers range from late to never. This can be very sad: three years ago a book by a local author appeared and I went to a great deal of bother to find a reviewer in the same field. I discovered one who had been a fellow student with the author and despatched the volume thereto with high hopes. Although the book was accepted, a review has not been forthcoming. Cases like this, involving some very eminent scientists, are rather distressing. Furthermore, a reviewer has no legal title to a book until a review has been published. In an attempt to ensure that authors and publishers get some mention within these pages we list all New Books, except that we pull a title off the list if its review is promptly to hand. Very rarely an unacceptable review is submitted: in such cases it is returned with constructive suggestions for resubmission.

Any properly qualified physical scientist affiliated with a recognised company or institution is well advised to apply to become a reviewer of books or software. A list of up to ten keywords should be supplied to indicate the areas of expertise where a competent review can be expected. Of course if the keywords are too arcane that nothing comes along to match them it could be a long wait. On the other hand, if the keywords are too general, the wait could be equally long!

Colin Keay
Reviews Editor

Reviews

Theory of Reflectance and Emittance Spectroscopy
B. Hapke
Cambridge University Press, Cambridge, 1993, xiii + 455pp., $220.00 (hardcover)

One of the great joys of being on Colin Keay’s list is that he keeps sending you interesting books to review, including excellent books which you otherwise may well have missed. The lives of working scientists are so over-filled these days that one rarely finds the time to peruse the literature outside one’s own specialty. This is a great pity, as disciplinary boundaries are seldom water-tight, and there are usually other scientists working in the same vineyard, even if they are seeking other fruit. This book is a case in point, at least for me. It basically addresses the physics of light scattering by the particles which make up planetary surfaces, differing from my own field of atmospheric scattering mainly in the density of the scatterers. I now have an insight into how another group of scientists approaches a field with many similarities to my own, as well as a bibliography of around 300 references.

The book is comprised of four parts. Three chapters cover electromagnetic wave propagation in continuous media, including absorption and reflection. This is followed by a chapter on scattering by spherical particles, and another on irregular particles. The treatment here is largely intuitive and empirical, which is probably acceptable to the task at hand. (There are plenty of books which cover this territory with varying degrees of rigour.)

The middle third of the book applies this basic theory to the scattering of radiation by distributed scatterers, with emphasis on the bidirectional reflectance in different geometries. While the emphasis is on surface reflectances, such as planetary regoliths and vegetation canopies, the treatment is quite general. As with the chapters on scattering, the emphasis is on intuition and logic, rather than rigour for its own sake.

The final three chapters address specialized areas, including polarization and thermal emission. (As this topic makes up less than 10% of the book, the title is a little misleading.) Four valuable appendices and an extensive bibliography complete the book.

It is unfortunate that the price of this book has placed it beyond the reach of all but the best supported scientists. It should, however, be regarded as indispensable for every University and CSIRO library, and one can only hope the publishers will rethink their decision and make this excellent text more accessible.

Michael Box
School of Physics
University of New South Wales

1994 International Conference on UNDERWATER ACOUSTICS
5 - 7 December 1994

For further details
Dr J.J. Dunlop, School of Physics, UNSW
1944 International Conference on UNDERWATER ACOUSTICS
5 - 7 December 1994

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Gas Source Molecular Beam Epitaxy

Growth and Properties of Phosphorus Containing III-V Heterostructures

M.B. Panish and H. Temkin
Springer Series in Materials Science 26
Springer-Verlag, Berlin 1993
x + 428 pp., DM98 (hardcover)

For a technique which is essentially an elaborate evaporator, molecular beam epitaxy (MBE) has had a major impact on the progress and understanding of semiconductor physics. From its humble beginnings as a basic research tool for investigations of reaction kinetics, MBE has developed into a practical technique used in research and industry for the production of a wide variety of epitaxial semiconductor materials including nearly all the III-V semiconductors, silicon, many II-VI semiconductors, optical materials, and even high temperature superconductors. While other epitaxial growth techniques have caught up to the capabilities of MBE, it is still MBE which leads the field in the generation of ultimate dimensional control for the production of quantum structures.

Early development of MBE for the growth of phosphorus containing III-V semiconductors, so important for optical communications, was limited by the difficulty in the use of solid sources of phosphorus (not the least of which was the cost of replacing equipment lost in expensive, if spectacular, phosphorus fires). The topic of this book, gas source molecular epitaxy, was the very successful response to these problems. The book covers in an eminently readable, yet accurate and informative way, the basics of MBE and gas source MBE in particular. Coverage is broken into two parts with the first giving a complete development of the gas source technique, including sample preparation, growth, handling, diagnostics, and safety as well as the theory of MBE growth. The second part covers in a less complete, though still informative discussion, the physics of the heterostructure devices in III-V semiconductors.

The book is aimed at two audiences - the MBE and III-V epitaxial growth community, for which is a useful background to MBE and good introduction to the problems of phosphides in MBE. The second audience is the semiconductor technologist, interested in passing in MBE, but with particular interests in semiconductor quantum structures and the devices fabricated from them. The prequisites for understanding are modest with an introductory knowledge of thermodynamics and quantum mechanics being the only essentials to readily reading the entire content. An extremely useful book, as would be expected from its authors.

John Dell
Department of Electrical & Electronic Engineering University of WA

Stochastic Quantisation

Mikio Namiki
Springer-Verlag, Berlin 1992
x + 217 pp., A$53.75 (hardcover)

Classical physics fails to describe phenomena at small scales and also at bigger scales when the phenomenon is the result of some collective effect originating from microscopic scales, such as the phenomenon of superconductivity. In quantum physics the microscopic fluctuations are
incorporated by the degree of operator non-commutativity or depicted by the trajectory fluctuations which are summed over in the Feynman path integral. In 1981 Parisi and Wu proposed the method of stochastic quantisation. In this picture, quantum fluctuations are manifest, but not explained, through stochastic fluctuations in an extra dimension of time, while ordinary time has purely imaginary values. The book in review is the first one solely devoted to the study of this quantisation framework.

The reader will need to be equipped with some quantum field theory background in order to take advantage of this book. The first two chapters introduce the general ideas and theory of stochastic processes. A general prescription of the stochastic quantisation follows for scalar, gauge as well as fermion fields. Essential ingredients of quantum field theory such as regularisation and renormalisation are introduced and compared to the more conventional approach. In dealing with gauge theory all the necessities of constrained systems and Ward-Takahashi identities are also developed. In particular, new and interesting perspectives on the Gribov problem and on quantum anomalies are pointed out. The short introductory chapter to numerical simulations based on the Langevin equation would need to be supplemented by material from elsewhere. The last chapter presents some attempts to tackle the complex Langevin equation, where violation of ergodicity is still a stumbling block for the study of many interesting systems in Minkowski space-time, strongly interacting fermions, finite density QCD and chiral gauge theory.

Overall, although the book is short, this is compensated for by its direct approach and an adequate bibliography. However, the book could be improved by the inclusion of an index.

Namiki’s compact volume is a delight to read. I wish to recommend it to anyone who has a vested interest in Theoretical Physics. Its timely publication serves well the promotion of an exciting field, which should soon become a standard component of graduate courses in Quantum Field Theory and Theoretical Particle Physics.

T.D. Kieu
School of Physics
University of Melbourne

New Books

Cosmic Wormholes: The Search for Interstellar Shortcuts
P. Happer
Plume (Penguin Books), New York 1993
x + 236pp., A$16.95 (paperback)

Parkes: Thirty Years of Radioastronomy
D.E. Goddard & D.K. Milne
CSIRO Publications, East Melbourne 1994
ix + 162 pp., A$40.00 (hardcover)

Quantum Mechanics on the Personal Computer - Third Edition
S. Brandt & H. Dahmen
Springer-Verlag, Berlin 1994
xii + 314pp., DM98 (hardcover with disk)◆

Nominations are sought for the 3rd award of the Bragg Gold Medal which is awarded annually, commemorating the work of W.L. & W.H. Bragg, to the author of the best PhD thesis in Australia completed in the 13 months prior to June 30th 1994.

The medal is a solid 9ct gold medal bearing the profile of W.L. Bragg in front of that of his father W.H. Bragg, and the words “W.L. & W.H. Bragg Medal for Excellence in Physics”.

Nominations should be made to the State Branch Secretaries whose addresses are given in this journal on page 128, by July 31st. The nomination should include a copy of the PhD thesis, a citation describing the significance of the work and the markers' reports if available.

CONDITIONS OF THE AWARD

1. The Australian Institute of Physics will award one gold medal annually to the student who is judged to have completed the most outstanding PhD thesis in Physics under the auspices of an Australian University, and whose degree has been approved by the ruling body, but not necessarily conferred, in the previous 13 months. No candidate may be nominated more than once.

2. The medal, commemorating the work of W.L. & W.H. Bragg, will be made of solid 9ct gold and will be known as the Bragg Gold Medal for Excellence in Physics.

3. The medal will be awarded to the chosen candidate at a function to be arranged by the AIP branch of the state of the candidate's university. The medal will not be awarded in absentia; the candidate must be present for the presentation at a time which is mutually convenient to both the candidate and the state branch. Reasonable expenses, including the cost of travel to Australia from overseas if necessary, will be met by the Council of the AIP.

4. Only one medal shall be awarded; there is no possibility of a dual award. If the committee considers that none of the theses submitted reaches an appropriate standard, no award will be made.
CONFERENCES & MEETINGS

1994

July 4 - 8  BRISPHYS 94, 6th Asia Pacific Physics Conference and 11th Australian Institute of Physics Congress in Brisbane QLD. Contact: Ross Dunlop, School of Physics, Queensland Institute of Technology, GPO Box 2434, Brisbane QLD 4001. Tel: 07-864-2227, fax: 07-864-1521 email: r.dunlop@qut.edu.au

July 31 - Aug 4  STATPHYS 19 to be held in Xiamen, China. Contact: Hao Bai-lin, Chairman STATPHYS! Institute of Theoretical Physics, PO Box 2735, Beijing 100080, People's Republic of China. Tel: 86-1-2541807, fax: 86-1-2362587, telex: 22040 BAOGS CN.

August 24 - 31  The Seventh International Symposium on World Trends in Science and Technology Education to be held in Veldhoven, The Netherlands. The theme is "Science and Technology Education in a Demanding Society". Contact: Associate Professor Graham Murrow, RMIT, Bundoora. Tel: 03-468-2497, fax: 03-467-3089.

Aug 15 - Nov 11  Research Workshop on High Temperature Superconductivity at the Australian National University in Canberra. Contact: Dr M.P. Das, Department of Theoretical Physics, Research School of Physical Sciences and Engineering, The Australian National University, Canberra ACT 0200. Tel: 06-249-3066 or 2943, fax 06-249-2943, email: MPD105@phys.anu.edu.au

September 26 - 28  Fourth Gordon Godfrey Workshop on Condensed Matter Physics: 'Atomic and Electron Fluids: The Microscopic Structure of Quantum and Classical Fluids', University of New South Wales, Sydney. Contact: David Neilson, School of Physics, University of New South Wales, Sydney 2052. Tel: 02-385-4564, fax: 02-663-3420, email: D.Neilson@unsw.edu.au

October 10 - 14  Course in Temperature Measurement, CSIRO Division of Applied Physics, Sydney. Contact: Robin Bentley, CSIRO Division of Applied Physics, PO Box 218, Lindfield NSW 2070. Tel: 02-413-7764, email robin@dap.csiro.au

December 5 - 7  1994 International Conference on Underwater Acoustics University of New South Wales, Kensington NSW. Contact: Dr J.J. Dunlop, School of Physics, UNSW, PO Box 1, Kensington NSW 2033, Tel: 02-697-4575, fax: 02-663-3420, email: jjd@newt.phys.unsw.edu.au

December 14 - 16  Symposium on Physics Curriculum Evaluation to be held at Airlangga University, Surabaya, Indonesia (organised by ASPEN - the Asia Physics Education Network) Contact: Dr Alex Mezzoli, Physics Department, Swinburne University of Technology, PO Box 218, Hawthorn NVIC 3122. Tel: 03-919-8866, fax: 03-819-0856, email: aspen@brain.physics.swin.edu.au

1995

Jan 16 - Feb 3  Eighth Physics Summer School: Cosmology: The Physics of the Universe at The Australian National University in Canberra. Contact: Dr B.A. Robson, Department of Theoretical Physics, RSPhysSE, The Australian National University, Canberra ACT 0200. Tel: 06-249-2971 or 06-249-2943, fax: 06-249-4676, email: BArn05@phys.anu.edu.au

February 7 - 10  ANZIP 19th Condensed Matter Physics Meeting, Charles Sturt University, Riverina, Wagga Wagga NSW. Contact: Dr Nick Savvides, CSIRO Division of Applied Physics, PO Box 218, Lindfield NSW 2070. Tel: 02-413-7359, fax: 02-413-7359, email: sav@dap.csiro.au

July 12 - 19  XXVI International Physics Olympiad, University of Canberra. Contact: Associate Professor Rodney Jory, Physics, Faculty of Science, ANU, Canberra ACT 0200. Tel 06-249-2777, fax 06-240-0741, email nss@anodec.anu.edu.au
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