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CONTENTS

PRESIDENT'S COLUMN 2
No Science Institutes, No Accountability. Geoff Stedman

EDITORIAL 3
"And All Was Light". Jak Kelly

ARTICLE 4
Nuclear Magnetic Resonance in Antarctica. Paul Callaghan & Craig Eccles

ARTICLE 9
Physics Education Research: Education or Physics?
The Sydney University Physics Education Research Group

OF INTEREST 13

ARTICLE 14
Dirac Plaque in Westminster Abbey. Heinrich Hora

PRODUCT NEWS 16

ARTICLE 18
Quarks and Deep-Inelastic Scattering. Wally Melnitchouk

RECENT NEWS 26

CONFERENCE & MEETINGS 28

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The CUBE detector shown on this month's cover has been designed and built at the Department of Nuclear Physics, RSPhySE, ANU. Its purpose is to detect and identify the products of nuclear reactions, in particular those following nuclear fusion. It consists of four low pressure multi-wire proportional counters, each 284 x 357mm2 active area, located 180mm from the target. This geometry gives a very wide coverage of angles, with correspondingly large solid angle (68% of 4π). The detectors are position sensitive in x and y, with a resolution of ±1mm, and give 250ps time resolution. From the angle and time information, the characteristics of the reaction can be reconstructed.

In the picture, the vacuum chamber lid is removed, and the position sensing wire grids and timing foils are not in place in the two nearest detectors. The laser beam shows the path of the beam from the accelerator, striking the target in the centre of the chamber.

First experiments have shown that the detector performance exceeds expectations: the capability to rapidly collect large amounts of data of the highest quality has already led to significant new insights into nuclear reaction dynamics. The CUBE detector provides the laboratory with a versatile new instrument whose capabilities are unmatched worldwide. Transparency submitted by David Hinde from the Institute of Advanced Studies within the Research School of Physical Sciences and Engineering at the Australian National University.
No Science Institutes; No Accountability

Did you know that if you jump out of a high-rise building 45 metres above the ground, that you will land on the ground in armchair comfort?

Congratulations on your affirmative answer; you are well poised to pass New Zealand School Certificate science. School Certificate is the first public fifth-form, or New Zealand third year high school/college examination course and is administered by the New Zealand Qualifications Authority (NZQA).

If that sounds just a little rich, let me give you the good oil. The exam question actually states: “A 250 g container of cherry stones fell 45 m to the ground from rest. It took 3 seconds to fall. Calculate the speed at which it hit the ground. Calculate its force as it hit the ground.” You are given the gravitational acceleration.

After much correspondence and public comment, NZQA repeatedly assure us that they are accepting as a correct answer the weight of the box and that “no candidate has been disadvantaged.” Rich indeed.

Can you tell NZQA the work it takes to carry a person (with such and such a weight) along a farm track - any farm track - of such and such a length?

If not, that’s your fault. “Despite the wording the candidates knew the questions’ intention”. This assurance comes on the occasion of NZQA’s first public admission of a problem with the exam, and weeks after our first publicity. There were several other major problems with that paper, by the way.

NZIP Council was heavily involved in preparing a letter to NZQA and then in wording a press release. Initially we hoped for a professionally acceptable resolution in private, and we resorted to fairly restrained newspaper publicity only when it became clear that NZQA would not cooperate with us.

Faced with adverse publicity from the institute in all major dailies, NZQA initially responded childishly, resorting to smokescreens playing on anti-university feeling, and stating “science attracts various viewpoints, particularly in universities” and “universities have problems with science,” despite our earlier explanation to them that half the NZIP membership were school teachers. Ad hominem arguments like “frankly I’m not quite sure of the professor’s (ie, my agenda)”, were thrown in and, worst of all, a revealing and truly alarming endorsement of constructivism run riot: “the science paper dealt with concepts, and it was not a physics examination.” This forced me to take the gloves off as in the recasting of the first paragraph. I then suggested that “the force I would experience meeting the ground (after a 45 m fall) is brutal indifferent to all such niceties (of consideration of viewpoints and concepts)” and that this indifference reflected the universal character of science.

Was NZQA persuaded? Their latest press release says: “the meaning of the flawed questions would only be unclear to those with an advanced knowledge of physics,” and “a university physicist will be aware of some aspects of physics which a fifth-former will not be, and will naturally find some questions unanswerable at an advanced level.” At least there is now one physics for all, even if “where ignorance is bliss, ’tis folly to be wise.”

The Minister for Education favours the NZQA for many vital national tasks fundamental to many levels of education in New Zealand. NZQA not only sets national secondary examinations but assesses the internal examination papers and accredits various bodies including polytechnics and their degree courses (eg in naturopathy - Aoraki Polytechnic, Timaru).

Against some opposition, NZQA is heavily promoting “unit standards”, partly to facilitate the portability of mini-qualifications between different tertiary programs and institutions. In the current NZQA strategy, portability to the international world of learning is of much less importance.

A variety of threatening actions are continually being conducted by NZQA against current University autonomy, the most doctrinaire of which would essentially demand NZQA accreditation for University degrees, and so accord NZQA influence over curriculum content, examinations etc. What that could mean is evident from the 1995 NZQA School Certificate science examination.

Some body with a relevant authority had to comment. The New Zealand Institute of Physics (NZIP) is the only body yet to query such atrocious questions and still more atrocious defences publicly. NZQA would have been even more successful in restraining publicity and in soothing dissent if it had been expressed by individuals.

NZIP is strongly committed to educational matters. It has a special Education Subcommittee with a budget of the order of that for all other NZIP activities. Council had no hesitation in concluding that public comment on standards as above is part of our function.

And in the event, the fact that the institute, including teachers and non-university physicists, was speaking and not just one professor added very considerable weight. In Christchurch alone, the “Press” published a superb editorial titled “Shabby response” in rebuttal of the latest NZQA response, as well as over 14 letters over the last month, every one of which applauds and enlarges on our statements. It will be hard for NZQA to ignore such a groundswell. In any case, some strategies for follow-up with for example the Royal Society of New Zealand, of which NZIP is a member body, are under discussion. We are not prepared to leave it as an isolated media event.

I am now convinced as never before that our institutes are of vital importance.

Geoff Stedman
phys040@cantva.canterbury.ac.nz

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"And All Was Light"

It has taken eleven years for a stone plaque in memory of Dirac to join those of Faraday, Green, Maxwell, Kelvin, Thomson and Rutherford near Newton’s memorial in Westminster Abbey. Stephen Hawking describes this delay as “a scandal that it has taken so long.” On the basis of true merit rewarded he is right but that is not how public awards now usually go. Admittedly there is a significant difference between a stone in the Abbey and being Australian Father of the Year but both now share the primary need for public awareness of the achievements of the recipient. In the case of the Abbey there is limited real estate so a certain amount of caution is to be expected, particularly in view of the very limited understanding of basic scientific achievements on the part of both church and government establishments.

The impressive monument to Newton, complete with admiring cherubim, around which the modest plaques of the other physicists gather, is a reflection of a different time. Sir Francis Bacon’s College of Philosophy became in 1662 the Royal Society under the leadership of the recently restored Charles II. Bacon himself had been Lord Chancellor of England and Charles II took a real interest in the Royal Society. The Establishment and Science were hence not divided as they now are. Science was struggling to emerge from alchemy and Bacon was spurring on by fear of a new dark age from those pernicious artifices and devices which have crept into the place of solid erudition I have augured a storm not less fatal for literature and science. We can understand the emotions that motivated the construction of Newton’s monument. He would have been perceived as having rolled back the forces of intellectual evil with his brilliant equations and his mastery of the gravitational forces that ruled the universe: the St. George and the Dragon image which so captures the imagination.

Nature’s laws
Lay wrapped in night
God said ‘Let Newton be’
And all was light

Alchemy and its cousins are still with us but it is not from them that dark age worries come. In fact all such fringe activities are a testament to a basic human need to understand and manipulate natural forces. It is just that their practitioners have not made the transition from animist beliefs to experimentation and the rational and objective analysis of the results. A good experiment bears a good incantation any day. Dark age worries come from other sources now. Declining standards of literacy, debasement of school examination standards, creationism, relativism or whatever the current word is for the claim that scientific laws are just a matter of opinion, and an increasing number of people who know the price of everything and the lasting value of nothing.

How can such things be in these more educated times? Information is available for most people to make well informed choices and therefore become less manipulated. This is not a good thing for many mass markets. Selling the same mediocre product to millions is more profitable than selling a variety of products that may be more what individuals really need. To maintain mediocre mass markets enormous advertising campaigns show that it is OK to be ignorant and to be a manipulated idiot. If you can’t try an egg or make a piece of toast the solution is not to spend ten minutes mastering these simple skills but to go out and buy breakfast at a junk food outlet.

Numerous such campaigns over the years have drilled into people that if at first you don’t succeed, give up. This is not how you become a scientist and so to a society conditioned to instant gratification and acceptance of the mediocre, scientists appear weird. If you crave easy public recognition don’t become a scientist. If you do, be prepared to accept that the forces of darkness are eternal and you will be opposing them all your life.

Jak Kelly, kelly@unsw.edu.au

*To follow this exciting adventure you should buy and read “From Faust to Strangelove” a splendid work on the public perception of scientists throughout history by Roslyn Haynes (The Johns Hopkins University Press).
NUCLEAR MAGNETIC RESONANCE IN ANTARCTICA

PAUL CALLAGHAN & CRAIG ECCLES

Australians & New Zealanders in Antarctica

The Antarctic has attracted scientists from Australia since the earliest days of exploration. The Australian Louis Bernacchi was physicist in Scott’s 1901-1904 expedition. Edgeworth David, who joined Shackleton’s expedition in 1908, led both the first party to reach the South Magnetic pole and the first to climb Erebus. Accompanying him on both journeys was the remarkable Australian, Douglas Mawson, whose later exploits form part of the annals of Antarctic heroism. In Scott’s ill-fated 1910-1913 expedition, the geologist Frank Debenham was Australian and Raymond Priestley, while born in the UK, had worked at Sydney University. While no New Zealand scientists were part of those early expeditions, the pioneer Antarctic explorers and scientists had strong links with New Zealand. The high level of New Zealand interest in Antarctica was to finally result in the establishment, by Ed Hillary, of Scott Base at Pram Point, Ross Island, during the International Geophysical Year 1956/57. During the summer of 1957/58 Hillary made the first motorised vehicle journey to the Pole. The scientist responsible for the first New Zealand scientific programme in the Antarctic was the geophysicist, Trevor Hatherton. One of New Zealand’s leading scientists, Trevor was Director of the Geophysics Division of the DSIR, and served as president of the Royal Society of New Zealand from 1985 to 1989. He died in 1992.

The business of science in the Antarctic no longer requires heroism. However the feats of the early scientific explorers add an element of mystique to the pursuit of knowledge in that remarkable environment. We too had always been attracted to the idea of visiting the Antarctic. For the average citizen the obstacles to such a visit are enormous. But as scientists we were uniquely privileged by having been actively encouraged to participate in New Zealand’s programme in McMurdo Sound. That encouragement came from our physics colleagues, Bill Robinson and Tim Haskell of Industrial Research CRI in Gracefield, Lower Hutt, both of whom have had wide Antarctic experience with research on sea ice properties.

Paul Callaghan and Craig Eccles are in the Department of Physics, Massey University, Palmerston North, New Zealand.

Proton NMR images of transverse and longitudinal slices selected in a sample of laboratory manufactured sea ice at -5°C. The field of view is 12 mm.

a) Sea ice (-5°C) horizontal slice.
b) Sea ice (-5°C) vertical slice.
The New Zealand Sea Ice Programme

The New Zealand Sea Ice Programme involves a collaboration between four New Zealand Universities (Otago, Victoria, Massey and Auckland) and the Industrial Research CRI. Funding support for the programme comes from the New Zealand Foundation for Research, Science and Technology and the US National Science Foundation while logistical support is provided by the New Zealand Antarctic Programme, the US Antarctic Programme, the Royal New Zealand Air Force and the US Air Force and US Navy. The responsibility of each of the groups and the scientists involved are as follows:

NZ Institute for Industrial Research
Dr Tim Haskell and Dr Bill Robinson: Overall coordination; sea ice mechanic properties; climate-related interpretation. Chris Gannon and Simon Gibson: Technical support.

Department of Physics and of Mathematics and Statistics, University of Otago:
Dr Patricia Langhome, Professor Vernon Squires: Sea ice phase behaviour and microstructure, rheology theory; wave-ice interaction; acoustic emission work; climate-related interpretation.

Department of Physics, Victoria University of Wellington:
Dr Joe Trodahl: Thermal conductivity measurements on sea ice.

Department of Physics, Massey University
Professor Paul Callaghan, Dr Craig Eccles: Nuclear Magnetic Resonance measurements on sea ice.

Department of Mathematics and Statistics, Auckland University
Dr Colin Fox: wave-ice interaction; remote sensing; climate-related interpretation.

We have in addition three US collaborators, Professor Hayley Shen and Ms Susan Frankenstein from Clarkson University and Dr Joe Seymour, who is based at Massey University during 1995/6 and who will assist with the NMR experiments in Antarctica this year. Some publications resulting from the recent work of our collaborators are listed in the references [1-5].

The Nuclear Magnetic Resonance Connection

Our involvement with the sea-ice programme began at the ANZIP Condensed Matter Physics meeting held at Hammer Springs in 1992, as a result of a conversation over lunch with Bill Robinson. One of us (PTC) had expressed enthusiasm for Antarctica and Bill responded in his usual forthright manner that we should think of an experiment. The tentative suggestion that we use the Earth's magnetic field to carry out an NMR investigation of the brine component in sea-ice was enthusiastically accepted by Bill. From then on both he and Tim Haskell ensured we were part of the team.

It was obvious that NMR would be quite a nice method for structural studies at the microscale. Figure 1 shows NMR images of laboratory manufactured sea ice which we have obtained using our NMR microscope at Massey University. The signal arises solely from unfrozen brine water which shows up in clearly marked striations. Of particular interest is the extent of brine water content as well as the rotational and translational mobility of this water in the porous medium. Rotational mobility can be related to water proton relaxation times while translational mobility can, in principle, be measured using Pulsed Gradient Spin Echo methods. While such measurements are relatively routine in the laboratory, the challenge for our project was to develop instrumentation suitable to carry out such measurements in the field.

The Antarctic Spectrometer

While Earth's field NMR has been utilised for many years for proton magnetometry, reports of use of the time-domain pulse techniques necessary for the experiments we envisaged are
NUCLEAR MAGNETIC RESONANCE IN ANTARCTICA

relatively few [6-8]. There is another difficulty. The Earth's field is very weak, with a value of around 65 microTeslas in the Antarctic corresponding to a proton precession frequency of 2.7 kHz. At such low frequencies, the intrinsic sensitivity of the method is also very low. This project therefore presents special instrumentation challenges. We had to make our instrument sufficiently flexible to carry out multi-pulse experiments and we needed to provide specialised coils and current control circuitry to generate pulsed magnetic field gradients. We also had to incorporate effective signal averaging if we were to obtain sufficient signal-to-noise ratio. Such averaging had not previously been carried out successfully in Earth Field NMR because of instability problems. Finally, the entire apparatus had to be capable of being operated under Antarctic field conditions.

During 1994 we developed the Earth’s Field Nuclear Magnetic Resonance system in our laboratories and workshops at Massey University. We were helped by having an old Earth’s Field system [6] as well as a discarded apparatus built by Hort Research Engineers at Ruakura. Neither was suitable for our purpose but they provided a useful reference. A schematic diagram of the new system, which included current switching units, filters and low noise audio amplifiers is shown in figure 2. A “Teac” NMR pulse sequencer, purchased with the aid of FRST funds, was used to control all current and a pulse switching and also functioned as a signal digitizer and averager. One nice feature of the system was the use of pulse programmer TTL pulses to generate the clock frequency for the a/f transmitter. This had the advantage that the a/f pulses were precisely phase-locked to the pulse sequence timing, thus ensuring the stability needed for signal averaging. The NMR system incorporated polarizing and receiving coils which were able to contain 75 mm diameter sea ice samples. Because of heating of the outer coil during polarizing, a glass dewar system was placed between the receiver and polarizer coils so as to provide a degree of thermal insulation.

After a frantic rush to complete the instrument we finally achieved success in the week before our departure for the Antarctic. An example of a single Free Induction decay from a sample of water, obtained at Massey University during that week, is shown in figure 3a. The signal to noise ratio is limited by the high degree of audio frequency interference present in an urban site. We were to find a completely different level of noise interference in McMurdo Sound!

Preparation for the Antarctica

As two scientists who had spent all our working lives in the laboratory, the thought of field work in such a place gave an edge of adventure to the normally straightforward observation of nuclear spin precession. We gained our first taste of that adventure in the pre-Antarctic training.

Training involves a one week course at Balmoral Military Camp, Lake Tekapo. We attended this course in August 1994 where we were to gain experience with riding in Iroquois helicopters, firefighting, radio communications, first aid, crevasse extraction methods, use of polar tents and cookers, use of Antarctic clothing, survival techniques and ice and snow skills.

The course culminated in a day and night building snow shelters and sleeping out in the mountains above Lake Tekapo. After the initial training come the medical checks. The New Zealand Antarctic Programme requires an embarrassingly thorough medical examination, along with a complete range of blood tests and dental certification. We were due to fly to Antarctica in October and for several months prior to this the rush was on to get the equipment ready.

The equipment, in excess of 200 kg, was finally freighted down to the NZAP headquarters in Christchurch the Wednesday before Labour Weekend, 1994. On the following Monday we travelled to Christchurch to be issued with our specialised clothing and dog tags, and boarded the US Air Force C-141 to McMurdo sound. Our first three days were spent at Scott Base, where we had to undergo further Antarctic field training before being transported, via Hagglands tracked vehicle, to our field camp 20 km away near Cape Evans. In October all of McMurdo Sound is frozen far to the north and we travelled the entire journey on a two metre crust above hundreds of metres of ocean. Our gear was placed in a ski trailer and humped its way across the frozen sea. Near Inaccessible Island we met the remaining four members of our party who had been making their sea ice measurements for the past fortnight. As with all personnel in Antarctica, we were known by a code number, in our case, K131.

After a warm welcome from our companions, we headed off again in the Hagglands to take advantage of a unique opportunity to visit the historic Huts close by at Cape Evans and at Cape Royds, some 10 km further to the North. Evans was the base of Scott’s illated 1910-1912 Terra Nova expedition while Royds was Shackleton’s base from 1908 to 1909. These huts, which are under the care of the New Zealand

Free Induction decays from a samples of water at around 10 C. The top signal (a) was obtained at Massey University while the lower signal (b) was obtained at the field camp in Antarctica and indicates the much lower noise level in McMurdo sound.
Field Measurements

Assembly of the gear took one day. Another day was needed to sort out initial teething problems caused by low temperature effects on electronic connections. Our probehead was placed in a snow cave while the electronics were placed in a nearby polar tent. This snow cave was dug out of a pile of snow which a D5 bulldozer from Scott Base had cleared from the surface of the sea ice so as to enable Tim's team to carry out the ice cutting. This cave was especially useful since it provided shelter and temperature stability for a crucial part of the instrument as well as a degree of screening from any audio-frequency noise caused by the diesel generator set, some 50m away with the rest of the K131 campsite. The photograph in figure 4 shows the arrangement of the campsite and the apparatus as well as the polar tents used for our measurements and our sleeping shelter.

To our surprise and pleasure we found that the signal-to-noise ratio in our apparatus was at least an order of magnitude better than at Massey University, as shown in the comparative Free Induction Decay in figure 3b. This was a result of the very low level of audiofrequency interference at our field camp site. We quickly discovered that the signal-averaging worked extremely well and that it was possible to detect the very weak signals available from the small brine water component in the ice core samples. Because of time limitations this season we decided to focus on making good quality measurements of brine water signal amplitude and spin-spin relaxation times, rather than attempting to carry out diffusion measurements. We had, after all, to leave some reason to travel south again!

The process of core removal is shown in figure 5. Core samples were extracted at 200 mm intervals from the surface to the sea at a depth of 1.9m, using a special auger provided by our IRL colleagues. Each sample was weighed and its temperature measured both before and after the NMR experiment. Electrical conductivity measurements were also made on these samples by Pat Langhorne in order to gain an estimation of salinity. The results we obtained are shown in figure 6, which give normalised conductivity, temperature, liquid water fraction, as determined by NMR and NMR relaxation times, as a function of depth. The salinity measurements, when taken together with the temperature data, can be used to estimate the brine water fraction based on the known phase behaviour for sea water. It is clear that strong correlations exist between the NMR data and the conductivity/temperature profiles. However, we did experience some change in temperature of the core samples (up to 5°C) during NMR data acquisition so caution is needed in interpretation.

Field camp, the return home and preparation for next season

In the Antarctic science is carried out in an extraordinary atmosphere. Just to put down the soldering iron or the computer keypad for a moment and glance outside the tent is, in itself a humbling
experience. Across McMurdo Sound is the Royal Society Range through which the Ferrar and Blue glaciers carry their vast streams of ice down from the Polar plateau. South, the horizon is dominated by Mount Discovery. Up the coast north of Cape Evans is the Barne Glacier. Immediately to the East was Mount Erebus, rising 13500 feet straight from the sea.

We ignored the clock, working according to our own routine, sometimes rising at midnight and having our evening meal at 1 am, and climbing up Inaccessible Island for after-dinner exercise at 3 am. The penguins paid us regular visits and we, in turn, took excursions to the tide cracks out in the sound to visit the Weddell seals basking by their access holes. When a blizzard came we tucked ourselves up inside the polar tent and slept as long as we could. The severity of the wind and the difficult conditions of camp life during that blizzard provided a remarkable experience for we novice Antarctic scientists. The struggle to fetch fresh snow for melting in the cooker, the agonising decision as to whether it was worth that trip outside to the toilet and the hours of good fellowship during the height of the gale are memories we shall not quickly lose.

After two days delay because of bad weather, the tractor train from Scott Base finally arrived to take us back. The journey took five hours under total whiteout conditions, with only the regular red flags on the route enabling us to find our way safely. On the last evening, after a sleep of deep exhaustion, we were able to climb Observation Hill for the last time, with that glimpse south towards the midnight sun which Scott’s companions had made so often in early 1912 as they waited for the southern party to return. The next day, after a visit to the 1902 Discovery Hut at Arrival Bay, and an all-American meal at the McMurdo Station mess, we were on our way once again to the ice runway, to our C-141 journey back to Christchurch. Two weeks in Antarctica had left their mark.

So it is clear that we must return south. In preparation we must improve our temperature control and thoroughly test the diffusion attachment. In the spring of 1995, when we go back with Tim Haskell and the K131 gang, we will have our new team member, Joe Seymour, a chemical engineering graduate from the University of California, Davis. Joe, who specialised in NMR imaging for his doctorate, has been awarded an NSF postdoctoral fellowship to enable him to join our project. He is coming, not for the science alone, but because he shares with us a fascination for the Antarctic environment. In that place, science is not only pre-eminently important, it is an extraordinary adventure.

Acknowledgments

We are especially grateful to the New Zealand Foundation for Research, Science and Technology for funding support.

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At the University of Sydney, a number of physicists have come together to form a group whose aim is to carry out research into tertiary physics education. This move has prompted the question to be reconsidered: what should be the influence of educational research on teaching in a university physics department?

Experience suggests that the kind of research done in Education faculties is not much heeded by physics lecturers, even those with genuine concern to improve the standard of teaching and learning of their students. Yet there are many insights to be gained from the results of mainstream educational research which could improve university physics teaching. This paper argues that an excellent way to achieve this end is to locate centres of research into physics education within physics departments, and for that research to be carried out by physicists.

### Background

In today's university milieu, the job description of academics includes both research and teaching; and while the ideal is that all should be equally interested in both activities, in reality there is a wide spectrum of commitment to either. There are those who prefer to spend all their time in research, in pushing forward the frontiers of knowledge in their subject. By and large our university system is tolerant of such people, drawing comfort from the fact that some of the world's most productive scientists have been indifferent teachers. Examples quoted usually include Kepler and Einstein. On the other hand, there are those who are more interested in teaching, in exploring ways to communicate this knowledge to students. Our university system is less comfortable with such people: there seems to be something of the "those who can, do; those who can't teach" attitude. Yet increasingly many academics believe that the process by which our subject is codified and passed on to the next generation is a worthwhile field of research in its own right. It is the purpose of this paper to make that argument, in the context of physics.

In the department to which the authors belong, a group of individuals have come together to form a research group, with the acronym of SUPER – the Sydney University Physics Education Research group. Its aim is to strengthen work being done in this area by pooling knowledge about research methods used in other educational disciplines. The formation of such a group does not, of itself, confer legitimacy on the enterprise. Two questions should be asked, and answered with as much rigour as possible.

- **Is such an activity useful to university physics teaching?**
- **If so, is it best done within a Physics department, rather than within an Education faculty?**

We will seek to answer these questions here by focusing on the apparent indifference of many tertiary physics teachers to the results of research carried out in Education departments; despite the apparent benefit that physics teaching and learning could gain from this kind of research, and the resolution of the problem by locating such research effort within physics departments.

There seems to be a conflict between Physics education and mainstream Education research. In that many, if not most, academic physicists contend that the kind of educational research carried out in mainstream Education faculties has
little impact on the teaching of physics in ordinary universities. Physicists give several reasons in support of this contention.

Many Education faculties devote most of their attention to the problems of pre-tertiary education, for the obvious reason that that is where most of their students will teach. Unfortunately the perception is that the insights gained by research in this area are of limited tertiary usefulness. Most tertiary teachers believe their relationship between teacher and student is fundamentally different, more like the master-apprentice model.

There have been many innovative teaching methods developed over the past few decades - for example, the Keller plan [1], Computer Aided Learning, Workshop Physics, to name but a few. These have been tried in isolated universities, with varying success. Nevertheless, the majority of Physics departments throughout the world still teach by the lecture/tutorial/laboratory model.

There is mistrust of the methods used in Educational research. In the social sciences, research is done by seeking opinions, analysing questionnaires, interviewing subjects. The outcomes are often context dependent and will vary with the particular group chosen. Such methods are perceived by physicists to be "soft" and their results unrepeatable. This is in opposition to the "hard" sciences in which results and opinions which cannot be validated are, at least in theory, ignored.

This lack of trust can be most clearly seen in practising physics teachers. Many of those who care about their teaching have heard of research results which suggest that, for example, ordinary lecturing is not, in general, a successful technique for helping students to learn physics. Yet they continue to conduct their classes in the traditional manner. When it comes to the crunch, they seem prepared to ignore the research findings, and adhere to the "it worked for me" philosophy.

An important issue is one of ownership. Academics have grown up with the belief that science is that which is done by scientists, and the only way it can be learnt is by modelling oneself on a scientist. Such a model is, by its very nature, highly personal, and most scientists are uncomfortable with the idea of using someone else's materials and approach in their teaching. Many an attempt at teaching reform has foundered on the "not-invented-here" syndrome.

Perhaps the best example occurred during the 1970s when departments all over the world were making televised lectures in the then fashionable belief that that was the way of the future. Remarkably few departments were willing to use programs made at other institutions, and much effort was spent duplicating materials being made elsewhere. The result was that the whole effort was soon deemed too expensive and fell into disuse.

The most important issue, however, seems to be whether the process of tertiary teaching can be divorced from the content. Irrespective of how they think students learn, most tertiary physics instructors believe that anyone who wants to teach the subject effectively at this level must have a deep understanding of the material. An outsider's views about how the subject should be taught may not be useful if they do not understand intimately what has to be learned and why.

There are many obvious examples within physics. As Feynman [3] has pointed out even so basic a concept as energy is full of unresolved difficulties. What then is the answer to the question: how can one best help students learn about energy?

It is hard to see how anyone could give other than very general advice on that question, unless they knew exactly what those difficulties are.

Whether or not these arguments stand up to rigorous analysis is debatable, but that is not the point. They are widely held, and it needs to be appreciated that they stand in the way of improvements in our teaching practices.

In many academic departments, approaches to teaching, particularly at the upper levels, are rarely sophisticated and sensitive to the needs of students. Improvements do not accumulate, and each new lecturer starts afresh. However there is much education research from all over the world, which suggests that this need not be the case. Like other forms of teaching, physics teaching can and should be researched to improve its effectiveness.

Gains from Mainstream Education Research

There are many issues with obvious relevance to physics teaching. In the current mainstream education literature. Some examples are given below.

Learning Theories

A recent shift in theoretical perspective, in the branch of education which deals with the process of learning, seems particularly relevant to physics. Previously, the most widely held models of learning were transmissive: absolute knowledge was seen as being passed from expert to novice. Currently, the social origin of learning is more widely appreciated and recent theories suggest that students’ and indeed all human thinking is construed through previous experiences. The mental models they evolve to explain what they observe are constructed from what they already know, in addition to what they are being taught. This model is known as constructivism.

These ideas have already shown important results in research carried out by many different workers within the mainstream education research community. The general idea investigated is that the point of view of students may differ from that on course designers and this cannot help but influence how they learn. Some phenomenological analysis suggests that many students’ experiences have resulted in learning outcomes quite different from those intended by their teachers.

The relevance to the university scene is obvious. A fundamental assumption that universities make is that the learning experiences provided for their graduates make a difference to their knowledge and capabilities. It is entirely possible that this is not true. We really need to understand the relationship between the way education is experienced by university students and the outcomes of their learning.

Teaching Strategies

One of the key thrusts of research and development in mainstream Education faculties is in the area of teaching (and assessment) strategies. The recent literature, for example, discusses research into the value of discussion in small tutorial groups, the effectiveness of formal and interactive lecture delivery, the feasibility of guided and open forms of enquiry and questioning strategies as a progressive evaluation tool.
At the university level, much of the teaching community seems unaware of these discussions. Farr and Brown [6] capture the essence of the problem: "Most intuitional decisions are made by forfeit; that is, by not recognising that a decision can be made or by not being aware of possible alternatives. The usual forfeit 'decision' involves continuation of a practice whether or not it is the most appropriate procedure for the situation."

While it is true that there always have been, and still are, good university teachers who do not seem to need to change the way they teach, surely it is without question that, in general, university physics teachers should be willing to try the results of this kind of research. At the very least, there should be systematic investigation of how effective such teaching strategies are in a physics context.

Research Methodologies

The widespread mistrust of the education methodologies mentioned above cannot really be justified and must surely be mere discipline chauvinism. Mainstream education workers have developed and categorized a wide range of proven research methods: descriptive methods such as surveys, interviews, observational studies and analysis of examination results; development methods investigating patterns of change as a function of time; case and field studies, to name but a few. This is not to imply that all these constitute a monolithic whole. As in all disciplines, a climate of change spawns different schools of thought. Recently, for example, there has been an increasing acceptance of a qualitative as well as the more usual quantitative approach. The researcher interested in using these methods must understand what compromises exist in their internal consistency and external transferability.

Each qualitative approach has its own standards and evaluation criteria, and the unwary researcher who chooses to mix elements from different approaches in a single study may not realize this difficulty. Those wishing to undertake research in physics education therefore have the double responsibility of learning what mainstream research methodologies are available, and applying them in such a way as to ensure external and internal credibility and validity for their research findings.

New Technologies

New technologies are having a large impact on learning everywhere. Most of this research has been at school level, for the simple reason that there are more students available as subjects. Preliminary results show that there are real differences between the representation and use of knowledge learned through traditional teaching methods, and that gained in, for example, computer based environments. Information technology presents a fundamental challenge to the older notion of human knowledge as memorized information and as the capacity to carry out routine procedures.

Here too, those investigations could and should be extended more widely into the tertiary domain. Already many physics departments the world over are changing their teaching practices to take advantage of the many benefits they see from computers, as is evidenced by conferences papers. This is often done without apparently recognising that these new approaches may involve radical changes in old conceptions for both staff and students. If the new technologies are to be used effectively, there is a need for research on the impact of these new experiences on students' learning within the actual disciplines.

There seems no doubt that such issues are relevant to physics teaching and there are many in our physics teaching community who believe that, in answer to the first question posed at the beginning of this paper, this kind of research is useful, and that the methods used in the social sciences are valid. For them the real question is: where and how should such research be done? The worry about divorcing learning from its context still remains, and it is worth noting that this worry is shared by educational researchers themselves.

The founder of phenomenography, ference Marton [11], puts it like this:

"All that is psychological includes consciousness but refers to something beyond consciousness itself. For example, we do not merely love, we love someone; we do not merely learn, we learn something; we do not merely think, we think about something. By changing that which has to be learned or understood, we change the relationship between the object of learning and the individual."

Many groups throughout the world have adopted the philosophy that this kind of educational research should be placed within Physics departments and conducted by experienced physicists - examples are those groups led by McDermott, Goldberg, Niederer, Redish, among many others. Whether this philosophy is appropriate is argued on several grounds. Basically they come down to the contention that university education in general, and university physics education in particular, must be considered to have their own unique needs and difficulties. Examples of these may be observed in the four areas of research already mentioned.

Learning Theories

When theories of learning are applied to the practical business of teaching, they need to be interpreted in the light of the context, particularly of the purposes for which the material is being taught. Epistemological issues are of fundamental importance in physics, perhaps more than any other branch of science. Physics claims to discover not only things about the 'objective' world, but also subjective aspects of how these things are understood. Ideas of modelling, interpretation, and the use of language are of key interest to the physicist. How students learn these ideas are therefore of crucial importance.

Physics has always prided itself on being the cutting edge of science, of developing genuinely new concepts and ways of looking at the world. The remark attributed to Lord Rutherford that "only physics is science, all else is stamp collecting", while perhaps facetiously meant, represents a genuine feeling on the part of many physicists. Yet such concerns are rarely explicitly thought about in teaching. Physics education research is one way of grappling with those kind of underpinning issues which are normally taken for granted by practising physicists.

It is also true that the mission of physics teaching in the eyes of its clients seems to be changing. There is continuing pressure from Engineering faculties, for example, to drop physics and to give their students more professionally oriented
courses. Then again, falling enrolments in mainstream physics classes suggests that the younger generation no longer see physics as the grand adventure of the human spirit. It is as though they no longer feel the need to understand our subject in the same way we do - particularly with its traditional heavy emphasis on mathematics. Again physics education researchers are in an ideal position to re-evaluate the link between what we teach and how we teach it.

Teaching Strategies

Teaching strategies developed for other contexts, for example for secondary schools, may be tried in the tertiary sphere, but they need to adapt to the different nature of university education. Those who teach in a university have a responsibility to their subject as well as to their students. Despite constraints, financial or otherwise, imposed on universities from outside, most academics would feel obligated to teach their subject even if very few students were interested in learning it. Scholars want their discipline to survive.

The university tradition is that the subject is taught by practitioners in the field. Those practitioners are responsible for choosing up-to-date curriculums, and choosing educational methods which will promote learning by students. It follows that teachers of physics have a professional responsibility not only to present the subject matter of physics to ensure a new generation of practitioners, but to do so in the most effective way. This also implies that there should be a clear idea of what students ought to learn and understand as a result of teaching, and of ascertaining whether the knowledge and understanding have been gained. Determining the relationships between teaching goals, teaching methods and learning outcomes is the role of educational research, to which the physics community itself can and should make a significant contribution.

Research Methodologies

It has already been pointed out that education research has its own ways of doing things. When these are transferred to a different context, they need to take account of the level of sophistication of the material being taught in the university context. Physicists have always objected to physics being taught by non-experts, because they believe that the depth of the subject will be missed by others. The only people qualified to analyse and specify the appropriate knowledge, skills and attitudes are most likely to be working within physics. Whether or not students are learning to build appropriate mental models of physics can really only be judged by those who understand, as professionals, what those mental models are.

New Technologies

Computers are used in physics teaching in a way which seems completely different from most other disciplines. While there are some physics departments around the world which use Computer Based Learning, where the computer simply presents the material, the relative number is not large.

On the other hand, computers have, in the last generation, changed how physics is done professionally, and this change is entering its teaching. One example is that computer simulations play an increasingly central role. Note that the word "simulation" is used here to describe a computational modelling, rather than a simulacrum of what might be observed in a laboratory. For physics, computation is part of the subject itself. There is an urgent need for work to be done on the effectiveness of this use of computers in physics teaching, and it can best be done in a physics department.

Conclusions

To summarize, we have argued that there are unsolved problems, which need elucidation, involved in teaching physics to the next generation. We have also argued that these are part of the proper concern, and indeed the responsibility, of practising physicists. We believe the answers to the questions posed at the head of this paper to be unambiguously "yes", i.e.

- Physics education research can be very useful to our teaching.
- There are cogent reasons why it should be done within a Physics department, rather than within an Education faculty.

Not the least of these is the time-honoured one of intellectual curiosity. We practising physicists have spent a long time learning our subject. We may or may not have found it difficult, we all found it rewarding. Why then do so many of our students find it hard and dull? We can only answer this by thinking deeply about physics and pedagogy at the same time. And, as the work of Aarons has shown, the pay off is that we can deepen our own understanding of our subject and possibly come up with new methods of passing it on to those who follow us.

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DIRAC PLAQUE IN WESTMINSTER ABBEY

HEINRICH HORA

Paul Adrien Maurice Dirac, who died 11 years ago, was described as "probably the country's greatest theoretical physicist since Newton" in remarks made by Stephen Hawking [1] at A Royal Society Dirac Commemoration Colloquium on 13 November 1995 on the occasion of the dedication of a plaque in honour of Dirac in Westminster Abbey.

Australia was represented by Emeritus Professor Heinrich Hora (UNSW), who in 1975 co-organised a three-week visit of Dirac to Australia [2].

The first talk at the Royal Society Colloquium was by the President, Professor Sir Michael Atiyah, master of Trinity College Cambridge, who spoke on "The Dirac Equation and Geometry." Professor David Olive of the University of Wales next discussed the hunt for "Monopoles", a Dirac prediction that has not yet been experimentally confirmed.

After lunch Professor Maurice Jacob [CERN], in his talk on "Antimatter", presented Dirac's notes, handwritten in English, for the lecture which he delivered in perfect French at the 1932 Solvay Conference. The notes showed his clear recognition of anti-particles, a concept that was strenuously opposed at the time. Jacob went on to review the work at CERN leading up to the successes of the Low Energy Antiproton Ring (LEAR), which is at present under threat of being lost to antiparticle physics. It is proposed to make LEAR part of a storage ring to increase the number of ions per pulse for the Large Hadron Collider (LHC) [3].

Professor Abraham Pais, of Rochester University, gave the last talk which included many fascinating reminiscences on the life and times of Dirac and the discoveries in physics during this epoch-making period. The Archbishop of Canterbury apparently did not agree easily to having Dirac’s plaque placed in the Abbey on the grounds that he was not baptised when he was born in Bristol in 1902. Dirac’s father came from a Catholic region of Switzerland and Paul Dirac was a Fellow of the Vatican Academy. A monument in St Maurice in Wallis, where his father came from, has a quote from Dirac: "God has utilised marvellous mathematics, but he did not make it simple."

Stephen Hawking currently holds the Lucasian Chair of Physics at Cambridge. Previous holders of this chair include Newton and Dirac, who occupied the chair from 1932 to 1968. A transcript of Hawking’s remarks on Dirac is published in Physics World 9 (Jan 1996) 49.

2 The lectures he delivered at various universities during his visit were published in 1978 under the title Directions in Physics by John Wiley, New York. A lasting memorial of the visit was the establishment, with Dirac’s support and that of AIP, of the Dirac Lectures and the Dirac Silver Medal, which is awarded to the Dirac lecturers.

3 In the opinion of the present writer, LEAR could be saved for antiparticle physics if the LHC ion source, an

Professor Heinrich Hora is in Physics, at UNSW.

From the left: Professor Abraham Pais (Rockefeller University, New York), Professor Heinrich Hora (University of New South Wales, Sydney) talking to Dr Monica Dirac (daughter of Paul and Margit Dirac) and Professor Maurice Jacob (CERN, Geneva), past president of the European Physical Society. In the background centre Professor RH Dalitz (Oxford University) talks to Dirac’s grandson and grand-daughter.
The Dirac Plaque at Westminster Abbey unveiled on 13 November 1995 by Dirac's daughter Dr Monica Dirac and her son Paul and daughter Victoria.

Electron Cyclotron Resonance type, were replaced by a laser-driven ion source of the type patented by Pease and Peacock and discussed by Helmut Hasch as in 'Advances in Accelerator Physics and Technology' (1993) Ed. Herwig Schopper, World Scientific, Singapore. Such a source should sufficiently increase the beam current without the need to use LEAR.

Editors note: Dirac is buried in Tallahassee, where he died in 1984. It could well have been otherwise. He was keen to go swimming in the sea during a picnic we arranged for him on Shark Island in Sydney Harbour in 1975. I explained to him why the island was so named and persuaded him to stay out of the water.

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**Australian Journal of Physics**

**Contents**

**Volume 48**

**Number 6**

1995

Atomic and Molecular Physics

Positronium-proton scattering at low energies. Jim Mittle 893

Study of squeezing properties in a two-level system. Rui-hua Xie, Geng-yu Xu and Dan-bao Lin 917

Fluids, Plasmas and Electric Discharges

Anomalous anisotropic diffusion of electron swarms in a.c. electric fields. R. D. White, R. E. Robson and K. F. Ness 925

Cross-Disciplinary Physics

Reactive plasma species in the modification of wool fibre. X. J. Dai, S. M. Hamberger and R. A. Bean 939

General Physics

Refereed papers presented at the inaugural Australian General Relativity Workshop held at the Australian National University, Canberra, in September 1994

Guest Editors: David E. McCord and Susan M. Scott

An overview of recycling in laser interferometric gravitational wave detectors. David E. McCord 953

Interferometers with internal and external phase modulation: Experimental and analytical comparison. Andrew J. Stevenson, Malcolm R. Gray, Charles C. Holm, David E. McCord and Hans-A. Bohr 971


The University of Western Australia's resonant-bar gravitational wave experiment. M. R. Tober, D. R. Blair, E. V. Ferrer, P. van Kamps, N. P. Loshorne, P. A. Toner and L. S. Hong 1007

Oscillating apparent horizons in numerically generated spacetimes. Peter A. Consolati, David Bernstein, Steve Brodt, David Hilditch, Ed Seidel and Larry Smarr 1027

Geometrical models of elementary particles. P. K. Smir 1045

Newtonian quantum gravity. K. R. W. Jones 1055

Modelling the large scale structure of the Universe after COBE. P. J. Quinn 1083

Progress in measuring the Hubble constant. Jeremy Mould 1093

Author Index to Volume 48 1101

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QUARKS AND DEEP-INELASTIC SCATTERING

WALLY MELNITCHOUK

Structure of Hadrons in Deep-Inelastic Scattering

The main unresolved problem of the Standard Model of particle and nuclear physics is the description from first principles of the strong nuclear interactions. Traditional low energy nuclear physics, where the strong nuclear force acts at relatively large distances, is for the most part successfully described in terms of hadronic variables: mesons (pions, kaons, etc.) and baryons (nucleons, isobars, hyperons, etc.). However, for a complete understanding of the strong interactions, nuclear phenomena must be reconciled with the more fundamental theory of quarks and gluons – Quantum Chromodynamics (QCD).

An Historical Perspective

Historically, the basic strong interaction which we have sought to explain has been that between protons and neutrons in the atomic nucleus. The original idea of massive particle exchange of Yukawa has been a guiding principle according to which later theories have been formulated. It was pointed out by Wick that this idea fitted in nicely with the Heisenberg Uncertainty principle, whereby the interaction range of the nuclear force is inversely proportional to the mass of the exchanged meson (pion). Over the years a quantitative description of the forces acting between nucleons has been developed within a meson-exchange picture.

Following the experimental confirmation of the pion in 1947, the 1950s and 1960s saw an explosion of newly discovered mesons and baryons, as particle accelerators were able to achieve ever higher energies. To bring some sense of order to the profusion of new particles Gell-Mann and Zweig introduced the idea of quarks, initially seen merely as useful bookkeeping devices. Soon after it was realised that a serious problem existed with the simple quark classifications, namely the $\Delta^{++}$ isobar. The quark model wave function for the $\Delta^{++}$ was predicted to be totally symmetric, however it was known that this particle obeyed Fermi-Dirac statistics. A solution to this problem was found by assigning extra colour quantum numbers to the quarks, in which baryons would have in addition an antisymmetric colour wave function. By imposing local gauge invariance on the colour fields, and including spin-1 gluon exchange as a means by which quarks interact, one obtains the essential elements of QCD.

Because QCD is an asymptotically free theory – the effective strong coupling constant decreases at short distances – processes involving large momentum transfers can be calculated using the tools of perturbation theory. Perturbative QCD works remarkably well in its region of applicability. Yet despite its successes, we are still unable to extract from QCD sufficient details regarding its long-distance properties. This is because in the infrared region the strong coupling constant grows, perturbation theory breaks down, and its predictive power becomes rather limited. In a sense it is ironic that the theory which arose out of the desire to understand nuclear forces is able to explain backgrounds in hadronic jets produced in high energy collisions, yet is unable to answer the fundamental questions of nuclear physics. Arguing that QCD can in principle explain all hadronic and nuclear phenomena is akin to being satisfied that Quantum Electrodynamics can in principle explain all of the physics of atoms, molecules and condensed matter. It is therefore perhaps the holy grail of the Standard Model to make the leap from QCD to traditional nuclear physics.

One way to overcome the difficulties of describing the strong interactions nonperturbatively is to solve the QCD equations of motion numerically by brute-force, discretising the space-time continuum on a grid, a method known as Lattice QCD. While progress with this approach can be expected as the power of modern supercomputers increases, sufficiently quantitative results for many observables are still some time away. The alternative approach to non-perturbative QCD involves constructing “QCD-inspired” models, which are consistent with the known properties of QCD, but which can be extrapolated into the low energy domain. The strategy then is to use experimental input to shed some light on the merits of the various models. To study the frontier between quark and hadron physics the most useful experiments to consider are naturally those in which both degrees of freedom may be relevant.

Looking for the Evidence – Deep-Inelastic Scattering

It has been said that “looking for quarks in the proton is like looking for the mafia in Sicily – everyone knows they’re there.”

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Quarks & Deep-Inelastic Scattering is a talk that was presented to the Australian Institute of Physics in May 1995.
but it's hard to find the evidence!" The process which has produced a lot of the evidence is inclusive deep-inelastic scattering (DIS) of leptons (electrons, muons, neutrinos) from hadrons. Because the Standard Model gives such a good account of electroweak interactions, the scattering of leptons from hadronic targets is a far more elegant method of probing the quark substructure of hadrons than purely hadronic collisions. Indeed, the first experimental evidence for the existence of point-like constituents of the nucleon was obtained through DIS measurements at the Stanford Linear Accelerator Center (SLAC) in the late 1960s. In recognition of their effort, Friedman, Kendall and Taylor were awarded the 1990 physics Nobel prize for using this method to deepen our understanding of the quark structure of matter.

The inclusive cross section, as a function of the scattering angle \( \theta \) of the recoiling lepton, and its energy \( E \), is proportional to the structure functions of the hadron, usually denoted by \( F_2 \):

\[
\frac{d^2 \sigma}{dE d\theta} \sim \frac{\alpha_{\text{em}}}{Q^4} F_2
\]

where \( \alpha_{\text{em}} \) is the electromagnetic fine structure constant, and \( Q^2 \) is the four-momentum transfer squared to the hadron. The connection of the hadronic structure function to the underlying quark dynamics was provided by Feynman's Quark Parton Model (QPM). Here the inelastic scattering from a hadron is described by the incoherent elastic scattering from point-like constituents of the hadron, or partons. Generally, in practice, the structure function \( F_2 \) is usually expressed as a function of \( Q^2 \) and the momentum fraction, \( x \), of the hadron that the parton is carrying when it is struck. Then in the QPM the \( F_2 \) structure function, say for a proton, is a linear combination of quark and antiquark momentum distribution functions (weighted by the squares of their charges): \( F_2^p = A \{ (2/3)u + (-2/3)d + (1/3)s \} + A \{ (2/3)\bar{u} + (-2/3)\bar{d} + (1/3)\bar{s} \} \). This expresses the probabilities to find up, down, and strange quarks, respectively, in the proton momentum fraction \( x \).

For a neutron target the structure function \( F_2^n \) would be related to \( F_2^p \) by interchanging \( u \leftrightarrow d \).

The experimental consequence of point-like partons is the non-vanishing of the inelastic structure functions at very large momentum transfers, a phenomenon known as Bjorken scaling. Actually, this is only the naive expectation - refinement of this model in the guise of QCD radiative corrections leads to small deviations from exact scaling. The mechanism here, described mathematically by the so-called \( Q^2 \)-evolution equations, is that a quark radiates off a gluon, which subsequently splits into a quark and antiquark pair, either of which can then radiate more gluons, etc. This process modifies the population density of quarks as a function of \( x \), so that the momentum carried by quarks is no longer a static property of the hadron, but now depends on the resolving power of the probe, \( Q^2 \). In general, the larger the \( Q^2 \), the better the resolution of the probe, the more substructure seen in the hadron. It is yet another triumph of QCD that it is able to give a quantitative description of the scaling violations, or in other words the \( Q^2 \) dependence of \( F_2(x, Q^2) \).

Recent Surprises

The QPM has been a remarkably useful framework which has allowed us to extract a number of important facts from DIS about the quark structure of hadrons. Apart from establishing that hadrons are made up of point-like, spin-1/2 constituents, we have also learned that for \( x \gtrsim 1/3 \) hadrons are composed mainly of "valence" quarks, while the smaller \( x \) region (\( x \lesssim 0.2 \)) is dominated by a "sea" of quark-antiquark pairs and gluons, carrying a significant amount of the proton's momentum.

Recently, however, a number of experiments have produced results that at first sight appeared inexplicable within the QPM. Chronologically, these have been:

- In 1983, the nuclear EMC effect, which showed that the nuclear structure function (per nucleon) was not equal to the sum of the nucleon structure functions: \( F_2^N = F_2^D + F_2^N \) [1], where \( F_2^N = (F_2^u + F_2^d) / 2 \).
- In 1988, the so-called proton spin crisis, which appeared to indicate that an anomalously small fraction of the proton's spin was carried by its constituent quarks [2].
- In 1991, the first conclusive evidence was produced that the sea of the proton was not flavour symmetric, but that one has a significant excess of \( d \) antiquarks over \( \bar{u} \) antiquarks [3].

The second surprise was covered in a previous ANZJP article [4]. In the next Section, the first and third phenomena will be discussed, starting with the latter.
Quarks and Nucleons – Symmetry Breaking in the Proton Sea

Because the gluons of QCD are flavour-blind, the perturbative process $g^2 \rightarrow q\bar{q}$ should produce a sea component of the nucleon that is symmetric in the quark flavours. Differences can arise, however, from different quark masses – the fact that the strange quark mass ($m_s \approx 200$ MeV/$c^2$) is somewhat larger than the up or down quark mass ($m_u, d \approx 5$–$10$ MeV/$c^2$) means that the strange sea is more difficult to produce: $\bar{x} \tilde{u}(x) \approx \bar{d}(x)$ or $d(x)$. In fact, experimentally the strange to non-strange antiquark ratio is found to be about 1:4 at a scale $Q^2 \approx 4$ (GeV/$c^2$)$^2$. On the other hand, because isospin symmetry is such a good symmetry in nature, one would expect that the sea of light quarks would be almost identical, $\bar{u}(x) \approx \bar{d}(x)$. It was therefore a surprise to many when measurements by the New Muon Collaboration (NMC) at CERN [3] of the proton and deuteron structure functions suggested a significant deviation from this simple QPM expectation. Indeed, it heralded a renewed interest in the application of ideas from non-perturbative QCD to deep-inelastic scattering analyses.

Gottfried Sum Rule

Specifically, the NMC experiment measured the integrated proton-neutron structure function difference:

$$S_G = \int dx F_2^p - F_2^n$$

Assuming that the $u$ quark distribution in the proton is the same as the $d$ quark distribution in the neutron (and vice versa), this can be rewritten as:

$$S_G = \frac{1}{3} - \frac{2}{3} \int dx (\bar{d} - \bar{u})$$

The expectation is therefore that $S_G = 1/3$ if $\bar{u} = \bar{d}$ which is known as the Gottfried sum rule. The experimental value, however, was somewhat lower: $S_G^{exp} = 0.235 \pm 0.026$, meaning that the $\bar{d} > \bar{u}$ in the proton.

A more recent experiment by the NA51 Collaboration at CERN, in which protons were scattered from protons and neutrons, producing pairs of muons, also found (at $x = 0.18$) $\bar{u}/\bar{d} = 0.51 \pm 0.06$ [5], confirming the NMC observation that the light sea in the proton is asymmetric.

Pions in the Nucleon

A simple and natural explanation of a $\bar{u} - \bar{d}$ asymmetry is readily obtained by considering the long range (i.e. non-perturbative) structure of the nucleon. Simply on the basis of the Heisenberg uncertainty principle we know that at large distances the nucleon must involve a pion cloud. For example, the non-zero value for the neutron charge radius can be easily understood in terms of the emission from a neutron of a light, negatively charged virtual pion, $n \rightarrow p + \pi^-$. Similarly in DIS from a proton, some of the time one sees the proton in a virtual $n + \pi^+$ configuration, figure 1. Because the $\pi^+$ is mainly composed of a $u$ quark and $\bar{d}$ antiquark, one automatically obtains an excess of $\bar{d}$ over $\bar{u}$. Of course there exists a probability for protons to dissociate into other virtual meson-baryon states, most notably $\pi$ and Delta $(\Delta)$ isobar configurations. The latter in fact cancels some of the $d$ excess, since the dominant transition there is $p \rightarrow \Delta^+ + \pi^-$, with the quark content of a $\pi^+$ being $d + \bar{u}$. Nevertheless, because the $\Delta$ is some $300$ MeV/$c^2$ heavier than the nucleon, the net asymmetry is still in favour of $d$, and is indeed further enhanced by considering other mesons such as the $\rho$ meson. In total, the meson structure of the nucleon is found to produce about half of the observed $\bar{d} - \bar{u}$ asymmetry [6].

A mechanism which could be considered a candidate for producing the remaining part of the asymmetry is one based on the Pauli exclusion principle. Because the proton has unequal numbers of valence $u$ and $d$ quarks, through Pauli blocking one expects creation of additional $gg$ pairs inside the proton to be sensitive to the number of quarks of each flavour already present. Since the proton contains 2 valence $u$ quarks compared with only 1 valence $d$ quark, $u\bar{u}$ pair creation will be suppressed relative to $d\bar{d}$ creation. Phenomenological fits to the data [7], in particular the $x$-dependence of $F_2^p - F_2^n$, as well as the individual antiquark distributions, and their integrated values, do indeed suggest the need for both mechanisms.

Free vs Bound Neutrons

An important consideration in interpreting the NMC and NAS1 data is the fact that the neutron structure function involved in both measurements is extracted from DIS on deuterium targets. Before drawing definitive conclusions about the flavour content of the proton, one must subtract any nuclear effects present in deuterium in extracting the free neutron structure function. Because the proton and neutron are very weakly bound inside the deuteron (the binding energy is only $0.1\%$ of its mass), it is tempting to conclude that nuclear effects in deuteron structure functions are negligible. As we shall see, however, even apparently insignificant corrections can become important in specific regions of kinematics.

Of particular importance is the region of small $x$, where the deuteron structure function may be “shadowed” in comparison with the free nucleon structure function. In the Gottfried sum this effect would be greatly enhanced by the factor $1/x$ in

![Proton as a neutron + configuration, leading to an excess of $\bar{d}$ quarks over $\bar{u}$.](image-url)
a momentum distribution, \( f_{NM}(y) \), of nucleons in the nucleus:

\[
F_2^N(x) = \int dy \ f_{NM}(y) \ F_2^N \left( \frac{y}{x} \right),
\]

where \( y \) is the fraction of the nucleon momentum carried by the struck nucleon. Implicit in equation (4) is the assumption that the structure function of a bound nucleon is not affected when the nucleon is bound, or in other words, when it no longer satisfies the usual on-mass-shell energy-momentum relation, \( p^2 = E^2 - p^2 = M^2 \).

Since nuclei are largely non-relativistic objects (ie binding is weak), the “smearing” function \( f_{NM}(y) \) peaks rather strongly about the central value \( y = 1 \), meaning that all nucleons share the momentum equally. Therefore the shape of the resulting nuclear structure function depends essentially on the shape and slope of \( F_2^N \). This becomes clear if one expands \( F_2^N(x/y) \) about the peak value, and writes \( F_2^N \) as a sum of derivatives of \( F_2^N \) [8]:

\[
F_2^A(x) = F_2^N(x) + c_1 \frac{\partial F_2^N(x)}{\partial x} + c_2 \frac{\partial^2 F_2^N(x)}{\partial x^2}.
\]

Because valence quarks are most likely to carry \(-1/3\) of the nucleon’s momentum, \( F_2^N \) will decrease with \( x \) for \( x \geq 1/3 \). In

\[\text{equation (2). Other nuclear effects, such as those due to nuclear binding, are known to be of importance at large } x \text{ as well. A careful examination of shadowing and other nuclear corrections to the neutron structure function is therefore of considerable importance.}\]

\[\text{Quarks and Nuclei} \]

\[\text{The Nuclear EMC Effect}\]

From DIS experiments on a variety of nuclei we know that ratios of nuclear to nucleon structure functions deviate significantly from unity: for a mass number \( A \) nucleus, \( F_2^A \neq F_2^N \) — known as the nuclear EMC effect. As can be seen in figure 2, at small \( x \) the \( F_2^A/F_2^N \) ratio falls somewhat below unity, while at large \( x \) it rises, and in fact diverges as \( x \to 1 \). Between the large and small \( x \) extremes, the most obvious effect is the “trough” centred around \( x = 0.6 \) - \( 0.7 \). A number of interesting phenomena have been invoked to explain these effects, some of which we now examine in more detail.

**Nuclear Smearing - Convolution Model**

At medium and large values of \( x \) (\( x \geq 0.3 \)), one can understand the shape of the structure function ratio from the so-called nuclear “impulse approximation” (IA). Here DIS from a nucleus is modeled in terms of incoherent scattering from individual nucleons bound inside the nucleus, figure 3. Non-relativistically (to order \( p^2/M^2 \), where \( p \) is the nucleon momentum and \( M \) its mass), the nuclear structure function can be represented as a convolution of the nucleon structure function and
QUARKS AND DEEP-INELASTIC SCATTERING

this region its slope, and therefore the A/N ratio, will be negative. The coefficient \( c_1 \), which is proportional to the nuclear binding energy, then determines the depth of the trough at \( x \sim 0.6 \). At larger \( x \) there is a delicate interplay between this binding term, and the second derivative term, which is positive. As \( x \to 1 \) the latter in fact becomes dominant, with the "Fermi motion" coefficient \( c_2 \), which depends on the nucleon kinetic energy, determining how quickly the A/N ratio rises.

In the very large \( x \) region \((x \gtrsim 0.8)\) one is more sensitive to the large-\( y \) components of \( f_{\text{local}}(y) \), which correspond to nucleons moving with relatively large velocities. Here one can expect relativistic effects to play a more important role. Indeed, relativistically one finds that the simple convolution picture itself breaks down - as well as \( p_2 \)-dependence of the \( F_2^N \) structure function, one has explicit corrections to the r.h.s. of equation (4): \( F_2^A \to F_2^A + \delta^{(A)} F_2^A [9] \). The relativistic corrections are in practice related to the degree to which the bound nucleons are off-mass-shell (\( p^2 \neq M^2 \)). Even for the deuteron they can be of the order 1-2%. In the next section we illustrate how neglecting the deuteron binding and off-shell effects can have rather important consequences for the neutron structure function.

The Deuteron: Large-x Neutron/Proton Ratio

In the symmetric quark model, the \( u \) and \( d \) quark distributions are connected by the simple relation: \( u + d = 2d \) which implies that \( F_2^{\text{nucleon}} = 2F_2^d \). In nature it is known, however, that this symmetry is broken, especially at large \( x \). Although the exact mechanism responsible for this breaking is not clear, two models have been proposed, based on rather different physical assumptions. Without going into details, their basic difference lies in what one assumes to be the composition of the nucleon in the limit when one of its three valence quarks carries all the momentum (\( x = 1 \)). In the first model, the important configurations are those in which the other two valence quarks that are spectators to the DIS process have total spin zero. In the second model the two-quark state has spin projection (along, say, the \( z \)-direction) zero. Consequently, the models predict rather different limits for \( F_2^{\text{off-shell}} \) as \( x \to 1 \), namely \( 1/4 \) in the first model, \( 3/7 \) in the second [10]. Exactly which value one extracts experimentally turns out to be very sensitive to how one handles the nuclear effects in the deuteron.

A model calculation of the \( F_2^{\text{on-shell}}/F_2^p \) ratio, taking into account nuclear Fermi motion and off-shell (binding and relativistic) effects shows that the ratio falls by up to 4-5% below unity in the "trough" region, \( x \sim 0.6 \), before rising again above \( x \sim 0.7 \) [11]. Previous calculations based on on-shell kinematics, in which off-shell effects were not included, produced much shallower troughs, \(<1\%\), and which rose above unity much faster. The consequences of such different behaviours are clear - since both \( F_2^N \) and \( F_2^p \) are experimental quantities, a smaller \( F_2^{\text{on-shell}}/F_2^p \) (recall that \( F_2^p = (F_2^u + F_2^d)/2 \)) at large \( x \) means a larger extracted \( F_2^N \), as seen in figure 4. In the "on-shell" calculation, the \( F_2^{\text{on-shell}}/F_2^p \) ratio tends towards the lower value of \( 1/4 \). However, including off-shell effects in the deuteron results in a ratio that is consistent with the \( 3/7 \) prediction. Clearly, then, one sees that ignoring seemingly small effects can lead to completely contradictory conclusions about the structure of the nucleon, and the underlying quark dynamics responsible for it.

Nuclear Shadowing

From the extreme large-\( x \) limit, let us now turn to the region of very small \( x \), where the nuclear EMC ratio drops significantly below unity. To understand the physics of the EMC effect here requires going beyond the simple incoherent IA picture. In particular, one must consider coherence effects, such as the rescattering of the projectile from more than one nucleon in the nucleus, which gives rise to a phenomenon known as nuclear "shadowing".

Semi-classically, the nuclear shadowing effect can be associated with configurations in the nucleus in which one nucleon moves behind - in the "shadow" of another, thereby reducing the overall cross section seen by the projectile. Quantum mechanically, this effect arises when the virtual photon emitted from the incident electron or muon splits into a virtual quark-antiquark pair. If the propagation length of the \( q\bar{q} \) pair is larger than the inter-nucleon separation, the pair can interact with, or be absorbed by, different nucleons as it traverses the nucleus, thereby decreasing the overall outgoing flux.

Experimentally, the amount of shadowing in nuclei of mass number \( A \) goes like the nuclear radius, \( A^{1/3} \), up to rather large values of \( A \), beyond which shadowing begins to saturate. For \(^{40}\text{Cu}\), for example, the depletion below \( x \sim 10^{-3} \) is around 15% [12], while for heavy nuclei like \(^{208}\text{Pb}\) it can be as large as 30-40%. Of relevance for the Gottfried sum rule is exactly how significant is the shadowing effect in the deuteron itself.

The Deuteron: Small-x Proton-Neutron Difference

To a good approximation at low \( x \) one can neglect the Fermi motion and off-shell effects associated with nuclear binding. In

An image of a graph is shown with the x-axis labeled with values from 0 to 1, and the y-axis labeled with values from 0 to 0.8. The graph includes two curves: one labeled "on-shell" and the other labeled "off-shell". The curve "on-shell" is solid, while the curve "off-shell" is dashed. The graph is used to illustrate the ratio \( F_2^{\text{on-shell}}/F_2^p \) for various values of \( x \).
this case the deuteron structure function can be written as a sum of free proton and neutron structure functions, plus a correction term due to shadowing: \( F_2^D = F_2^p + F_2^n + \delta_{\text{shadow}} F_2^p \). Numerically, the (negative) shadowing correction is around 1-2% as a fraction of the total \( F_2^p \), depending on the exact behaviour of the deuteron wave function at small inter-nucleon separations [13]. This translates into a 2-3% depletion in the \( \frac{F_2^p}{F_2^n} \) ratio for \( x \lesssim 10^{-2} \), figure 5. The latest data from the NMC and the E665 Collaboration at Fermilab do appear to support a shadowing effect of this magnitude.

If one neglects the shadowing correction, as was commonly done in previous analyses, the resulting \( F_2^p \) will be underestimated. Including this correction means that the true value for the Gottfried sum, which involves the \( p - n \) difference, will then be even smaller:

\[
S_G^{\text{(corrected)}} = S_G + \int dx \delta_{\text{shadow}} F_2^p / x
\]  

(6)

Because of the \( 1/x \) weighting factor in equation (6), the small 1-2% correction to \( F_2^p \) translates into a 10-20% effect in \( S_G \). Therefore a more realistic value for the Gottfried sum is something around 1/5, which in the end represents a deviation from the QPM prediction of \( > 30\% \). This leaves even more room for \( u - d \) symmetry violating effects, and indicates a possibly much greater role for the Pauli blocking mechanism in the proton sea. Thus, once again, the moral is that one should ignore 2% effects at one's own peril!

**Future Challenges**

Thanks to recent advances in accelerator technology that have enabled precise data to be collected at CERN, SLAC and Fermilab, we have been able to probe the fascinating inner structure of nucleons and nuclei with unprecedented clarity. Though much has been learned from inclusive DIS experiments, future analyses of hadronic structure will focus more on semi-inclusive reactions, in which individual hadrons will be identified in the final state. This will enable one to more reliably pin down the spin and flavour composition of protons and neutrons, as well as understand how this structure is modified by the nuclear medium. In addition, it will open up the challenging new field of hadronisation, the space-time formation of hadrons from individual quarks. To achieve this one will need to fully utilise the high luminosities and machine duty factors that will soon be available at facilities such as the Continuous Electron Beam Accelerator Facility (CEBAF) in Virginia, the Relativistic Heavy Ion Collider at Brookhaven, and with the HERMES program at the Deutsches Elektronen Synchrotron (DESY) in Hamburg. This new generation of experiments is bound to reveal much more of the intriguing world of sub-nucleonic dynamics, and bring us closer to understanding the quark structure of matter.

**Acknowledgements**

I would like to thank Tony Thomas for his inspiration and support during my PhD, and for his collaboration on the work presented here. Thanks also go to Andreas Schreiber, with whom it was a valuable experience to work on some of the topics discussed here.

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REVIEWS

Prompt Critical

Two Very Poor Volumes from Reputable Publishers

Looked at from the standpoint of probability, it may not be surprising for an otherwise reputable scientific publishing house to occasionally present pseudoscience dressed up as science. Fortunately this does not occur often, but this month two examples have surfaced.

The first was published by Kluwer Academic Publishers, as one volume in a series. It is entitled The Enigmatic Photon, Volume Two: Non-Abelian Electrodynamics by M Evans and J-P Vigier. We have never had Volume One for review, which may be just as well. To me it looked rather high-powered, so it was despatched to a high-powered reviewer: Tony Thomas. He returned it to me with some pithy comments, such as labelling it "more or less anti-science". He suggested if I didn't agree I should seek a second opinion, otherwise put it straight in the bin!

Because the publisher is one of high repute I thought I had better seek the second opinion, so I sent the book to Don Melrose, not letting on that the book was already damned! The second opinion confirmed the first. When Don pointed out that the theory expounded in the book implied a non-zero photon mass, I knew it would either shake physics to its foundations by its "fundamental magnetising field of electromagnetic radiation", or the book should indeed be binned. Furthermore, and I should have picked up this giveaway, the authors refer only to their own work! It is surprising that those chosen by the publisher to assess the manuscript failed to appreciate its aberrations and the lack of experimental evidence in favour of the authors' thesis.

The other book which floats an untenable thesis was published by the Stanford University Press. It is "Dinosaurs, Diamonds, and Things from Outer Space" by David Carlisle, an environmental scientist working for the Canadian government, who presents a new theory for the cause of the mass extinction 65 million years ago. Carlisle argues that a nearby supernova accelerated a host of new comets inward from the Oort cloud to bombard the solar system at that time.

His dynamical arguments for this scenario are quite Velikovskian in their absurdity, being based on an appalling misunderstanding of gravitation theory and orbital mechanics. It is impossible to take Carlisle's hypothesis seriously. He completely perverts the concept of escape velocity, imagining that an approaching object travelling at a lesser velocity cannot impact a planet, it being "shouldered aside" by the planet's gravity field. For this flawed reason he argues that none of the swarm of comets could impact Jupiter. He also states that drag on an orbiting body sends it into a higher orbit because it slows the body down.

I am incompetent to judge the geological arguments presented by Carlisle, but I can confidently assert that a referee familiar with orbital mechanics would have rejected Carlisle's manuscript, or at least demanded that the invalid arguments be corrected. But that would have totally removed any need for a nearby supernova to accelerate the destructive comets to higher than the solar escape velocity. Instead of Carlisle producing a worthless manuscript and having it published, he should have first presented his salient arguments in appropriate refereed journals, where his fatal misconceptions could have been identified. A good referee would have set him right. And this goes for the publisher's referees. They must not have had any training in elementary astronomy. It is most regrettable that these two books have seen the light of day.

Colin Keay
Reviews Editor

Material for Reviews Should Be Handled in the Following Manner

Email your review (not in "LaTeX" format) to:
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The snail-mail copy is essential for proof-reading, to ensure accurate mathematical formulæ and correct punctuation.

Reviews

Quantum Networks: Dynamics of Open Nanostructures

Gunter Mahler & Volker A Weber
Springer-Verlag, Berlin, 1995
390pp., DM 98 (hardcover)
ISBN 3 540 58850 7

This book attempts a detailed density matrix approach to quantum effects in coupled arrays of nanostructures which form the networks of the title of the book. The treatment is opened with a brief introduction to the emerging technological significance of quantum mechanics, covering topics such as laser cooling, through applications and fabrication technologies for low-dimensional systems (quantum wells, wires and dots), to quantum cryptography. Many of the applications discussed in the introduction are then treated formally later in the text using the mathematical tools acquired as part of the density matrix formalism developed. Other examples from areas such as quantum measurement theory, quantum noise, and quantum optics are treated in some detail making the book topical and interesting while giving the reader some relief at timely stages through the quite rigorous mathematical development.

The preface indicates that the book is aimed not only at specialists, but also "students trying to gain some working knowledge of quantum mechanics". Unfortunately the book does not fulfill this latter aim. A relatively good working knowledge of quantum mechanics and group theory, and a solid background in vector analysis and vector algebra are essential if one is to obtain the full benefit of this interesting and topical book.

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Microwave and Optical Waveguides

NJ Cronin
Institute of Physics Publishing (UK)
xii + 119 pp., £15.00 (paperback)
ISBN 0 7503 0216 X

Most senior courses in electromagnetism include some discussion of rectangular metallic waveguides. This short textbook, aimed at such courses, treats a range of waveguides but extends to optical waveguides (optical fibres) which have
now assumed major technological significance. The book emphasises the common underlying principles of operation of all types of waveguides, without dwelling on the physical differences between them. In discussing solutions of Maxwell’s equations in a variety of geometries, it is easy to be lost in a sea of notation and mathematical functions. A strength of the book is in its interpretation of the practical implications and consequences of the messy mathematics.

The main chapters discuss transmission lines, rectangular waveguides, circular metal-pipe waveguides, planar dielectric guides and circular dielectric guides (optical fibres). The author states that the material is suitable for a 20-hour lecture course. These chapter headings show that the book can be used by those who wish to extend the waveguide part of an electromagnetism course to include some discussion of fibre optics. As the discussion of fibres is limited to the step-index fibre, there is not a sufficient basis for a course in fibre optics. However, as supplementary reading for a course on fibres, the book concisely shows how fibres fit in with other types of waveguides.

There are two other matters to comment on—the index and the price. The index is unusual—it has twelve main headings (nearly all are types of waveguides) with alphabetical entries under these. Thus, I find “Goos-Hänchen shift” under the headings “Asymmetric planar dielectric waveguide” and “Circular dielectric waveguide.” I think this style of index has its limitations. I would not usually comment on the price of a book but the preface specifically states that “an objective of the book is to be relatively inexpensive and within the budget of today’s hard-pressed students”. Perhaps I am out of touch, but 36¢/page for a paperback book seems excessive (especially when one can photocopy 2 pages of the book onto an A4 sheet). (But no more than one chapter - Rev.Ed.)

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The Quantum Hall Effects: Fractional and Integral Second Edition
T Chakraborty & P Pietilainen
Springer-Verlag, Berlin, 1995
xii + 302 pp. DM58 (paperback)
ISBN 3 540 58589 X

If a system of electrons is confined to move in a plane and placed in a magnetic field perpendicular to the plane at low temperatures then the Hall conductance is quantised in units of $e^2/h$ to better than one part in ten million (the integer quantum Hall effect). At particularly high magnetic fields and low temperatures the Hall conductance can be some fraction of $e^2/h$ over some range of fields (the fractional quantum Hall effect). The fractional quantum Hall effect has been a particularly rich field of study for theoretical physicists because new concepts such as fractional charge, composite fermions, and particles with fractional statistics (anyons) rather than Fermi-Dirac or Bose-Einstein statistics become experimentally realisable. This book focuses on the fractional quantum Hall effect and particularly Laughlin’s wavefunction which describes the fractional quantum Hall states for incompressible quantum fluids. The discussion is easy to follow, and contains useful details often hard to find in the literature. Consequently, the book is a useful resource for workers in the field. However, as a second edition the book is rather disappointing. Although sections have been added on the integer quantum Hall effect, magneto-optical experiments, anyons, and spin-reversed states, important recent theoretical developments that are of considerable relevance to experimentalists receive scant or no mention. Recently Jain has given a unified description of both the integer and fractional quantum Hall effects in terms of composite fermions [for an introduction see JK Jain, Science, vol. 266, 1199 (1994)] which consist of electrons with an even number of magnetic flux quanta attached to them. Composite fermions are discussed for only four pages and Jain’s work receives only one brief reference. Finally, there is no mention of the work of Wen on conformal field theory and chiral Luttinger liquids.

Ross H McKenzie
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Scanning Tunnelling Microscopy II
R Viesendanger & H-J Guntherodt (eds)
Springer, Berlin 1995
xiv + 349pp., DM69 (paperback)
ISBN 3 540 58589 3

In 1991, Springer commenced the publication of three volumes on scanning tunnelling microscopy. Scanning Tunnelling Microscopy II was published in 1992 and addressed the broad range of applications arising from the testing of the original STM instruments in air and in liquids, applying the raster scanning technique to magnetic domains, force fields, the liquid-solid interface, especially for electrolytes and biological surfaces, and optical tunnelling, or scanning near-field optical microscopy. The title of the book dates from the early days of the scanning force microscopy but the text covers force microscopy and other related devices. There is a comprehensive account of the probes which have been developed for these applications.

The editors have gathered contributions from sixteen experts in this wide range of applications. The presentations are notable for their clarity and the carefully selected 167 figures. The bibliography is extensive and the second edition brings the range to the end of 1994.

The first eight chapters appeared in the first edition and have been printed with some editing in the second edition. An additional chapter appears in this new edition where seven of the original contributors have contributed twenty-six pages on scanning tunnelling and scanning force microscopy, scanning probe microscopy in biology, near-field optical microscopy and surface modifications by scanning probe methods. Consequently the final chapter is more a summary of developments since 1992 but the extensive bibliography which follows the chapter is a valuable compensation for the very compressed writing.

The fundamentals of tunnelling and force microscopy in electrochemistry are covered in the early chapters and the new chapter addresses current investigations of the surface structure and morphology of metal, carbon, semiconductor and conducting polymer electrodes. These processes are germane to the study of corrosion and galvanic phase-formation and the nature of the tip-surface interaction in electrolytes during tunnelling. The lowering of tunnelling barriers in electrolytic solutions appears to be dependent upon the concentration of the electrolyte. Dynamic studies of ion exchange processes have been reported.

The section on STM and AFM begins with a negative view of developments and is disappointed that DNA sequencing has not yet been achieved but then reports solid achievement in the imaging of nucleic acids, polysaccharides, proteins and enzymes, antibodies, structural proteins, viruses and organelles. A surprising omission is reference to the Basel group’s work on imaging soft biological surfaces by AFM using the non-contact mode. In the contact mode, the AFM tip indent.
the surface and the strong repulsive forces can distort soft surfaces. In non-contact scanning the AFM tip scans 1 to 2 nm above the surface, the attractive forces between the tip and surface are van der Waals and capillary type. By modulating the cantilever at frequencies close to resonance it is possible to extract from the resonance shifts during scanning, topographic surface images in air and in solution with vertical and lateral resolutions of 0.1 nm and 2 nm respectively.

Very brief references are made to an hybrid STM and scanning confocal laser microscope, the detection of individual fluorescing molecules by scanning near-field optical microscopy (SNOM) and the work at Stanford using a scanning capacitance microscope to store charge in layered materials for read-out devices.

This edition has its strength in the original eight chapters and the bibliography covering the period from 1991 to 1994.

B Mainsbridge
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Murdock University

Beyond Quasicrystals

This book is a collection of written versions of the Courses (19 of them) given at the Winter School Beyond Quasicrystals in Les Houches, 1994. An aim of the School was, to quote, "to promote theoretical and experimental inter-disciplinary communication between mathematicians, theoretical and experimental physicists on the topic of the nature of geometric order in solids, beyond standard periodicity and quasiperiodicity".

Quasicrystals seem to have been the starting point for most of the audience of the School, and the appreciation of the book will certainly require a background and strong interest in this field. Contributing authors were asked to make an effort to render the contents of their courses accessible to non-specialists, and indeed the book will provide the non-specialist with a glimpse of a fascinating and diverse array of topics related to and extending from quasicrystalinity. For a full appreciation, however, the book remains very much for the specialist, with a fair proportion of the topics being quite mathematical.

Richard Welberry
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Sun, Earth and Sky
Kenneth R Lang

What do you get when a Professor of astronomy and author of various astrophysical data books writes a book on solar-terrestrial physics for his daughter? Answer: a little masterpiece, sprinkled with music, metaphors and motive, written for everyone who has become a bit too cynical and serious and has forgotten what the magic in physics looks like.

As modern as tomorrow and superbly illustrated, this book provides a lucid and compelling account of the key issues in solar-terrestrial physics: the neutrino problem; helioseismology, bipolar magnetic regions; granulation; solar wind and flares; auroras; greenhouse effect; solar variability; ozone hole and sun-weather.

While the treatment is in the same tenor as Giovannelli's in Secrets of the Sun, Kenneth Lang covers much more ground, and with careful emphasis on modern applications. Thus, there is a section on the Ulysses spacecraft, another on the effects of flares and magnetic storms on pilots and astronauts, a discussion on global warming, and a description of the GALEX experiment (30 tonnes of gallium 1.4 km underground).

While keeping the text strictly non-mathematical, Lang provides numerous references to, and interpretations of recent scientific literature. In an era of fashionable quackery and charlatanry, his careful yet stimulating prose is tonic. The story-like nature of the text is further enhanced using focus sections, one page blocks expanding on recent developments in selected topics.

Sun, Earth and Sky is an unusual book because it provides a thoroughly readable and accurate scientific bridge between the layman's coffee table and the specialist. While it could not serve as a text except in a liberal arts context, its greater value will be as a stimulating gift to young (and not so young) scientists. It would be enjoyed by senior school and university students of physics, and by all of their teachers and lecturers as well. It's a jolly good book!

Richard Welberry
Research School of Chemistry
Australian National University

Computerised Glow Curve Deconvolution: Application to Thermoluminescence Dosimetry
YS Horowitz & D Yossian
Nuclear Technology Publishing
Ashford, Kent 1995 iv + 114pp., US$66.50 (hardcover) ISBN 1 870965 36 1

From time to time the specialist journal, Radiation Protection Dosimetry devotes an issue to a theme and from time to time it republiches an issue as a hard cover monograph. The journal itself contains a good deal of material of interest to physicists, including the present book which is a reprint of vol.60, No.1, 1995. It is a good account of the technique and its applications and has an excellent set of references. However, even in its original context it would have to be described as highly specialised. It is not really out of the research stage yet and most users of thermoluminescence for routine dosimetry will wait for the computer routines to be available commercially. The authors declare their hope that the book will stimulate this development.

JR Prescott
Physics and Mathematical Physics
University of Adelaide

Hartung's Astronomical Objects for Southern Telescopes: A Handbook for Amateur Observers
Second edition
David Malin & David J Frew

E J Hartung's book, Astronomical Objects for Southern Telescopes is a well-known and much-used guide for amateur astronomers. It lists over a thousand or so of the most interesting objects.
objects in the southern sky and describes the telescopic appearance of each. However, the book was published in 1968 and is now showing its age. There have been many changes in astronomy since 1968; both in our understanding of the Universe and the techniques and equipment that are used in its study.

Thus the revision of the book by David Malin and David Frew is very timely. And what a good job they have done! The book is liberally illustrated with the wonderful astronomical photographs for which David Malin is famous. It is full of carefully thought out touches that make the book easy-to-use and an authoritative reference.

The structure of the new edition is similar to that of the first edition; a set of introductory chapters giving a concise outline of astronomy, a table of objects in right ascension (coordinate) order and the descriptions of constellations and objects. The new introductory chapters contain very good material to update and revise the knowledge of someone who is already fairly familiar with astronomy, but are far too succinct to be useful to a beginner. The numerous black and white photographs included with the object descriptions are especially welcome. I was pleased to see photographs of the Trapezium stars included; they are the main feature of the Orion Nebula for a visual observer and are almost always burnt-out in published photographs.

This book will be an essential reference work for the serious amateur astronomer.

Nick Lomb
Sydney Observatory
Powerhouse Museum

New Books

Polarization Spectroscopy of Ionized Gases
SA Kazantsev & J-C Henoux
214pp., US$114 (hardcover)
ISBN 0 7923 3474 4

Force and Geometry in Newton's Principia
F de Gandt
xvi + 296pp., US$49.50 (hardcover)
ISBN 0 691 03367 6

Newton's Principia for the Common Reader
S Chandrasekhar
Oxford University Press, Oxford 1995
xxiii + 595pp., A $180.00 (hardcover)
ISBN 0 19 851740 0

Quantum Mechanics Revised Second Edition
F Schwabl
Springer-Verlag, Berlin 1995
xvi + 416pp., DM58 (softcover)
ISBN 3 540 59187 7

Classical Mechanics With MAPLE
RL Greene
Springer-Verlag, New York 1995
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Contact (Scientific Program) Prof BJ Fraser, Physics Department, University of Newcastle, NSW 2308. Fax (049) 21 6907, email: phbfj@cc.newcastle.edu.au

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January 20 - 24
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