LETTER

Discussion of AIP Policy

Sirs: — I have been asked to write to you in the following terms:

The May issue of the Australian Physicist published an article by the Honorary Treasurer entitled "Financing the Institute". He pointed out that a review of subscription rates would be made at the Council meeting on 15—16 May and gave a well-documented case for a 50% increase in order to retain the present services to members.

Earlier, in April, a note was sent to all ACT Branch members seeking their opinions on a likely rise of 50% in subscriptions for 1976. This elicited a predictably wide range of responses with, however, a closer consensus of views on what method should be used in deciding on subscriptions. The aim of this letter is not to emphasize our anguish that such (to us) sensible views have not been adopted, but to comment that there is a need for a forum at which such questions of fundamental importance to members should be discussed in advance.

We have the impression that Branch Chairmen act, at Council, as delegates from their states, and come as such well prepared to represent the varied attitudes of their branches: so much so, indeed, that they seem unable to vary their different stances to find any common ground. This is all right where matters of limited interest are to be decided, but when all are involved, it seems inevitable that the defeated minority will feel that nothing more than a counting of heads has taken place.

An obvious remedy would seem to be to have informed debate on important issues well in advance of a decision. Steps should be taken through the Australian Physicist to ensure that individual members' opinions be invited for consideration by all. The obvious benefit for Council meetings would be that the Branches would then have some familiarity with others' attitudes and a constructive concensus of opinion might emerge.

The particular outlook of the ACT Branch, referred to above was not considered of merit by the Council, and we do not wish to argue it here. We do, however, wish to point out that our suggested question "What service do members want, and what will they pay for?" does not seem to have been taken up by other Branches, or the Executive. We would like to think that Council has noted this and that the Institute will in future proceed with appropriate caution on matters — such as subscriptions — that have a direct bearing on the interests of present and future members. After considerable discussion we are of the belief that the best way of handling such items will be for them to be advised in the Australian Physicist, well in advance of Council meetings, with an invitation to members and Branches to submit their views. Not only should this result in better-informed Council meetings, but also it should help to produce better agreement between delegates before the meetings.

—C.S. Newton,
for ACT Branch Committee
LETTER

Laser Safety

SIR.—Mr Walden in his comment (Australian Physicist, May 1975) on my article on Laser Safety cites the WRE Technical Note on Laser Safety as evidence of the lack of uniformity of views on the subject of threshold values for exposure hazards, lack of uniformity in the use of units and the fact that the current approach is to educate laser users rather than restrict the equipment available.

The only point on which I would agree is his statement that the WRE document is an excellent one. It is, however, over four years old and when referring to overseas codes it cites the US Air Force “Safe Laser Radiation Exposure Levels” which came out in 1968 and the British Ministry of Technology “Laser Systems Code” which came out in 1967. Both documents have been many times superseded by more recent ones from various countries, some of which were mentioned in my paper, and it is to be hoped that Mr Walden has some more recent documents to support his assertions.

To state that there is a lack of uniformity in views on threshold of exposure hazards for lasers is as pointless as saying the same thing for ionizing radiation. Health Physicists have been debating the latter subject for over half a century, yet we still have universally agreed on maximum permitted exposure values. In the same way there is, if anything, a remarkable unanimity in world wide views on what output ranges should be permitted for the various classes of lasers and what exposure values should be permitted for direct beam and diffuse reflection viewing.

The most recent publication from the International Electrotechnical Commission (Technical Committee No. 76: “Laser Equipment”, May 1975) gives identical accessible emission limits for the various classes of lasers as are given in the American “Laser Products Proposed Performance Standard” (Federal Register 39: 172, 4 September 1974). The exposure limits are identical to the most up-to-date American Standard for the “Safe Use of Lasers” (ANSI Z 136.1—1973). How much more unanimous is it possible to get?

On the subject of units not much need be said. For radiant exposure the joules cm⁻² has generally been used and for irradiance the watt cm⁻² has generally been used for some considerable time.* Except in the use of sub-units of these, I see no evidence of any discord on this subject.

As far as education is concerned this is a need I have never disputed except to wonder who is going to educate whom, how and by what means. Is education a course, is it a lecture, is it a set of notes or is it a ‘man to man’ talk? With such diversity of users and users of lasers I would want to see some very concrete and good proposals before agreeing that education would act as a substitute for restricting the availability of instruments or for setting definite codes or even legislative directions on how lasers should be used.

The IEC document named above, for example, is actually a code on “Radiation safety of laser products and a guide for their safe use”. It devotes almost no space to education in general but is very emphatic on the types of lasers to be used in various circumstances and what safeguards should be required. While this constitutes a form of education, essentially it is a recommendation that only those people who are prepared to follow these guide lines can be considered reasonably safe as far as themselves and others around them are concerned. There is an overwhelming impression of the need to make equipment as safe as practicable and to make sure that users are adequately informed of the hazard rating of the type of equipment they have. The American Standard, in its general introductory note, also emphasizes the need to know what kind of laser is best for a particular job.

The need to educate users is recognized but what is perhaps not as recognized is the need to educate manufacturing and sales interests into the proper attitudes towards the distribution and use of a potentially hazardous device.

—A.W. Fleischmann
Second Officer, Radiation Branch, Health Commission of NSW

*The preferred SI units are J m⁻² and W m⁻². — Editor

WHAT PEOPLE ARE SAYING

Alchemy

“Big science has lived for 30 years on the proceeds of a confidence trick. The proposition that devotion to science, however useless and costly, will bring its reward in useful technology was invented and successfully exploited by the alchemists, who were also enthusiastic about the spiritual value of knowledge for its own sake. Are we much wiser than the gullible monarchs of old?” — J.M.A. Lenihan, Physics Bulletin June 1975.
ARE YOU READY TO BE RE-DIRECTED?

"It is my belief that the problems which science and technology have created along with their countless benefits, can only be solved by the application of a redirected scientific and technological effort. To provide the necessary redirection, a partnership is needed between scientists, technologists and the community at large. This is what the Australian Government hopes to achieve with ASTEC (the Australian Science and Technology Council)."

Who said this? It was none other than the newly appointed Minister for Science and Consumer Affairs, the Hon. Clyde Cameron speaking on 14 June 1975.

Whether we like it or not the old adage still applies that he who pays the piper calls the tune. Because nearly all the scientific research done in Australia is funded, one way or another, by the Australian Government we should not be surprised if it makes some attempt to politically control the directions in which scientific and technological research takes place. We should also not be surprised if the Australian Government attempts to determine the manner in which the research is done.

What can we, as members of the Australian Institute of Physics, do to exercise some influence over the redirection of scientific and technological effort which the Minister of Science and Consumer Affairs says the Government is seeking? Just because one physicist (Professor R. Street) has been appointed to the 12-man ASTEC council we cannot sit back and assume that he will adequately express our views.

What are our views anyway? What does the Institute of Physics think about the desirability of the Australian Government building a $1000 million uranium enrichment plant? What does it think about the consequent need to increase our electrical generating capacity by one eighth to operate the enrichment plant? What does it think about resurrecting the currently defunct plan to build a 500 megawatt nuclear power station at Jervis Bay in NSW? What does it think about the idea of building a plant costing hundreds of millions of dollars to convert coal and natural gas into synthetic oil and petrol?

As individual physicists we might be fully in favour of every one of these possible projects. There is no doubt that the demand for physicists would increase and even the rates of pay for physicists might increase. But a selfish individualist attitude is not the only view which can be taken about these possible developments.

If the Government really means what it says it will actively and openly seek the advice of many institutions in Australia. Will the AIP be able to provide the considered advice the Government seeks from it? How will the Institute find out the facts about a particular proposal? Will the Institute be able to give advice which represents the majority opinion of its members?

I think the first step will be for the State branches of the Institute to invite the Minister for Science and Consumer Affairs and the Minister for Minerals and Energy to address well publicized meetings. The Ministers should indicate projects on which advice might be sought. They should also be asked to agree that subsequent meetings of the Institute be addressed on specific projects by government specialists dealing with those projects. For example the Australian Atomic Energy Commission could provide a speaker to discuss the pros and cons of centrifuge versus diffusion enrichment processes and give some idea of relative costs.

It is only with an adequate supply of information that the Institute of Physics will be able to supply considered advice to the Government. If free and open discussion of facts does not take place then I can foresee the Institute and ASTEC being used to rubber stamp policies which the Government has already decided upon.

Let me return to the Minister for Science and Consumer Affairs, Mr Cameron speaking about ASTEC’s terms of reference. He said “it is usually easy to obtain advice on the scientific and technological merit of an individual project within a defined field. It is not easy to obtain advice on the relative merits of dissimilar scientific or technological proposals. And, since no country can afford, simultaneously, to do all of the things which may be desirable, fixing the order of priorities can be even more important than deciding the range of things that ought to be done.”

Mr Cameron stated that he wants ASTEC to consider the impact that the operations of multinational corporations are having on Australian Science and Technology. Mr Cameron considers that the constant and persistent efforts of multinational corporations to optimize their own welfare is done regardless of the economic effects and damage caused to the ecology and environment of the host country.

Are you ready to re-direct your efforts to the study of the activities of multinational companies in Australia? If you haven’t previously thought about scientific advice in quite these terms now is the time to start. Even if there is a change of Government at the next elections I feel certain that ASTEC or its equivalent will continue to exist and the AIP will continue to be asked for its advice on a wide range of national projects.

—Ian Bisset

"We were impressed with your new theory of pulsars and feel that you should now apply this to multinational…"
THE URANIUM DEBATE

J.R. Bird, W. Gemmell
Box 363, Sutherland, NSW 2232

The following introductory digest of information and references, relevant to the question as to whether to mine, process and sell Australian uranium, has been prepared as a starting point for those who wish to brief themselves on these problems. It is not intended as an answer to the questions involved, but as a basis for further discussion. The numbers quoted throughout are meant to illustrate magnitudes since, in most cases, rapid changes are occurring and different results can be found in different references.

Some of the Incentives

Australian Uranium Resources

An account of Australian uranium is given by South [1972] and this is updated each year in the Annual Reports of the Australian Atomic Energy Commission. The position at the end of 1974 is summarized in table 1. The grade of the main Australian deposits compares favourably with those being mined overseas. For example, in the USA the Colorado plateau deposit contains 150 000 tonnes of U₃O₅ at a concentration of 0.27%.

An important feature of many Australian deposits is that they occur at or near the surface and are suitable for open-cut mining. Although nearly 20% of US reserves occur at depths between 600 and 1200 m, little exploration at depth seems to have been done in Australia.

The total estimated reserves in Australia (recoverable at costs up to $A21/kg U) are approximately 1.4 million tonnes. This represents 8% of the reserves available to the western world and includes 14% of the reserves recoverable at costs up to $A14/kg U (equivalent to $US10 per lb U₃O₅). However, our knowledge of the extent of uranium deposits is still quite rudimentary and changing rapidly.

Brink [1968] estimated that more than 10 million tonnes (and possibly as much as 80 million tonnes) of uranium may be found in the future and developed at costs comparable to those above. In addition, there are large shale deposits in the USA and Sweden (~100 ppm U) which could be recovered at costs in the neighbourhood of $A100/kg U although environmental considerations may inhibit their use. There is also the possibility of recovering uranium from phosphate deposits (~100 ppm) and seawater (~3μg/l).

Whatever the long term status of uranium resources, the important point is that Australia, with less than 1% of the world's population, has at least 8% of the supply currently available to the western world. New discoveries may well maintain this situation for some time to come.

Australian Requirements

In 1974, the installed electrical generating capacity in Australia was 19 GW (e) [ESSA, 1975]. Any requirement for uranium for a power program in Australia seems unlikely before 1985, by which time the installed capacity is expected to be 30 GW (e) [Hayes, 1972]. Extrapolating to the year 2000 suggests a requirement of 85 GW (e) installed capacity by then. Since Australia has considerable quantities of other energy resources, only a small fraction of the total should need to be provided from nuclear power stations, e.g. 20 GW (e) by the year 2000.

There is considerable variation in fuel requirements for the various reactor types but, typically, 120 to 160 t/GW (e) per year of natural uranium is needed for light water reactors.

Table 1

<table>
<thead>
<tr>
<th>Company</th>
<th>Deposit</th>
<th>Reserves (tonnes U)</th>
<th>Grade % U₃O₅</th>
<th>Orders (tonnes U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MKU</td>
<td>Queensland</td>
<td>8 000</td>
<td>0.1</td>
<td>3 840</td>
</tr>
<tr>
<td>Queensland Mines</td>
<td>Westmoreland</td>
<td>13 600</td>
<td>&lt;0.2</td>
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<tr>
<td>Naborlek</td>
<td>Range</td>
<td>7 700</td>
<td>2.35</td>
<td>3 000</td>
</tr>
<tr>
<td>Peko-EZI</td>
<td>Ranger</td>
<td>92 000</td>
<td>0.2</td>
<td>3 000</td>
</tr>
<tr>
<td>Pancontinental</td>
<td>Jabiru</td>
<td>50 000</td>
<td>0.4</td>
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<tr>
<td>Noranda</td>
<td>Koongarra</td>
<td>*</td>
<td>0.35</td>
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<tr>
<td>WMC</td>
<td>Yeelirrie</td>
<td>39 000</td>
<td>0.15</td>
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<tr>
<td>Petromin</td>
<td>Lake Frome</td>
<td>13 500</td>
<td>&lt;0.1</td>
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<td></td>
<td>Beverley</td>
<td>17 500</td>
<td>&lt;0.1</td>
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</tbody>
</table>

*Thought to be similar to WMC Yeelirrie deposit

Sources: AAEC Annual reports 1972/3 and 1973/4, Sunday Telegraph 19 January 1975
reactors. The predicted installed capacity of 20 GW(e) would require approximately 80,000 tonnes of uranium during a lifetime 30 years. This represents about one third of the present estimated reserves.

The decision to be made by Australians is whether to exploit the known resources of uranium which, at S21/Kg U, are worth approximately 5A6 x 10^6, whether to delay exploitation on the assumption that demand and prices will rise, or whether to leave the uranium in the ground.

**Overseas Demand**

The rate of growth of installed nuclear capacity has been modified in recent years by many factors including construction holdups, shortage of capital, reduced load growth, as well as greater stringency in safety and environmental investigations. There is thus insufficient evidence upon which to establish accurate trends in the demand for uranium.

Estimates of the possible growth of nuclear power are being progressively updated by such organizations as the OECD [1973] and USAEC [1974].

In 1974 the installed capacity of power stations was 56 GW(e) with a further 125 GW(e) under construction. The current production of uranium in the western world is approximately 25,000 t/year [BNES, 1974]. This is so low, when compared with reserves, that there has been only limited demand for Australian uranium in the past decade. Extrapolation to the future depends on many factors.

(a) The world population is expected [United Nations, 1973] to increase at 2% per year but the proportion in developed countries seems likely to decrease from 31% in 1965 to 22% in 2000.

(b) Figures for 1970 [BNES, 1973] show a per capita energy consumption in developed countries of 2.5 to 7 MWh per year. Analysis shows that there has been a consistent linear relationship between log (GDP) and log (energy consumption per capita). Combining these factors leads to a predicted average growth in electricity demand of at least 4% per year. While there is a growing feeling in the developed countries that rates of growth should be moderated, in many developing countries the demand for high efficiency sources of energy is outstripping supply from indigenous sources. There is thus considerable pressure for growth rates as high as 7% or even 10% per year.

(c) The percentage of energy derived from nuclear sources has been predicted to increase rapidly on the assumption that rises in costs and increasing demands for fossil fuels will favour the use of nuclear power. The USAEC [1974] give as their lowest estimate a required generating capacity of 1575 GW (e) in the year 2000, with 50% per cent from nuclear sources. Twice this nuclear capacity is predicted to be needed in the rest of the world. Concern over safety in nuclear plants, problems with waste disposal and other difficulties, may reduce the demand for nuclear power in the short term, while the development of new energy sources may replace nuclear power in the long term.

(d) Within the nuclear industry, alternative strategies affect the uranium requirement significantly. Most projections assume that the recycling of plutonium will reduce the demand for uranium by up to 15% in the 1980s. Likewise the assumption is made that fast breeder reactors will assume an increasingly important role during the 1980s — possibly providing 10 to 15% of the installed nuclear capacity by the year 2000 and limiting the requirement for enrichment.

By combining all these factors, estimates of the cumulative demand for uranium in the western world up to the year 2000 range from 2 to 4 x 10^6 tonne, or even higher. This is similar to the present estimated reserves — a situation which may be compared with that for oil for which reserves for many years have remained equivalent to about 30 years supply at current consumption rates. Views differ as to the prospects for continuing to keep oil reserves at this level, but it would be surprising if considerable increases in uranium reserves did not result from further exploration.

In summary, the demand for energy is likely to be met in part by expanding use of nuclear energy sources — whether Australia participates or not. The world reserves of uranium are sufficient to allow this to take place whether Australia markets its uranium or not. Presumably up to about 10% of the current world market could be met from Australia, if we so desire.

**Processing and Enrichment**

Light water reactors, which are the most numerous at present, use uranium enriched in U235 between 2 and 3%.

Gas-cooled and heavy water reactors use natural uranium but some designs, including high temperature reactors and research reactors, use fuel enriched to as much as 93% U235. On the assumption that power reactors will continue to be based mainly on fuel enriched to the vicinity of 3% U235, the value of Australian uranium can be increased by suitable processing.

Overseas reviews of the demand for enrichment capacity [Ishijan, 1973, BNES 1974, OECD 1973] indicate that the present capacity in the USA (17 x 10^6 SWU/year) and Europe (0.8 x 10^6 SWU/year) plus planned additions (15 x 10^6 SWU/year) should be adequate until the 1980s. The date at which extra plant will be needed depends more on the rate of introduction of nuclear power than on other factors such as reactor strategy, plutonium recycling and the introduction of fast breeder reactors. OECD estimates range from 1982 to 1987 by varying the assumptions used.

Once the current reserves of both enriched uranium and enrichment capacity are fully utilized, the demand for enrichment is expected to increase very rapidly, possibly to 300 x 10^6 SWU/year by the year 2000. Supply of separative work from, for example, the USSR could lead to a later need for new plant.

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a One separative Work Unit converts 2.4 kg of natural uranium to 1 kg with double the U235 concentration, plus depleted uranium with 0.2% U235.
The basis for Australian interest in enrichment has been discussed by Wright [1972]. This interest is largely one of economic incentives, whereas in countries with established nuclear power programs, plans for new processing plant are considered, not on the basis of their own economic sufficiency, but on the need to meet fuel commitments for reactor construction programs.

Calculations of the added value arising from uranium enrichment are rendered difficult by rapidly changing economic factors. Figures given by Golan and Salomon [1973] indicate that an approximate doubling of the value of uranium reserves could be expected. However, current US enrichment charges ($US53–61 per SWU) are almost double the 1973 figures and URENCO's current enrichment price is $US100 per SWU for delivery in 1980. The only firm economic figures are those which are agreed for particular contracts.

Hood [1974] gives sizes of uranium processing plants which would be economically worthwhile for independent operation as:

- **Conversion to UF₆**: 2000 t/year U – 3–4 years
- **Enrichment (diffusion)**: 9 x 10⁶ SWU/year – 6–8 years
- **Enrichment (centrifuge)**: 2 x 10⁶ SWU/year – 4–5 years

(The number of years indicate the time required for construction and commissioning such plants under conditions of experience similar to those in the UK). These numbers can be expected to change as the uranium industry develops.

The capital cost of a 5000 t U/year plant for UF₆ production was of the order of $A2 x 10⁶ [Golan and Salomon, 1973] and would increase the value of the uranium by roughly 10%.

Capital costs for a diffusion enrichment plant are in the neighbourhood of $A10⁸ for a plant capacity of 9 x 10⁶ SWU/year, plus $A0.6 x 10⁶ for a power station to provide 2.5 GW e [Abajian, 1973; Exxon, 1975]. The estimated demand for enriched uranium in the western world could require one such installation each one to two years from 1985 onward.

The capital costs of centrifuge plants are the same as, or possibly less than, for diffusion plants of the same capacity. Although smaller plants are economically viable, the same total capacity would be needed to satisfy a particular level of uranium enrichment demand. Costs of associated electrical power plants would, however, be lower by a factor of 5–10.

Sabine has pointed out (ACT Branch Meeting) that if Australia aims at 10% of the enriched uranium market, this could involve production of about 300 centrifuges per day, each 1 m long and providing 5 SWU/year capacity. The industrial impact could be compared with the motor car industry producing 1000 cars per day with similar secondary industry and employment opportunities.

The processing of enriched uranium to produce nuclear fuel as well as the reprocessing and storage of nuclear wastes are further stages in the nuclear fuel cycle which, if carried out in Australia would increase earnings and employment. These possibilities will depend on the existence of a local market for the products.

Some of the Problems

**Mining Hazards**

Uranium ores are often associated with sandstone and siliceous dust must be taken into account as one of the typical hazards of mining. Radioactivity such as from radium, thorium and radon is also associated with many mining projects. For example, gold miners in South Africa have always been exposed to radioactivity from low levels of uranium associated with the gold. Even although a study of 1100 South African miners [Basson, 1971] showed no increase in the incidence of lung cancer, the mining of higher grades of uranium ore requires careful attention to the effects of radiation and radioactivity – especially in underground mines.

The radiation level at 1 m from a high grade ore (2% U₃O₈) can be as high as 10 mrem/h, so that mining practice must be such as to avoid over-exposure of workers. An additional important hazard arises from the inhalation of radioactive dust and also of radion which diffuses out of uranium bearing rocks. The inhalation of radon leads to irradiation of the lung, chiefly by alpha-particles emitted by short-lived radon daughters.

The ICRP recommendation for the maximum permissible concentration for continuous exposure to radon in equilibrium with its daughters is 10 pC/l. The importance of this limit is evident from US experience in underground mines. Radon levels of 2 to 5 mC/l were common until just before World War II and even in 1970, 30% of US mines had levels exceeding the working level (30 pC/l) [Watson, 1973]. A study of 3414 Colorado miners showed an incidence of lung cancer six times that of a comparable non-mining population [Lundin, 1969] but the trend is towards a limit of 4 WLM for annual exposure of mine workers of 0.1 WLM for non-occupational exposure. These limits are expected to be included in a new Australian Code of Practice.

For ore bodies such as those in Northern Australia which can be mined by open cut methods, natural ventilation can be expected to keep radon levels below the acceptable level. Measurements [Davy, 1974] confirm this except under conditions of still air. Care in the planning and control of mining practice and adequate monitoring should make it possible to avoid dust inhalation hazards and over-exposure of personnel to radon and radium, but this is something which has not often been achieved until recently.

**Pollution**

Streams and springs in the neighbourhood of uranium deposits in the Northern Territory carry higher than normal concentrations of radioactive elements, but usually less than 3 pC/l which is the WHO recommendation for drinking water [Alligator Rivers Study, 1973]. At times of

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1 Working Level Month is defined as the inhalation of air with 1.3 x 10⁵ MeV/litre of alpha activity, for 170 working hours.
low flow — at the end of the dry season — the concentration of radioactive materials may rise by as much as a factor of 100. Measurements of the radium content of local foods show that this may be 16 times the average in the United Kingdom and close to the limit recommended by the ICRP (a dietary content of 8 nCi/year). These kinds of conditions are met with in various parts of the world and help to provide evidence for the levels of natural radioactivity which can be taken as acceptable. However, mining operations could further increase the concentrations in both water and foods to levels which would be unacceptable. Other metals such as copper, lead and zinc, which often accompany uranium ores, must also be considered as potential pollutants along with chemicals used in ore processing.

Precautions needed to restrict pollution include the careful placement and protection of mining dumps, the minimisation of leaching and dust formation, the collection of wastes from treatment plants, etc. Although the requirements for adequate pollution control may be reasonably understood in principle, their implementation will require careful study and planning for each individual project. This degree of sophistication in mining practice is again relatively new and could be quite expensive [IAEA, 1975].

Land Use

Most of the important uranium deposits in Northern Australia occur close to or in aboriginal reserves or national parks. The general area contains a rich heritage in aboriginal art, including many sites with special significance to the aboriginal people [Alligator Rivers Study, 1973]. These sites are already threatened in many ways such as by natural weathering and disintegration, effects of dust and abrasive sand from traffic, vandalism, and just from the discontinuation of regular retouching.

The scenic areas associated with sandstone gorges and escarpments have considerable tourist potential and many sites are of major archaeological significance. Some areas are used for buffalo and cattle farming. There is thus a complex network of types of land use which are already in conflict in many ways. Mining activities, including the establishment of mining settlements add to the complexity of these problems including the need to restore areas developed for mining purposes once the relatively small areas of ore have been worked out. On the other hand, they could also have beneficial effects since miners would be residents, interested in avoiding deleterious effects, whereas tourists and vandals are not.

Environmental Impact Statement

The EIS issued by Ranger Uranium Mines Pty. Ltd. [Ranger, 1975] describes proposals to mine 3000 to 6000 tonnes/year of U₃O₈ at Jabiru (see figure). Jabiru is close to the escarpment of Mount Brockman at the head of tributaries of the East Alligator River and about 50 km SW of Oenpelli Mission.

The proposals envisage open-cut mining with on-site treatment of the ore to produce yellow-cake which would be trucked to the east coast. The project would involve a temporary construction camp for about 600 people, a treatment plant with associated power, water, sewerage and other services, stockpiles, waste dumps, tailing dams, etc. This would occupy an area of about 1000 hectares.

A new regional centre for 2000 inhabitants has been proposed by the Department of the Northern Australia and most staff would live there during the 28 (or 14) years of life of mining operations on the presently proven ore body.

The precautions which are proposed to minimize hazards and environmental effects can be illustrated by the following examples.

- Collection of dust at crucial places such as crushers and yellowcake packaging areas with watering of operating areas to minimize dust production. It is estimated that several kilograms of dust — some of it radioactive — would be released to the atmosphere each day and most of this would be removed by rain and deposited as silt in low-lying areas.

- Protective measures to keep the exposure of workers to radiation and radionuclides as well as silicous and other non-radioactive materials to within the levels recommended by the National Health and Medical Research Council. It is estimated that several curies of radon would be released to the atmosphere per day.

- Containment of all waste water plus early wet season run-off with release of the surplus into creek channels during wet season peak floods. These releases and seepage into groundwaters are estimated to involve a total radium activity of the order of 10 mCi. This can be compared with estimates of natural flows of radium in Magela Creek averaging 200 mCi per year. The release of other heavy metals is also estimated to be substantially less than concentrations that occur in natural flows.
Precautions to prevent hazardous releases of chemicals such as \( \text{SO}_2 \), ammonia, acid etc. The \( \text{SO}_2 \) concentration at the Regional Centre is estimated will average 1 \( \mu \text{g/m}^3 \), occasionally rising to 250 \( \mu \text{g/m}^3 \). The average concentration is approximately 1% of the level which could be expected to have adverse effects on vegetation or human health.

- Training and control of staff and visitors to minimize interference with local flora and fauna as well as the art and archaeological sites at Mount Brockman.

- Clearing of vegetation and landscaping of dumps is planned to minimize visual impact. Approximately half of the total works area will be restored to its natural condition after completion of the project.

Information from the Alligator Rivers Region Environmental Fact Finding Study is being supplemented by continuing measurement of meteorology, hydrology and ecology of the region. The results are used to update estimates of the release of hazardous materials and their effects on local species and the population at the proposed regional centre. For example, estimates of the additional annual radiation dose to members of the public at the regional centre suggest that this would be at most a few percent of the ICRP recommended limits and comparable to naturally occurring variations in radiation levels.

**Economic and Social Issues**

The economic incentive to exploit uranium (including enrichment) must be weighed against the problems of obtaining sufficient capital, the conditions applying to the procurement and use of such capital and the advantages of possible alternative uses of capital and manpower resources. Probably every physicist will have his own ideas as to how large sums of money (such as \( \text{SA}10^9 \) or more as required for an enrichment plant) should be used. Of particular relevance, however, are the needs of other energy studies such as fusion and solar energy, a hydrogen economy, etc.

A digest of a variety of pamphlets highlighting the objections to exploitation of Australian uranium shows the following themes:

- Terms and conditions might be applied to the import of money or technology and to contracts of sale of uranium. Such conditions might be applied by other countries to Australia's detriment or by Australia as part of international resources diplomacy.

- Uranium processing facilities in Australia could become the focus for extremist activities such as sabotage, blackmail or hijacking. The mere threat of these might lead to an erosion of traditional freedoms in order to safeguard facilities and valuable or dangerous products.

- The sale of uranium to power hungry countries can be likened to selling dope to an addict — they should be encouraged to develop lower energy economies.

- Australia should refuse to sell uranium to countries manufacturing or testing nuclear weapons. Such a refusal would set an example to the rest of the world. Australian uranium, used in overseas reactors, would result in the production of plutonium which could also be used in nuclear weapons.

- The risks associated with nuclear power are so great that Australia should refuse to sell uranium for any use other than research and biomedical needs.

- If Australia becomes dependent on uranium sales it could find itself obliged to accept nuclear waste from other countries for reprocessing or for long-term storage whether this was originally planned or not. Many other consequences could conceivably be attached to riders to sales agreements.

- An entrenched uranium industry could seek to promote its own growth without regard for wider issues. In particular, it might show a greater affinity with world-wide nuclear power interest than with local interests. It could pave the way for unnecessary introduction of nuclear power and even weapons into Australia, with the associated wider range of problems. The spectrum of views on such social and political problems is probably as wide amongst physicists as it is amongst the public in general. It is important to discover how many can be clarified by informed debate.

**References**


The Australian Physicist, September 1975 119
Regular Sources of Information
Atom (Monthly Bulletin of UKAEA)
British Nuclear Forum (UK).
Bulletin of Atomic Scientists (Federation of Atomic Scientists, USA).

Hearings, Joint Committee on Atomic Energy (US Congress).
Nuclear Engineering International (Temple Press, UK).
Nuclear News (American Nuclear Society, USA).
Nucleonics Week (McGraw-Hill, USA).
Proceedings of IAEA Conferences and Symposia.

Institute Affairs

THE REGISTER

CHANGES IN MEMBERSHIP FROM 11 MARCH 1975 TO 1 JULY 1975

HONORARY FELLOWSHIP

Transfer
A.F.A. Harper (NSW) Metric Conversion Board

FELLOWSHIP

Transfers
R.B. Beavers (NSW) J. Clark (Vic)
L.S. Falconer (NSW) H. Hora (NSW)
S.K. Kunda (O/S) D.G. Lampard (Vic)
R.J.J. Stewart (NSW)

MEMBERSHIP

New Elections
S.S. Ahmad (ACT) T.E. Freeman (NSW)
P.R.W. Hudson (Vic) M.S.H. Khan (Qld)
B.P. Kellow (Vic) R.S. Seymour (SA)
G.H. Thompson (WA) E.R. Vance (ACT)

Transfer
D.R.M. Mills

Deceased
R.D. Carman (Vic) D.G. Salier (NSW)

Resignations
C.E. Curnow (NSW) A.L. Doobov (ACT)
J.W. Higbie (Qld)

Removals from Register under Clause 13 of Articles of Association
G.C. Kerrigan (WA) R.S. Mackintosh (ACT)
J.N. Mathur (NSW) M.P. Papworth (O/S)

Removals from Register – Address Unknown
P. Duerden
J.L. Morgan
G.R. Towers

Reinstatement
J.N. Mathur (NSW)

New Elections
D.V. Bartlett (NSW) J.N. Carras (WA)
S.J. Charles (Vic) I.J. Cooper (NSW)
R.J. Craig (WA) A.D. Gates (WA)
S.C. Goh (WA) J.L. Goodsell (Qld)
M.V. Kecantok (NSW) R.B. Knott (NSW)
A.R. Law (NSW) T.J. Lazarus (Vic)
I.C. Maclean (ACT) M.M. Malone (WA)
P.J. Rye (WA) S.J. Song (WA)
P.R. Taylor (Vic) J.C. Thomas (WA)
S. Thwaites (WA) E.A.S. Toots (Qld)
B.F. Usher (WA) W.H. Williams (NSW)
M.G. Zadnik (WA)

Transfers
J.A. Barden (NSW) J.W. Chapman (Vic)
M.M. Lee (Vic) K.R. Parker (Vic)
M. Poldoja (Vic) E.D.M. Reen (Vic)

Deceased
A.S. Pearl (ACT) D.H. Sofer (Vic)

Resignations
J. McGee Hall (SA) G.J. Mulhearn (NSW)
W.S. Patterson (ACT) J.R. Pyke (NSW)
G. Vecchio (SA) S.J. West (Vic)

Removals from Register, Address Unknown
D.L. Dockray (SA) N.R. Heckenberg (Vic)
I.L. McGarry (Vic) I.C. Potter (WA)
R.P. Rodgers (WA) R. Roekmantara (Vic)
W.G. Shortis (WA) J.A. R. Vuattoux
M.J. Wallace

ASSOCIATES

New Elections
N.D. Birell (SA) K.L. Cornish (Qld)
R.J. Irvine (NSW) K.R. Taylor (WA)
G.K. Tetis (Vic) H.F. Van der Heyden (SA)
D.A. Wood (WA)

Transfers
P.R. Ainslie (Qld) J.K. Doody (Qld)

STUDENTS

New Elections
M. Acimovic (NSW) M.J. Costes (WA)
T.A. Cumpston (NSW) P.J. Duarte (NSW)
S.J. Farish (Vic) A. Franke (WA)
S.D. James (Vic) I.K. Jenkins (WA)
D.R. Keiller (Vic) A.C.J. Imerito (WA)
G.D. Lamb (Vic) C.P. Mclnnes (WA)
N. Mermelengas (Vic) D.J. Morello (WA)
D.F. Neely (NSW) A.J. Oates (Vic)
C. Pullen (Vic) W.J. Ross (Vic)
W.G. Sainey (NSW) P.F. Scharf (WA)
J. Soderbaum (WA) C.W. Taylor (Vic)
S.D. Tyrrell (Vic) G. Vignone (Vic)
S.J. Wallace (NSW) J.W. Wilkinson (Vic)
P.F.B. Williams (Vic) G. Zajo (NSW)

The Australian Physicist, September 1975
Alan Harper graduated from Sydney University with the University Medal in Physics in 1933 and was awarded the MSc in 1934 for work on the absolute velocity of β-rays from radium Ra (B+C). In 1935 he was appointed to the Sydney University Cancer Research Department as NSW State Physicist to Hospitals.

In 1939 he went overseas on a Science and Industrial Research scholarship as a precursor to joining the National Standards Laboratory as a ‘foundation member’. As leader of the Heat Section, Harper was responsible for the provision of temperature standards throughout Australia and for the calibration of industrial heat treatment facilities in NSW and Queensland.

After the war the Heat Section undertook research and development in temperature measurement, viscometry and hygrometry. Harper was also personally involved in early studies on the use of AgI and solid CO₂ for rain making, the application of hypothermia and heart-lung machines to surgery and the establishment of the first Australian facilities for research at liquid helium temperatures.

While the NSL had the responsibility of maintaining national physical standards it was not until 1948 that steps were taken to remove the anomaly that these standards had no legal status. Harper's interest in units and standards of measurement led to his becoming deeply involved in framing Regulations for Commonwealth units and standards of measurement under the Weights and Measures (National Standards) Act and later, as Secretary of the National Standards Commission, in the establishment of facilities for the approval of patterns of instruments for use in trade throughout Australia and in helping the State weights and measures authorities to develop uniform packaging requirements.

When a Select Committee of the Senate was established to inquire into the practicability of Australia’s adoption of the metric system Harper was asked to give the initial briefing evidence and, with the concurrence of CSIRO, was attached to the Committee as its Technical Consultant.

With the establishment of the Metric Conversion Board as a Statutory Authority, Harper was appointed as full time Executive Member and accordingly resigned from his position as a Senior Principal Research Scientist of CSIRO in 1970. He is also a member of the Papua New Guinea Metric Commission.

As Secretary of the Australian Branch of the Institute of Physics Alan Harper became the foundation Secretary of its successor, the AIP.

He has been President of the AIP, the CSIRO Officers’ Association and the Royal Society of NSW.

He is a member of the Council of SAA and was for many years Chairman of the Heat and Temperature Measurement Registration Advisory Committee of NATA. He was the Australian national representative on the International Organisation for Legal Metrology and as a member of the Consultative Committee of Thermometry of the International Committee of Weights and Measures he played a part in framing the International Practical Temperature Scale.

In 1967 he was awarded the Medal of the Royal Society of NSW for meritorious contributions to the advancement of science.

New Federal Industry Liaison Officer

Dr R.M. Green, formerly of Western Australian Institute of Technology, and now working in the Bureau of Environmental Studies, Department of Environment, Canberra, has accepted the position of Industry Liaison Officer for the Institute.
WOMEN IN PHYSICS: A REVIEW OF CURRENT THINKING

Gillian Robertson

As a result of the editorial paragraph, “Physics for Women” (The Australian Physicist, February 1975), a number of contributions has been received from members of the AIP. These contributions are concerned with the aptitude of women for scientific careers and the social pressures which affect their decisions to study physics, or to continue in this profession. They include references to the literature and to people with research interests in the field. The purpose of this article is to summarize the views of correspondents, to review the publications which have most relevance to the situation in Australia, and to define the area of proposed further investigation by the AIP. Results from a pilot study of university enrollments in South Australia are also presented.

Why so few women become physicists is part of the more general problem of women’s difficulties in establishing themselves in professional roles which do not conflict with their role in raising children. Women’s Liberation organizations are concentrating on questions which affect the professional woman, such as part-time work and more flexible working hours, child-minding arrangements, maternity leave, retraining after some time away from the job, equal pay and discrimination in hiring and promotion. Any advances in these fields will no doubt benefit the women physicists along with women in other professions. Eventually they will lead to the retention of married women who under present conditions are lost to the profession. It is perhaps appropriate for the AIP to concentrate on the special problem of why so few women are attracted to a career in physics even although many appear to have the necessary combination of talents.

Correspondents’ views

There is general agreement that aptitude for physics requires high spatial ability which is the ability to manipulate structures mentally. Correspondents also placed importance on personality traits of independence and persistence in problem solving. Psychologists tend to agree that there are genetic factors as well as environmental factors in these attributes. One authority claims that outstanding spatial ability seems to be linked with masculinity but there are nevertheless some women who possess this attribute. Others claim that this could be affected to a significant extent by early childhood experience.

Childhood influences featured largely in the comments of AIP members, who stressed that boys receive more early encouragement in activities fostering the ability to handle instruments, and to solve problems of an abstract kind. It is indeed rare to find girls encouraged to take up hobbies with a scientific element and they are rarely provided with home workshop facilities like those provided for boys. Girls may show less initiative in seeking these facilities for themselves, but many girls enjoy making things and would respond to encouragement to extend this range of interests.

School influences must be important, but opinions vary about the best situations in which girls learn physics. The experiences of our correspondents varied according to where they went to school: in Australia or in England; to a co-ed school or to a girls’ school; a state school or a private school; in the city or in the country. One correspondent claimed that she was better off in a co-ed rural school — where there were well qualified male teachers of maths and physics — than her contemporaries who went to city girls’ schools which were staffed by unqualified female teachers. It is generally assumed that girls are better off learning physics in a mixed class, but one authority claims that they gain more confidence by not having to compete with boys.

It is interesting that all our correspondents considered themselves fortunate in their school opportunities or felt that they had been favourably influenced by relatives who were themselves mathematicians and scientists.

Teachers report that girls tend to find physics difficult. Those who take it, enjoy it, but are more likely to go on to medicine or applied science. Many of those hoping to gain a place in the more competitive faculties, like medicine, avoid the exacting physics and double maths course, and take biology and general maths in which they are more likely to score high passes.

The editorial suggestion that physics might be more attractive to girls if presented in more inspiring literary style produced a comment on the standard of physics text books with their poor graphic content and boring problems. All agreed that there is little point in trying to substitute a literary approach in physics teaching, when it is a subject which relies essentially on being able to visualize, abstract and express in symbolic form. It would be better to stimulate interest in those who have some aptitude in these directions. More emphasis on the social implications of science could be of interest to boys and girls alike.

None of our female correspondents, practising physicists and presumably successful students, mentioned any feelings of inadequacy during their university courses. Some recent female students have mentioned the difficulties of being in a minority in their class, of feeling that they were not taken seriously by their male companions, and of being regarded as incapable of some of the practical tasks required of them — experiences which may deter them from taking physics beyond first year. Those who do survive the three-year course and wish to do postgraduate work, may find supervisors who believe that
females are unsuited to the constructional aspects of a research programme, and assign them to the least satisfying place in the research team.

One of the most common reasons put forward to account for the limited number of girls who consider physics as a possible career, is the fact that they meet few practising women physicists, either as physics teachers or in research positions, on whom they can model themselves. Another reason given is that girls prefer careers in which they have contact with people rather than things.

More publicity could be given to the kinds of work available to a female physics graduate. This should include more positive assurance that a woman could have equal status with the men and compete for promotion without discrimination. The most appropriate years for this information to be publicised would be in senior secondary school and during the first year of a university course, two points in a girl's career at which decisions need to be made. Career advisors might do much in distributing this information, especially to girls who appear to have the appropriate abilities.

One correspondent suggested that the AIP would do well to nominate women to its committees, even to consider electing one of distinction as its president eventually. The women may be willing, even eager to serve, but are "culturally inhibited from pushing themselves forward".

Review of Publications

Over the last few years several studies have been carried out to show the sex differences amongst science students. The Victorian Universities and Schools Examination Board report (1974) has received notice in the popular press. It shows that of all the subjects studied at the Higher School Certificate level in 1972 and 1973, physics was the only one in which boys did consistently better than girls. For example, in 1973, 75.99% of the boys obtained a D level or better compared with 71.58% of the girls. The total number of students taking the subject was 5808 and there was a boy to girl ratio of 2.8.

Keeves [1974] compared figures from six Australian states on school enrolments in different science subjects. The 1970 figures show striking differences between the sex ratio in biology (0.5 - 0.9) compared with physics (2.7 - 5.4); it appears that biology is for girls, physics for boys. Among students attending different types of schools at pre-university level, nearly half attend single sex schools. Boys spend more time studying science and they do better in achievement tests at both the 14 year old and pre-university level. Similarly boys are more interested in science.

In university enrolments in science, as in all subjects, there has been a steady increase in the proportion of females. For example, for the whole of Australia, the sex ratio amongst new science students decreased from 3.4 in 1961 to 2.1 in 1973.

In the employment field, figures are given for science-based occupations in succeeding decades, beginning in 1911. In the most relevant classifications (Scientists and University Teachers) the sex-ratios are:

<table>
<thead>
<tr>
<th>Year</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1911</td>
<td>6.3</td>
</tr>
<tr>
<td>1921</td>
<td>3.7</td>
</tr>
<tr>
<td>1933</td>
<td>12.5</td>
</tr>
<tr>
<td>1947</td>
<td>11.2</td>
</tr>
<tr>
<td>1961</td>
<td>9.1</td>
</tr>
<tr>
<td>1966</td>
<td>7.6</td>
</tr>
<tr>
<td>1971</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Differences in performance between the sexes are demonstrated in an American study [Hansen and Neujahr, 1974] of a group of students enrolled in a science enrichment programme at Colombia University. The students were nominated for the course on the basis of interests and talents, and were further selected by standardized test scores and interviews. In the group finally selected 22% were females. All had very superior intelligence (mean for the group 140, similar in males and females), but the males scored significantly better in standardized tests of maths and science. More of the males had science related hobbies (72% c.f. 37%) and more of the males had a science laboratory in the home (35% c.f. 9%). All did well in graduate and postgraduate studies, but the males tended to publish more. The general conclusion was that if more females were to be attracted into the physical sciences, changes in attitude and interests must begin much earlier in a girl's development.

Gardner [1974] discusses the reasons for the imbalance of the sexes in science. Cognitively, there is no evidence that girls are less intelligent than boys, or that girls display less scholastic ability. There is evidence that girls' abilities are more homogeneous, that is, there are more boys at the upper and lower ends of the intelligence scale. There is also evidence that special abilities are required to study physics successfully and boys possess these abilities to a high degree more often than girls. The differences between the sexes are small compared with the variation within the sexes, so that differences in spatial ability alone could not account for the discrepancy between the numbers of boys and girls taking the subject.

Attitude surveys over a range of age groups starting with the very young, show that males have a more favourable approach to science. Moreover males are consistently more interested in the physical sciences, females in the biological sciences. The differences are substantial and Gardner concludes that attitudes are more important than cognitive factors in accounting for subject choice.

In discussing how sex-linked differences arise he believes both personality and social environment are implicated. Males display greater aggression and are encouraged to be more self-reliant and striving, whereas females display greater conformity, nurturance, affiliation and anxiety. Children's perceptions of their sex roles in science are reinforced by parents, school, TV and story books.

Even if social influences were to change fairly rapidly so that boys' and girls' experiences became more alike, it would be generations before we could say with certainty how much of boys' present greater aptitude for science is innate and how much learned.

The Australian Physicist, September 1975 123
The most important conclusion for those involved in curriculum development is that if more girls are to be attracted to science, it will be necessary to place more emphasis on "the humanitarian aspects of science, its historical origins and its social consequences". The Australian Science Education Project, as well as similar projects in America and England, are already moving in this direction.

Kelly [1974] starts with the assumption that women should be encouraged to become scientists. They could provide a new source of talent in times of shortage and are undoubtedly needed in the teaching force. A scientifically trained female population is desirable in an age of technology. She suggests some short-term measures for increasing the number of women scientists:

(a) encourage more girls to study science by providing "simpler and more relevant science courses, together with later choices and more imaginative careers advice";

(b) make industry "aware of the advantages of employing older women, and be more flexible to meet their requirements".

New data from South Australia

As a first step towards collecting information on women studying physics at university level, the enrolment and performance statistics of students at Adelaide University have been obtained from student records. The students were enrolled in the faculties of Science and, from 1973, Mathematical Sciences also.

Table I shows the total numbers of students enrolled in each of the undergraduate courses in the years 1967 - 74, and in the postgraduate courses in the years 1972 - 74. The ratios of the number of males to females have been calculated for individual years and subjects and for the total enrolments in each subject.

In Table 2 the grades of passes obtained by students in all the years (1967 - 74) are given. D indicates a pass with distinction, C a pass with credit and P an ordinary pass.

<table>
<thead>
<tr>
<th>Year</th>
<th>Physics I Total</th>
<th>Physics II Total</th>
<th>Physics III Total</th>
<th>Honours Total</th>
<th>MSc Total</th>
<th>PhD Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M/F</td>
<td>M/F</td>
<td>M/F</td>
<td>M/F</td>
<td>M/F</td>
<td>M/F</td>
</tr>
<tr>
<td>1967</td>
<td>300</td>
<td>3.8</td>
<td>75</td>
<td>17.8</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>1968</td>
<td>350</td>
<td>3.8</td>
<td>61</td>
<td>11.2</td>
<td>28</td>
<td>27.0</td>
</tr>
<tr>
<td>1969</td>
<td>335</td>
<td>4.3</td>
<td>87</td>
<td>13.5</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>1970</td>
<td>390</td>
<td>3.6</td>
<td>77</td>
<td>10.0</td>
<td>39</td>
<td>8.8</td>
</tr>
<tr>
<td>1971</td>
<td>308</td>
<td>4.4</td>
<td>80</td>
<td>7.0</td>
<td>19</td>
<td>8.5</td>
</tr>
<tr>
<td>1972</td>
<td>294</td>
<td>3.4</td>
<td>77</td>
<td>6.0</td>
<td>37</td>
<td>6.4</td>
</tr>
<tr>
<td>1973</td>
<td>272</td>
<td>4.1</td>
<td>76</td>
<td>24.3</td>
<td>29</td>
<td>8.7</td>
</tr>
<tr>
<td>1974</td>
<td>241</td>
<td>3.4</td>
<td>68</td>
<td>12.6</td>
<td>31</td>
<td>30.0</td>
</tr>
<tr>
<td>All years</td>
<td>2490</td>
<td>3.8</td>
<td>601</td>
<td>11.6</td>
<td>203</td>
<td>11.6</td>
</tr>
</tbody>
</table>

* indicates no females enrolled

Grade N includes those students who did not pass the exam, those who did not sit and those who were excluded. The total numbers of students obtaining each of these grades of passes is shown, together with the male to female ratio in each grade.

The total enrolments in the first year physics course may have been influenced by several factors operating together. One factor is the well-known disenchantment of students generally with the technological and allied scientific courses. Another may be the greater range of subject choices in the Faculty of Science in recent years. Male and female enrolments could be affected in different ways, though the male to female ratios observed do not give an indication of a trend either way. The 1967 value agrees with the value given by Keeves [1974] for the ratio amongst new science students in South Australian universities, but the subsequent values do not show the same decrease (to 3.2) in 1973.

The second year enrolments remained steady over the period studied, the third year figures showed a slight increase in the 1971 - 74 period compared with the earlier four years. The ratio of males to females, however, increased dramatically in second year and remained stable in subsequent years. It is evident that the largest wastage of female talent, compared with male, occurs after first year.

At Adelaide University the honours course may be followed by either MSc or PhD. The total numbers taking MSc are small compared with those taking PhD, but evidently females prefer the less ambitious course.

The grades of passes obtained by males and females over the three year course showed interesting differences. In Physics I fewer females proportionately passed with distinction and credit and fewer failed, more proportionately were placed in the pass grade. In Physics II the situation was reversed with females proportionately better represented in the passes with distinction (and in the N grade in one case) than in the other grades. Though the differences are not statistically significant with the small numbers of students involved, they are consistent. In the
Table 2

<table>
<thead>
<tr>
<th>Grade</th>
<th>Physics I Total</th>
<th>M/F</th>
<th>Physics II Total</th>
<th>M/F</th>
<th>Physics III Total</th>
<th>M/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>246</td>
<td>4.8*</td>
<td>72</td>
<td>7.9*</td>
<td>39</td>
<td>8.8*</td>
</tr>
<tr>
<td>C</td>
<td>347</td>
<td>5.0</td>
<td>107</td>
<td>14.4</td>
<td>65</td>
<td>12.0</td>
</tr>
<tr>
<td>P</td>
<td>1330</td>
<td>3.3</td>
<td>333</td>
<td>10.8</td>
<td>76</td>
<td>18.0</td>
</tr>
<tr>
<td>N</td>
<td>567</td>
<td>4.3</td>
<td>89</td>
<td>11.7</td>
<td>23</td>
<td>6.7</td>
</tr>
<tr>
<td>All grades</td>
<td>2490</td>
<td>3.8</td>
<td>601</td>
<td>10.8</td>
<td>203</td>
<td>11.6</td>
</tr>
</tbody>
</table>

* Differences significant at the 5% level.
+ Differences not significant.

honours year two females obtained a division I and five obtained a division II A out of a total of nine candidates over the eight years. This is almost as good as the results obtained by the males.

One reason for a science student to choose physics amongst the first year subjects, is to keep the options open so that the area of specialization can be decided at the end of first year. It may be that amongst the women, only those who obtain a superior result in first year have the confidence to go on to second year physics. Those who do not, probably choose another course, though their results in other subjects may be no better. In the more highly selected group of females who do go on, their superiority persists in later years and the proportion going on to higher degrees is the same as in the male group.

A note should be added about the varying cultural backgrounds amongst the Adelaide students. There were many students of European origin whose expectations about professional training for girls could differ from those of Australians. The same condition could apply to the significant numbers of Asian students who were living in this country temporarily. Both groups could influence the male to female ratio amongst the student population.

References


NOTICE TO AIP MEMBERS

Annual Subscriptions

Members' 1976 subscription notices will be mailed to them early in October 1975. Prompt payment will be appreciated, and in order to encourage members to pay their subscriptions promptly, a remission of $1.00 will apply to all subscriptions paid before 1 November 1975.

The use of bankers' orders is discouraged because it frequently results in double payment or other administrative difficulties. It is in the members' own interests that we recommend against their use.

The Institute of Physics

IOP membership and journal subscriptions should be paid directly to the IOP. Foundation members of the AIP who were members of the Australian Branch of the IOP at the time of foundation should calculate the amount of their subscription as 25% of the overseas rate for their IOP grade when their IOP notice is received.

Australian Journal of Physics

Subscriptions to the Australian Journal of Physics may be paid through the AIP. The special rate for AIP members for 1976 is $8.50 provided it is paid before 1 January, otherwise it will be $25.00. Please note the change in rates.

Concessions

The following concessions are available to certain corporate members on written application:

1. The subscription of a Member or Graduate member who is a full-time postgraduate student may be reduced to half.
2. The subscription of a member absent from Australia for a continuous period of 12 months or more, may be reduced to half (except in the case of a postgraduate student already paying a reduced subscription).
3. The subscription of a member who has attained the age of 60 years and has been a member for 10 or more years may be waived.

Benevolent Fund

The Institute maintains a Benevolent Fund to assist members, past members and their close relatives in case of need. It is hoped that the generous donations of the past will continue and that more members will contribute in this way; even the rounding off of your payment to the nearest dollar is appreciated.

J.K. Mackenzie, Hon. Treasurer.
BOOKS RECEIVED

The following books have been received recently for review. Space limitations will probably not permit the publication of reviews or notices of all of them. Would anyone interested in reviewing a particular book please communicate with the Book Review Editor, G.A. Bell, National Measurement Laboratory, Chippendale NSW 2008.

ELECTRON MICROPROBE ANALYSIS, S.J.B. Reed. Cambridge University Press, 1975. xvi + 400 pp. £12.00


BOOK REVIEWS


Reviewed by P. Lloyd, Physics Department, Monash University, Clayton, Vic.

In this book quantum field theory is developed by means of 'functional equations', rather than by the more usual quantized field equations. In this approach the basic quantity to be studied is the generating functional, Z(k), which may be defined as the functional Fourier transform.

\[ Z(k) = \int dx \ e^{iS(x)} e^{ikx} \]

of the exponential of the action of the (classical) fields. Fried, however, does not define the generating functional by means of a functional integral, and in fact never actually introduces a functional integral, but derives his basic starting equation, namely

\[ Z(k) = e^{iS_1 \frac{\partial}{\partial k} \int dx \ e^{ikx} e^{S_0(k)}} \]

when \( S = S_0 + S_1 \), by Symanzik's method. In one sense this is unfortunate as it makes these ideas appear to be pure quantum field theoretical, whereas similar techniques are also applicable in other fields, such as statistical mechanics (where Z(k) becomes the partition function). However the author is only interested in quantum field theory and he elegantly shows how to use this approach to find the dressed propagators, and the S-matrix, etc. Standard perturbation theory is derived but the promise of the technique is the possibility of non-perturbative approaches and for this reason the most important parts of the book is the application of the technique to the problem of soft particle production and to the relativistic eikonal approximation.

This book contains a good account of these methods and can be recommended.


Reviewed by J.D. Campbell, CSIRO Division of Chemical Physics.

This is a book written by a chemist who 'envisioned an audience of postgraduate chemists'. Consequently the book may not be a suitable introductory text for most readers of the Australian Physicist. Those of us who have an interest in the overlapping regions of physics and chemistry will however benefit by reading it.

The author starts by explaining the general features of electron spin resonance and then discusses in some detail the interpretation of spectra due to free radicals in solution. The well established theory of transition metal ions is understandably treated briefly. So far so good for the intended reader. After this the going gets tough. Subsequent chapters discuss relaxation theory and line shapes using the techniques of the density matrix and the relaxation matrix. This theory is then applied to chemical exchange processes. The treatment here of these topics is thorough and consistent, and rewarding for the persistent reader. The last chapters describe double resonance techniques and gas phase resonance.

The standard of production of the book is reasonable, but more illustrative material and actual spectra would have enlivened the text. (There is an unreasonable number of small, obvious misprints).

If you are already working in the field then this book will be a useful addition to your library. However, if you are a newcomer and hope to be set on fire, then read one of the recent alternative expositions, for example ESR by Wertz and Bolton.

Reviewed by A.J.D. Farmer, National Measurement Laboratory, Chippendale, NSW.

With this book the author has provided a much needed link between the wide variety of techniques, instrumentation and physical applications of experimental spectroscopy, all of which are treated individually in the existing literature. The book is written at a level suitable for first degree students or graduate students beginning research in the applied spectroscopy fields and references are given at the end of each chapter to the more detailed treatments.

The first two chapters contain a general introduction to spectroscopy, followed by a summary of atomic and molecular structure and its terminology. This is of necessity brief but serves adequately as an introduction to the field. Four chapters follow which are concerned with the instrumentation used in the soft X-ray - sub mm region of the spectrum, particularly that leading to high resolution and/or intensity measurements. A brief survey of the techniques of microwave and radio-frequency spectroscopy has also been included, mainly for comparison purposes. The subject of line profiles both in emission and absorption is presented clearly and logically and the reader is led, via the concepts of equivalent width and curves of growth, into the problems of radiative transfer. The book concludes with a short account of some of the more common experimental methods for measuring transition probabilities and a chapter devoted to the applications of spectroscopy to plasma research.

In summary, this book is a worthwhile addition to the literature, if for no other reason than it ties together many of the diverse aspects of experimental “optical” spectroscopy. This, together with its logical presentation and “readability”, assures that it will be welcomed equally by beginning students and established workers in the field.


Reviewed by D.F. Lynch, CSIRO Division of Chemical Physics, Clayton, Vic.

The field of low-energy electron diffraction has been in great need of a book to summarize its current position, especially on the theoretical side. This book fills this need. The treatment of the LEED problem is, of course, biased towards the author’s own method stemming from band-structure calculations and the use of Bloch waves and muffin tin constructions.

The book has an excellent bibliography and useful appendices on some of the mathematical methods and functions. There are also listings of computer programs which could be extremely useful for those wanting to do quantitative calculations. There are some small inconsistencies arising from the jargon used only in this small part of diffraction, which may lead to some difficulty in interpretation for workers in other areas: for example, the use of the term kinematic for the pseudo-kinematic theory (Hoenii) instead of the first Born approximation to the scattering (Fujikawa).

Since the book is written by one of the most successful of the mathematical physicists in the field, it represents a very useful text for graduates and may also be of interest to band theorists.

SYMMETRY PRINCIPLES IN SOLID STATE AND MOLECULAR PHYSICS, Melvin Lax, Wiley, New York, London and Sydney, 1974, xi + 499 pp. $15.55 (paperback)

Reviewed by G.C. Fletcher, Physics Department, Monash University.

This book was prepared from lecture courses given by the author and three others over a period of twelve years, apparently to graduate students and established research workers. There is no suggested audience for the book but a good understanding of quantum mechanics, atomic, molecular and solid state theory is assumed so that it is at this level that it might form the basis of a lecture course or be used for individual learning. The book covers much the same field as Tinkham, namely crystal field theory and crystal tensors, molecular vibrations and wave functions, electronic energy bands and lattice vibrations in crystals. The coverage is very thorough but more difficult to assimilate at a first reading than Tinkham. However, the worked examples in the text and the many excellent problems set for the reader at the end of each chapter make this a good book for individual self-instruction. Apart from subject, symbol and author indices, eight appendices including character tables and basis functions for single and double point groups, their multiplier representations, Brillouin zones and correlation of different group notations will prove very useful.


Reviewed by I.D. Johnston, School of Physics, University of Sydney.

It is an interesting phenomenon, which some future trend hound may like to study, how various obscure corners of physics come and go in what is fashionable to do research in. A very good case in point is gravitational collapse - or black holes. These were first studied by Laplace in 1798 and perhaps the last time before the 1960’s when anything significant was published was in the late 1930’s. But in the last 15 to 20 years, the enormous advances in astronomical technology have brought detection of the black hole out of the realm of the inconceivable to that of the barely possible. And so the subject has become very fashionable again.
Take this book as an example. It is in fact a reasonably clear and concise exposition of some of the modern ideas concerning the space-time structure of the universe—and of general relativity in particular. It is clearly aimed at the applied mathematician or the theoretical physicist rather than the experimenter. But it is a good, complete coverage. And if you have ever wondered what “worm holes” were or what was the Kerr solution, you will find the answer here. However in the preface the authors aver that their discussion is primarily aimed (in part) at developing the concept of a black hole.

One thing this book does contain, as Appendix A, is Laplace’s original essay on Gravitational Collapse, which one does not generally come across. And the whole book seems to me to be worthwhile just for that. Especially when you realize that most current discussion in the literature of experimental observation concerning black holes, needs no more understanding than Laplace had. It is really true to say that theoretical speculation is so far ahead of experiment it isn’t funny.

To sum up then, this book would make a valuable addition to the shelves of any theoretician working in

**NEWS**

**New agency for Springer books**

Springer-Verlag, publishers of many scientific books and serials, have appointed Dutch-Australian Book Depot Pty Ltd, 927 Whitehorse Road, Box Hill, Vic 3128, as sole Australian agents. A complete range of new books, and a selection of earlier titles, will be available from stock.

**Other Institutions**

**ANZAAAS Medal, 1976**

Nominations are invited for the 1976 ANZAAAS Medal, which will be presented at the Hobart Congress in May. The closing date is 10 November 1975. Details from the General Secretary, ANZAAAS, 157 Gloucester Street, Sydney NSW 2000.

**Subscriptions to IOP Journals**

The Institute of Physics, London, will introduce air-speeded delivery in 1976. Journals will be airfreighted in bulk to Australia or New Zealand, and then posted by local surface mail. Alternatively, microfiche editions will be airmailed directly. To maintain continuity, subscribers should send payment in good time to Physics Trust Publications, Blackhorse Road, Letchworth, Herts SG6 1HN, England.
LATE NEWS

ASTEC vacancy filled by physicist

One position on the Australian Science and Technology Council was left vacant when the NSW Premier refused to allow a member of the NSW Public Service to accept the post. That position has now been filled by Dr Rachel Makinson, a senior principal research scientist of the CSIRO Division of Textile Physics, who is the first woman to become a member of the council.

ANTARCTIC RESEARCH POLICY

Following publication of the green paper on Antarctic scientific research earlier this year, a small committee is being formed under the chairmanship of Professor Keith Cole (La Trobe University) to collect views of AIP members and draft a statement of AIP policy on the subject.

AIP members are now invited to make submissions to that committee. They should be addressed to the Hon Secretary, AIP, PO Box 52, Parkville, VIC 3052, before 21 October 1975.

WHAT PEOPLE ARE SAYING

Speaking English

"It is not rare, actually, to state that in a series of lectures of different nationalities expressing themselves in English, the one we follow with most difficulty is the Englishman! This is why I would ask those who take the floor in European meeting to have always present in their mind the end of their speech that the majority of their listeners need to hear not only snatches of phrases but all the words they pronounce and they should remember that from hearing to comprehension the process is long for those who know a language badly. Could the British, before a European audience, for once borrow the bad manners of certain continental tribes, speak loudly and distinctly, articulate each word, even make some gestures, lose provisionally the sense of humour so as to act as if they consider what they are saying to be important and to let themselves go in wishing to convince their listeners?" – A. Guttier, Europhysics News June 1975.

Information

"One way the scientific societies of all the various disciplines are in an excellent position to contribute is that of making scientific information more easily and quickly available on a world-wide basis... A problem in this area that merits priority attention is how to make scientific information more available to scientists in developing countries where often the ordinary channels of dissemination break down because the systems of physical communication are inadequate or the costs are simply out of reach". – Harold L. Davis, Physics Today March 1975.
UNIVERSITY OF CANTERBURY, CHRISTCHURCH, NEW ZEALAND

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Applications close on 15 October, 1975 with the undersigned from whom further particulars can be obtained.

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