The Australian Physicist

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1978 PAWSEY LECTURE
This will be given by
Dr J. P. WILD of CSIRO
on the subject
INTERSCAN
The lecture will be at 8 p.m.
Tuesday, September 5th 1978 in the
CLANCY AUDITORIUM, UNIVERSITY OF NSW

INCOMPLETE COPIES
About 30 Copies of the July issue distributed this month were incomplete. If people
who received such a copy advise us we will send a replacement.
President's Column

In this issue, the Institute is publishing the prize-winning entry to its essay competition on the Nuclear Debate. In the following issue, the entry which won second prize will be published. The subject of the essay was The Nuclear Debate and the judges were Professor C. Kerr, Professor of Preventive and Social Medicine, School of Public Health and Tropical Medicine, the University of Sydney, the Honourable H. F. Jensen, Minister for Local Government, the NSW Government, and myself.

We hope that an essay competition of this type will be repeated annually. The subjects cannot be set in advance, but will depend on which public issue involving physicists is being considered by the country and by Parliament. We think the Institute has a valuable contribution to make in clarifying the scientific issues. These issues are very often distorted by both sides in a debate which creates as much public controversy as the Nuclear Debate.

This debate has quietened, but is not over. Thus, the Deputy Prime Minister, Mr. Anthony, was reported as announcing in Paris the construction of an enrichment plant in Australia (Sydney Morning Herald, July 24, 1978). No official announcement of Australian research into waste disposal has been made, but the subject must be under consideration.

The prizes will be formally awarded at the Third National Congress of the Australian Institute of Physics in Perth from January 15 to January 19, 1979.

Institute Affairs

31st Council Meeting

A change has been necessary in the dates for the 31st Council Meeting which will now be held on 7-8 September 1978. Among the topics which are expected to receive attention are:

The results of the Employment Committee’s survey which was included with the 1978 Subscriptions Notices:

A proposal for the formation of a “Science and Engineering Conference” to facilitate joint action by professional institutes;

The problems of scientists in the area of human rights; and many other subjects.

AIP members who wish to put forward suggestions or views on any aspect of Institute Affairs should contact a member of their Branch Committee or the Honorary Secretary of the AIP.

Science and Human Rights

If you have been reading Physics Today or Physics Bulletin you will be aware of the concern within physics societies about physicists who are involved in the human rights issue which has had much publicity in recent months. However, there has been little discussion of this issue within the Australian Institute of Physics.

The President of the American Physics Society has written to the President of the AIP outlining the actions which are being taken by the APS and expressing the hope that concerted efforts can be developed “in which an international body of scientists expresses concern for colleagues in trouble based on the provisions which exist for science in international human rights law; the exchange of detailed information regarding individual cases; and the active exchange of ideas and strategies to make our efforts more effective”.

Activities of The American Physical Society have taken the following forms:
1. Active cooperation and information gathering with other societies and organizations, such as the National Academy of Science (NAS), the American Association for the Advancement of Science (AAAS), the Committee of Concerned Scientists (CCS), the International League for Human Rights, Amnesty International, and the Inter-American Commission on Human Rights of the Organization of American States, and with the organizers of international scientific conferences.

2. Case histories of individual scientists are compiled and a letter of inquiry and appeal is sent to the scientist's government. Furthermore, we communicate this information to other human rights groups which are actively involved in the human rights problems of that country.

3. The APS has submitted a resolution on behalf of scientists in Argentina to the Organization of American State's Inter-American Commission on Human Rights.

4. Testimony has been submitted by Professor Herman Feshbach, Chairman of the Panel on Public Affairs of the APS, and Dr. John Parmentola, his assistant, to the Commission on Security and Cooperation in Europe, Helsinki.

5. The APS has sponsored visits to the United States of scientists who have been able to emigrate from their countries. In particular the APS, in cooperation with the AAAS, NAS, and FAS, sponsored a visit by Dr. Maximo Victoria, an Argentine scientist, who testified before the Organization of American States' Inter-American Commission on Human Rights on May 25, 1977, and sponsored, in cooperation with AAAS, NAS, and CCS, a visit by Professor Mark Azbel, a Soviet scientist who has been the leader of the refusnik movement in the Soviet Union.

6. In order to inform the entire APS membership of human rights issues, we publish an annual summary in Physics Today of actions taken by the APS and of current events in human rights.

7. The APS has compiled a list of Soviet refusnik physicists according to their fields of specialization.

Members of the Australian Institute of Physics are urged to make their views on these topics known through The Australian Physicist and to members of their Branch Committees.

THE MEMBERSHIP DRIVE

The Membership Committee reported pleasure at the results to date of the membership drive which commenced at the end of 1977. The table shows the movement of members by grade in and out of the Institute from December 1976 to July 1977. The corresponding figures for the period December 1976 to July 1977 are given in brackets. The table does not include transfers between grades of membership. New applications are still being received at a steady rate, and the Committee is very grateful to all those members who are assisting recruitment into the Institute.

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<thead>
<tr>
<th>Grade</th>
<th>New Elections</th>
<th>Removals</th>
<th>Net Increase</th>
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<td>Fellow</td>
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Dear Friend,

I am addressing myself to you, my friend, because in common we share a deep concern about this urgent problem of our time and generation, the problem of nuclear power. This concern will be the pivot of our communication. It will not matter that our backgrounds are different and that our thoughts may differ, because throughout I wish to stress in my attitude that your thoughts and your concern matter to me, and that they are essential not only in conducting a debate but in finding solutions to our problem.

You may become aware of my constant quotations from the Royal Commission on Environmental Pollution, Sixth Report, also known as the Flowers Report, because I consider it so outstanding in its breadth of vision and its detail. I would like to draw your attention to its biblical brilliance. At present you can obtain copies from major libraries or by writing to Her Majesty’s Stationery Office, London, England. The fact that it is not more widely available is a matter of concern to me. Reading it encourages me to believe that, if we proceed to tackle the problems with the honesty and power of this report, we need not be discouraged and will find solutions even if they do require unprecedented acts of cooperation on the part of all mankind.

First I will relate the scientific facts to you. Of course, you must realize that in this short letter, I must confine my argument to a very necessary outline only. If you are somewhat confused by this outline the Flowers Report can come to your aid, and so can the Australian Government Report, the Ranger Uranium Environmental Inquiry, First Report, known as the Fox Report.

I will present the facts in historical context for reasons that will become clear to you when we discuss the problem. Man has always been and we know that even primitive civilizations which have survived into our times, like the Aboriginal population of Australia, have asked themselves many questions about their origins. Even if their answers, in our modern sense, have no scientific content, the Dreamtime does present an answer to their questions. In our western civilization the earliest scientific answers were given by the Greeks culminating in Lucretius’ fascinating book “The Nature of the Universe.” This was written 2,000 years ago. An excellent translation of his work exists and you should study him, you will see how modern his approach has been and how he was truly an atomist. For reasons which are perhaps only partially understood 1600 years were to pass before mankind re-applied themselves to his thoughts.

In the late 18th and the early 19th century scientists redefined the atom as the smallest part of matter that behaved in the same way as the element itself, and by most ingenious reasoning they were able to show that the atom occupied about one $10^{-24}$th part of the macroscopic element. This famous number, Avogadro’s number, is probably known to you and represents the factor that couples the microscopic world of atoms to the macroscopic world of our surroundings. It is almost inconceivable for me to imagine such a number, but this difficulty did not deter scientists from seeking further knowledge as to the structure of the atom. Throughout the latter part of the 19th century and early in this century, scientists by thought and experiment revealed that the atom consists of a negatively charged electron cloud surrounding a positively charged central nucleus. Their discoveries also revealed that the outer electrons in the electron cloud control all chemical reactions of the atom thus providing a completely new understanding of chemistry. The electron when removed from the cloud was found to be the agent of electricity and a close relationship was shown to exist between the movement of electrons in the cloud and emitted light. So you can see how very inter-related all these physical phenomena were found to be.

We now must proceed to the elucidation of the nucleus itself which brings us to the beginning of this century. It took only 50 years of research to understand the basic structure of the nucleus, a great accomplishment when you consider that the radius of the nucleus is $10^{-13}$ cm in size, 10,000 times smaller than the atom.

Although the nucleus is so small it contains almost all the mass or weight of the atom which in macroscopic units is called the atomic weight. The principal constituents of the nucleus are two types of particles, protons which are positively charged particles each having a mass unit of one, and neutrons which are neutral particles...
each having a similar mass to the proton. The number of protons in the nucleus is electrically balanced by the number of electrons in the cloud surrounding the nucleus thus forming a neutral atom. It is this number, the atomic number, which determines the chemical characteristics of the element. The neutrons which act as spacer particles prevent positively charged protons from repelling each other and thus give stability to the nucleus. Of the 92 elements which are found on this earth most of them are found to be stable, but among those with more than 83 protons, the neutron-proton ratio is not large enough and nuclear instabilities result. The nucleus in endeavouring to find a stable position emits radiation. This phenomenon is called radioactivity or radioactive decay. It consists mainly of alpha particles, beta particles and gamma rays.

Alpha particles, which are the heaviest, are tightly bound combinations of two protons and two neutrons, thus carrying two positive charges and an atomic weight of four. On emission of an alpha particle the old nucleus is transformed into a new nucleus which has a lower atomic weight by 4 and a lower atomic number by 2. This new nucleus may be stable or may continue to decay in a chain which usually ends in the stable nucleus of lead with atomic number 82. Beta particles are electrons which carry one negative charge each. Before a beta particle is emitted from the nucleus, the neutron in the nucleus transforms into a proton plus an electron, and the electron only is emitted. The nucleus has thus gained a positive charge of 1 and has raised its atomic number by 1 but not changed its atomic weight. This process is of very great importance to the understanding of our problem. Gamma rays when emitted change the nucleus from an excited state, which is a minor instability, to its ground or stable state. We cannot tell which nucleus in the sample will decay or what affects this decay, nor can we influence it. We have, however, observed that each radioactive nucleus decays at its own rate and the time when half of the amount present has decayed, is called the half life of this nucleus. The number of disintegrations per second from a sample is measured in curies, a unit which is about to be changed to a new unit called becquerels.

This brings the scientific saga to 1930 and I would like you to be sure of these scientific facts before we proceed.

The neutron, being electrically neutral, is able to penetrate into the nucleus with relative ease. Most nuclei absorb a neutron adding 1 mass unit only to the old nucleus. The new nucleus thus created has the same atomic number i.e. it is chemically the same element, but with an added weight of one mass unit. Such a nucleus is called an isotope of the original nucleus. Isotopes are found in nature usually in a stable state but, when created artificially by neutron absorption, they are often unstable and the new nucleus is radioactive. The symbol uranium 238 means the isotopic nucleus of uranium with atomic weight 238 i.e. 92 protons and 146 neutrons.

Just prior to World War II came the scientific discovery that has changed our lives and thoughts. This discovery is fission and it underlies all nuclear power production. Some nuclei, uranium 235 in particular, capture the neutron and break into two fractions of similar size and on rare occasions they fission spontaneously. Excess neutrons and an enormous amount of energy equivalent to the net mass loss are released during this process. The excess neutrons will trigger further fission nuclei causing a chain reaction. If sufficient fissile material is present — known as the critical size — the released energy will cause an explosion. This is the process of the atomic bomb. If the excess neutron distribution is carefully controlled we achieve power production in a nuclear power station.

I think that you will have seen a picture of a nuclear power station. Inside the station a huge steel tank contains the fuel rods. These are long, thin aluminium cans, called cladding, filled with uranium 238 whose isotopic content of uranium 235 has been artificially enriched to make the materials more fissile. The fuel rods are surrounded by the moderator which slows down and absorbs neutrons ensuring a steady and controlled chain reaction which cannot explode. Interspaced are shut off rods to shut down the reaction for routine maintenance or in an emergency. The slowed down neutrons are known as thermal neutrons. Sufficiently high temperatures must be reached to allow the coolant to remove enough power capable of driving turbines which convert the heat to electricity. Many different designs have been tested all with an aim to improve commercial viability. A detailed table of these reactors is found on page 37 of the Flowers report. Most of the prototypes for these reactors had been assembled by the end of the 1940's and early 1950's.

In all reactors, however, another reaction takes place which we have not discussed so far. This reaction is the major crux of the whole dilemma and I would like you to give it your special attention. When uranium 238 captures a neutron it forms an isotope of uranium, uranium 239 whose half life is very short. This, by beta decay forms a new element neptunium 239 which also immediately decays with a beta particle to form plutonium 239. These two new elements neptunium and plutonium for the first two elements with atomic numbers higher than uranium and are known as transuranic elements. You must note that these new elements are being created in the atomic reactor. As far as we can tell they have not existed on this earth since man has inhabited it. Plutonium 239 is much more fissile than uranium 235. It is therefore an excellent material for making atomic bombs. Only 4 kg of pure material occupying an 8 cm sphere are needed to achieve a critical assembly. Eight cm is the size of a tennis ball. Plutonium 239 emits alpha particles and has a half life of 24,400 years. I am not sure whether the element was named after Pluto, the Prince of Darkness, in irony or by accident, but whenever I think about these facts an uncomfortable shudder goes down my spine—what about yours?

These discoveries lead us to the beginning of the 1950's when, as you may have read or remember the public discussion had turned away from atomic bombs of the above variety and was centered on a very much more destructive weapon called the hydrogen bomb.

I must introduce you now to the physical principle governing this process. The nuclear process underlying the hydrogen bomb explosion is the fusion of two hydrogen atoms or heavy hydrogen atoms (one proton plus one neutron) or tritium (one proton and two neutrons) to form helium (two protons and two neutrons) plus energy. The release of energy per nucleus is six times greater for hydrogen fusion than for uranium fission. The fusion of
hydrogen atoms is the process by which the sun shines and sends us warmth. This fusion can only take place under extreme conditions of temperature and pressure as are found in the sun and stars, but we manage to create these extreme conditions in a nuclear fission explosion which then triggers the fusion reaction. If this huge fusion reaction can be controlled and released slowly, unlimited supplies of energy will be available for mankind with few radioactive problems. In the 1950s scientists in America, England and the USSR started to work independently on the project of nuclear fusion for power production, first in great secrecy, but after 1956 open discourse between the three nations proved most successful. Work on this project was often slowed down by insufficient funds but is now continuing at an increasing pace.

Also in the 1950s other scientists began work on the design of plutonium reactors. In the UK the site for the first reactor was chosen to be Dounreay, a small place in Scotland, far removed from any centre of population as these experiments were known to be fraught with danger. The centre of the core of these reactors is a mixture of uranium and plutonium oxide, in the ratio 5:1. The plutonium oxide provides the major reactivity. This centre is surrounded by a blanket of uranium 238 which will have been depleted previously of its uranium 235 component in a thermal reactor. The blanket which absorbs fast neutrons producing plutonium 239, breeds 10% - 20% more plutonium than is used in the core of the reactor. In order to achieve a sufficient neutron flux to convert sufficient uranium to plutonium, neutrons must be used without a moderator i.e. in the energetic state with which they are expelled from the fissioning nuclei. Such energetic neutrons are called fast neutrons. Hence the name Fast Breeder Reactor (FBR). The fuel is removed at intervals and extracted in a reprocessing plant. Once the reactor has been built and provided with its inventory of plutonium it will run indefinitely on the depleted uranium that is left over by the thermal reactors and produce a net output of plutonium that can be used in other reactors. In order to provide enough plutonium to form the initial inventory (4 tonnes of plutonium per GW, gigawatt, electrical output), it is necessary to run a thermal reactor for 10 - 30 years. Thus although in the long run FBRs offer the prospect of near independence from uranium supplies in the short term a large fast breeder reactor programme will necessitate a big thermal reactor programme and hence a big uranium demand.

Three of these fast breeder reactors are now actually functioning, one in Russia, one in France and one in England. It is envisaged that a full scale commercial fast reactor of 1.3 GW would drive two standard 660 MW turbo alternators. The heat produced has to be pumped through the core to remove heat sufficiently fast. Unlike thermal reactors, which use moderators, an accidental change in shape will increase the chance of criticality rather than reduce it and make the fast breeder reactor potentially a more dangerous installation. There is no doubt, however, that this type of reactor represents a fantastic achievement of human ingenuity, as one kg of plutonium can produce as much energy in a power station as 1700 tonnes of oil.

This is where the scientific facts and history ends and the huge problems start.

Radiation, due to its inherent energy, destroys living cells by a process known as ionisation. This process consists of radiation stripping some outer electrons from the electron cloud surrounding the nucleus and thus interfering with the chemical function of the atoms that comprise the living cell. The amount of damage caused by radiation varies greatly but it can be summarised by saying that alpha and beta radiation do the maximum damage if ingested into the body but, due to their short range, are relatively less dangerous outside the body, where gamma rays and neutrons with their great penetrating power are the problem. Some isotopes such as iodine 131 and strontium 90 which are products of the fission process are especially dangerous to man because the body tends to concentrate them in particular organs such as the thyroid and bone. Radio gas and thoron gas found as by-products of mining and milling settle in the lungs and so will plutonium oxide dust. Soluble heavy metal compounds usually accumulate in the liver. Wherever radioactive material accumulates it destroys the tissue and acts as a carcinogen. Man cannot sense radioactivity, and pain through burning of the skin will only be experienced when the damage is huge and often lethal.

At present maximum radiation safety standards are recommended by a body called the International Commission of Radiological Protection, the ICRP. Twelve radiologists are chosen every 4 years by the International Congress of Radiology on the basis of their individual scientific reputation. The ICRP is independent of any government and is not a United Nations agency; it is answerable to the world's professional radiologists meeting in congress and its publications and recommendations are used by all major countries as a basis for protection. At present for the recommendations to be put into effect the standards have to be endorsed by the individual governments who translate the recommendations into codes of practice for the operators.

In Australia, where mining and milling are at present the major nuclear industries, the authoritative document is the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1975, published by the Commonwealth Department of Health. It is obtainable from any Australian Government Publishing Service bookshop. Together with the Ranger reports you can see what excellent work has been done. But you may also perceive, as I have, that unlike the position of the ICRP who are an independent scientific body, the owners (Ranger is largely government owned) known as the operator in the Code of Practice, the manager of the mine and the radiation protection officer, both employees of the operator, form a monolithic structure. Nowhere are there checks and balances incorporated to ensure that the recommendations of the Code of Practice will be taken under all circumstances be carried out. The qualifications of the Radiation Safety Officer are nowhere defined, and his powers under the manager in case of controversy appear to be inadequate. On the international scale I think it will be imperative that radiation safety control be supervised by an independent body. At present the International Atomic Energy Agency (IAEA) in Vienna is the most important body promoting the peaceful use of atomic energy. It is a UN agency since 1957 with 100 countries as members. It has among its functions the promotion of the peaceful uses of nuclear power and the establishment and administration of safeguards in connection with nuclear activities including the transport of nuclear materials and the protection of fissile materials. Its radiation...
standards are binding only to those countries which receive IAEA materials and where the IAEA provides inspection. I see the IAEA as one of the main organisations on which our hopes and future are based. Through the years it has acquired much scientific and legal expertise which will be needed if the great dangers of an expanded nuclear industry are to be avoided. Especially in the field of waste disposal, stringent controls will be required to prevent disasters on a local or global scale. On the local scene I would again like to quote to you from the Fox Report, where in dealing with tailings from mining and milling the report points out that the concentrated radioactivity left behind after the ore has been extracted will take 100,000 years to decay to insignificant levels. The worst offender is radium which finds its way into the water supply. Having regard to the very great uncertainties in data concerning radium uptake in food the Commission finds the Ranger proposal for radium releases, which are outside the ICRP standards, completely unacceptable.

On the global scene wastes from power stations are accumulating at an alarming rate. At present these are dealt with in the following manner. By remote control the cladding is removed from the fuel rod by an escape of krypton-85 gas which will have to be absorbed in future to avoid it polluting the atmosphere. The uranium and plutonium are extracted from acid solutions by organic solvents, a dangerous process. Plutonium is separated from uranium and converted to the dioxide. It is extremely valuable and is stored in vaults with enormous physical protection. Great care has to be taken in the storage to avoid a critical assembly. After 100 kwhr of electricity has been generated by one of the larger thermal stations per year, 50 million curies of radioactivity are measured in the waste at six months after discharge and after 99% of the uranium and plutonium has been removed. This waste contains many transuranic elements mainly alpha emitters, and the fission products from arsenic 33 to europium 63 mainly beta emitters. Cesium, an alpha emitter, with a shorter half life than plutonium 239 is six times more radiotoxic per unit of activity than plutonium. These wastes decay in the following manner:— For the first 500 years the alpha activity is mainly associated with cerium, then, as cerium decays, americium dominates and finally plutonium 239 with its 24,400 year half life is the active component. It is of interest to note that it has been calculated that a world fission power programme rising to 1200 GW in the year 2000 would by then generated such large quantities of radioactivity that even if they were dispersed uniformly in the vast bulk of the oceans, the resulting concentrations would be within one or two orders of magnitude of maximum permissible concentration for drinking water. This would not be satisfactory because of the many food chains that could concentrate the radioisotopes and return them to man. Although there are an increasing number of international agreements covering radioactive waste disposal, they do not create any coherent set of international rules and standards. Countries are only bound by the treaties to which they are a party. Hence, even an agreement as important as the Ocean Dumping Convention which has as parties three major nuclear countries, is reduced in significance by the large number of countries that have not acceded to it. Furthermore all arrangements suffer from the fact that countries are reluctant to allow other nations to exercise jurisdiction over their ships or nationals. As you can see the problem of dealing with the wastes stagger the imagination. I must tell you, however, that, because the problem is so huge, an outstanding scientific effort in the industry has prevented large accidents from occurring in the past and only minor ones have occurred on relatively few occasions. The accident rate in the industry is one of the lowest on record. On the other hand the amount of ocean dumping is difficult to ascertain and will have to be most carefully monitored to prevent a permanent and irreparable disaster.

In future it is proposed to vitrify the waste products, a process which consists of incorporating the amount generated from a power station, after uranium and plutonium extraction, in a glass cylinder of 50 cm diameter and about 75 cm high. These cylinders will be stored in water filled ponds to remove heat until a final disposal site has been allocated. Only in 1975 did the Atomic Energy Commission in the UK ask the Institute of Geological Science to prepare a programme that would provide the underlying research and development to dispose of high level vitrified cylinders. This programme now envisages that it will require 20 years before a safe disposal facility can be constructed.

Not only storage but spillage and accidents during the transport of waste material, which is envisaged to occur on a much larger scale in future, give rise to great concern. It is during transport that the biggest problem may arise; that is the diversion of plutonium from its intended use as a fuel in power stations for bombs. This can be accomplished by terrorists or “legitimate” governments. The proliferation of plutonium is clearly understood when you realise that in a plutonium economy we are talking of plutonium in tonnes per station. As 1 tonne is 1000 kgs and 4 kgs, as I have mentioned to you before, can be used to make a bomb, you can see that we do have a severe problem.

If divided into 2 sections of 2 kg surrounded by lead foil the plutonium could escape detection on removal. If properly detonated it could wipe out a city like Perth, as burnt plutonium oxide would pollute the air. A few micrograms of plutonium oxide when inhaled would encourage the formation of cancer in the lung and millicurie quantities when inhaled would result in certain death.

It seems fitting, therefore, to end my letter to you with some of the summarising statements of the Flowers and Fox reports:

Flowers: “There should be no commitment to a large programme of nuclear fission power until it has been demonstrated beyond reasonable doubt that a method exists to ensure the safe containment of long lived highly radioactive waste for the indefinite future.

The abandonment of nuclear fission power would, however, be neither wise nor justified, but major commitment to fission power and a plutonium economy should be postponed as long as possible”.

Fox: “Policy respecting Australian uranium exports should be based on a full recognition of the hazards, dangers and problems of and associated with the production of nuclear energy, and should therefore seek to limit or restrict expansion of that production. No sales of Australian uranium should take place to any country not
party to the Nuclear Proliferation Treaty”.

So here is our dilemma, dear friends. We have the knowledge of plutonium in all its glory. You may call it “a Faustian bargain” or you may recall the line from Genesis “lest he put forth his hand and take also of the tree of life”. Be that as it may, should we decide to suppress our knowledge of plutonium it will surely re-emerge like the thoughts of the Greek atomists a thousand years later. Discoveries like the creation of plutonium cannot be isolated from the many related discoveries of our time and we have to face the dreadful fact that adaptation to this knowledge is a necessity. Should power from nuclear fusion become a reality we may be fortunate enough to avoid a full scale plutonium economy and for this reason a major effort must be launched in that direction. Fusion power alone would make plutonium power look like the horse and buggy in the automobile age, and men’s greed would be diverted. In the meantime I would like to emphasise to you my friend, that if we proceed we must do so with maximum caution and very hard work. For we must be able to reach international agreements commensurate with the problems, an unprecedented task. On no account should we let false pressures or false information drive us into actions which we may later regret.

As an example of such false pressures I would like to mention the present sudden energy crisis when only 20 years ago the same oil companies, by lowering the price of oil and bringing pressure to bear on western governments, determinedly undermined funding for all nuclear power research and development work. In fact both fusion and storage of atomic waste would today be in a very much better state of development had financial support not been withdrawn on such a large scale. It may not be you or me who will suffer, nor perhaps even our children, but we are thinking about 24,000 years and that is eternity.

May I know your thoughts?

Your friend,

Trudi Thompson

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Dr Thompson, the writer of this prize winning essay has been in Australia since 1974 and is at present a Hospital Physicist at the Sir Charles Gairdner Hospital in Perth, W.A.

She was born in Germany in 1924, left as a refugee in 1939 and became a British subject in 1947. In 1944 she graduated with Honours in Physics with Radio at Birmingham University and was then employed as an assistant Physicist for Magnesium Elektron Ltd., Manchester. By 1948 she had completed a Ph.D. in crystallography at Birmingham and for the following four years was at the National Research Council, Chalk River, Canada. Here she held an International Fellowship of the Association of University Women (1948-49) and was a Research Officer (1949-51).

An appointment as Research Fellow at the Clarendon Laboratory followed and between 1953 and 1956 was an X-ray Crystallographer for Esso Research. The care of a family filled the next years and she returned to physics in 1973 with a degree in Biomedical Technology from Grossmont College, California.

Her published papers reflect her varied and changing interest in crystallography, X-rays and medical physics and in addition she has interest in drama, music, rocks and fossils, gardening and travel.
Physics Roundabout

Series On Women Engineers

"Engineers Australia" is at present featuring a series of articles on women in engineering. They are concerned with questions such as: What problems do aspiring women engineers encounter in education? What are the consequences of sexism? What is the attitude of academics? What is the future for women engineers?

In 1977, 2.4% of students enrolled in Bachelor Degree Courses in Engineering at Australian Universities were women. This may be compared with 29% in architecture, town planning and building courses, 32% in medicine and 40% in all bachelor courses.

Some figures, from results of Victorian HNC examinations, seem to indicate that "females are superior to males in mathematics and chemistry at least at HSC level, although males seem to excel at physics". A survey by Keith Leconte in 1973 showed that "The proportion of girls passing chemistry and applied mathematics was four percent higher than the proportion of boys. Pure mathematics was equal and boys exceeded girls by about four percent in physics".

[Comment: It is strange that a four percent better performance in chemistry is termed "superior" whereas a four percent better performance in physics has the word "excel" attached. Do I detect a whiff of sexism in an article entitled "Sexism problem in education"? B. Posingtonham].

Engineers Australia, June 16, 1978.

Review of Astronomical Observatories

The Minister for Science, Senator Webster, has announced that the Government has completed its consideration of a report prepared by a committee established to review astronomical observatory facilities funded wholly or in part by the Commonwealth.

The committee comprised representatives of the Departments of Education, Finance, and Science and the Public Service Board, and was assisted by an expert sub-committee which met under the chairmanship of Professor K. C. Westfold of Monash University.

The review committee's report has been referred to the Australian Science and Technology Council, and ASTEC's comments had been taken into account by the Government in reaching its decisions.

The Government's decisions reflected its confidence in Australian astronomy and in its desire to see that full advantage was taken of the considerable sums now being spent on astronomy. During 1976-77 approximately $8.7 million was spent on astronomical research in Australia and of this $7.6 million was provided by the Commonwealth.

The Government's new plans called for the establishment of an Astronomy Advisory Committee to advise the Minister for Science. All major proposals for Commonwealth support for astronomy would in future be referred to the Minister, who would be assisted in his consideration of the proposals by the Astronomy Advisory Committee. Very costly proposals would be examined by ASTEC before being submitted to the Government for decision.

Any major astronomical facility which may in the future be acquired with Commonwealth funds should be operated as a national facility. In the interests of economy the Government considered that national facilities should be operated by existing institutions and sited in existing observatories unless there was some compelling reason to the contrary.

Access to national facilities would be controlled by time-allocation panels which would receive applications from astronomers for time to undertake specific research projects. The applications would be judged on a competitive basis using such criteria as the scientific merit of the proposed project, its feasibility and its value in the training of post-graduate students. Each panel would comprise five members who would be appointed by the organisation operating the facility. Two of the five would be nominated by the Astronomy Advisory Committee and the remainder by the operating organisation. Coordination of the activities of time-allocation panels would be achieved by means of overlapping membership. The panels would issue annual reports to the Astronomy Advisory Committee and these reports would be made available to the astronomical community.

Senator Webster praised the efforts of the expert sub-committee which had assisted the review committee and said that the papers which the sub-committee had prepared for the review contained a valuable body of information about Australian astronomy and this would be published in the near future.

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A New Journal — The European Journal of Science Education

The journal will be devoted to the publication of articles, research reports and information relating to all major aspects of science education and technology education. It is one of the aims of the journal to view science education in the broadest possible sense, for example, by including among its themes aspects of the social sciences and of the history and philosophy of science inasmuch as these relate to science education and technology education in a contemporary setting.

Among the specific areas to be covered are:

'General' science and technology education;

Vocationally-oriented science/technology education, including technical education and industrial training schemes;

'Out-of-school' science education; agencies involved in the popularisation of science and technology;

Science/technology teacher training programmes, of both the preservice and inservice type.

It should be noted that no area of science education will be excluded. Also, science education and technology education will be interpreted fairly widely so as to include, e.g. the social implications of science and technology, issues relating to institutional planning, manpower supply and planning, the relationship between science education and societal expectations and industrial
needs, etc.

In its coverage of science education research, the journal will emphasize applicable research, i.e., research capable of being applied but not necessarily already applied, to teaching.

There is a very deliberate attempt to make it international and papers from Australia will be very acceptable.

Aims of the Journal

The broad aims of the European Journal of Science Education will be:

- to publish major advances and report current trends in the theory and practice of science education;
- to act as a means for the dissemination of research and research findings in science education;
- to facilitate the transfer and the cross-fertilisation of knowledge in science education between countries;
- to promote the recognition and understanding of the interaction of science education and such external forces as industry, government, economics, and the attitudes of society as a whole;
- to provide a forum for the exchange of views and opinions on all matters of science education.

Being a journal devoted to science education, the European Journal of Science Education will encompass in its preview educational issues relating to 'combined/integrated' science as well as to the separate sciences. Coverage of industrial and vocational education will link it with industry and commerce.

First Issue—September 1978

Editor in Chief (for enquiries and to whom papers should be sent)

Dr. Karl Frey,
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Real Sociedad Española de Física y Química

The Spanish Royal Society of Physics and Chemistry will celebrate the 70th Anniversary of its founding from the 2-7 October 1978. The President of the AIP wishes to know of any members of the Australian Institute of Physics who is likely to be in Spain at that time and would like to attend. Please write directly to:

Professor T. M. Sabine,
President Australian Institute of Physics,
Science Centre, 34-43 Clarence Street,

Building particles from new quarks.

The observation at Fermilab of high mass enhancement in muon pairs provides tentative evidence for the existence of a new heavy quark.

The study of the spectroscopy of the now abundant charmed mesons has enabled physicists to parameterise the interaction between heavy quark-antiquark pairs and months before the sighting of the Upsilon enhancements by the Columbia/Fermilab/Stony Brook collaboration, E. Eichten and K. Gottfried from Cornell had pointed out that heavy quarks, if they existed, would have an even richer spectroscopy. The structure which already seems to be seen in the Upsilon enhancements could bear this out.

By analogy with the positronium bound states of an electron and a positron, these quarks-antiquark bound states are often referred to by an "onium" suffix: so that the bound states of a charmed quark and a charmed antiquark (the J/psi family) are examples of "charmonium".

For the lightest quarks, quark-antiquark binding is not powerful enough to form proper "onium" states but only resonances which decay strongly. For the strange quark(s) the situation is marginal. The phi meson, for example, is only just above the threshold energy for strong decay into KK. If the ss binding were a little more powerful then a "strangeonium" bound state would be seen. — Cern Courier, September 1977.

University of W.A.—U.S. Visitor

For a period of nine months from September 1978, Professor John H. Reynolds, Member of the US Academy of Sciences, will be visiting our Department from the Physics Department of the University of California, Berkeley campus.

He is leader of one of the outstanding groups interested in the study of the rare gases as they occur in nature. His discovery of the presence of a $^{129}$Xe excess in meteorites, from the decay of now extinct $^{129}$I, opened up a new area of research investigation which has provided quantitative information concerning the sequence of events which preceded the formation of the Solar system.

During his stay in Perth he will be carrying out research in the area of rare gas mass spectrometry. Groups interested in having Professor Reynolds visit their laboratories should contact the undersigned:

Dr P. M. Jeffery FAIP
Reader in Physics
Physics Department
University of Western Australia
INTRODUCTION

The coupling between the magnetic spins on two near atoms in a solid arises from the exchange interactions between the electrons on the atoms. In some cases these interactions are direct, but in others they occur indirectly, via intermediate atoms in insulators or via conduction electrons in metals. Attention is focussed here on the latter situation.

The theory of indirect exchange interactions between localized spins in metals is associated with the names of Ruderman and Kittel, Kasuya and Yosida (RKKY). An outline of the main theory itself can readily be given, and will be presented below, but it is almost an impossible task to review all its very many applications. For this reason only a few particular areas of interest to the author will be considered, namely the rare earths, temperature effects, Heusler alloys, amorphous magnetic alloys and small particles.

THE ISF INTERACTION

The basic interaction between two independent electrons in orbitals \(\Psi(t_1)\) and \(\phi(t_2)\) is through their Coulomb repulsion \(e^2/|t_1 - t_2|\). Because the total wave function is an antisymmetric product, two types of energy term arise:

\[
U = \left\{ \begin{array}{c}
\psi^*(t_1)\phi^*(t_2) \frac{e^2}{|t_1 - t_2|} \Psi(t_1)\phi(t_2) dt_1 dt_2 \\
J = \left\{ \begin{array}{c}
\psi^*(t_1)\phi^*(t_2) \frac{e^2}{|t_1 - t_2|} \Psi(t_2)\phi(t_1) dt_1 dt_2
\end{array} \right.
\]

The first is the Coulomb energy. The second, the exchange energy, is only non-zero for electrons with parallel spins, thereby favouring magnetic alignment, and is often approximated by the simple form \(J = -J_1, J_2\).

When the electrons are on different atoms it is clear that \(J\) is only finite if the orbitals \(\psi\) and \(\phi\) overlap (direct exchange). For rare earth ions the magnetic 4f electrons are very localized and there is no direct overlap. However, in a metallic system an exchange interaction \(H_{Sf}\) is possible between the 4f electrons \(\Psi(t)\) and the Bloch electrons \(\phi(t, k)\), and this gives rise to the indirect exchange process of interest here. From the expression for \(J\) it can be seen that for a single Bloch electron

\[
H_{Sf} = -\sum_{i \neq j} \left\{ \psi^*_i(t_1)\psi^*_i(t_2) \frac{e^2}{|t_1 - t_2|} \psi^*_i(t_1)\psi^*_i(t_2) dt_1 dt_2
\]

This is obviously difficult to evaluate. All the functions involved can be expanded in spherical harmonics and, with suitable approximations, the leading term has the form:

\[
H_{Sf} = -A(q)S \cdot \hat{S}
\]

or transforming

\[
H_{Sf} = -A(t-B)S \cdot \hat{S}
\]

where \(t, S\) and \(B, S\) are the positions and spins of the electron and atom respectively, and

\[
A(q) = \sum_{\ell} A(\ell) e^{i\ell \cdot \hat{q}}
\]

In the usual RKKY theory two assumptions are made:

(i) \(A(q) = A_0\), a constant, or, equivalently that \(A(q) = A_0 \delta(q)\).

(ii) the conduction electrons are plane waves. A great deal of work has been done on improving one or other of these approximations.

ELECTRON SPIN POLARIZATION

The effect of a single localized atomic spin \(S_i\) in a Fermi sea is to produce a difference in density between states with up-spin \(\rho_+(t)\) and down spin \(\rho_-(t)\), leading to a spin polarization \(P(t) = \rho_+(t) - \rho_-(t)\). The RKKY theory predicts that \(P(t)\) has the oscillatory, long range behaviour shown in Figure 1. This polarization can interact, again through \(H_{Sf}\), with a second atomic spin \(S_j\) to produce an indirect exchange coupling \(H_{ij}\) between the two spins. Depending on the separation of the atoms, the polarization will favour either parallel or anti-parallel alignment of the spins.

![Fig. 1. Oscillatory form of the spin polarization](image)

To first order in \(H_{Sf}\) the perturbed wavefunctions \(\Psi(t, k)\) of the conduction electrons are

\[
\Psi_{\pm}(t, k) = \phi_{\pm}(t, k) + \sum_{E(k)} \frac{\langle \psi_{\pm}(t, k)|H_{Sf}|\psi_{\pm}(t, k)\rangle}{E(k) - E(k')} \phi_{\pm}(t, k')
\]

and

\[
\rho_{\pm}(t) = \sum_{E(k)} |\Psi_{\pm}(t, k)|^2
\]

where \(E(k)\) is the occupancy of state \(k\). For free electrons, at zero temperature, these results give

\[
P(t) = \frac{2m \hbar^2}{\pi^2 \hbar^2} \int A(t') \frac{j_1(2kr' l)}{l_0^2 - l'^2} dt' S^2
\]
where $j_l$ is a spherical Bessel function and $k_f$ is the Fermi momentum. For $A(r) = A_0 \delta(r)$ the polarization behaves as

$$P(t) \sim j_1(x)/x^2 \sim \frac{\cos \theta - \sin \theta}{x^4}; x = 2k_f t$$

which is the function shown in Figure 1.

Alternatively the response of the electrons to $H_{sf}$ can be written in terms of a spin susceptibility function $\chi(q)$:

$$\chi(q) = \sum_k \frac{n(k) - n(k + q)}{E(k + q) - E(k)}$$

so that

$$P(t) = \sum_q \chi(q) \mu(q) e^{i\omega t}$$

The free electron form of $\chi(q)$, obtained by employing $E(k) = \hbar^2 k^2/2m$ and a spherical Fermi surface, is essentially the Fourier transform of $j_1(x)/x^2$.

**TWO ION INTERACTION**

The spin polarization produced by an atom at $R_i$ interacts with a spin at $R_j$ to produce a coupling energy

$$H_{ij} = \sum_{q} \left[ P_{q} (R_i - R_j) S_i \cdot S_j - J(R_{ij}) S_i \cdot S_j \right]$$

Within the RKKY theory $J(R)$ is just

$$J(R) = A_0 P(R) \equiv \sum_{q} \frac{A_0^2 \chi(q) e^{i\omega t}}{q}$$

Going beyond the simple theory, a number of modifications have been considered:

(a) mean free path ($\ell$) affects $$H_{ij} \sim (RKKY)e^{x(-R/\ell)}$$

(b) non-spherical Fermi surfaces (free electron) sphere

$$H_{ij} \sim R^{-3}$$

(c) anisotropic exchange

$$H_{ij} = RKKY + F(L_{ij} S_i \cdot S_j)$$

**PARAMAGNETIC CURIE TEMPERATURES**

Employing the molecular field approximation, the paramagnetic Curie temperature $\theta_p$ is given by

$$\theta_p = \frac{2S(S+1)}{3k_B} \sum_{i \neq j} J(R_{ij})$$

Because $J(R_{ij})$ is of such long range, it is necessary to sum over many shells of atoms out from the selected site $R_i$. Within the RKKY theory the sums have been evaluated for the common lattice structures, and it is found that $\theta_p$ is an oscillatory function of the Fermi momentum $k_f$.

This type of behaviour has been observed experimentally for various rare earth alloy systems.

**TEMPERATURE EFFECTS**

Exchange interactions are usually assumed to be independent of temperature and the thermal properties of spin systems are determined by statistical mechanics. However, in dealing with semiconductors it might be supposed that an indirect coupling could vary appreciably with temperature through changes in the occupancy of the electron states, i.e. through $f(E) = \exp((E - E_f)/kT) + 1)^{-1}$.

Denoting by $P(T, E)$ the RKKY Spin polarization at zero temperature for Fermi energy $E$, the temperature dependent result is given by

$$P(T) = \int_0^\infty f(E) P(T, E) dE$$

At high temperature $f(E)$ tends to a Boltzmann distribution and the characteristic oscillations in $P(T, 0)$, which result from the sharpness of the Fermi surface, are smeared out. In this limit the polarization has the exponential form

$$P(T) \propto \frac{1}{r} e^{-2\pi^2 T}$$

where $\alpha$ is a constant.
Noting that $K(r)$ is proportional to $P(r)$ and employing expression (3), it can be shown (Darby 1970, see also Berdyshev 1966) that in some circumstances two values of $\theta_p$ are predicted as illustrated in Figure 2. However, it is unlikely that an indirect exchange mechanism is dominant in semiconductors.

**Fig. 2. Typical predicted behaviour for the reduced magnetization of a magnetic semiconductor.**

**HEUSLER ALLOYS**

Heusler alloys of composition $X_2 MnY$, where $X$ is a 3d atom, exhibit magnetic order and, since the magnetic Mn atoms are well separated, an indirect interaction is thought to be important. The situation for the 3d atoms is more complicated than for the rare earths, but a much used theory by Caroli and Blandin (1966) predicts that the interaction has the RKKY form modified by a constant phase factor. However, analysis of some recent experiments by Ishikawa and Noda (1976) indicates that while this theory fits the long range interactions, it cannot account for the nearest and next nearest neighbour exchange constants.

Modifications to the theory have been sought for the interaction between near spins, leading to preasymptotic formulae like $J(r) = \cos[2k_r e^{+\eta(r)}]/r^3$. An important factor here should be the spatial distribution of the atomic spins. Within the RKKY theory its effect has been investigated (Darby 1977b) by employing a distribution $A(r) = e^{-\lambda r}$ in equation (2) for the spin polarization. A second spin samples this polarization over an extended region $A(r)$ and it is predicted that $J(r)$ can decrease monotonically in the preasymptotic region. The situation is thought to be more complicated in the Huesler alloys, e.g. Price (1978).

**CURIE TEMPERATURE OF AMORPHOUS ALLOYS**

For some dilute magnetic alloys, e.g. $\sim 10\%$ Gd in La, it is found that the measured paramagnetic Curie temperature is non-zero for compacted (crystalline) samples but vanishes for evaporated films having an amorphous structure. This has been explained by Kok and Anderson (1971) in terms of differences in the molecular field produced by summing the RKKY interactions. For the crystalline alloy expression (3) is only modified by a factor equal to the concentration of Gd, and therefore gives a finite $\theta_p$. However, for the amorphous structure the summation over lattice site must be replaced by an integral involving the radial distribution function $g(r)$, i.e.

$$\Sigma_{\text{r}} J(r) = \int g(r)e^{-r}dr,$$

and Kok and Andsen have shown that $\theta_p \sim 0^\circ K$ in this case.

**SMALL PARTICLES**

The electronic properties of very small metallic particles ($\text{radii} < 10\AA$) differ from those of the bulk material in that there is no longer translational symmetry, and the electron energy levels are more widely spaced. The influence of these effects on the RKKY interaction between magnetic atoms in particles has been considered by Darby (1976, 1977a).

For a spherical particle the free electron wavefunctions have the well known form $\psi(\rho) = (4\pi/\hbar)^{1/2} e^{-\rho/2\hbar}$, where $k_0$ is determined by the boundary conditions, and the corresponding energies are $E_n = en^2 \pi^2/2$. A single spin perturbs the electron gas through $H_{\text{eff}}$ and the new wavefunctions can be computed from (1). The corresponding expression for the spin polarization is complicated, but the new feature is that it is a function of the position of the atomic spin in the particle, and consequently the exchange coupling between two spins depends on their absolute locations. The magnetic ordering temperatures are determined by an average molecular field and, for particle radii $\sim 10\AA$, they are found to be essentially zero. It would therefore appear that very fine particles in which an RKKY interaction dominates are non-magnetic.

**REFERENCES**


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Fundamental Physics Research in Australia

Interim Report prepared by the Science Policy Committee

The Australian Science and Technology Council (ASTEC) is preparing an overview of science and technology in Australia. They set up committees to prepare twenty-five position papers to act as background material in the writing of the overview, and one of these position papers was on Fundamental Research. The Department of Science was asked to assemble material for the preparation of this position paper on Fundamental Research. Last September the Department sought the co-operation of several societies, including the Australian Institute of Physics. The information was wanted at short notice and the Science Policy Committee canvassed opinions from a selected group of our members whom we believed were representative of the different interests within the physics community and published a brief note asking for other submissions in the October, 1977 issue of the Australian Physicist. We publish below our interim report on this topic which we have sent to ASTEC. An earlier version which did not differ greatly from this one was sent to the officers of the Department of Science who were collecting the information for the position paper. The Science Policy Committee is publishing this interim report in the hope that it will stimulate further discussion and that several members will send comments on the report either to the Science Policy Committee or to the Editor.

As we said in our note in the October, 1977 issue, in the present context fundamental research has been defined as “original investigation with the primary aim of obtaining a more complete understanding of the subject under study” and applied research as “original investigation with the primary aim of solving recognised practical problems”.

1. Methods of Evaluation

The only widely accepted method for evaluating fundamental research in Physics is peer review, although it is not without its shortcomings. Factors which may be taken into account in such a review includes:

i. Number and quality of publications;
ii. Frequency of citations, particularly in reviews and books;
iii. The ability to attract overseas visitors for work in Australia; and to attract international conferences to Australia;
iv. Invitations to deliver special lectures at conferences, etc.;
v. Important applications that have followed from the research;
vi. Invitations to serve on international organisations and such as those affiliated with the International Council of Scientific Unions, etc.;
vii. Receipt of awards or prizes.

In awarding research grants, the ARGC supplements such information with confidential reports from referees nominated by the proposer and assessors nominated by the Committee, and with interviews and visits to inspect projects. The procedures adopted by the ARGC are generally accepted in Australia as satisfactory for identifying projects and scientists to receive grants. One source of information on areas of research in which Australia enjoys a reasonable reputation is therefore the list of projects which receive ARGC grants. However, this is by no means a complete list of projects with international standing, being restricted to research undertaken in tertiary institution and industrial laboratories and not including government laboratories. Moreover, it does not provide any scale of measurement of such standing.

In its deliberations, the ARGC considers both the merit of a proposal and the merit of the proposer. In general, the former is the most crucial to the prospects of success. On the other hand, the true merit of a proposal can only be established as a result of later work and it may take decades for an adequate perspective to be obtained. There is thus a need to avoid criteria which are too narrow when evaluating research proposals and results.

The proper use of these review techniques is only possible with considerable time and resources and it has not been possible for the Australian Institute of Physics to attempt a thorough assessment of “areas of fundamental research in which Australia enjoys internationally acknowledged high standing.”

2. Summary of Responses

(a) To Areas of fundamental research in which Australia enjoys internationally acknowledged high standing with reasons for choosing such areas.

The information provided to us by members of the Physics profession shows that within the type of evaluation described in the previous section, it is possible to conclude that Australia has a high international standing in many areas of physics research. The following examples with such reasons as have been offered must not be regarded as a complete nor authoritative list:

Crystallography – a field in which equipment has been of relatively low cost. Australian workers pioneered the theory on which the interpretation of electron diffraction patterns rests. Other significant work has been carried out on biological molecules by X-ray diffraction and on hydrogen bonding by neutron diffraction.

Solid State Physics – the great variety of materials available for study have provided tremendous scope for innovation and advances in understanding. Tertiary institutions, together with government laboratories have made important contributions to the study of defect properties, transport properties, radiation damage, magnetic properties, fracture and many other aspects of the properties of materials. The special properties of
surfaces have also been an area in which important Australian contributions have been made.

Theoretical Physics — The expansion in tertiary institutions has also led to expansion in the number of theoretical physics departments which have established reputations in work on relativity, statistical mechanics, field theory, etc.

Radioastronomy — The wartime involvement in the development and application of radar provided Australian scientists with an early opportunity to study radio signals from the sun and beyond. Innovation in equipment design, considerable support through CSIRO and universities and the fact that many important aspects can only be studied from the southern hemisphere, have kept Australia in the forefront.

Optical Astronomy — The combination of geographic position and instruments such as the Intensity Interferometer at Narrabri and the Anglo-Australian telescope have allowed Australia to make important contributions in this field.

Cosmic Rays — Like astronomy, the study of cosmic rays has geographic features which bring overseas physicists to Australia and Australian physicists to the study of cosmic rays. The post-war expeditions to the Antarctic have provided continuing impetus to this work which is an important part of world studies.

Ionospheric Physics — This was a field of study which was supported by the Radio Research Board. The availability of support encouraged work in this field which attracted many physicists who have made important contributions both in physics and in applications.

Oceanography — Innovation in experimental techniques, coupled with theoretical developments have produced important results in physical oceanography.

Geophysics — During a period when striking progress has been made in geophysics and other studies of the earth, a number of Australian scientists have both participated in and provided leadership in this field.

Nuclear Physics — A period spent gaining experience overseas has been the basic pattern for Australian scientists and they have necessarily brought back an enthusiasm for the fields in which exciting developments are occurring. Contributions have been made first to atomic physics, then nuclear physics and now particle physics. However, it has become increasingly necessary to take advantage of opportunities to collaborate in the use of large overseas accelerators because the construction of these is well beyond our resources. Major Australian contributions have been made to nuclear physics theory.

Plasma Physics — Australian laboratories have been able to make worthwhile contributions to this field with small plasma sources of modest cost. Our contribution to understanding the properties of toroidal plasmas and plasma waves may not have been possible in a laboratory based on a larger machine.

These are only some of the broader areas mentioned in responses by members of the Australian Institute of Physics. Other topics mentioned as having international standing include: chemical physics, fluid dynamics, optics, atomic absorption and other aspects of spectroscopy, electron diffraction, astrophysics, environmental physics, and so on. It is clear that Australia is contributing important fundamental research in a broad range of physics topics.

(b) "Identification of areas of fundamental research which warrant further support and expansion." The following considerations should be included in identifying areas which warrant future support and expansion:

(i) The most successful research workers, and their immediate research group, should receive priority in funding. However, worthwhile proposals by younger or less well-known workers should also be encouraged and supported.

(ii) Support should be given to areas such as earth science, marine science, meteorology, astronomy, flora and fauna which involve the study of unique aspects of Australia's environment and location.

(iii) Areas of fundamental research which will provide Australia with the high levels of scientific education and competency needed as a basis for expanding Australian technology, should receive some priority in funding.

Countries with small population and financial resources have greater difficulty in maintaining an adequate base of fundamental research than those which are able to support work in all fields. The problem is one of encouraging diversity but nevertheless establishing centres of excellence which need to be of a critical size in order to be effective.

New areas which were proposed for support include:

(i) Australia should play a bigger role in the important and growing area of Antarctic oceanography.

(ii) The determination of the structure of biologically important molecules by diffraction methods, because of Australia's strong effort in biological research.

(iii) Fundamental research related to Australian needs in future availability of liquid fuels, water conservation, communications, etc.

Fundamental research on materials should continue to receive support because it combines the need for only moderately expensive equipment with a high probability of yielding results of practical significance.

Proposals for moderately expensive facilities which should be provided in the near future include a sophisticated electron microscope, the provision of a cold source for neutron diffraction and the provision of suitable ships for physical oceanography and other marine studies.

(c) "What sort of reorganisation or changes in financial arrangements should be introduced to bring about any desired improvements".

The way in which ARGC operates is seen, in general, to be satisfactory although, as might be expected, most physicists would like to see the scale of funding increased. Some would like to see the timing improved in order that whether a grant was to be available was known earlier in the previous year. If possible, ARGC grants or similarly assessed grants should be used more to promote basic research in industrial laboratories. The ARGC policy should be one of supporting the person with ideas whilst having some concern for matching up the programs they support against perceived national needs. Many of our members who provided us with contri-
butions are of the opinion that the strength of Physics in Australia is due to the large amount of freedom which able people have had in choosing their particular research topic.

However, there is need for extra funding above that now provided by the ARGC for the equipment required to set up new facilities which are seen to fill a national need, which may cost $0.25M to $5M. When established, these expensive facilities should be available to workers from all institutions and not only the university or other institution in which the facility is housed. Greater provision for travel money and technical staff may be required for this to happen. Good examples are the widespread use (through ANSE) of the Lucas Heights facilities, the Parkes radio telescope and the Anglo-Australian telescope. Some large facilities in university laboratories have not been used much by workers from outside that university.

More funds are needed to bring visiting research workers to Australia. Workers in universities find it difficult to contribute fully to international co-operative programmes such as IGY, IQSY, GARP, IMS, etc., because of the high cost of making, analysing and circulating continuous routine observations.

The growth of scientific research in the 60's coupled with the recent cut back has greatly reduced the numbers of 25-35 year-old researchers. One proposal, borrowed from an American suggestion, to overcome this problem is the absence of the age group who are often the most productive and enthusiastic is to provide money for a few fixed term appointments which would cease when those on the staff who are now aged 55-60 retire.

S. Dryden
April 1978

Appendix

A survey of physics research in tertiary educational institutions was published in The Australian scientist for September 1974 (p 169) with an erratum in the January 1975 issue (p 2). Although this survey suffers from the limitations inherent in a survey which depends on the response to a circular there are few apparent omissions and it can provide a basis for assessing the scale of the effort (in 1974) in various aspects of physics research and the range of topics covered. We have listed in Table 1 the staff plus students involved in the different areas of research.

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<td>Particle</td>
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<td>Nuclear</td>
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<td>Astro; Radio Astro</td>
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<td>Ionospheric</td>
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<td>Atmospheric</td>
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<td>Cosmic Ray</td>
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<td>Solar, Near Space</td>
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<td>Low Temperature</td>
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<td>Environment, Energy Etc.</td>
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<td>Quantum, Field theory</td>
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<td>Statistical Mechanics</td>
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<td>Relativity</td>
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</table>

TOTAL Approx. 870

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**Stonehenge again**

Dear Sir,

During the last 15 years or so a great deal of astronomical work has been done on the ancient monument of Stonehenge in Wiltshire, England. The work of G. Hawkins (1963) and F. Hoyle (1966) in particular has shown that the builders of Stonehenge may have been astronomers of considerable intellect.

One of the most remarkable features of Stonehenge is the set of 56 Aubrey holes surrounding the central monument (Hoyle has shown that these holes, laid in approximately 2600 B.C., could have been used as an eclipse predictor). An interesting numerical coincidence occurs if we call the diameter of this Aubrey circle 1 unit of length; the spacing between any two adjacent holes then becomes π/56 which is 0.056 of these units in length. Of course, this is no more than an interesting numerical coincidence as π was not known to the Stoneage Britons . . . .

J. DODS,
B. WILKINSON, M.A.I.P.
Environmental Studies Department,
S.C.V. Rusden

The Australian Physicist, August 1978 111
METHODS IN COMPUTATION PHYSICS VOL. 16
Reviewed by R. L. Dewar, Research School of Physical Sciences, ANU, Canberra.

This book performs the valuable service of recording the thoughts of some of the leading exponents in the field of plasma simulation on the technical considerations going into the writing of the various diffusion, hydrodynamic, kinetic and microinstability codes (in decreasing order of timescale) which are used to simulate plasma phenomena. Comparison with Vol. 9 of this series shows that there has been a shift towards longer timescales over the last six years. Simulation is as much an art as a science, needing a skilful blend of numerical and physical intuition to set up and interpret a simplified numerical model. The articles present and justify the equations to be solved, discuss particular numerical approaches, and usually include some sample physical results.

Phenomena on the timescale of spatial diffusion as treated by one-dimensional transport codes are discussed by Hogan and by Watkins et al. The hydrodynamic models can be approached either by straightforward evolution simulation (Brackbill, Potter, Boris and Book), or by equilibrium and linear normal mode analysis (McNamara, Grimm et al). Kinetic regimes, where velocity-space evolutions must be handled accurately, are treated by Fokker-Planck models (Killeen et al.) and by ‘particle-pushing’ techniques (Dawson et al., Langdon and Lasinski, Nielsen and Lewis).

Though some of the material is necessarily ephemeral, there is enough detail not recorded elsewhere that the useful life of the book will be at least ten years. Anyone contemplating numerical plasma simulation (either in relation to magnetic confinement, to laser fusion or to astrophysics) should see that his library has a copy. I also recommend the book to numerical analysts as a source of ideas for further development. Unfortunately the price puts private ownership out of the reach of most people. Perhaps Academic Press could get a subsidy from the computer manufacturers?

Reviewed by R. P. Netterfield, National Measurement Laboratory, CSIRO, Sydney.

Ellipsometry was first used to study the optical properties of surfaces and thin films late last century and has experienced mixed popularity since. There has been a resurgence of interest in recent years since the development of digital computers which have greatly simplified data reduction. It is somewhat surprising that a book in English entirely devoted to this subject has not previously appeared. It is fitting that such a book should be written by Azzam and Bashara as they have contributed much to the recent literature.

The treatment of polarized light and the propagation of light through polarizing components in itself is extensive, developing in detail the Jones, Mueller and Stokes matrices and Poincaré sphere representation, in conventional and generalized co-ordinate systems.

A comprehensive description of ellipsometer systems is given together with methods of determining and correcting for component imperfections. A full and up-to-date survey of the uses of ellipsometry together with methods of data reduction is included.

The mathematics is developed step by step from basic principles using an accepted consistent set of units, and a liberal number of footnotes has been used to expand items in the text. It should thus be easily understood by students and beginners in the field, I would recommend this book as a reference to anyone who has interests in ellipsometry or polarized light but unfortunately it is current exceptionally high price takes it out of the reach of most individuals.

NEW PATHWAYS IN HIGH-ENERGY PHYSICS I –
Magnetic Charge and Other Fundamental Approaches. A. Perlmutter (Ed), Plenum Press (New York) 1976, x + 401 pp. US$47.00
Reviewed by L. J. Tassie.

This expensive book, Volume II of the proceedings of Orbis Scientiae 1976 held at the University of Miami, Coral Gables, contains six papers on magnetic monopoles, including a very interesting paper by Dirac, and eight papers on other fundamental questions, including one paper about the possibility of unstable integer charge quarks. The emphasis on magnetic monopoles was no doubt due to the controversy surrounding the event reported in 1975 as evidence for a monopole. Two papers discuss this controversy, which is now only of historical interest, but the other papers on magnetic monopoles deal with more enduring questions. The other papers cover a wide variety of topics, including one paper on the possibility of unstable quarks with integer charges.

Reviewed by W. R. Blevin, National Measurement Laboratory NSW.

This book is concerned with the visual detection, recognition, and identification of objects. It treats such diverse topics as the properties of the human visual system, thresholds for detection and recognition, models for predicting visual performance, visual aids, characteristics of visual targets and backgrounds, and atmospheric effects on vision. The author is Chief Optics Engineer with the British Aircraft Corporation (Guided Weapons Division).

It is difficult to write a good book on a subject that involves many diverse disciplines. Overington has succeeded in providing a reference book that should prove valuable to most researchers of visual acquisition. I do not regard the books as very readable for people having only a casual interest in the subject. In such a wide-ranging book many subjects have to be treated in terse and almost superficial way.

The book suffers from inexcusably poor editing and proof reading. For example, the word ‘predominant’ is misspelt three times on pages 3 and 4. The Preface states that SI units are used throughout the book but that curious non-SI unit, the troland, is not only used but is variously misspelt as troland and trolard. Would you recognize ‘c/m rad’ as an abbreviation for cycles per milliradian?

The volume is certainly not ‘one that libraries must have’, but I recommend it to researchers on visual acquisition as a useful reference.
The Biological Effects of Electromagnetic Radiation
A conference will be held in Sydney from 28-29 August, 1978 and repeated in Melbourne, 31 August - 1 September, 1978. The scope of the seminar is intended to consider the immediate, short term and long term, harmful biological effects of electromagnetic radiation at all frequencies between ELF and SHF.
Information is available from: The Secretary, IREE-ERDA Seminar, The Institution of Radio and Electronics Engineers (Aust.), Box N127, Grosvenor Street Post Office, Sydney, NSW 2001.

Australian Acoustical Society Annual Conference
This conference will be held in Sydney from 1-3 September, 1978. Further information: Mr Waugh or Mr Macrae, National Acoustics Laboratories, 5 Hickson Road, Mullers Point, NSW 2000. Telephone (02) 20537.

11th International Engineering Exhibition

International Astronomical Union
The first Asian-South Pacific Regional Meeting of the above organisation will be held in Wellington, New Zealand from 5-8 December 1978. Information can be obtained from Dr B. J. Robinson, CSIRO, Epping, NSW 2112.

Changing Trends in Variable Star Research
An IAU colloquium will be held in Hamilton, New Zealand from 27 November - 1 December 1978. Further information may be obtained from F. M. Bateson, 18 Poole's Road, Greerton, Tauranga, New Zealand.

Gaseous Electronics
The 1978 annual gaseous electronics conference will be held on 17-20 October in Buffalo, New York, USA. This is a topical conference of the American Physical Society and is sponsored by the Division of Electronic and Atomic Physics.
Enquiries should be addressed to Professor D. M. Benenson, Department of Electrical Engineering, State University of New York, 4232 Ridge Lea Road, Amherst, NY, 14226, USA.

International Spectroscopy
The 21st colloquium spectrosopicum international and 8th internation conference on atomic spectroscopy is to be held in Cambridge UK on 1-6 July 1979. The conference is being sponsored by the Association of British Spectroscopists under the auspices of the Royal Society, Chemical Society and Institute of Physics.
All branches of spectroscopy will be covered but particular emphasis will be placed on the general theme of analytical spectroscopy. Specific one, two and three day symposia will be arranged to feature advances in the following: molecular, x-ray, optical emission and atomic absorption spectroscopy, x-ray and neutron activation techniques, mass spectrometry and Auger, ESCA and photoelectron spectroscopy.

Materials Under Strain
A conference will be held at the Department of Engineering Science, University of Oxford, on 28-30 March 1979, sponsored by both the Materials and Testing Group of the Institute of Physics and by the Institution of Mechanical Engineers.
Information about the programme may be obtained from Dr J. Harding, Department of Engineering Science, University of Oxford, Parks Road, Oxford OX1 3PJ, UK. Registration forms are available from the Meetings Officer, Institute of Physics, 47 Belgrave Square, London SW1X 8QX.

Future Energy
An international conference on future energy concepts will be held at the IEE London on 30 January - 1 February 1979. Information: IEE Conference Department, Savoy Place, London WC2R OBL.

Laser-Plasma Interactions
A conference will be held at the University College of North Wales, Bangor on 4-5 January 1979. Information may be obtained from: The Meetings Officer, Institute of Physics, 47 Belgrave Square, London SW1X 8QX.

IMS Symposium 1979
The first major Symposium on the results of the International Magnetospheric Study (IMS) will be held at the Symposium of the International Association of Geomagnetism and Aeronomy (IAGA) as part of the General Assembly of the International Union of Geodesy and Geophysics (IUGG).
The IMS Symposium will be held at La Trobe University in Bundoora, a suburb of the city of Melbourne, Victoria, Australia, from Tuesday November 26th to Saturday December 1, 1979.
The rest of the General Assembly of IUGG will be at Canberra in the following two weeks.
To register for the IMS Symposium write to:
Dr. B. P. Lambert
Executive Director
Organising Committee
XVII Assembly General of IUGG
Australian Academy of Science
PO Box 783
Canberra City, ACT 2601, Australia.