The Australian Institute of Physics

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ADDRESS:
Science Centre,
35-43 Clarence St.,
Sydney, NSW 2000.
Telephone 29 7747. Telex 25578.

CONFERENCE

Australian Conference on Molecular Physics and Quantum Chemistry
Sydney Science Centre, 17-20 February, 1980.
The Conference is sponsored by a number of organisations including the Australian Institute of Physics. It will bring together chemists and physicists, experimentists and theoreticians, involved in the fields of atomic and molecular physics, chemical physics and quantum chemistry.

It is anticipated that a number of scientists from overseas will attend the Conference, including: R. Ahlrichs (Karlsruhe); R. A. Bonham (Indiana); R. J. Buenker (Wuppertal); G. F. Diercks (Munich); A. Faessler (Julich/Bonn); M. L. Klein (Ottawa); W. C. Lineberger (Colorado); F. Lindner (Kaiserslautern); W. Meyer (Kaiserslautern); J. H. Moore (Maryland); R. K. Nesbet (San Jose); S. D. Peyerimhoff (Bonn); G. Scoles (Waterloo/Trento); K. Takayanagi (Tokyo); J. P. Toennies (Gottingen).

Submitted papers are sought in the following areas:
- Electronic, atomic and molecular collision processes
- Interaction of radiation with atoms, molecules and ions
- Electronic and vibrational structure of many electron systems
- Intermolecular forces and molecular dynamics
- Energy transfer in gases
- Applied quantum chemistry

A brochure giving further details concerning registration, submission of abstracts and program can be obtained from The Secretary, MPOC, Science Centre, 35-43 Clarence Street, Sydney NSW 2000.

Questions regarding the scientific content of the Conference should be directed to Dr. R. O. Watts, The Australian National University, P.O. Box 4, Canberra ACT 2600.
PRESIDENT’S COLUMN

On a visit to a research laboratory recently, the question arose of the relative importance of pure and applied research in physics. Two things seemed to be assumed and they arise frequently in such discussions: firstly, that the two kinds of physics are easily differentiated and, secondly, that pure research was harder (and better in some unspecified sense) than applied research. I have always found both assumptions difficult to accept in general. Certainly very abstract theoretical physics must be accepted as pure but a lot of research is done within a framework of accepted knowledge. In the language of Thomas Kuhn in his book “The Structure of Scientific Revolutions,” this would be called working within the paradigm of the research field. For me the boundaries between pure and applied physics are by no means sharp.

EDITORIAL

The September 1979 issue of the Cern Courier celebrates the 25th Anniversary of the establishment of CERN. It is a place where many Australian physicists have worked or visited and returned enlivened with new ideas which they have passed on to their colleagues. This establishment, which transcends national boundaries, is both a scientific centre and a political experiment—a guide for new centres in new areas of big science in other parts of the world. The Japan - India - Australia triangle with a centre of gravity in S.E. Asia is a possible grouping to which we might make a proper contribution.

The issue contains extracts from three speeches and their flavour is perhaps best gathered by quotations from three well-known people:

V. Weisskopf:
Seven. . . For me the development of CERN in the last three decades is not only an impressive story of success but also a fulfillment of a dream. Our dream was to see a great and active laboratory of fundamental physics in Europe that transcends national boundaries and is a symbol of a bright future, when humanity will be united and when national pride does not refer to any specific country but refers to the whole of our great planet Earth.

Professor Casimir:
. . . it must be admitted that particle physics has now been with us for more than forty years . . . If practical applications finally do appear, the time delay between fundamental research and application will have been unusually long. From this I conclude that if applications turn up they will almost certainly be far outside the range of our present technology and even beyond the scope of our imagination.

I hope that the time-lag will be longer still. Nuclear physics has put into the hands of mankind formidable power. We are still struggling with the problem of how to use nuclear energy efficiently and safely, we are rightly alarmed at the accumulation of nuclear weapons of annihilation. Until mankind has shown that it can deal wisely with nuclear power, it is not prepared for something entirely new. Until the last nuclear warhead has either been dispatched to outer space or quietly blown up as fuel in an energy-producing reactor, I would not welcome an entirely new development. I have often said that I am in favour of supporting high energy physics, providing that the high energy physicists can promise not to produce applicable results within the next twenty-five years. I am usually not taken seriously when I make such remarks. I do, however, mean them very seriously.

Professor Tellnic:
. . . in order to realize the promise that physics holds out to us, it is essential that there should be continuity in the slow and difficult acquisition of knowledge. If continuity is broken, people are soon dispersed, confidence and optimism evaporate, young people are no longer attracted. The creation of a laboratory is a long and painstaking process: it is not done by merely assembling people, any more than a forest is created by merely planting trees next to each other.

H C Bolton

Bill Bondy
INSTITUTE AFFAIRS

At the meeting of the AIP Executive held on 4 September 1979, the welcome news was received that the Australian Journal of Physics is flourishing in spite of recent difficulties and may go from six to twelve issues per year. Discussions within the Australian Academy of Science and the Australian Institute of Physics have stressed that publication of the AJP is an important national function performed by the CSIRO. Australian science has progressed past the stage at which it is essential to publish overseas to gain recognition and an Australian journal can help in many ways to foster and publicize a lively physics community in Australia.

It is not only publishing activities that are under pressure. A continuing sequence of inquiries and falling student members are bringing one department after another under scrutiny. The AIP Executive decided that this is a topic which requires action. Contributions are being collected which will provide a definition of the proper framework of physics activity which must be maintained to ensure sound training of future generations whether they are embarking on a career in physics itself or in other fields requiring a knowledge of physics. An AIP leaflet on careers in physics is also being prepared.

The AIP has approved the following two courses as meeting the standards for corporate membership of the Institute:

B.App.Sc. with major in physics at the NSW Institute of Technology;

Biophysics Programme within the B.Sc. course with major in physics at the University of NSW.

R. Bird
Hon. Secretary

BOOK OFFERS

Unfortunately the supply of copies of A Random Walk in Science ran out before all the AIP orders had been filled. The IOP have indicated that this book will be reprinted — possibly by the end of the year. However, it has been decided to refund payment to AIP members whose orders have not been fulfilled and we apologize to them for this situation even although it has been outside our control.

LETTERS

Dear Sir,

The scene is England. A travelling circus is wending its way from one small town to another. The seventeen elephants are strung out in single file and decreasing size, each one holding the tail of the one in front, as is the custom with elephants.

They come to a level crossing. All is clear, but the elephants take so long on the crossing that a train arrives and hits the last one for six. The train stops and the driver and his assistant walk back to look at the dead elephant; the assistant goes further back to contact the circus. On returning he says “Bill, we’ve made a terrible bloody mess of them.” “What do you mean? Them? We only hit this last little one,” “But” says the assistant, who is studying physics at the Open University, “When we hit it we started a chain reaction and have pulled all the tails off the other sixteen.”

Tell me, if I tell this didactic story will I be in trouble with the RSPCA?

D. H. Macey
Floreat Park, W.A.

Dear Sir,

I am writing in response to the invitation from the AIP Membership Committee to comment on the membership qualifications for the Institute.

I have long been of the opinion that the distinction between the Graduate, Member and Fellow grades are unnecessary particularly since I have never viewed the distinction between the grades as conveying any academic standing additional to those qualifications already held by the Member. I have had the point made to me that this is a narrow viewpoint, based upon University employment, which neglects the significance which is attached to the Fellowship grade outside University circles.

Should this be so, and I have yet to be convinced that there is any evidence for it, then I would accept the desirability of retaining the Fellow Grade only if the entry requirements were more consistent with proven achievement rather than appropriate length of service. As it stands at present, I see little value in applying for Fellowship and I have declined all invitations to do so.

I would rather see the conditions for election to Fellowship elevated to be more compatible with those currently applied for Honorary Fellowship. Could not both grades be amalgamated and membership restricted to, say, no more than 5% - 10% of the total membership.

I strongly support the suggestion that the Graduate and Member Grades could be amalgamated. Furthermore, I believe the Institute should broaden its outlook on membership and dispense with the distinction between Member and Associate.

T. F. Smith
Department of Physics
Monash University, Victoria
The very successful series of meetings of the Victorian Branch continued with two topics concerned with energy.

In June, Professor A. E. Ringwood from ANU discussed SYNROC, his suggested solution to the problem of nuclear waste disposal. SYNROC is synthetic rock whose constituent minerals are capable of incorporating all but two of the radioactive elements produced in a reactor. It is much more stable in conditions of high temperature and pressure than borosilicate glasses, the alternative substances in which the waste could be incorporated. Although radiation damage tests are still to be carried out, the natural occurrence of similar materials, which have retained all their radioactive atoms for over 20 million years, encourages confidence in the stability of SYNROC.

The process of incorporating radioactive waste into SYNROC, by sealing the mixture in a nickel container and hot-pressing it is being developed in Sweden. In comparing the two methods of waste disposal, Professor Ringwood claims not that borosilicate glasses are inadequate, but that SYNROC is much better, and it is no more expensive. Waste incorporated in SYNROC could be deposited either in drill holes or in mined repositories. Consequently he believes that the waste disposal problem can no longer be considered the prime objection to the use of nuclear power.

A different aspect of energy provision was presented in July by Professor J. Goodenough from Oxford University in his talk “Solar Energy: Challenges to Materials Science”. After a summary of the advantages of solar energy and the major paths of solar energy conversion, he concentrated on two aspects: the conversion of low temperature heat from a solar collector to air conditioning, and the development of efficient photovoltaic cells.

One possible solution to the first problem was presented, but only a motion picture could do justice to the device. Basically it involves a hydrated salt or similar substance which absorbs water at low temperatures and loses it at high temperatures. As this substance goes through its cycle of heating during the day and cooling at night, the water circulates through a system of reservoirs and heat exchangers. When the water is driven off, it supplies heat, e.g. to preheat water for a hot water system, and when it is reabsorbed it draws heat from a cold store which then provides the air-conditioning.

To convert solar energy into electrical energy in a photovoltaic cell, both a potential difference and a current must be obtained. This requires the separation of the electrons and holes produced by the absorption of the solar radiation, a process which may be conveniently achieved using a semi-conducting electrode in the cell. Professor Goodenough spent the remainder of his talk describing some attempts to develop a system in which the band gap gives reasonable efficiency with solar photons, and the electrodes are chemically stable enough that it is the water, and not an electrode, which decomposes.

In August the Branch meeting took the form of a tour of the Kodak Research Laboratories, Coburg. After a general introduction during which the preparation of a simple emulsion was demonstrated, the party was broken up into small groups for the tour. This highlighted the scientific and technological activities on which the photographic industry is based. Demonstrations included static electrification experiments, radiometry and densitometry, particle-size analysis and the coating, printing and processing of the emulsion prepared earlier in the evening. In all it was a very successful evening and the Branch greatly appreciated the warm hospitality offered by Kodak.

The Victorian Youth Lecture series was also held during July and August with well attended talks being given at Horsham, Bendigo and Melbourne. This year’s Youth Lecturer was Dr. Graham Sargood from Melbourne University. His topic was ‘wave motion’ and incorporated a wide variety of excellent demonstrations involving light, sound and electromagnetic waves, with digressions to water waves and the problems of boating.

Dr. Sargood’s lively presentation was a joy to watch and his talks were greatly appreciated by both students and teachers. One was left with the distinct impression that physics could be fun.

J. Pollard  
T. F. Smith

The Vacuum Physics Group Committee:

Chairman: Dr. D. B. Prowse  
Secretary/Treasurer: Mr. J. J. Gosling  
Members: Mr. J. A. Birch  
Dr. R. C. Kemp

The address of all members is:

National Measurement Laboratory,  
P.O. Box 218,  
LINDFIELD, NSW. 2070.

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OBITUARY——PROFESSOR JOHN CONRAD JAEGGER

Professor John Conrad Jaeger, Emeritus Professor of Geophysics in the Australian National University, died on May 15, 1979 after a long illness, aged 71 years. Born in Sydney on July 30, 1907, he was educated at the Church of England Grammar School, Sydney, and at the University of Sydney from which he graduated Bachelor of Science in 1928 with first class honours and university medals in mathematics and physics. In that year he proceeded to Cambridge University where he obtained first class honours in Mathematical Tripos. Following five years of research at Cambridge in theoretical physics, he joined the University of Tasmania in 1936 as Lecturer in Mathematics, subsequently becoming Professor of Applied Mathematics in that University. In 1942 he was awarded the degree of Doctor of Science in the University of Sydney.

Shortly after the founding of the Australian National University, John Jaeger was invited to accept a Chair and to set up a Department in the Research School of Physical Sciences. He took up his appointment as Professor and Head of the Department of Geophysics in 1952, and remained in that post until his retirement in 1972. Under his direction, the Department of Geophysics developed rapidly into one of the leading research groups of its kind in the world. In 1965, it became the Department of Geophysics and Geochemistry and more recently (1973), was reconstituted to form the Research School of Earth Sciences, at least in part in recognition of the high international reputation that the Department established under John Jaeger’s leadership. The direction of development of the Department was largely based upon his strongly held belief that the application of the basic sciences of mathematics, physics, and chemistry, in concert with more conventional geological methods, to the study of the earth, would result in major advances in our understanding of the origin and history of the earth. His recognition of the importance of interdisciplinary fields, together with his ability to attract staff and students, were major factors in the establishment of the high reputation of the Department, both nationally and internationally, in a relatively short period. Studies undertaken in the Department played a significant role in the revolution that has taken place during the last 15 years concerning understanding the earth. As part of this revolution the long-debated hypothesis of continental drift now has virtually universal acceptance.

John Jaeger had a most distinguished career as mathematician, physicist and geophysicist. His scientific contributions covered an extraordinarily diverse range of interests, including theoretical physics, radiophysics, ionospheric and solar physics and meteorology, but the main emphasis of his research was in the application of mathematical techniques to a wide variety of theoretical and practical problems, especially the conduction of heat. On establishing the Department of Geophysics in the Australian National University he embarked upon vigorous experimental programmes concerned with heat flow in the Australian continent, and the behaviour of rocks under stress (rock mechanics). John Jaeger was a man of great scholastic achievement; he published more than 130 articles in the scientific literature, and was author and coauthor of six books in applied mathematics and rock mechanics, which are regarded as standard works in their fields. His book (with Carslaw) *The Conduction of Heat in Solids* is widely accepted as a classic in this area.

In recognition of his achievements, Jaeger, in 1954, was elected a Fellow of the Australian Academy of Science, of which body he was Vice-President in 1958-1959, and in 1970 he was elected a Fellow of the Royal Society (London). He was also Doctor of Science (honoris causae) of the University of Tasmania. In 1971, he was awarded the Rankine Lecture by the Institution of Civil Engineers (London).

John Jaeger was a big man, both physically and mentally. He was a man of great humanity but basically very shy. He never sought the limelight and was extremely modest about his own achievements. He set high standards for himself and expected staff and students alike to strive for excellence. His influence in many fields, including the earth sciences, in Australia and indeed in the world, has been profound. He will be sorely missed.

Ian McDougall

"In this monograph I have attempted to set out, in as elementary form as possible, the basic mathematics of the theories of elasticity, viscosity, and rheology, together with a discussion of the properties of the materials involved and the way in which they are idealized to form a basis for the mathematical theory. There are many mathematical text-books on these subjects, but they are largely devoted to methods for the solution of special problems, and, while the present book may be regarded as an introduction to these, it is also intended for the large class of readers such as engineers and geologists who are more interested in the detailed analysis of stress and strain, the properties of some of the materials they use, criteria for flow and fracture, and so on, and whose interest in the theory is rather in the assumptions involved in it and the way in which they affect the solutions than in the study of special problems."

J. C. Jaeger
AIP YOUTH LECTURE
BUDGETING WITH ENERGY

Dr. R. A. O'SULLIVAN, Senior Lecturer, Department of Applied Physics. R.M.I.T

This is a condensed version of the 1978 Youth Lecture sponsored by the Victorian Branch

THE PROBLEM

Whenever supplies are limited, there is a need to budget. The most familiar example involves money. If we have a fixed allowance, with which to buy lunches, pay for entertainment and fares, or save for a holiday, we try to spend our money efficiently, not buying lunches so expensive that nothing is left for other needs.

If we look at natural systems, we find that they have evolved ways of budgeting with substances which are in short supply. The camel, for example, has a number of clever techniques for conserving water. On the other hand, substances which are abundant are often used inefficiently. Perhaps the most wasteful creatures on earth are human beings. Where supplies of water, food, minerals and energy are abundant, we organize our use of them not to maximise efficiency but to maximise our convenience. As long as supplies remain abundant and provided our inefficient use does not cause excessive pollution, this is a reasonable way to behave.

Our present way of life developed in a world where wood, coal and later oil were abundant. Under these circumstances, we invented the motor car and later developed it by adding on the automatic transmission, heaters, air conditioners, power steering and brakes and even electrically operated windows. All of these added to our comfort and sometimes our safety but they also increased the energy consumption. Similarly, we built houses with large windows, plenty of uncontrolled ventilation and poor insulation because they were pleasant to live in and less expensive to build, but we had to use large amounts of fuel to heat them in winter. As the world's population has grown, energy consumption has grown even faster, with little improvement in the efficiency of energy consumption and not much effort to develop new sources of energy.

Until recently, almost all our energy was provided by burning wood, coal, oil or gas. These fuels are forms of solar energy, converted by plants using photosynthesis. Coal, oil and gas are fossilized forms of vegetation and hence are called "fossil fuels". It took hundreds of millions of years to build up the earth's store of fossil fuels, but if our present rate of consumption continues, they will be exhausted in a couple of hundred years. Hence we are using them about a million times faster than they are being replenished (see Fig. 1). For practical purposes, fossil fuels can be regarded as non-renewable forms of energy. It was therefore inevitable that, sooner or later, they would become scarce.

We have now begun to see other sources of energy, but these also have their limitations. A recent estimate of Australia's energy resources is given in Fig. 2. Realising the limitations of traditional energy resources, people now talk of the need to "conserve" energy or to use it more efficiently. To understand the arguments involved, we must understand what energy is and how it changes from one form to another.

AUSTRALIAN RESERVES

Millions of Terajoules

- 26.7% Coal (295)
- 26.6% Oil (10)
- 26.6% Gas (173)
- 0.3% Gas Liquids (2.8)
- 20.6% Uranium (225)
- 40% Black Coal (514)

Fig. 2. Source: Victorian Government, 1977.

WHAT IS ENERGY

All human activity involves physical change and all physical change involves energy transfer from one object to another or energy transformation from one form to another. Energy is defined in physics as the capacity to do work and work is done whenever a force moves an object through a distance.

The use of energy is governed by the First and Second Laws of Thermodynamics. The first law states that energy can neither be created nor destroyed. This may provoke the question: how can we have an energy crisis if energy is never destroyed? In order to answer this question and to lay the foundations for energy budgeting, we must introduce the concept of "energy quality" or "grades of energy"; energy cannot be created or destroyed, but different forms of energy are not equivalent.

Fig. 1. World Energy Consumption (kWhr/years) (Chapman 1975c)

Extrapolation at constant growth rate from 1970. (This is not expected to occur.)

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For our purposes, energy can be divided into five kinds: three kinds of potential energy, that is, energy stored by the various fundamental forces in nature and two kinds of kinetic energy, i.e. energy of motion. The three kinds of potential energy are:

(i) gravitational, for example, the energy stored in water in a high reservoir, which can do work by falling onto the blades of a turbine.

(ii) electromagnetic, including the chemical energy stored in food, hydrocarbon fuels or charged batteries and the wave energy of sunlight, x-rays or radio waves.

(iii) nuclear, including the binding energy released when a nucleus of uranium 235 breaks up or when two deuterium nuclei fuse to form helium.

The two kinds of kinetic energy are:

(i) ordered kinetic energy, for example, the energy of a moving vehicle;

(ii) the random or disordered kinetic energy of the atoms or molecules of a hot body; this form of energy is called heat.

A comparison of the last two kinds of energy gives a straightforward introduction to the idea of energy quality. The ordered kinetic energy of a motor car moving at 100 km/h can be used in a variety of ways: it can transport the passengers several hundred metres along the road as the car rolls to a stop, or it can produce considerable deformation in the car body or other objects in a collision; alternatively, it could generate enough electricity to keep a 100 watt bulb burning for over an hour. But if the brakes are applied and the car is quickly brought to rest, its energy is transformed into heat, initially in the brake drums and linings, rapidly diffusing into the road and air, leaving the environment infinitesimally warmer than it was before. No energy has been destroyed but energy has been converted from a useful to a useless form.

Degradation into low temperature heat is in fact the ultimate fate of every unit of energy involved in every industrial or biological process on earth. When coal, oil or gas are burnt in a power station to produce electricity, approximately one third of the initial energy content is unavoidably lost to the environment as heat via the cooling water or air, one third is converted to heat by friction and one third is converted into electricity. From the moment it leaves the power station, the electrical energy itself begins turning into heat, and the last remnant is degraded to heat in the bearings of electric machinery or in the walls and furnishings which absorb the radiation from electric lights or heaters.

To provide domestic or commercial heating, the coal, oil or gas could have been burnt directly at the point where the heat was required. In this case one would need only a third to a half of the fossil fuel which would have been burnt at the power station to provide the same amount of heat from electric resistance heaters. Some waste gases would then be released at the point of use, instead of two to three times the amount at the power station. The decision between these alternatives would depend on the relative values placed by decision makers on

(i) saving fuel, and

(ii) clean air.

If the power station happens to be sited in the middle of a city, however, the decision ought to be simple!

The grade of a particular form of energy is expressed quantitatively by its “available work” (or by the related concept of “free energy”). The available work of any form of energy is the maximum amount of work that it can perform under any circumstances. This quantity is significant because available work is the best overall measure of ability to perform any task. Electrical and gravitational potential energy are high grade forms of energy - they can be converted to work with a theoretical efficiency of 100%.

In practical devices the efficiency is always somewhat lower: electric motors have efficiencies of over 90% and hydro-electric power stations convert the gravitational energy of stored water to electricity with an efficiency of about 80%. The chemical energy stored in petrol and coal can be converted to work with a theoretical efficiency of 100% but there is no existing device (such as an idealised fuel cell) capable of doing this. Actual power plants only achieve efficiencies of 20 to 30%. This is because such power plants, which form the backbone of existing technology, perform work via the medium of heat energy, obtained by burning fossil fuels. Heat is a low grade form of energy; its available work is given by the Second Law of Thermodynamics, which relates the amount of work available to the difference between the engine’s operating temperature and the temperature of the environment. Since operating temperatures are limited by the properties of the metals used in the construction of engines, the theoretical maximum efficiency of conventional engines (including steam or gas turbines, internal combustion engines and steam piston engines) is only about 65%.

The concept of available work leads to the definition of Second Law Efficiency. This is a much more useful concept in defining energy goals and policies rather than the traditional First Law Efficiency. First Law Efficiency is defined as:

Energy transfer (of desired kind) achieved by the device (or process) divided by the energy input to the device.

Second Law Efficiency may be defined as:

Minimum available work capable of doing the task divided by the actual available work used by the device (or process to perform the work).

The emphasis given by Second Law Efficiency to the task to be performed is important. Since the Second Law Efficiency for converting electricity to work is only 90%, whereas for heat engines using coal and oil it is only 20-30%, it makes good sense to use electricity to perform work, e.g., for propelling vehicles or bending metal sheets. In this case, the overall efficiencies for conversion of the original fossil fuel to work are similar, but the centralised burning of fossil fuel to generate electricity allows more efficient pollution control and more efficient maintenance. If, on the other hand, the task is to provide heat, the use of electricity in resistance heaters is wasteful.

To illustrate the difference between First and Second Law Efficiencies, consider a domestic heater using oil or gas. This might be described as “60% efficient” (First Law Efficiency), meaning that the ratio of heat usefully delivered within the house to the heat of combustion of the fuel is 0.6. This measure suggests that a 100% efficient furnace would be “perfect”, which is incorrect. One could do better in various ways - for instance, by feeding the fuel to an engine driving a heat pump. This

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Heat output kW</th>
<th>Power consumed kW</th>
<th>COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>3.4</td>
<td>2.96</td>
<td>1.15</td>
</tr>
<tr>
<td>30</td>
<td>4.06</td>
<td>2.96</td>
<td>1.35</td>
</tr>
<tr>
<td>70</td>
<td>2.63</td>
<td>2.08</td>
<td>1.26</td>
</tr>
</tbody>
</table>

Source: Freund et al. (1976).
is a device which extracts heat from the surroundings and "pumps" it into the house (like a refrigerator in reverse). A heat pump could provide more heat to the house than the heat of combustion of the fuel.

The ratio of the heat delivered inside the house to the energy consumed by the heat pump is called its "coefficient of performance" (COP). Table 1 gives the COPs of some commercially available heat pumps.

The maximum value of Second Law Efficiency is 100% in all cases (which is not the case for First Law Efficiency). Hence it provides an immediate insight into the quality of performance of any device, relative to what it ideally could be. It shows how much room there is for improvement in principle and provides an absolute measure of the waste of fuel. Estimated overall Second Law Efficiencies for the United States are given in Table 2.

**TABLE 2 Estimated Overall 2nd Law Efficiencies (C)**

<table>
<thead>
<tr>
<th>ENERGY USE CATEGORY</th>
<th>% OF U.S. FUEL CONSUMPTION</th>
<th>ESTIMATED OVERALL 2ND LAW EFFICIENCIES (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic:</td>
<td></td>
<td></td>
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<tr>
<td>Space Heating</td>
<td>10</td>
<td>0.06</td>
</tr>
<tr>
<td>Water Heating</td>
<td>4</td>
<td>0.03</td>
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<tr>
<td>Cooking</td>
<td>1.3</td>
<td></td>
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<td>7.5</td>
<td>0.05</td>
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<td>Refrigeration</td>
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<td>0.04</td>
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<tr>
<td>Industrial:</td>
<td></td>
<td></td>
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<tr>
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<td>Direct Heat</td>
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<td>Electric Drive</td>
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<td>0.3</td>
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<td>Electrolytic Process</td>
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</tr>
<tr>
<td>Transportation:</td>
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<td></td>
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<tr>
<td>Automobile</td>
<td>13</td>
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</tr>
<tr>
<td>Truck</td>
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<td>0.1</td>
</tr>
<tr>
<td>Bus</td>
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<td>0.2</td>
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<td>Train</td>
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<td></td>
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<tr>
<td>Aeroplanes</td>
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<tr>
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</tr>
<tr>
<td>Total</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

(* = unknown)

(Source: Efficient Use of Energy, American Institute of Physics, Conference Proceedings No. 25, 1975.)

The end use allocation of primary fuels, 1970-71.

**Fig. 3. Source: Kalma, 1976.**

**HOW WE USE ENERGY**

Fig. 3 shows how primary energy is used in Australia. Primary energy is energy in the form in which it is extracted from its source. Crude oil and black coal are forms of primary energy. Primary energy is usually processed to some degree before it is supplied to the consumer. The forms of energy which result from this processing are called secondary energy. Petrol, coke and electricity are examples of secondary energy. As we have seen, all energy conversion processes consume some energy so that each unit (joule) of primary energy produces less than one unit of secondary energy. In Australia, about 26% of primary energy is dissipated in conversion losses and the remaining 74% is available for consumption. Fig. 4 shows how this 74% is divided between the various sectors of the economy.

![Diagram showing energy allocation](image)

The end use of primary and secondary fuels, 1970-71 (excluding conversion losses in electricity generation, town gas manufacture, oil refineries and briquette factories).

**Fig. 4. Source: Kalma, 1976.**

Energy budgeting requires detailed information about how much energy is used for different purposes. Each of the sectors in Fig. 4 can be divided into sub-sectors and these in turn can be divided to give a detailed picture of the use of energy in the community. In Fig. 5, for example, we see the breakdown of domestic electricity consumption for the two largest Australian cities and, for comparison, of the U.S.A. There are obvious differences between consumption in these three regions, which are partly due to climate and lifestyle, but also due to the use of other forms of energy, e.g. natural gas.

Fig. 6 shows the energy consumed by various appliances which are included under the "Miscellaneous" heading in Fig. 5.

![Graph showing energy consumption](image)

The use of electricity in the domestic sector in 1970 in Sydney and Melbourne, and in 1968 in the USA.

**Fig. 5. Source: Kalma, 1976.**

The Australian Physicist, October 1979 143
Average annual electricity use of some individual household appliances and average electricity use for miscellaneous appliances per consumer household. Fig. 6. Source: Kaima, 1976.

In the light of such information, we can estimate the potential energy savings of substituting one device for another. For example, we can see that an electric clothes dryer is a large consumer of electricity. On the other hand, there is a well-known alternative way of doing the same job: the solar clothes dryer, consisting of a few metres of cord and some pegs! A slightly more sophisticated form of solar clothes dryer, the "Hills Hoist" can be converted to a wind-powered clothes dryer in winter by being covered with a plastic sheet.

It is obvious that a solar clothes dryer saves the energy required to run an electric dryer, but it also requires much less energy to produce. In other words, the solar clothes dryer has a lower capital energy cost as well as a lower energy running cost. In order to compare the capital energy costs of different devices, we need to know the primary energy costs of materials and manufacturing processes. For example, about 300 Megajoules of primary energy are used in mining, processing and melting to produce one kilogram of aluminium and about 60 Megajoules are required to produce a kilogram of steel. By adding the energy costs of all the materials and manufacturing stages, it has been calculated that it takes about 100,000 Megajoules to produce a 1500 c.c. motor car and about 900,000 Megajoules to produce a 142 square metre house (Chapman, 1975a, Hill 1978).

In an energy-conscious world, it is necessary to compare both the running costs and the capital costs if we want to decide between alternative devices to do the same job. For indoor lighting, we can choose between incandescent bulbs and fluorescent tubes. It takes 2.7 Megajoules to produce a 60 watt incandescent bulb and 10 Megajoules to produce a 40 watt fluorescent tube. The tube is more efficient at converting electrical energy into visible light than the bulb and one tube produces about as much light as four bulbs. Fig. 7 shows that the tube uses much less energy over its lifetime. (The higher initial energy requirement for the fluorescent light is due to the energy cost of the starter and the fitting which holds the tube).

![Energy Consumption vs Time](image)

**Fig. 7. Energy Consumption of Incandescent and Fluorescent Lighting Systems (O'Sullivan, Goss & Owen).**

It is difficult to compare machines which use different kinds of energy. Most cars use petrol but some people suggest that we could save energy by using battery-powered cars. We must remember, however, that batteries are charged from the electricity supply and most electricity today is produced by burning fossil fuel. If the electric power station burns oil, it can be calculated that it takes approximately the same amount of oil to run an electric car as it does to run a petrol-driven car (see Table 3). In the case of electric cars, fossil fuels are burnt in the power station to produce electricity, which is carried by transmission lines to the charging station, stored in the car's batteries and finally converted into useful work by the electric motor. In the conventional vehicle, the fossil fuel is refined to produce petrol, which is transported to the filling station, stored in the car's petrol tank and finally converted, rather inefficiently, into work by the internal combustion engine. As shown by Table 3, the overall efficiencies of the two systems are about the same. Knowing this, one can compare other aspects of the two systems. The petrol-engined vehicle has a higher power/weight ratio, a long development history and is integrated into our existing way of life. On the other hand, the electric car produces no pollution at the point of use and offers the possibility of further improvement in efficiency, by the use of "regenerative braking", i.e. using the motor in reverse as a generator driven by the rear wheels, as a means of stopping the car. Furthermore, the electric car can use electricity produced from gravitational ("hydro"), nuclear or solar energy.

**TABLE 3**

<table>
<thead>
<tr>
<th>Units of Primary Fuel given:</th>
<th>Electric Car</th>
<th>I.E.C. Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units of Energy supplied to vehicle</td>
<td>25 (electricity in batteries)</td>
<td>31 (petrol in fuel tank)</td>
</tr>
<tr>
<td>Units of Energy lost in power train at constant speed</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Useful Work of Propulsion:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) at constant speed</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>(b) in urban driving</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>

The fact that a pure electric car and a conventional petrol-driven car may both consume about the same amount of fossil fuel energy leads us to consider other kinds of vehicles. One alternative is the petrol-electric or diesel-electric hybrid car. This is a vehicle which uses a small petrol or diesel engine, running at its most efficient speed, to charge a battery and propel the car by means of an electric motor. Such a car can use fossil fuel much more efficiently than either a conventional or a purely electric car.
Our comparison on the overall efficiencies of electric and petrol-driven cars indicates finally that we cannot consider the efficient use of energy in isolation from the way energy is produced.

HOW WE PRODUCE ENERGY

We have seen that materials and processes can be costed in terms of energy. But the energy we use is itself a product with an energy cost and we need to consider the "energy cost of energy". We know that energy is consumed in converting primary energy (e.g. coal) into secondary energy (e.g. electricity) so that, on average, 3 to 4 joules of coal energy are required to produce 1 joule of electrical energy. But there is an energy cost even when primary energy is delivered direct to the consumer: coal mining and oil refining, for example, both require energy and energy is also required to drive coal trains and petrol tankers. Table 4 gives the efficiencies of the main energy industries in Great Britain.

**TABLE 4 Efficiencies of Energy Industries**

<table>
<thead>
<tr>
<th>Industry</th>
<th>1968</th>
<th>1969</th>
<th>1971/72</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>1.042</td>
<td>95.49</td>
<td>95.49</td>
</tr>
<tr>
<td>Coke</td>
<td>1.181</td>
<td>94.71</td>
<td>75.54</td>
</tr>
<tr>
<td>Gas</td>
<td>1.390</td>
<td>71.92</td>
<td>64.74</td>
</tr>
<tr>
<td>Oil</td>
<td>1.234</td>
<td>89.21</td>
<td>80.92</td>
</tr>
<tr>
<td>Electricity</td>
<td>1.495</td>
<td>23.45</td>
<td>22.02</td>
</tr>
</tbody>
</table>

*This result is less accurate than others due to lack of date for coke-oven 1971/72.

Source: Chapman et al. (1974).

One of the most important areas of energy budgeting involves new forms of energy. The two most popular new forms today are nuclear energy and solar energy. These are forms of primary energy and, as such, are alternatives to the dwindling reserves of fossil fuel. At present, however, the use of both nuclear energy and solar energy actually depends on the consumption of fossil fuels!

In the case of nuclear power, energy is required to build, equip and service the reactor, to mine, mill and enrich the uranium and to fabricate it into fuel rods. If large amounts of energy are available from existing nuclear reactors, the energy requirement is provided mainly by fossil fuels. The total amount of fossil fuel required depends critically on the grade of uranium ore mined. For high grade ores (e.g. 0.3% uranium oxide), it has been calculated that the ratio of net electrical energy output from the reactor to fossil fuel input ranges from 8 to 19 [Chapman 1975c]. Most of the fossil fuel, however, is consumed before the reactor begins to produce electricity, so that each reactor built represents an initial period (about 5 years) of net energy consumption followed by a longer period (about 25 years) of net energy output. Table 5 shows the ratio of electrical output to fossil fuel input for various kinds of reactors.

There had been a vigorous debate among scientists on the energy budgets of nuclear reactors [Chapman 1975b,c, Brookes 1975, Leach 1975, Symonds et al. 1975]. Two main points have emerged from this debate. Firstly, there is no longer any likelihood of a period of sustained, rapid (exponential) growth in the number of nuclear power stations in which more energy would be consumed than would be produced. Secondly, whether a nuclear power program results initially in a saving of energy or a more rapid depletion of fossil fuel resources depends on how the electricity is used. A nuclear power station can be regarded as a device for producing electricity from fossil fuels (as well as uranium). Overall, it produces several units of electrical energy for each unit of fossil fuel energy used. If this electricity merely replaces electricity from conventional power stations, then the nuclear power program gives a huge reduction in fossil fuel consumption over its lifetime. Some people, however, have promoted nuclear electricity as a primary fuel, feeding an "all-electric economy", in which nuclear power stations would substitute not only for fossil-fired power stations but also for the coal used in industry and for the oil and gas used in motors, boilers and furnaces.

Solar energy is often seen as an alternative to nuclear energy. At present, however, solar energy also involves the consumption of fossil fuel. To be of use, solar energy must be converted into other forms. It is mostly used today to produce hot water in the home. This requires solar collector units, pipes, insulation and a tank. Table 6 shows the energy required to produce a typical flat plate solar hot water system used in Australia today [O'Sullivan, 1979]. The payback time for such a system depends on the amount of sunshine available and varies from place to place. In Sydney, it is about 11 months, in Melbourne about 14 months and in Darwin about 9 months.

**TABLE 5 Energy Ratios for Different Reactors**

<table>
<thead>
<tr>
<th>Reactor Type</th>
<th>0.3% ore (3kg U3O8/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAGNOX</td>
<td>15.1 ± 3</td>
</tr>
<tr>
<td>SGHWR</td>
<td>11.2 ± 2</td>
</tr>
<tr>
<td>PWR</td>
<td>16.5 ± 3</td>
</tr>
<tr>
<td>AGR</td>
<td>10.5 ± 2</td>
</tr>
<tr>
<td>CANDU</td>
<td>11.1 ± 2</td>
</tr>
<tr>
<td>HTR</td>
<td>15.8 ± 3</td>
</tr>
</tbody>
</table>

Fossil fuel stations have E_F = 0.25

Source: Chapman (1975c).

**TABLE 6 Gross Energy Requirements of Flat Plate Solar Hot Water System (O'Sullivan, 1979)**

<table>
<thead>
<tr>
<th>Component</th>
<th>Gross Energy Requirement (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alumina Collector Units</td>
</tr>
<tr>
<td>Materials: Collector Units (2 x 2.16 m²)</td>
<td>11,046 ± 705</td>
</tr>
<tr>
<td>Storage Tank</td>
<td>2,416 ± 430</td>
</tr>
<tr>
<td>Puffer Pipes</td>
<td>681 ± 79</td>
</tr>
<tr>
<td>Total Materials</td>
<td>14,943 ± 1216</td>
</tr>
<tr>
<td>Process Energy</td>
<td>15 ± 5</td>
</tr>
<tr>
<td>Transport</td>
<td>80 ± 20</td>
</tr>
<tr>
<td>Capital Equipment &amp; Buildings</td>
<td>27 ± 6</td>
</tr>
<tr>
<td>Heating &amp; Lighting</td>
<td>6 ± 2</td>
</tr>
<tr>
<td>Total Capital Energy</td>
<td>15,021 ± 1247</td>
</tr>
<tr>
<td>Maintenance (% of capital)</td>
<td>754 ± 151</td>
</tr>
<tr>
<td>Total</td>
<td>15,025 ± 1390</td>
</tr>
</tbody>
</table>


We have seen that both nuclear and solar energy devices are consumers of fossil fuels but give a much greater output of useful energy than the same amount of fossil fuel in a conventional system. There is no violation of the First Law of Thermodynamics, of course, since each device consumes large amounts of non-fossil energy. Interestingly, the payback time for the fossil fuel consumed by some nuclear reactors is similar to that for a solar water heater. The energy...
bunds quoted for nuclear power stations have, however, been criticized because they ignore the possible energy costs of treating and storing nuclear wastes, of dealing with nuclear accidents, of new safeguards which may be imposed and the costs of restoring mining sites to their original condition.

WHERE ARE WE HEADING?

We are now entering an exciting new age in which our technology and our way of life must be adjusted to a change in one of the basic assumptions on which they were built: the assumption that energy was cheap and abundant. The designs of our heaters, our cars, our houses, our aeroplanes and our cities, which may have been reasonable in an age of abundant energy, are now being questioned. There will be plenty of work for the next generation of scientists and engineers if all these systems are to be re-designed to use energy in different forms and to use it more efficiently.

There is already a large amount of research going on to tap sources of energy which are hardly used today. These include wind energy, tidal energy, wave energy, solar energy stored in the warm surface layers of the ocean, geothermal energy and the nuclear energy released by the fusion of heavy hydrogen nuclei. Even before power plants have been designed to use these resources, physics can give some idea of what they may be more profitable to pursue. Energy will have to be used to build devices to collect energy from these new sources and the required energy input will depend, among other things, on the "energy density" of the source, that is, on the amount of energy available per unit volume. The energy density of ocean waves, for example, is greater than that of the wind or the tides. The energy density of an ionized heavy hydrogen gas ("plasma") can be very great, but not as great as that of a solid nuclear fuel. Hence there is research into the possibility of fusion reactors using solid fuel, in addition to the earlier program to develop reactors in which a plasma is confined by a magnetic field.

Research is also being done into more efficient ways of using conventional energy sources: conversion of fossil fuels and sunlight directly into electricity, production of liquid fuels from crops, and nuclear fission reactors which obtain energy from Uranium-235 or Thorium ("breeder reactors"). The development of energy conversion devices which do not involve combustion or heat is very important for the future of mankind. For we have not only reached the point where our energy use has made an impact on the earth's fuel and mineral resources; the waste products of our use of these resources (especially carbon dioxide and heat) are perhaps beginning to affect the earth's climate. We must begin to consider the earth as a single physical system, which has existed for long periods of time almost in a steady state. In such a system, nothing can grow exponentially for very long. One of the biggest challenges for the generation of school is how to adjust society and technology to a steady state world, so that you and your descendants can continue to enjoy the benefits we enjoy today.

REFERENCES

Brookes, L. (1975), N. Scientist 68:143.

SLOW ELECTRONS

As demonstrated in an earlier article,¹ the traditional textbook description of the Franck-Hertz experiment can be incorrect with regard to the physical mechanism by which slow electrons are separated from fast electrons. The result for a more detailed analysis of electron diffusion between the grid and the anode is described here.

The parameter of greatest significance is the ratio \( I_0/(I_0 + I_A) \) for the anode current \( I_A \) and the total current \( I_0 + I_A \) to the grid and anode. The simplest theory uses a zero voltage between the grid and anode and the result is very similar to an earlier one due to Langmuir.² It is \( I_0/(I_0 + I_A) = \frac{4}{3} \left( \frac{E_{\text{res}}}{E} \right)^{2/3} \), where \( E \) is the electron mean free path at energy \( E \), \( L_0 \) is the separation of the grid and anode, \( S_A \) is the inner surface area of the cylindrical anode, \( S_C \) is the total surface area of the grid wires and \( T_g \) is the probability of an electron incident upon the grid being reflected. Note that \( r_A \) does not enter the formula. This is because electrons which manage to reach the anode and are reflected have nevertheless practially no chance of getting back to the grid and are ultimately collected by the anode. The assumptions of the derivations are \( I_0/(I_0 + I_A) < 0.1 \), \( E < 5 \) and \( L < 1 \) radii of the grid and anode. Energy loss by electrons in elastic collisions is neglected. A major uncertainty of the derivation is the complication of a grid electrode is a grid rather than a simpler surface acting as an electron source as in Langmuir's theory.

\( I_0 + I_A \) increases smoothly with accelerating voltage whereas \( I_A \) goes through the usual maxima and minima. This implies that \( \sigma(E) \) varies with electron energy and indeed this effect is well known for atomic vapours as the Ramsauer-Townsend effect.³ \( \sigma(E) \) is inversely proportional to the momentum-transfer cross-section which for mercury vapour has been observed to strongly decrease with electron energy.⁴ The apparent variation of \( \sigma(E) \) in the Franck-Hertz experiment is roughly consistent with the known variation of the momentum-transfer cross-section for mercury vapour.

References

Leo Szilard
'My Version of the Facts'

In Britain there were a number of German refugees such as Simon, Peierls, and Frisch, who at the beginning of the war were not permitted to work on anything of military significance, and therefore took to working on uranium. Simon was interested in the separation of uranium-235; Frisch and Peierls were interested in nuclear properties. Nothing prevented them from talking to each other. They put two and two together and they informed the British government of the possibility of making uranium-235 bombs with quantities of material that were industrially available. The British government informed the American government. So for the first time our attention was directed to the problem of making atomic bombs rather than merely to the problem of making a chain reaction ... For the first time the government realized that our project was important.

Oliphan came over from England and attended a meeting of the Uranium Committee which neither Fermi nor I were permitted to attend. He realized that something was very wrong and that the work on uranium was not being pushed in an effective way. He travelled across this continent from the Atlantic to the Pacific and disregarding international etiquette told all those who were willing to listen what he thought of us. Considerations other than those of military security prevent me from revealing the exact expressions which he used. If Congress knew the true history of the atomic energy project, I have no doubt that it would create a special medal to be given to meddling foreigners for distinguished services, and Dr. Oliphan would be the first to receive one. [Bulletin of Atomic Scientists, April 1979]

Device Gauges Effectiveness of Solar Surfaces

If solar collectors are to perform adequately, their surfaces must absorb a high proportion of the radiation falling on them. In the past, however, rapid measurement of the amount of solar radiation absorbed, or solar absorptance as it is called, has not been easy.

A simple device designed by Dr Brian Window of Sydney University appears to have solved this problem.

For the past two years, Dr Keith Cathro of the CSIRO Division of Mineral Chemistry has been using an instrument based on Dr Window's design to measure the solar absorptance of a range of selective-absorber coatings.

The solar absorptance of an opaque material is assessed from measurement of the reflectance of the surface. The assessment has usually been made with a spectroradiometer or spectrophotometer fitted with a suitable reflectance-measuring attachment. However, these instruments are expensive and measurements obtained by them are relatively slow. The spectral curve obtained has to be integrated, making due allowance for the energy distribution in the solar spectrum.

The new device overcomes the need to integrate the spectral curve by using a quartz-halogen lamp, with an inbuilt reflector and filter, that gives a fairly match of sunlight. This allows the reflectance of a surface to be measured directly as reflected radiation.

In the instrument, diffuse light illuminates a sample of the material whose solar absorptance is being measured. A simple lens focuses light reflected from the sample onto a detector, which converts the optical signal into an electric one. When suitably amplified and converted from alternating to direct current, the signal shows up in a meter.

For more information: CSIRO Division of Mineral Chemistry, P.O. Box 124, Port Melbourne, Vic. 3207. Phone (03) 647 0211 [CSIRO Industrial Research News, July 1979].

Workshop on Amorphous Materials

Monday 10th December 1979, School of Physics, The University of New South Wales.

Preliminary Announcement

A small informal meeting is planned. There is currently a great deal of interest in amorphous solids spanning several research fields including materials science, metallurgy and solid state physics. We would like to bring together people with different research interests to exchange ideas and find out what other workers are doing.

We would like to invite those interested to give a twenty minute talk. The talks can be reviews of topics of current interest, reports of recent work, or reports of work being attempted. Since we are aiming at a wide cross-section of interests, talks should not be too specialised. Anyone interested should contact Dr A. M. Stewart, School of Physics, The University of New South Wales, Kensington, NSW 2033.

Murdoch Mentors help Young Mathematicians

Once a fortnight 16-year-old Paul White forges the opportunity to lose himself in a science fiction novel and tackles logic and computing at Murdoch University.

The year eleven John Curtin High School student cycles to the University to take part in a new scheme designed to “stretch” the abilities of young mathematicians.

Two members of the School of Mathematical and Physical Sciences, Dr Walter Bloom and Dr Ken...
Quantum Effects from the Earth's Rotation

An unusual experiment at the University of Missouri Research Reactor has shown how the rotation of the Earth produces quantum mechanical effects in neutron beams.

The experiment involves splitting a primary neutron beam in a crystal and passing the two emergent beams through the two halves of a vertically-aligned rectangular interferometer. Because of the gravity, the kinematics of the beams are different in the horizontal and vertical directions of the interferometer, and this results in a phase difference when the two beams are recombined.

This phase difference due to gravity was measured by interferometry in a previous experiment in 1975 at the University of Michigan, and the results agreed with the predicted value, obtained from an unusual calculation involving both Planck's constant and the acceleration of gravity.

The latest experiment attempted to detect the additional effect due to the rotation of the Earth when the interferometer is turned about a vertical axis.

This additional effect is only about two per cent of the gravitational phase shift, but the measured value is in excellent agreement with the predicted value.

The experiment is the quantum mechanical analogue of a 1925 investigation by Michelson which succeeded in detecting the effect of the Earth's rotation on the propagation of light. Michelson used an interferometer measuring 2010 feet by 1113, but the new neutron beam measurements relied on an interferometer with an area less than 9 cm². [CERN Courier July/August 1979].

Visit by Professor Robert Karplus

Professor Robert Karplus is an invited speaker for the Jubilee ANZAS Congress in Adelaide, May 12-16, 1980. After the Congress Professor Karplus has indicated a willingness to spend a further ten days in Australia to visit Universities and Colleges of Advanced Education to give talks and have discussions with staff and students.

Professor Karplus' most recent research at the Lawrence Hall of Science, University of California where he is Associate Director, has dealt with the implications of Piaget's theory of cognitive development for the teaching and learning of science. He directed the Science Curriculum Improvement Study (SCIS) and has been primarily responsible for the famous workshop materials "Physics Teaching and the Development of Reasoning", "Biology Teaching and the Development of Reasoning", "Science Teaching and the Development of Reasoning" and "College Teaching and the Development of Reasoning". His work is relevant to teaching at all levels.

If you are interested in having this distinguished researcher and scholar visit your institution in May 1980 please contact Ronald G. Tindall at Adelaide College of the Arts and Education, Kintore Avenue, Adelaide, S.A. as he is coordinating Professor Karplus' short visit to this country.

New Chief for CSIRO Division of Chemical Physics

An internationally recognised solid state physicist has been appointed Chief of CSIRO's Division of Chemical Physics.

Dr Lewis T. Chadderton (41) Professor of Physics at the H. C. Osted Institute of the University of Copenhagen will succeed Dr A. L. G. Rees as Chief of the Melbourne-based Division. Dr Rees retired in May 1978.

Professor Chadderton will bring to the Division a great deal of international experience as a physicist, and at 41 will become one of CSIRO's youngest Divisional Chiefs. After working at the Cavendish Laboratory in Cambridge, Professor Chadderton was appointed in 1966 as resident physicist at the North American Rockwell Science Centre in California. During this period he worked on research into the general area of radiation damage and its effects, and studied the physics of the moon's surface. At the same time, Professor Chadderton became editor of the journal Radiation Effects. Professor Chadderton was appointed to the University of Copenhagen in 1972 and was awarded a Doctorate of Science in 1973.

The Division of Chemical Physics, located adjacent to Monash University, is within the CSIRO Institute of Physical Sciences. It is involved in research into spectroscopy, diffraction studies and solid state investigations.

The Division's pioneer work during the 1950s laid the foundation for a local scientific instrument industry. [CSIRO News Release, No. 21, 31.7.79]

BOOK REVIEW

LECTURES IN GROUP THEORY AND PARTICLE THEORY, H. Bary, Gordon and Breach, 1977, viii + 580 pp, £32.70

Except in a few respects and the valuable up-to-date bibliography, this book is a translation of the French book written in 1965-66, and is a set of lecture notes rather than a comprehensive text book. The usefulness of this translation would have been much greater if it had been available in the late sixties. It will be of interest to those teaching the application of group theory in physics to have Bary's approach to the subject available in English. While the material on particle physics is still very relevant, especially the chapters on the Lorentz and Poincare groups, it is unfortunate that none of the developments since 1966 have been included.
THE QUARTZ TIME CAPSULE

A. J. MORTLOCK, Physics Department, Faculty of Science, Australian National University, Canberra.

INTRODUCTION
A technical facility of the thermoluminescence dating of ancient ceramic and ceramic-like objects was set up in the Physics Department at the ANU early in 1972. This has been operated continuously since then and many varied samples have been tested. Those concerned with this work have travelled both within Australia and overseas to visit archaeological sites and obtain detailed environmental information to aid the calculations associated with samples from these sites. Numerous technical problems have been overcome and some interesting (even quaint) personalities encountered.

In view of the fact that similar facilities have since been set up in Adelaide, Melbourne and Sydney it would seem worthwhile looking back over this seven year period to see where some of the main gains have been made and also to take a broad look at where the subject seems to be going.

BASICS
For the uninitiated a few words need to be devoted to the background of the technique. Detailed accounts are available in the literature: see Aitken (1974).

The fabric of a piece of pottery, say, contains a large number of tiny crystals of quartz. These are continuously bombarded by the nuclear particles emanating from the long-lived radioactive isotopes \( {\text{U}}^{238} \), \( {\text{Th}}^{232} \) and \( {\text{K}}^{40} \) in the surrounding matrix. Energy from this bombardment is stored in the lattice of the quartz crystals and may be released as light radiation (thermoluminescence or TL) on heating at a constant rate up to a temperature of 500°C in what is called a glow curve. Providing the pot has been fired at a sufficiently high temperature at its initial point of manufacture, thereby removing all previously stored energy of this type, the amount of light radiation observed in the laboratory heating of a suitable test sample is proportional to the archaeological age of the pot. Calibration techniques based on the use of powerful laboratory radioactive sources of radiation which allow energy storage of this type to be achieved in minutes enable this thermoluminescence light radiation to be translated into an equivalent radiation dose in rads. Providing the amounts of the relevant radioactive isotopes in the matrix can be measured, and the radiation dose contribution from the environment is known, the annual rate of energy storage in the quartz crystals can be calculated. The apparent thermoluminescence (TL) age is then given by:

\[
\text{Age (yr)} = \frac{\text{Total stored energy (rads)}}{\text{Annual rate of energy storage (rads/yr)}}
\]

It is seen, therefore, that the quartz crystals act like tiny time capsules storing within their volume information about the archaeological past. Corrections for non-linearity of TL response to dose, effects of ground water and radon gas loss on absorbed dose, all need to be taken account of as well in these calculations if the ultimate accuracy of the technique is to be achieved - ±5-10% in the best cases.

SOME TECHNICAL POINTS
The early work in Canberra was based largely on what is known as the fine grain technique pioneered at Oxford University by Zimmerman (1971). He died late last year tragically in a sporting accident at the comparatively young age of 40 years. His technique utilizes small quartz grains in the size range 1-8 \( \mu \text{m} \). These are obtained by drilling two or three small (\( \sim 1 \text{ mm diameter} \)) holes in some inconsiderable part of the test object and then selecting out the wanted size range by a settling technique using the waste drill powder and acetone.

This particular method is simple and easy to use. It does, however, have a subtle difficulty because it is not mineral specific. That is to say other minerals besides quartz, which is normally fade free, may also be present in the final powdered sample which is heated in the laboratory glow oven. These minerals may themselves store TL energy but are commonly subject to substantial fading of the stored TL energy. If no correction is made this can lead to an age figure which is too small. Such corrections can themselves be so inaccurate that, even in cases where they are made, the final result is of poor accuracy. One simple protection against this defect in the method is to reject all test objects the samples from which show a fading of 10% or more over a period of, say, one month after a laboratory irradiation.

The other technique, known as the inclusion method, makes use of much larger (\( \sim 100 \text{ \mu m} \)) quartz grains only, which are obtained by a magnetic separation technique. The method, although more reliable, is longer and takes much more material.

Around 25% of the total radiation dose received by the (buried) pot comes from its environment. Most of this is from the same long-lived radioactive isotopes as before but this time present in a sphere of earth centred on the pot and radius of 30 cm, the effective range of the \( \gamma \)-rays involved. If the burial soil has the same composition as the pot then the calculation of the environmental dose is easy using a table (3.2) already published by Aitken (1974) and later updated by Bell (1976). However, this is usually not the case, and the presence of rocks or other discontinuities dose by can upset the basic assumptions.

Some success in overcoming this problem can be achieved by placing sensitive radiation dosimeters in the field situation for two or three months. These can be in the form of phosphors (doped CaSO\(_4\), or LiF) or calibrated electronic devices which integrate the dose rate received by a radiation detector such as a GM tube or scintillation Xtal. Another method of attack is to
use both the fine grain and the inclusion technique when analysing the samples. The former picks up the dose due to $\alpha$, $\beta$, $\gamma$ and cosmic radiation while the latter (after etching away from the surface layer of the 100 $\mu$m crystals containing the $\alpha$ dose stored energy) includes only dose due to $\beta$ (reduced), $\gamma$ and cosmic radiation. Subtraction leads to a dose rate which is independent of $\gamma$ and cosmic radiation and therefore independent of the environment. Unfortunately the amount of work involved here is fairly large if the error limits are to be reasonable.

In this connection it must be pointed out that the accurate TL dating of an isolated ceramic the environmental history of which is unknown and from which only a small powder test samples may be taken is not really possible. Determination of whether the object is young or old is certainly possible and this may be improved upon depending upon general knowledge of the class of the ceramic. For example, Fleming (1975) has analysed Tang wares and found that the environmental dose rate varies from 0.09 to 0.26 rads/year which probably correlates with the variation in the radioactivity of the burial soil along the Yellow River in China where most of the Tang tombs are located. By taking a mean environmental dose rate of 0.15 rads/year an age figure for an isolated Tang object may be calculated and not unreasonable error limits of, for example, $\pm$ 12% assigned. However, in other cases where the environmental dose rate may vary over a much wider range, as for objects coming from little known parts of Northern Thailand, say, the correspondingly wide error limits on the calculated age figure make such calculations of little value.

Sutton and Zimmerman (1976) have introduced an entirely new method of overcoming the environmental problem. This is based on the use of zircon crystals derived by rather difficult laboratory procedures from the parent object. These crystals are so rich in uranium and thorium themselves ($\sim 100$ ppm) that the contribution to the total radiation dose from the environment falls to insignificant levels by comparison. However, at the present time the new method is tedious and time consuming to apply, it does give great promise for the future though, and is in principle free of the need for the troublesome corrections which dog the quartz crystal techniques.

A photograph of the Canberra TL dating laboratory is displayed in Figure 1.

The two glow ovens are located in the bases of the vertical cylinders mounted at the front of the two sets of apparatus shown. In the upper part of each of these cylinders is a photomultiplier which detects the thermoluminescence light output which accompanies heating of the sample. The so-called glow curves which indicate the strength of the TL signal as a function of temperature are traced on the XY recorder immediately to the left of the operator. Other apparatus of significance includes the small black leg-mounted cylinder on the right hand bench for the $\alpha$ irradiation under vacuum of samples to test their TL susceptibility to this form of radiation, which is much less than for $\beta$ and $\gamma$ radiation. Further to the right on the same bench is an $\alpha$ counter for measurement of the dose rate due to U and Th. This is less used now than previously, since direct determination of the U and Th utilising XRF and neutron activation followed by $\gamma$ spectrometry is more often employed.

SOME LOCAL SUCCESSES

The main thrust of the work in the Canberra Laboratory has been to apply the technique to local materials. To this end a particular study was made of some important ancient Aboriginal fireplaces at Lake Mungo near Mildura, NSW. The samples were baked sand/silt from a number of these fireplaces, and the final results obtained by Bell (1978) following the earlier pioneering work of Adams and Mortlock (1974) are listed below together with corresponding radiocarbon ages:

<table>
<thead>
<tr>
<th>Fireplace</th>
<th>TL Age</th>
<th>Radiocarbon Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>F6</td>
<td>31,400 y</td>
<td>27,000 y</td>
</tr>
<tr>
<td>F7</td>
<td>36,400</td>
<td>31,700</td>
</tr>
<tr>
<td>F8</td>
<td>32,700</td>
<td>29,200</td>
</tr>
<tr>
<td>F9</td>
<td>33,500</td>
<td>28,400</td>
</tr>
</tbody>
</table>

It is seen that the ages obtained by the two methods

Fig. 1. The Thermoluminescence dating laboratory at the Australian National University, Canberra.

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are generally consistent. The small systematic discrepancy of about 10% to 15% has been attributed by Bell to variations in the Earth's magnetic field which changes the rate of production of $^{14}$C in the upper atmosphere and therefore the essential assumption of radiocarbon dating that the quantity of $^{14}$C in the atmosphere reservoir is constant. Uncorrected this leads to error in the calculated radiocarbon age, the latter being too small.

Other successes with various volcanic residues, Hinde (1976), and some relatively young cooking stones, Bell (1976), have been noted earlier by Mortlock (1977). As yet unreported studies with burnt sea shells showed the possibility of relative if not absolute dating in this case, Franklin (1975).

Local endeavours at the present time include a major study of S.E. Asian archaeology using natural potsherds from a range of origins in the area supplied by Dr H. H. E. Louf of the Department of Asian Civilisations at the ANU, and an interesting smaller investigation of the confused archaeology of Chinese Skelkwan ware in co-operation with the University of Hong Kong (Mrs. F. M. Scollard).

DOUBTS AND ERRORS

The question may well be asked whether archaeologists trust age figures deduced from TL-dating procedures. Unfortunately it is too said that the variation in TL ages from certain sites have raised doubts about the validity of the technique. For example, ceramic artefacts, from the now famous Guelph site in the Massif Central of France, Aitken (1977), and Ban Chiang in Northern Thailand, Chin Yong-de (1975), have shown apparent TL ages inconsistent with other observations or simply variations in apparent ages from sample to sample far beyond expectation. These difficulties have still not been completely resolved and have left the practicing archaeologist with reservations.

It must also be said, however, that where the sample material has come from a physical situation which is well defined and, furthermore, that it exhibits good TL characteristics, then excellent agreement with known ages can result. Thus, two samples of terracotta brick from Italy, one from the famous Certosa at Pavia and the other from Ostia near Rome have yielded apparent TL ages close to their known ages, which fall within the last two millennia. These measurements were carried out in Canberra and clearly demonstrate the accuracy of local laboratory technique. Similar cross checking procedures are essential for any new laboratory setting up to carry out datings of this nature.

It is sometimes loosely stated by archaeologists that the quoted error limits for radiocarbon dating are small compared to those for equivalent TL dates. The fact is that the radiocarbon error limits commonly simple reflect the statistics of the associated radioactive counting and take no account of uncertainty in other large systematic errors likely to be present. On the other hand the wise TL dater tries to draw attention separately to the two types of error, random and systematic, Aitken (1977).

QUO VADIS

It is always a dangerous thing to attempt to predict the future development of a subject as new ideas can suddenly arise to change the direction of this develop-

ment. In the case of TL dating it is clear that the classical procedures of fine and inclusion dating yield good results under appropriate circumstances. The ever-present difficulty of taking account of the radiation contribution from the environment may be overcome in future by the wider application of the zircon crystal method, which by then will probably be simplified in its laboratory technique.

New applications of the dating method will also probably arise. For example, Bowler (1978) has drawn attention to the work of the Chinese who have dated layered sedimentary deposits in geological situations using TL procedures. The idea here would seem to be that, when these deposits are on the free surface, sunlight will bleach out the geologically stored TL. As new layers deposit on top the initial layer will be cut off from the sun's radiation and subsequent TL dating will, therefore, be to the time of this cut-off. According to Bowler the results obtained so far seem to be consistent with other separate geological evidence.

The physicist entering the field should be aware that many interesting and diverse aspects of his discipline are present in elucidating and improving the basic dating procedures. However, he should also be aware that there is a great danger that he, through his dating facility, will be limited to providing a routine and personally somewhat unrewarding service to archaeologists and others. While there is nothing wrong in this, we as scientists should be prepared to help each other, care must be taken that his total role is not this alone. One way of ensuring this is to give priority to those dating problems which give indication of the need for new thinking.

Will the general technique slowly mature towards being a well-known and widely used method of dating appropriate to certain specialised materials, not unlike the development of radiocarbon dating? The answer to this is surely yes, and one can probably say that this state of affairs is already here for those who fully understand the method. However, as Aitken (1977) has pointed out, the real hope for the future is that TL dating will take us into new areas (e.g. large extensions of the dating time range) which are closed to procedures like radiocarbon, and perhaps this is where the greatest effort should be directed at the present time.

REFERENCES
Chin, Yong-de (1975), Ban Chiang Prehistoric Cultures, (Fine Art Department, Bangkok).

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EUROPEAN JOURNAL OF SCIENCE EDUCATION

With increased activities and interest in science education throughout the world, it is not surprising to see a new journal to provide a communication medium between science teachers, science educators and researchers. This journal aims to publish articles, research reports and information on all major aspects of science and technology education. The editorial board has interpreted science and technology education in a broad sense so as to include the social implications of society and technology, issues related to institutional planning, manpower supply and planning, the relationship between science education and societal expectations and industrial needs. In the research area the journal intends to emphasize, applicable research, research capable of being applied but not necessarily already applied, to teaching. The broad aims of the European Journal of Science Education as outlined in an introductory statement are:

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

In the first volume, January-March, 1979, items of interest to physics educators are found in several sections of the Journal. In General Articles Fritz Kubli discusses “Piaget’s Cognitive Psychology and its Consequences for the Teaching of Science”. This article deals with several key ideas of Piaget's theory and discusses their implications for the teaching of science. While Piaget’s work has been known to researchers and curriculum developers for some time, little has been applied to classroom practice. The examples discussed in the consequences sections are taken from physics teaching. While Piaget's experiments do not explain everything concerning children's intellectual development, they do represent major initiatives for investigations which may give rise to new approaches to science teaching.

In the section on Innovation and Development, L. K. Kikoin and E. E. Ewontchick show that Newton's three laws constitute a unified system in a paper entitled "The Treatment of the Laws of Dynamics in Higher Level Schools". The authors give particular attention to the second Law, which they show follows the experiments showing that for bodies of different masses submitted to the same force the products of their masses by the accelerations are equal and may serve as the measure of the force. The concept of mass is introduced independently of the second law. The often used approach in which mass is the constant of proportionality between a statically measured force and acceleration is rejected by the authors.

Also in this section is an article on “Teaching Thermodynamics to Physics Students using the Keller Plan”. Professor L. R. B. Elton provides some general comments on “Teaching by the Keller Plan”. Other articles of interest include “Science and Technology in the Classroom”, “Some Characteristics of Effective Science Teaching”, “Concept Formation in Biology: the Concept Growth” and “Trends in Research in Chemical Education”. The latter appears to be a most comprehensive review.

The publication is well produced on glossy paper. English, German and French summaries of the major articles are printed at the end of the article. If future journals continue the high standard of this first issue, the editors will have contributed to the formation of a successful professional journal.

Ted Sandercock

COMPUTER ABUSE

COMPUTER ABUSE RESEARCH BUREAU – A non profit organization aimed at profiling and preventing computer abuse. 900 Dandenong Road, Caulfield East, Victoria, 3145. Australia.

CIT-CARB (Computer Abuse Research Bureau) was established in August 1978 by a group of interested people from Commercial, Industrial and Academic fields for the purpose of exploring ways in which Computer Abuse can be profiled and prevented.

Computer Abuse has been defined by CIT-CARB as — Theft, Fraud, Embezzlement, Damage etc. related to Computers and includes:

(i) Unauthorized Manipulation of Computer Input and/or Output;
(ii) Unauthorized Access to the System through Terminals;
(iii) Unauthorized Modification or Use of Application Programs;
(iv) Trespass on Data Processing Installation, Theft of Equipment, Files or Output;
(v) Sabotage of Computer Installation Equipment;
(vi) Unauthorized Data Interception.

Should any organizations wishing to contribute to the survey, and not in receipt of any questionnaire to this date, please contact Mr. Alan Hamstead, Secretary CIT-CARB, Caulfield Institute of Technology, Phone No. (03) 7722 Ext. 133.
GASEOUS ELECTRONICS MEETING
SYDNEY FEBRUARY 21st.—22nd., 1980.

The First Gaseous Electronics Meeting will be held on 21-22 February 1980 at the School of Electrical Engineering, Sydney University. The meeting is also supported by the CSIRO Division of Applied Physics and the Australian Institute of Physics.

The subject matter of the meeting will be electrical discharge phenomena in gases and will include the following topics: electron atomic and molecular collisions; electron transport phenomena in gases including drift, diffusion, attachment, ionization and detachment; electrical breakdown in gases including corona; glow discharges including discharge aspects of gas lasers; arc discharges including the physics of arcs in circuit breakers, arc furnaces and arc welding; gas discharge aspects of MHD; shock phenomena in plasmas and plasma diagnostics.

It is felt that the interaction of various groups working in gaseous electronics at the conference will be most beneficial. Gaseous electronics research in Australia has made a significant impact internationally. But there is a need for the various groups to interact and become aware of where they can contribute to one another. In particular there is room for co-operation between the physics groups, who examine basic transport phenomena, and electrical engineering groups working on electrical breakdown, electrical arcs, corona, MHD, lasers, etc.

If the meeting is successful it is proposed to hold further meetings bi-annually to alternate with the AINSE plasma physics conference.

Abstracts for 10-15 minute talks should reach the secretary not later than January 7th, 1980. Talks are not restricted to completed work; descriptions of work in progress and current problems would be particularly welcome. Abstracts of up to 200 words are to be typed, single spaced, within a rectangular of size 12cm x 10.5cm on A4 paper (using a “Courier 12” ballot if possible).

Student members of the AIP should approach their local State branches for support to attend the meeting.

Enquiries should be addressed to the secretary of the conference:

Dr. R. Morrow,
CSIRO Division of Applied Physics,
National Measurement Laboratory,
P.O. Box 218,
LINDFIELD, N.S.W. 2070.
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