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PHILIPS
A HELICAL PHYSICS CURRICULUM

Edward R. Sandercock*
Bedford Park Teachers College, South Australia

Introduction
One of the many educational problems in the smaller colleges and universities in the USA is the proliferation of introductory physics courses. Such courses must cater to a wide range of students from the humanities student to the physics major. While many students take physics before entering their tertiary courses, some students are introduced to the discipline of physics at tertiary level. While this situation is unusual in Australia, more relaxed and enlightened matriculation requirements will allow secondary-school students to escape the traditional introduction to physics. Some Australian tertiary institutions have already recognized the need for some science for the non-science major and have either introduced or discussed the introduction of liberal-arts physics courses. Tertiary institutions which aim to cover a wide spectrum of physics courses will be interested in the helical physics project developed at the University of Michigan, Flint College. This project at present is the largest National Science Foundation financial excursion into this area of physics education.

The Problems
The helical project was begun in the University of Michigan, Flint College in an attempt to solve some of the educational problems in the smaller colleges of the USA. In many American colleges and universities introductory physics courses are offered at three levels:
(a) courses for non-science majors,
(b) courses for biology majors and medical students,
(c) courses for physics, chemistry and engineering majors.
In an institution which offered all three levels each year, this often required at least seven introductory courses. This requires a considerable amount of faculty time and organization. These traditional introductory programmes have led to many problems in the smaller colleges, especially those with few physics faculty members.
The three related problems of omission, transfer and duplication are especially prominent in these institutions.

(1) Omission: In a small physics department it is not feasible to offer each of the three levels every year.

In too many cases the courses suitable for the non-science major are omitted.

(2) Transfer: The offering of introductory physics at several levels causes many problems when students wish to transfer to less or more advanced levels. The non-science student who finds that physics is interesting and wishes to pursue the subject to further depth is frustrated if he is enrolled in a terminal course. An important group are the future primary- and secondary-school teachers, who want and need better preparation in science but are discouraged from further physics studies.

(3) Duplication: In many introductory physics programmes the high school physics background is ignored and a student with a good background is bored and wastes his time. FLIPS attempts to provide solutions to these problems.

History of the Project
In October 1967, the USA National Science Foundation announced its support of a project to develop a four-semester introductory physics curriculum which became known as the Flint Introductory Physics Sequence Curriculum Project (FLIPS). The support was for an initial year, with an intention of continued support for the second and third years of the project. The project's advisory panel consists of Professors Bill G. Aldridge, Arnold Arons replacing Kenneth E. Davis, Ralph W. Krone, Robert L. Sells, and Arnold A. Strassenburg. The project staff is headed by Professor Donald E. DeGraaf of the University of Michigan, Flint College. The NSF support has enabled the course to be trialed in eighteen selected colleges throughout the USA. A wide variety of colleges were selected ranging from colleges having a high proportion of very able students to those having large numbers of students with low academic achievement in senior high school. The total enrolments of these colleges vary from 10000 students to 415 students. These colleges include two- and four-year colleges, state and privately endowed colleges, and a college for women only. Since September 1968, finance has been provided to initiate the FLIPS programmes in the eighteen colleges. The total number of students enrolled in the FLIPS courses since September 1968 is a little over 4000. There are fewer than 4000 individuals as some students have participated in two or three and even four courses. These numbers represent approximately

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1-2 per cent. of the total 1969 Fall enrolments in introductory physics in the USA. In the 1969 Fall semester there are 1639 students enrolled in FLIPS programmes.

The FLIPS Programme

The FLIPS programme is a sequence of four one semester physics courses (I, II, III, and IV) presented in a helical approach. The topics in each course were chosen partly on the basis of the required mathematical techniques and the physical concepts needed to comprehend the topics. It is claimed that in any of the four courses the topics are of comparable difficulty. The topics in courses I and II include those which the project staff think are desirable for and of interest to non-science majors. Course III includes additional material which was considered important in the education of premedical and biology students, who will be using modern scientific instruments in the laboratory or clinic. Some calculus (simple differentiation and integration) is used in this course, and the necessary mathematical material is introduced and explained in this course. The physical importance of the material is emphasized. Topics considered to be desirable in an introductory course for physics, chemistry, and engineering majors but which require substantial calculi have been placed in course IV. Figure 1 shows the programme in schematic form.

![Diagram of FLIPS Programme]

**Figure 1**
Outline of the Flint Introductory Physics Sequence (FLIPS) Curriculum Project.

An outline of the topics covered in the respective FLIPS courses is given below:

**Course I: THE PHYSICAL UNIVERSE**

Survey of the physical universe from galaxies to elementary particles; uniform motion of a particle in a straight line and in a circle; Newton's laws of motion; gravitational, electric, and magnetic forces on a particle; fields; momentum and impulse; work and energy; motion and interference of waves; physics of space exploration.

**Course II: MICROPHYSICS**

States of matter, solids, liquids, and gases; fluid statics; elementary kinetic theory of an ideal gas; heat, thermal conduction, first law of thermodynamics; sound waves and acoustics phenomena; electrostatics of point charges in free space; steady d.c. currents and circuits; light waves, interference and diffraction phenomena, photons, photoelectric effect, quantum ideas; the structure of atoms, Bohr model, simple wave model; radioactivity and nuclear physics.

**Course III: MACROPHYSICS**

Capacitance, electromagnetism, magnetic forces on currents, Ampere's law, Faraday's law, Lenz's law, self-inductance; series RLC circuits with steady state sinusoidal currents; statics and dynamics of a particle in three dimensions; forces, work, and energy; simple harmonic motion; superposition of sinusoidal waves; geometrical optics and optical instruments; physical optics.

**Course IV: ANALYTICAL PHYSICS**

Special theory of relativity; momentum and collisions; matter waves; quantum physics, lasers, rotational kinematics, and dynamics; dynamics of rigid bodies; kinetic theory and specific heats of non-ideal gases; second law of thermodynamics, heat engines, entropy; fluid dynamics, electric currents; electric and magnetic fields, Gauss's law, energy in electromagnetic fields; magnetic materials, magnetic dipoles.

A student can enter the sequence at a level appropriate to his background and continue as far as he is able and willing to proceed, provided he attains the increased mathematical background for succeeding courses.

A flow diagram has been developed to give the programme flexibility and to allow the instructor choice in his approach and choice of topics. The diagram indicates the topics which have been covered before attempting the new topic and where the new topic will lead. The instructor can choose from several paths when he constructs the syllabus for a particular course. The flow diagram is shown in figure 2. The numbers in figure 2 refer to the chapters and sub headings in the FLIPS student guides. The letter A refers to the appendices of the guides.

**Course Materials**

As there are no textbooks designed for these courses the project staff director, Professor DeGraaf, has written a student guide for each course. Each guide contains an outline of the relevant material, a large selection of questions and exercises, several mathematical appendices, and lists of physical constants and tables. In addition, the project staff is preparing teacher's guides and resource material handbooks. These books contain suggested approaches, lists of some suitable laboratory experiments, solutions to problems, lists of reference books, and large list of selected 8-mm film loops and 16-mm films suitable for teaching the courses. Most participating colleges use a text in addition to the student guide. A non-calculus text is used for course I while a calculus text is used for courses II to IV. For economic reasons some colleges use a non-calculus text for Course II.
At a recent FLIPS conference at Lake Forest College, North Chicago, the panel members and project members discussed the problem of students using the guides as texts. As it was not the intention of the project staff for the guides to be used as texts, the conference members decided that the student guides should be rewritten. The new look student guides will contain instructional objectives, specific text-book references, questions and exercises, in addition to suitable problems found in the text-book references, mathematical appendices, and lists of physical constants. This approach of selecting material from textbooks with regard to content level, correct presentation, literary merit, and comparison of interpretations of phenomena is unique in US physics-curriculum development.

Some Further Thoughts

Problems similar to those which confront the two and four year US colleges will arise in some areas of tertiary education in Australia. The Colleges of Advanced Education and Institutes of Technology already have physics courses for architects, engineers, pharmacists, chemists, physicists, etc. Some institutions have one introductory physics course while others have several. The introduction of courses for non-science majors will further complicate the situation. The FLIPS project should provide a starting point for investigations into an adaptation of a helical approach to teaching introductory physics in Australia.

The helical approach gives the non-science student a broad introduction to physics at a level which is appropriate to his background and enables him to continue with further physics if he so desires. This new approach allows the science major to enter physics at a level appropriate to his background. Too often in introductory physics courses the prospective physics major is subjected to material he has covered at secondary school and consequently may decide to major in another, more interesting scientific field. Between these extremes, the helical approach has material for the large range of student interest. The FLIPS project is the forerunner of programmes in physics which consider the students and the learning processes rather than the overall content.

In conclusion I would like to thank the members of the FLIPS project staff for their cooperation in the preparation of this article and especially Professor DeGraaf for his advice and his permission to use the FLIPS flow charts.

Acknowledgement

I would like to thank the Harkness Fellowship Commonwealth Fund for financial assistance, which enabled me to participate in the FLIPS project.

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**LETTER**

Sir:—The Sciences Club has now been operating for two years and has not yet fulfilled the role which so many of us had in mind on formation. There are reasons for this, and little would be gained by going over them all now. We have no problems which would remain unsolved if we had the whole-hearted cooperation of members of societies which use Clunies Ross House. The purpose of this letter is to tell you therefore that a comparatively small increase in membership would make the Sciences Club into the sort of club we all so keenly envisage. The club committee feels that committees of the societies are in the best position to increase membership of the club and to gain from it.

It is not often appreciated what a unique organization we have in the Sciences Club. It became obvious during the visit to the Club of the Duke of Edinburgh a few months ago how well the facilities available could bring together so many branches of the sciences and technologies.

Our committee is very conscious of the need to make the Club operate more effectively as a real club. To this end we are adding a large club room for members only and we are endeavouring to institute other facilities so that advantages will accrue more to members of the Club than to those non-members who so frequently visit the Club, and are signed in as visitors.

These visitors have come to expect to be able to use the Club, little realizing that it is a completely separate entity from the Ian Clunies Ross Memorial Foundation. One of the major purposes of the Club is to integrate in an attractive atmosphere the many branches of science and technology through Club membership.

The new Club year commenced on 1 July 1970. We would like your co-operation in pressing the advantages of membership of the Club to all your members. May I point out that Club subscriptions and entrance fees are tax deductible, which gives membership at very low cost. The entrance fee for ordinary membership is $20.00 and the annual subscription is $15.00.

There can only be a Sciences Club if sufficient members of the societies who participate in the facilities of Clunies Ross House in one way or another are prepared to support it.

Would you therefore take as much action as you can, even to printing this letter in your journal, with support from your President, or drawing to the attention of your members in other appropriate ways.

The Sciences Club
191 Royal Parade,
Parkville, Vic. 3052

J. E. CUMMINS
S. R. J. NICHOLLS
Committee Members

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EINSTEIN MEMORIAL LECTURE—1970

THE ORIGINS OF MODERN TECHNOLOGY

A. L. G. Rees
Chief of the Division of Chemical Physics, CSIRO

The text of an address, given as the Einstein Memorial Lecture, on Wednesday, 14 October in the Horace Lamb Theatre of the University of Adelaide.

Much of Einstein’s early work was of such importance to chemistry that the Institute of Physics can be pardoned for inviting a chemist to deliver this Lecture. Because I believe that it is desirable for a memorial lecture to have as its theme something that is relevant to the life and work of the man being honoured, I am encouraged to argue the proposition that the origins of modern technology are to be found in ‘pure science’, in defence of which so much illustration can be drawn from Einstein’s scientific work.

Titles of lectures can often be misleading simply because it is impossible to condense into two or three words the purpose of the arguments that one wishes to present, so it is probably prudent at the outset to explain that I am not setting out to justify pure science as a worthwhile pursuit in isolation—although there are more than adequate reasons for its practice as a scholarly and cultural activity—but rather to demonstrate its place as an essential, but continuing, component of human civilization. Moreover, I am not implying that applied research and the application of the discoveries of pure science through development and innovation are not also desirable activities in the interests of the community.

In recent years it has been claimed that there is an extensive disenchantment with science, a point of view that has received a good deal of publicity, and in the developed countries of the Western world there has been a repeated demand from the more vocal non-scientific sections of the community that science should justify the support that it derives from public funds. The motives prompting these demands are diverse, certainly complex, and often transparently emotional.

The Nature of Science and its Derivatives

Most educated people these days have an appreciation of the scope of natural science, although the interfaces with the social sciences on the one hand and pure mathematics on the other are matters on which scientists have differing opinions. The distinction between ‘technology and science is less understood and the meanings associated with words such as pure, applied, research, development, etc., are so different from person to person that much confusion and misunderstanding has been generated. In an attempt to avoid adding to this confusion I shall give brief outlines of my own meanings of the several words that I shall use throughout the lecture.

Natural science is the accumulation of knowledge and understanding that has arisen from man’s curiosity about his surroundings. Technology is the application of the results of science to the production of the material needs and wants of man, although there is still a substantial component of technology derived from the adaptation of natural resources to man’s needs, as found in the traditional industries, for example, the textile industry.

The interplay of science and technology is undoubtedly complex. In my opinion modern technology is science-based, that is, it uses established scientific fact and theory or the more recent results of creative science. Science on the other hand depends quite heavily on progress in technology; for instance, recent progress in many areas of theoretical physics and theoretical chemistry has been possible only because of the spectacular development of computer technology, which in turn has depended on advances in solid-state physics and chemistry. The existence of these feedback loops is perhaps the most characteristic feature of the development of modern science and technology.

The further analysis of science and its derivative human activities is confused and somewhat hazardous. For some time it has been customary to use the words ‘pure’ and ‘applied’ to distinguish two main areas of science, but the word ‘applied’ is interpreted in widely different ways by different people. My own preference is to distinguish between ‘research’ and ‘non-research’ in science and its derivatives, although it is quite frankly impossible to construct mutually exclusive definitions of these terms. However, research is characterized by creativity through which real progress is made in understanding. While much of what is called ‘research’ today is scientific inquiry, based exclusively on known principles, I believe that the word should be reserved for those studies that penetrate the frontiers of knowledge and that go beyond what is established or accepted. Research can certainly be pure or applied, although I prefer the words ‘committed’ and ‘uncommitted’, used in the economic sense. Pure science is uncommitted research, curiosity-oriented, basic, fundamental, and often referred to as ‘ivory-tower’. Through the recognition of its potential economic value an uncommitted research study may become a committed research investigation overnight, but still retain the essential quality of creativity.

Non-research activities include development, leading
to technological innovation, and the various activities that constitute professional and industrial practice. Successful developmental work is characterized by ingenuity, which is distinguished from creativity in that it is the clever manipulation of existing understanding in the solution of technical problems.

It is 'pure science' that I wish to discuss. J. B. S. Haldane's definition is perhaps a realistic one—'What is called "pure science" . . . is really long-range science—that is to say, science which will not find a practical application for some years to come'. It has been stated in the report on 'US National Policies on the Support of Science and Universities' that the support of pure science is necessary 'to solve tomorrow's unknown problems'. Each of these statements predicts practical benefit to the human community as the ultimate aim of pure science.

**Current Attitudes to Pure Science**

Because the sums of money allocated by governments for the support of science are of such magnitude that they can no longer be ignored, increasing pressure is being exerted on science to justify this support. It has become commonplace for economists and social scientists to search for relationships between national expenditure on research and development and direct economic and social benefits to the community. The growing literature on this issue has certainly generated a hard-line attitude to pure science and a concern among scientists for the effects of these pressures—these are getting close to the assertion that pure science is unnecessary—and the emphasis in the public area on the undesirable effects of the application of the results of pure science to the exclusion of the benefits. This attitude is well illustrated by such statements as:

'Science and technology are in retreat, not only in the universities, but in industry and in the country as a whole' (US National Policies on the Support of Science and Universities).

'Indeed, the defenders of academic research still seem to be clinging to an unsound position; that the fruits of academic research are essential to industrial progress' (J. Langrish, *Science Journal*, 5A, 81 (1969)).

Many of these conclusions have their origins in:

(i) the assumption that direct economic benefit is the only criterion of justification;

(ii) the opinion that it is impossible to relate current expenditure on research and development directly to economic growth;

(iii) the belief that it is rare for a single outstanding scientific discovery to lead directly and unequivocally to industrial products or processes;

(iv) the conviction that, because it is rarely possible to apply the techniques of cost-benefit analysis to it, pure research has no economic justification;

(v) a misunderstanding of the inter-relation of science and technology, exemplified by statements such as—'It sometimes seems that science and technology are two quite separate activities which occasionally come into contact with each other' (J. Langrish, *Science Journal*, 5A, 81 (1969)) and 'the advancing bodies of science and technology are separate at the research fronts, but are in contact at a distance in time equal to about one generation of students' (J. D. de Solla Price—paraphrased by J. Langrish, *loc. cit.*);

(vi) a lack of understanding of the nature of creative research and of the dependence of technological progress on a multiplicity of scientific advances, many of which have in fact a remote but nevertheless direct bearing on the possibility of any particular technological innovation.

Some extremists propose that the clock be turned back or that a halt should be called. This is clearly against human inclination and represents an impractical attitude. Others suggest that pure science should be stopped and that a committed attitude should be taken to all research ('. . . it is possible that scientific discoveries made without any thought of commercial application could have been made by industrial scientists at the time when there began to be a need for such discoveries' (Langrish—*loc. cit.*)).

In spite of such current attitudes, I shall attempt to demonstrate that pure science and exploitation are closely interrelated and that pure science is 'an economically sound natural resource'. Fortunately, to the demand for science to justify its support there has been a reaction by groups who have made a detailed analysis of the primary contributory factors that have led to selected major technological innovations. While these do not provide any basis for predicting the success or failure of future innovations, they do show that 'Every technological innovation depends at various points in its antecedents on basic science, either in the form of a body of fundamental knowledge and understanding or in a single key research discovery'.

In the remainder of this lecture I shall first examine the dependence of a multiplicity of current industries and innovations on a few of Einstein's theoretical studies and illustrate other points by a few specific examples drawn from the scientific work of the CSIRO Division of Chemical Physics.

**Einstein's Work and Modern Technology**

Einstein's influence on the development of modern science can hardly be overestimated. His name is usually associated, both by the scientist and layman alike, with his theories of relativity. While general relativity is beyond the competence of ordinary mortals, the implications of special relativity can be understood. So much has been written on the subject, which is a familiar part of any physicist's training, that I do not propose to spend any time in discussion of it. However, I would like to remind you of the dependence of the subsequent development of physics on the incorporation of relativistic effects and to draw attention to the central importance of the relation between mass and
energy, deduced by Einstein as a consequence of relativity, both in atomic and nuclear physics and in the realization of nuclear power generation.

Before 1905 diffusion theory was based on force considerations which are not physically acceptable in the theoretical description of random motion phenomena. Einstein developed diffusion theory on a sound physical basis and identified the diffusion coefficient $D$ as an average $\langle \xi^2 \rangle / 2 \tau$, where $\langle \xi^2 \rangle$ is a mean square displacement occurring in a time $\tau$. The constancy of $\langle \xi^2 \rangle / 2 \tau$ and the experimental proof of Einstein's relation was established for colloidal particles by Perrin. The immediate application of Einstein's derivation was the explanation of the Brownian motion of microscopic particles, but it led to explanations of rotational Brownian motion and of the behaviour of polar molecules in external fields. It was, in fact, the first direct evidence for the existence of molecules. This paper, together with Einstein's further development of the theory, has basic importance in the understanding of the dielectric properties of condensed phases on the one hand, with its implications in electrotechnology, and in the development of polymer science on the other, with obvious connection with the polymer industry.

Closely related in its importance in polymer science and technology is Einstein's theory of light scattering based on fluctuations in the density of an element of the scattering medium about an average. By showing that the mean square amplitude of scattered radiation $\langle A^2 \rangle_{\text{rms}}$ was related to this departure, Einstein was able to relate scattering to macroscopically observable quantities such as temperature, specific volume, refractive index change, and the derivative of compressibility. Light scattering has been used for the determination of molecular size and shape in colloids and polymers.

Although Planck was the originator of the quantum hypothesis, it was Einstein who proposed that parcels of radiant energy of magnitude $h\nu$, $2h\nu$, etc. had an independent existence in free space. His use of this in the treatment of absorption and emission of radiation, in the construction of a theory of the photoelectric effect and in the establishment of the law of photochemical equivalence is well known. Little imagination is needed to identify the various branches of modern technology that can be traced back to this, quite apart from the large areas of science.

It was, however, Einstein's papers on the interaction of radiation and matter that were published in 1916 and 1917 that opened the way to the prediction of the intensities of spectral lines and laid the foundations of modern spectroscopy. Einstein was primarily motivated in deriving the Planck radiation law by considering the equilibrium between a number of atoms and a radiation field in an enclosure. He realized for the first time that atoms making transitions up and down between various levels must involve besides radiation-induced absorption and spontaneous emission—an additional induced or stimulated emission, whose probability is proportional to the radiation density $u_o$, so that the rate of stimulated transitions from an upper state $j$ to a lower state $i$ is equal to $B_{ij} u_o N_i$, where $B_{ij}$ is a coefficient and $N_i$ the number of atoms in state $j$. Equilibrium occurs when detailed balance exists between the rates of the transitions $i \rightarrow j$ and $i \leftarrow j$, that is,

$$\langle A_{ij} + B_{ij} u_o \rangle N_i = B_{ij} u_o N_i,$$

where $A_{ij}$ and $u_o B_{ij}$ are the probabilities of spontaneous emission and absorption per unit time and $N_i$ is the number of atoms in the lower state $i$. These general arguments led to a new derivation of Planck's radiation law, to the calculation of transition probabilities, of the widths of spectral lines and of the life-times of excited states, and to the evaluation of the Einstein coefficients from the measured absorption coefficients. The influence of these two papers on the subsequent development of physics and chemical physics was and still is immense. What is not generally realized is that they contained the basic theory of amplification by stimulated emission. The integrated absorption of a spectral line was shown by Einstein to be related to the coefficients $B_{ij}$ and $A_{ij}$ and the populations $N_i$ and $N_i$ by

$$\int_0^\infty \sigma \, dv = h\nu/c \left[ B_{ij} N_i - B_{ij} N_j \right],$$

from which it is clear that the effect of stimulated emission (since there are phase relations between the incident and stimulated emitted waves) is that of a negative component absorption. It is also clear that, if $N_i/N_j$ can be made great enough to make the second term in the equation for integrated absorption larger than the first, the total absorption becomes negative, that is, amplification of the primary wave has occurred. The experimental realization of population inversion and sensible amplification through the use of resonant cavities has led to the practical devices known as masers and lasers. The technological applications of these devices are legion—microwave technology, holography, precise measurement of distance, surveying, line of sight communication, to name but a few.

Einstein made other contributions that have had far-reaching effects in science and technology; they are summarized in the accompanying table, which is a type of case history going forward in time from one individual scientist's personal scientific work.

There can be no argument that Einstein's scientific work was other than pure science, uncommitted to any economic objective. Nor can there be any dispute that enormous areas of science and technology could not have developed without Einstein's work. The fact that it was Einstein who initiated all these advances and not another scientist, or even a number of scientists, does not matter; it is clear that these discoveries could not have been made in a committed industrial context. The fact that economists cannot do a cost-benefit study of Einstein's work is irrelevant; it is obvious that the human community through its technology has derived immense benefit from Einstein's work.

**Problems in the Exploitation of Pure Science**

Perhaps the most important contribution of pure science to technology, but completely beyond economic assessment, is the pool of new knowledge and under
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standing to which even low-key research contributes and from which applied science and technology draw. All science and technology, irrespective of national boundaries, contribute to this pool and draw on it. Surely each human community has an obligation, within its capacity, to contribute its share to this common international pool. The low-key research is consolidating rather than spear-heading; its value to industry is great, but rarely acknowledged. It takes the form of new compounds, new reactions, new techniques, new materials, new methods, and new or better data. There does not appear to be any particular problem associated with access to and use of this pool by technologically competent industry.

By contrast, the exploitation of a new research result of value in itself presents substantial difficulties. The primary problem is the recognition that the research is exploitable or has potential application. The responsibility for recognizing the commercial potential of a new research result rests with the pure scientist himself. Contrary to what is popularly believed, the pure scientist is more often than not very alive to the possible applications of his discoveries, even though he may not be in a position to assess the economic feasibility of its exploitation. Consequently the scientist or his immediate colleagues must initiate the process which ultimately leads to exploitation; often he has the responsibility of protecting his discovery by making an application for patent cover. The subsequent steps, particularly that of endeavouring to interest a possible manufacturer, depend for their success on the level of development of the appropriate technology in the country and whether the facilities for development are available either in industry or in the research institution in which the scientist works. The pre-eminence of USA in exploiting new research results has been the subject of many analyses, but it is probably relevant that US industry has always supported in-house uncommitted research to a much greater extent than has industry in other countries. It is the scientists who are alive to the useful ideas appearing in the literature, and who through contacts with other scientists throughout the world obtain pre-publication information of new results. The value of scientists employed by industry to do uncommitted research is not necessarily that they produce exploitable ideas and inventions themselves, but that they recognize them elsewhere.

To illustrate the various points I would like to discuss briefly two or three examples from the work of the Division of Chemical Physics, where, after 25 years, considerable expertise in promoting the manufacture of scientific instruments has been accumulated.

You will undoubtedly have heard something of the story of atomic absorption spectroscopy, which was originated as a new branch of scientific study and as an analytical technique by Dr A. Walsh in 1953. Many of you will have listened to Dr Walsh's Einstein Lecture in 1967, so I do not intend to make any remarks about the scientific and technical aspects of this development. However, both the idea that the absorption of radiation by isolated atoms could be used for the determination of their concentration and the scientific studies that demonstrated the practical feasibility of these ideas were the result of uncommitted research. The recognition that this was an exploitable result was immediate, but there was at the time no scientific instrument manufacturer in Australia with experience in the field of spectroscopic instruments. Moreover, the ideas did not produce much reaction among the major scientific instrument manufacturers elsewhere in the world, and it was only through further development and promotion that even the major scientific-instrument manufacturers recognized the value of this work. This conservatism in industry is one of the major barriers to technological innovation based on a completely new research result. Some of the reticence in the scientific instrument industry may have been due to the fact that atomic absorption spectroscopy was a new scientific field and that at the time not even the research and development personnel in these firms had any background knowledge or understanding of it. Ultimately, the exploitation was taken up by a number of firms abroad and manufacture in Australia was gradually developed. The recognition that this was a useful technique in analytical work came only when application in Australian industry and various research organizations had demonstrated its value. The story is a fascinating one and I can recommend a study of it to any of you who are really concerned about the problems of exploitation and innovation. What, however, is the real payoff from a project of this kind? There is certainly the obvious economic pay-off in the form of licence fees for use of the patents covering the invention. Consolidated Revenue has now received $650 000 from some 20 licensees to date. Moreover, one can readily see the value to Australia's balance of trade of the income derived from export of atomic absorption spectrophotometers. However, neither of these economic benefits is of the same importance as the productivity gains in various industries that have been made possible through the use of atomic absorption spectroscopy as an analytical method. The project is to some extent unique in that from its origin the information necessary for a cost-benefit analysis from a national point of view was available. This enabled Mr A. W. Brown (The Economic Record, p. 158, June 1969) to undertake such a study, from which it is established that the benefits to date are of the order of $40 000 000 and the estimate of the total productivity benefits up to 1978 is of the order of $150 000 000. In addition there are non-quantifiable benefits which are undoubtedly of considerable value nationally, namely, the development of special skills in the national work force, the contribution to medicine through the clinical applications of the technique, and the opening up of a new area of scientific study which in itself provides the background for the generation of other exploitable results. It is very rarely possible to undertake a cost-benefit study of such completeness as that on atomic absorption spectroscopy, because the necessary in-
formation is either not available or is dispersed to a great extent. The inability to do such an analysis is no argument against the value of uncommitted research; in fact, the value of the study on atomic absorption is that it can be used inductively to support the case for pure science.

During the 1950's the research programme of the Division of Chemical Physics required optical diffraction gratings as the light dispersing components of special spectroscopic instruments. The difficulties in obtaining these prompted a study of the ruling of optical diffraction gratings and ultimately led to the construction of a ruling engine. By 1960 the first ruling engine, designed by Mr D. A. Davies and constructed by Mr G. M. Stiff, was operating and producing diffraction gratings of high quality. Until recently spectroscopic instruments used prisms as dispersing elements, simply because diffraction gratings were far too expensive for use except in the most sophisticated equipment. Various attempts to replicate diffraction gratings to produce identical copies of a master ruling were under investigation in two or three centres around the world; the ultimate development of a reasonably satisfactory copying process allowed the introduction of diffraction gratings as standard components of many spectroscopic instruments. Replication was studied and is still being studied within the Division of Chemical Physics. The pay-off from the original uncommitted excursion into the ruling of diffraction gratings came when an Australian firm took the decision to produce integrated atomic absorption spectrophotometers incorporating locally made monochromators. This monochromator was designed to use diffraction gratings produced on the Division of Chemical Physics's engine. It was possible to make gratings available from which the local firm could produce copies under licence for commercial purposes. This enterprise has also produced quite substantial royalties and is an expanding export item. However, there are other advantages accruing from this project. Diffraction-grating-ruling engines are the ultimate in mechanical precision; through this project the Division acquired the capability of working to tolerances of one millionth of an inch and experience in other precision engineering methods. Not only has this had immediate advantages in other areas of the Division's work, but it has been possible to train personnel from industry in the various special technical and engineering aspects of grating production. Moreover, it has been possible to provide special gratings for evaluation in university departments and other CSIRO Divisions; from time to time these will be incorporated in the commercial range of gratings. It is quite unthinkable that a project of this sort could have been initiated within industry, or even at this stage handed over completely to industry within Australia.

A final example concerns one small facet of a programme concerned with electron scattering and electron optics. The Division's research demanded the development of a specimen manipulator for electron microscopy at high resolution, but having a wide range of controls of higher stability and reproducibility than was available in any commercial instrument. The problem amounted to the manipulation of an electron microscope specimen in three orthogonal directions, together with tilting around the clock to at least 45 degrees. It was further necessary for this to be done while the microscope was operating at high resolution and the specimen completely protected from contamination, heated to temperatures in excess of 1000°C and exposed to extremely small quantities of gas during observation. Since this had to be accommodated within the 5-mm bore of the objective lens and controlled from outside the vacuum, the problem was quite formidable. This was achieved without drift or vibration of amplitude greater than 1 Å during observation. Mr J. C. Mills and Mr A. F. Moodie were so successful in the solution of their problem that the original uncommitted project became a commercial possibility and its manufacture has been licensed to a major overseas firm that has now incorporated the manipulator as a standard part of its electron microscopes. The fact that the manufacture has been undertaken outside Australia illustrates the point that the state of the supporting technology is an important prerequisite of exploitation. Australia does not have an electron-optical industry and in such a case one must license new components to an established overseas manufacturer. Ultimately, of course, it is desirable for Australia to engage in this type of manufacture, provided further relevant original developments appear. This story does not end there. In the first use of this new instrument in the Division's research a solid-state reaction was observed at high resolution and became the subject of a cinematographic film. This not only had enormous scientific interest, but led to a cooperative exploitation programme with Mr H. de Bruin of the Flinders University. A completely new method of sealing metals to non-metals has been developed, which seems to have enormous industrial potential. Among other applications it appears to have solved a long-standing problem in experimental spectroscopy, namely, sealing windows of a radiation-transparent material to a lamp or cell body of dissimilar material. This is a good example of one of the main features of uncommitted research, that the field of application of the outcome of the research is unpredictable.

Conclusions

To do justice to a topic of this sort would require a substantial monograph, but in summary the points I have attempted to make are:

1. Pure science is an essential component of human activity and is particularly essential to technological development. While technology contributes through feed-back to the development of pure science, the main stream of progress is initiated and sustained by the flow of ideas, information and understanding from pure science through to technology.
2. The initial step in the useful application of the results of pure science is the recognition of a potential exploitable result. Where a combination of uncommitted and committed research can be pursued in the one research environment then this recognition becomes much surer.

3. The results of uncommitted research can be exploited only if the supporting technology is at an appropriate stage of development.

4. Pure scientific activity contributes to the pool of scientific and technological competence within the community.

All of this, I submit, supports the contention that the origins of modern technology are to be found in pure science.

EXPERIMENTAL STUDIES OF IONIC COLLISIONS IN THE GAS PHASE

K. R. Ryan
CSIRO, Camden, NSW

At the Upper Atmosphere Section of CSIRO in Camden, NSW, studies of the interactions of charged and neutral particles in the gas phase have been in progress for several years. The immediate interest stems from the fact that ions produced in the high atmosphere are known to undergo rapid reactions on collision with neutral gas atoms and molecules. More generally ion-molecule collisions constitute an important class of reactions and must be considered in radiation chemistry, gaseous discharges and plasmas, or in any environment where sufficient energy is available to produce ions.

The method used so far to study these ion-molecule reactions at Camden is the classical one of high-pressure mass spectrometry. What this means, in fact, is that a mass spectrometer is used in which it is possible to operate the ion source at a pressure which is several orders of magnitude higher than would normally be the case. The technique may most readily be understood with the aid of the diagram. In the figure, F represents an electron-emitting filament, the electrons from which are directed through the collision chamber C to be collected on the trap T. Provided that the electrons have sufficient energy, positive ions can be formed along the electron track and these are pushed out of the collision chamber by the ion repeller R. If the pressure in the collision chamber is in excess of about 10⁻³ torr, a measurable fraction of ions will collide with neutral gas molecules and one will be able to detect, after mass analysis, ions which are products of these collisions as well as those formed in the electron beam. For example, the detection of \( \text{H}_2\text{O}^+ \) in the high-pressure mass spectrum of water vapour is strong evidence for the reaction

\[
\text{H}_2\text{O}^+ + \text{H}_2\text{O} \rightarrow \text{H}_2\text{O}^+ + \text{OH},
\]

since in this case \( \text{H}_2\text{O}^+ \) can only be formed as a result of a collision between an ion and a molecule.

The apparatus was designed and constructed in the laboratory specifically for the study of ion-molecule reactions. It is a 15-cm 60° magnetic-sector instrument, which differs from a conventional gas analyser in two important ways. First, the vacuum system is designed to produce a high pumping speed outside the collision chamber and to have an independent pumping system on the analyser. This combination allows one to operate the collision chamber at \( 10^4 \) times the pressure in the analyser tube and thus enhance the possibility of a reactive collision without any impairment of the performance of the analyser. The second important difference is that the operator has a great deal of flexibility in the control of the spectrometer. For example, a digital readout is provided to aid in the precision of adjustment of the voltage on every electrode of the instrument. This is particularly convenient in the operation of the ion source, which is also the reaction chamber of these studies. Furthermore the electron current can be regulated over the range of \( 4 \times 10^{-9} \) A to \( 10^{-5} \) A. Low electron currents are often necessary to reduce space-charge effects within the collision chamber. The instrument also has facilities for measuring very small ion intensities by pulse-counting techniques, which permit useful information to be obtained in the electron-energy region around the ionization threshold.

A fairly simple theory derived from the ion-mobility studies of Langlevin in 1905 predicts that the collision cross section \( \sigma (g) \) for ion-molecule collisions can be expressed by

\[
\sigma (g) = \frac{2\pi e}{g} \left( \frac{\alpha}{\mu} \right)^{1/2},
\]

where \( e \) is the electronic charge, \( g \) the relative velocity of the reactants, \( \alpha \) the polarizability of the neutral reactant and \( \mu \) the reduced mass of the reacting pair. This relationship leads immediately to the expression

\[
\text{The Australian Physicist, November 1970} \quad 173
\]
\[ k = 2 \pi e \left( \frac{\alpha}{\mu} \right)^4 \]

for the rate coefficient.

While some work on the dependence of cross section and rate coefficient on the relative velocity has been carried out at Camden, the main areas of interest have been:

(a) the lifetime and reactivity of ions in electronically excited states and,

(b) the competition between charge transfer and ion-molecule reactions.

When ionization occurs, some ions may be formed in electronically excited states which have lifetimes which are long in comparison to the time between the formation of the ion and its collision with a neutral particle. No clear picture of collision processes in the ionosphere or other environments can emerge until the electronic distribution of ions available for reaction is known. This requires a knowledge of both the initial ionic distribution following ionization and the lifetime of each electronic state. If an electronically excited ion undergoes an ion-molecule reaction for which the ground-state ion is incapable of reaction, and if at the same time the excited ion decays to a non-reacting state, then the half-life of the excited state can be determined. For example an excited \( \text{N}_2^+ \) ion, possibly the \( 2\Sigma_u^+ \) state, which is a metastable ion, some 5.5 electron volts above the ground electronic state, on collision with \( \text{N}_2 \), produces \( \text{N}_2^+ \) by the reaction:

\[ (\text{N}_2^+)_{\text{exc}} + \text{N}_2 \rightarrow \text{N}_2^+ + \text{N}_2 \]

and this same excited species deactivates by some unimolecular process. Since \( \text{N}_2^+ \) cannot be produced by collisions of \( \text{N}_2^+ \) in its ground state, a measurement of the production of \( \text{N}_2^+ \) as a function of reaction time by the technique outlined above has resulted in a calculation of the half-life of the excited ion.

As another example, it is thought that the \( \text{O}_2^+ a^3 \Pi_u \) ion, which is a metastable ion whose energy is about 4 eV above the ground-state ion, is produced in some abundance in the ionosphere. Measurements on this apparatus have shown that the excited ion is capable of two reactions which are not possible for the ion in its ground electronic state. These are:

\[ \text{O}_2^+ a^3 \Pi_u + \text{N}_2 \rightarrow \text{N}_2^+ + \text{O}_2, \quad \text{and} \]

\[ \text{O}_2^+ a^3 \Pi_u + \text{N}_2 \rightarrow \text{N}_2 + \text{O}_2^+ + \text{O}. \]

Of the two reactions, the one simply involving electron transfer is about two orders of magnitude faster than the one requiring rearrangement of the chemical bonds in the reacting system.

Other systems have been studied in which the electron-transfer reaction does not dominate the ion-molecule reaction. For example, in water vapour the \( \text{OH}^+ \) ion is capable of two reactions:

\[ \text{OH}^+ + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{O}, \quad \text{and} \]

\[ \text{OH}^+ + \text{H}_2\text{O} \rightarrow \text{H}_2\text{O}^+ + \text{OH}. \]

It has been shown that at very low ion velocities the \( \text{OH}^+ \) is removed almost exclusively by the ion-molecule reaction which produces \( \text{H}_3\text{O}^+ \). At higher ion velocities the situation is reversed and practically all collisions result in the electron-transfer process.

The study of gas-phase collisions between ions and neutral particles is still very much in its elementary stages. The structure and subsequent breakdown modes of the complex formed on collision is very poorly understood. Related to this problem is the effect of internal energy and the conversion of translational energy to internal energy of the colliding pair. It is clear at this stage that much more precise experimental investigations will be required than has normally been carried out in the past. This point has been generally realized and has led to the development of the so-called tandem instruments. These devices incorporate two mass spectrometers in such a way that a mass-resolved ion beam from the first instrument passes into a collision chamber where reactions may occur. The charged reactants and products are then withdrawn from the reaction region and pass into the second mass analyser. Instruments of this type can lead to a very considerable simplification in the interpretation of experimental observations. For example the charge-exchange reaction between \( \text{O}_2^+ a^3 \Pi_u \) and \( \text{N}_2 \) mentioned above was studied in the single-source apparatus. This meant that under conditions where the \( \text{O}_2^+ a^3 \Pi_u \) ion was formed by electron impact, \( \text{N}_2^+ \) in its ground electronic state was also present in the ion beam. Accordingly the charge-transfer reaction:

\[ \text{N}_2^+ + \text{O}_2 \rightarrow \text{O}_2^+ + \text{N}_2 \]

occurs in addition to the one involving the \( \text{O}_2^+ a^3 \Pi_u \) ion. This complication makes the interpretation of results difficult.

With tandem instruments, however, no such difficulty arises. For this problem, for example, only oxygen would be admitted to the ion source of the first mass spectrometer. A beam of oxygen ions containing some \( \text{O}_2^+ a^3 \Pi_u \) could then be injected into the collision chamber, which would contain only \( \text{N}_2 \) as the neutral gas. Thus under these conditions the only source of \( \text{N}_2^+ \) ions would be from charge exchange between \( \text{O}_2^+ \) and \( \text{N}_2 \).

Under construction at Camden is a tandem instrument which should be of great assistance in problems of this kind. The mass analysers used will be of low resolution but quite adequate for the problems envisaged. One future development planned for this device is to analyse the neutral products following ionic collisions. This type of apparatus also presents an opportunity to measure the reaction products of ion-electron and ion-ion neutralization. These last two areas of research should prove to be extremely interesting, as there is practically no information available concerning the electronic, vibrational, or rotational states of neutral products or the nature of the products of charge-neutralization processes.
INSTITUTE AFFAIRS

EINSTEIN MEMORIAL LECTURE

Albert Einstein died in 1955. His contributions to science and natural philosophy were outstanding. In 1956 the South Australian Division of the Australian Branch of the Institute of Physics decided to commemorate Einstein’s name by an annual lecture to be known as the Einstein Memorial Lecture. The intention was to bring before a public audience an eminent scientist to discourse on a recent development in science which had association with the work of the great physicist. The first lecture of the series was given on 15 November 1957 in the Bonynge Hall at the University of Adelaide by Professor Sir Mark Oliphant before an audience of eight hundred. He spoke on the problems and possibilities of harnessing the energy released in fusion reactions under the title ‘Hydrogen Bomb or Thermonuclear Power’.

Subsequent lectures have not always been so directly related to Einstein’s specific research interests. However, this has not marred the lecture series from the viewpoint of the audience since the topics presented have been of great current interest. This can be seen from the list of Einstein Memorial lecturers and lectures below:

1958 Professor Bart J. Bok
   ‘Stellar Evolution’

1959 Professor K. E. Bullen
   ‘The Internal Constitution of the Earth and Planets’

1960 Professor Sir Laurence Bragg
   ‘Molecules of Living Matter’

1961 Professor C. N. Watson-Munro
   ‘The Atom in the Service of Mankind’

1962 Professor Fred Hoyle
   ‘The Arrow of Time’

When the Australian Institute of Physics was formed in 1963, the South Australian Branch decided to continue the Einstein Memorial Lectures. The first lecture under the new auspices was delivered on 18 September 1963 by Dr D. F. Martyn on ‘Space Research’.

Subsequent lecturers and lectures are given below:

1964 Dr W. Boas
   ‘Why are Metals Weak?’

1965 Dr E. G. Bowen
   ‘The Work of the 210 ft Radio Telescope at Parkes’

1966 Professor E. W. Titterton
   ‘Matter and Energy’

1967 Dr A. Walsh
   ‘Atomic Absorption Spectroscopy’

1968 Dr C. H. B. Priestley
   ‘The Future of Meteorology’

1969 Dr R. G. Giovaneli
   ‘The Magnetism of the Sun’

This year the lecture was delivered by Dr A. L. G. Rees on Wednesday, 14 October in the Horace Lamb Theatre, Library Building, University of Adelaide. Dr Rees is the Chief of the CSIRO Division of Chemical Physics and his lecture, entitled ‘The Origins of Modern Technology’, appears elsewhere in this Journal.

NOTES AND NEWS

IUPAP News

International Conferences

The complete list of international conferences sponsored by the International Union of Pure and Applied Physics for the year 1970 was published in our November 1969 issue. Conference No 9 on Statistical Mechanics originally planned for Mexico, 19-24 October will now be held in Chicago, USA, from 29 March—2 April, 1971, particulars from Professor S. A. Rice.

World System for Abstracting

The ICSU Abstracting Board, of which Professor H. W. Koch (USA) is IUPAP’s representative, has announced its plans to go ahead with the first stage of a world-system for abstracting and indexing services for science and technology. The stage will be planned by eleven of the world’s major abstracting services from France, Germany, USA, USSR, and the United Kingdom. Each of these will be responsible for abstracting journals in a certain area and contributing the abstracts to a pool. This will greatly reduce the duplication of work and reduce the number of articles processed by each service.

The History of Physics

Growing interest in the history of Physics, particularly its spectacular developments in the 20th century, was underlined at the recent IUPAP-sponsored Conference on the Role of History of Physics in Physics Education held at MIT 13-17 July. Consideration was given to the need for preserving archival materials, and for publications in this field. Cooperation with the International Union of History and Philosophy of Science was also discussed. Formal proposals will soon be made to the IUPAP Executive for action.

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Peter Nicol Russell Medal

Professor W. N. Christiansen, FAIP, has been awarded the Peter Nicol Russell Memorial Medal for 1970 for his outstanding contribution to the design and development of radio telescopes. The medal, the highest award for Engineers in Australia, is awarded each year for notable contribution to the science and practice of engineering.

Dr Christiansen is Professor of Electrical Engineering at Sydney University. He is well-known for introducing the grating radio interferometer which gave a beam about 10 times narrower than any existing aerials and which now forms the basis of many of the world's biggest radio telescopes.

Mass Spectrometry

The formation of The Australian Society for Mass Spectrometry was announced in our September issue (with the word 'Spectroscopy' used in error, for which we apologize). The Society now has 84 applications for membership and plans to hold the 'First Australian Conference on Mass Spectrometry' at Macquarie University in August 1971. Advance notice of papers is requested by 1 December to Mr P. T. Greenhalgh, 48 Atchison Street, St Leonards NSW 2065.

New Company to Promote Innovation

The Australian Innovation Corporation Limited has commenced operation. This is a new company which aims to seek out, promote, and finance ventures based on scientific or technological innovation in any field of activity.

While similar in some respects to the National Research Development Corporation in Britain, the AIC is a private-enterprise operation more along the lines of the Canadian Enterprise Development Corporation Limited. Its shareholders are thirty Australian companies, mainly in the fields of finance, insurance, manufacturing, and mining.

The Chairman of the new company is Mr L. W. Weickhardt, who is also Deputy Chancellor of the University of Melbourne and who retired earlier this year from the position of Executive and Research Director of ICANZ Ltd. The General Manager is Mr J. H. Seidler, previously Manager, Planning and Economics, with Shell Chemicals (Australia) Pty Ltd.

The Corporation is now seeking proposals based on innovation which offer worthwhile opportunities of commercial success. Further details are available from the General Manager, Australian Innovation Corporation Ltd, 150 Queen Street, Melbourne.

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**THE REGISTER**

**Changes in Membership from 14 September 1970 to 12 October 1970**

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<tr>
<th>Fellowship</th>
<th>New Election</th>
<th>University of Sydney, NSW</th>
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<tbody>
<tr>
<td></td>
<td>Reinstatement</td>
<td>CSIRO, Div. of Meteorological Physics, Vic.</td>
</tr>
<tr>
<td>(a) New Election</td>
<td>Davis, J.</td>
<td>University of Sydney, NSW</td>
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<tr>
<td></td>
<td>Berson, A. F. A.</td>
<td>CSIRO, Div. of Meteorological Physics, Vic.</td>
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<tr>
<td>(b) Reinstatement</td>
<td>Berson, A. F. A.</td>
<td>CSIRO, Div. of Meteorological Physics, Vic.</td>
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<tr>
<td>(c) Removals</td>
<td>Bingham, R. T. W. (Vic.) Deceased</td>
<td>Resigned</td>
</tr>
<tr>
<td></td>
<td>Hirst, H. (Vic.)</td>
<td>Resigned</td>
</tr>
<tr>
<td>Associateship</td>
<td>C. New Elections</td>
<td>Swinburne College of Technology, Vic.</td>
</tr>
<tr>
<td>(a) New Elections</td>
<td>Clark, J.</td>
<td>Monash University, Vic.</td>
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<tr>
<td></td>
<td>Clark, P. E.</td>
<td>University of Queensland</td>
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<td></td>
<td>Dalton, B. J.</td>
<td>University of Queensland</td>
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<td></td>
<td>Higbie, J. W.</td>
<td>University of Queensland</td>
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<tr>
<td>(b) Transfers</td>
<td>Hewitt, R. G.</td>
<td>University of Sydney, NSW</td>
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<tr>
<td></td>
<td>Sutherland, J. W.</td>
<td>CSIRO, Division of Mechanical Engineering, Vic.</td>
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<td></td>
<td>Wells, M. S.</td>
<td>AWA Physical Laboratory, NSW</td>
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<tr>
<td>(c) Resignation</td>
<td>Carwardine, E. P.</td>
<td>(WA)</td>
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**Graduateship**

<table>
<thead>
<tr>
<th>(a) New Elections</th>
<th>University of Melbourne, Vic.</th>
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<tbody>
<tr>
<td>Gold, E.</td>
<td></td>
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<tr>
<td>Hain, T. F.</td>
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<td>Hatt, D. J.</td>
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<td>Norris, D. J.</td>
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<td>Walton, D.</td>
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<tr>
<td>Wilson, J. T.</td>
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</table>

**Students**

<table>
<thead>
<tr>
<th>New Elections</th>
<th>University of Melbourne, Vic.</th>
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<tbody>
<tr>
<td>Jackson, I. N. S. (Qld)</td>
<td>MacGillivray, W. R. (Qld)</td>
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<tr>
<td>Lettau, K. E. (NSW)</td>
<td>Stirzaker, L. R. (NSW)</td>
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</table>

**Subscribers**

<table>
<thead>
<tr>
<th>New Elections</th>
<th>University of Melbourne, Vic.</th>
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<tbody>
<tr>
<td>Bell, E. J. (Qld)</td>
<td>MacGillivray, W. R. (Qld)</td>
</tr>
<tr>
<td>Ruff, R. J. (Qld)</td>
<td>Stirzaker, L. R. (NSW)</td>
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Location: Perth.
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