The Australian Physicist

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Cover Photo: A sketch of the 30 Doradus Nebula in the
Large Magellanic Cloud, made by Mr. Albert Le Sueur in
March 1870 using the Great Melbourne Telescope. A photo-
graph of the same object is shown for comparison.
In 1870 photographic techniques were not sufficiently
sensitive to obtain images of the faint emission from
nebulae.

The photograph of 30 Doradus is reproduced by the
courtesy of Dr D. J. Faulkner of Mt. Stromlo Observatory.
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EDITORIAL ADDRESS: The Editor, Australian Physicist, Box 1, Ingle Farm, S.A. 5098.

Editorial

Our Vice-President peripatetic, Professor Bert Bolton has been sending back cuttings from the English newspapers which express the anxieties and uncertainties that the informed public are feeling about science, scientific research and teaching.

Sir Andrew Huxley, President of the British Association has criticised "the unscientific response of some scientists and of a wider public" to the IQ controversy. He pleads for a sharp distinction "between questions of fact, to be decided on evidence, and questions of the policy that should be adopted in the light of the facts." Our own local controversies come to mind and the discoveries and special knowledge of physics, which we as a profession have in our care to assess and extend, are the source of our responsibility in helping to shape social and economic policy. The policy committee of the Institute will be glad to hear from you.

In a letter to The Times 29/7/77 Professor Kenneth Mellanby has written at some length on making scientific research effective, for he thinks that the taxpayer is getting poor value for money because of ineffective use of funds, and resources.

His remarks are echoed in the staff rooms of our own research establishments and teaching institutions - "Many previously productive scientists have no time to spare for work at the laboratory bench; they are fully stretched producing reams of useless paper". In the distant past research councils supported the productive man and gave him limited funds and a great deal of freedom. Professor Mellanby believes that a time when funds are scarce may be the best time to return to this attitude.

While the statement may be extreme the letter does suggest that the relation between government funding and the national science structure is a delicate one and has application in the Australian scene to ASTEC, the Commonwealth and the scientists.

Letter

Sir,

In your Editorial of August 1977 you write:

"Physicists must be seen more as people who have much to give to our social as well as technical and physical development. This does not imply that physicists alone can do that which requires total cooperation but perhaps the image of the withdrawn scientist can be erased."

How right! and how to do it? Here is one suggestion.

Physicists are supposed to be able to communicate. Often they can - but only with physicists. A few distinguished ones have been able to communicate with ordinary people; I have no doubt that they realised the need and trained themselves to do so - it didn't just happen.

The AIP should begin a project to persuade the Schools of Physics to require, as a condition for the award of a degree, demonstration of ability to communicate with the public.

The undergraduate would be required to write a short article suitable for a magazine or newspaper about some aspect of physics that interested him. One of the Schools in the Humanities area would assess the articles using two criteria only;

Was it easy to understand?
Was it interesting?

For the Ph.D. candidate the requirement would be the same. The assessor would be a professional journalist who would be asked one question:

Would you (with perhaps some editorial amendment of your own) be prepared to offer this article to the editor of a newspaper or magazine?

Having got this under way it would become the business of the AIP (perhaps one of its major functions) to have contacts in journalism for the placement of articles about physics.

There would be numerous objections, especially from the "not time for this, we can't handle what we have now" brigade. That's easy - a little less physics and a lot more communication with Joe Blow who pays for it all and who might be a Personnel Director in industry.

From experience I can tell you that doing this is difficult, interesting and most educational!

Yours faithfully,

H. J. TURNER
MAIP.
The Great Melbourne Telescope
R.D. Watson, Department of Physics and J.M. Watson,
Department of Mathematics, University of Tasmania

The installation in 1869 of the great 48-inch reflecting telescope at the Melbourne Observatory can be said to mark the first attempt on this continent at what we would term 'big science'. At the time of its installation it was exceeded in size only by Lord Rosse's 72-inch reflector in Ireland, essentially a transit instrument which was, by comparison, relatively clumsy to handle. No other substantial telescope existed in the southern hemisphere. Although the subsequent history of the Great Melbourne Telescope, as it was known, was a rather unfortunate one, the events leading up to its design and eventual erection in Melbourne provide an interesting insight into nineteenth century astronomical aspirations.

BACKGROUND

By the middle of the nineteenth century observations of 'nebulae' had become of central interest to many astronomers. The term 'nebulae' was then used to refer to all of those faint hazy patches of light now classified variously as star clusters, galaxies, gaseous nebulae and planetary nebulae. During the years 1834 to 1838, Sir John Herschel had taken an 18-inch reflector to the Cape of Good Hope and surveyed nebulae in the southern sky. However, the need for further study of southern nebulae had become pressing by the 1850's, particularly in view of the detection by Lord Rosse's reflector of a spiral structure in some objects. A large light-collecting area was required for such a study. This led the Royal Society in 1852 to resolve as follows:

That the President and Council agree with the British Association in considering it desirable to proceed without delay in obtaining the establishment of a telescope of great optical power for the observation of Nebulae in a convenient locality in the southern hemisphere, and that a Committee be appointed to take such steps as they deem most desirable to carry out this resolution. The Committee to consist of the President, Officers and Council of the Royal Society, with the addition of the following gentlemen: Lord Wrottesley, Dr. Robinson, J. C. Adams, Esq., The Astronomer Royal, J. Nuytsmyth Esq., W. Lassell Esq., Sir David Brewster, E. J. Cooper Esq., Sir John Herschel, Sir John Lubbock, and the Dean of Ely.

Debate amongst members of the Committee then proceeded as to the most suitable telescope design and the most favourable site for its location. James Nasmyth, historically perhaps best known for his development of the steam hammer, suggested one design which involved the observer being suspended at the Newtonian focus in a cage attached to the top of the telescope tube. This scheme was eventually discarded for a variety of reasons, including the fact that the observer would be at the
merce of a negligent or sleepy night assistant. Such a system did eventuate almost a century later with the completion of the 200-inch Palomar reflector.

In connection with the siting of the telescope, 'Cape Town', 'Sydney' and 'Hobartown' were mentioned. Sir John Lubbock, however, considered Australia "out of the question by reason of the abnormal state of the Colony" in those early goldrush days. Mr. Cooper argued in favour of Tasmania. A letter in a similar vein was sent to the Committee by Sir William Denison, then Lieutenant Governor of Van Diemen's Land who, in a tactful reference to the abundance of convict labour, reminded the Committee that "I have the means of erecting cheaply all the buildings which might be required". Interestingly enough, Piazza Smyth suggested to the Committee that, bearing in mind the advantages offered by a site above the worst of the atmosphere, "the elevated plains of Andes would appear to be the most favourable". Only in the last decade has the full potential of this suggested site been developed following the establishment of European and United States observatories in Chile. Political reality however would not have permitted the telescope to be sited other than in one of Her Majesty's Dominions.

Within six months the Committee had selected a design for a 48-inch reflector proposed by Mr. Thomas Grubb of Dublin, and resolved that application be made to the Government for the necessary funds. It was never necessary to settle the question of the site because the £5000 required for the telescope was not forthcoming. Subsequent commitments in the Crimea presumably placed considerable strain on the Treasury. Thus the project lapsed.

THE VICTORIAN PROPOSAL

A decade later, in 1862, a despatch from the Governor of Victoria, Sir Henry Barkly, was conveyed through the Secretary of State for the Colonies to the then President of the Royal Society, General Sabine. This despatch intimated that the Board of Visitors of the newly established Melbourne Observatory wished to install a large telescope to further the study of Southern Nebulae, and sought advice concerning "the most suitable construction of the telescope for the purpose, both as to the optical part and the mounting; its probable cost, and the time requisite for its completion". The former Williamstown Observatory, established in 1853 with R. L. J. Ellery in charge, was at that stage about to be closed and astronomical operations moved to a new site in Melbourne's Domain Park, just south of the city centre. This circumstance must have contributed to the later difficulties in operation of the large telescope. A location near the centre of a growing city was recognized as undesirable even in that era. In the aftermath of the goldrush, Victoria was a prosperous and energetic colony, and the Governor's communication noted "that the pecuniary cooperation of the British Government was not applied for" as regards the telescope. In fact, financial cooperation between British and Australian Governments in large telescope construction did not eventuate until recent times with the development of the 150-inch Anglo-Australian Telescope. Thus the advisory committee set up by the Royal Society, consisting of Lord Rosse, Dr. Robinson, Mr. De la Rue and Mr. Lassell, was required to deal only with constructional matters.

By December 1862 the Committee had forwarded through the Royal Society a set of draft recommendations to the Victorians. Two possibilities were placed before the Melbourne Observatory Board of Visitors for consideration: an existing 48-inch telescope of Mr. Lassell's, and a 48-inch design of Mr. Grubb, which was basically the same as resulted from the 1852 deliberations. Lassell's reflector, which he offered to present to the Observatory, was one he had used in Malta for observations of nebulae. This offer was politely declined in favour of a more manageable instrument, and by August 1865 the final decision in favour of the Grubb design had been taken. A sum of £5000 was appropriated for the project by the colonial legislature. The similarity of this amount with the estimate made in 1853 says something for the absence of inflation.

The reasons behind some of the basic features incorporated in the Grubb designs are of interest. The choice of 48-inch aperture was, as one would expect, a compromise between the need for a large collecting area and the prevailing constraints of technology and finance. The choice of a reflector rather than a refractor was made on the grounds that "it is not probable that an achromatic can ever be made which shall have as much light as a 4-feet reflector; and if it could, the cost of it would be tremendous". Subsequent history has demonstrated the validity of this argument. The largest refractor presently existing, commissioned in 1897 at Yerkes Observatory, Illinois, has only a 40-inch aperture. Cassegrain construction was adopted largely because of the convenience it afforded to the visual observer who could thereby be located near ground level. An open lattice design for the telescope tube was considered essential to minimize the disturbing influence of air currents above the mirror. It was recommended that the mirror be cast of metal, following the design of all large reflectors up to that point in time.

Silvering of glass mirrors was then at the experimental stage and had only been successfully attempted for small disks. The Committee was unwilling to risk this technique on such a large casting and had reservations concerning the durability of the silver surface.

Use of metal mirrors, though a well established technology, had the major disadvantage that polishing a tarnished metal reflecting surface also meant simul-
taneously refiguring the surface. This task required an expertise which at that time was possessed by only a few people. The problem of polishing, magnified by the isolation of the telescope site from this expertise, proved later to be the greatest impediment to the successful operation of the telescope. Foreseeing this problem, Lord Rosse had suggested to the advisory Committee that it was "essential that someone should accompany the telescope as a mechanical assistant - he having been the principal operator in the grinding and polishing of the specula". This opinion was generally accepted and a Mr. Albert le Sueur was eventually recommended for the position. Further, two mirrors were to be provided so that one could be polished while the other was in use in the telescope. A polishing machine, driven by a steam engine, was to be supplied as part of Grubb's contract. The Great Melbourne Telescope was the last large refractor to employ metal mirrors.

CONSTRUCTION AND INSTALLATION

The contract with Thomas Grubb was signed in February 1866 and construction of the telescope began immediately. This began an association of the name Grubb with large reflecting telescopes in Australia which has continued, under the auspices of the Sir Howard Grubb Parsons and Co. Ltd., through the construction of the 74-inch telescope at Mt Stromlo Observatory and components of the giant Anglo-Australian Telescope.

After one faulty casting, the two metal disks for the Great Melbourne Telescope were successfully completed in September and November of 1866. Each weighed 3000 lbs. By late 1867 the telescope had been completed and erected for trials at Mr. Grubb's works in Dublin. Robinson, De Ruy and Lasell undertook an inspection of the instrument early in 1868 and reported very favourably to the Royal Society. Lasell however submitted an additional separate report which gave the impression that, although he unreservedly approved of the general efficiency and completeness of the mechanics of the instrument, he considered that sky conditions had not been adequate to permit a very critical test of the optics. Thus it is possible that slight optical imperfections went unnoticed. This may have had some bearing on the problems which beset the instrument in Melbourne. The telescope was subsequently dismantled and packed for transport to Victoria, its metal mirrors having been covered with shellac varnish for protection. With it went great hope, eloquently voiced by Robinson:

"It is impossible to contemplate without enthusiasm the treasures of discovery which are opening before the accomplished astronomer who is about to sweep with an instrument that has but one superior in the world, a sky whose wonders only one has yet explored, in a climate such as British astronomers can only dream of."

The telescope left Liverpool in July 1868 on the Empress of the Seas and arrived late in that year after an exceptionally long passage. The long wait had stirred some anxiety in the Victorians, but in fact the various parts of the instrument were all in good order on arrival. Le Sueur reached Melbourne two months before the telescope. Together with Ellery, the Government Astronomer, he supervised the completion of the building in the Domain which was to house the great instrument. The building was designed with a roll-back roof leaving the telescope completely exposed when in use. Wind vibration of the long focal length tube was thus one of the difficulties with which the observers later had to contend. A further unwanted side effect of the open instrument appears in a later comment by Le Sueur, who alluded to "occasional heavy dew rendering it almost impractical to use the sketching and other papers" while at the eyepiece.

By the middle of 1869 installation of the telescope had been completed, though not without problems. The principal problem encountered was the removal of the varnish coating from the mirrors. Later correspondence on the matter suggested that Ellery and Le Sueur adopted an incorrect procedure. As a result, one of the two mirrors tarnished rapidly and soon had to be replaced in the telescope by the second, less affected mirror. Question also arose as to the quality of definition that the telescope gave. It is not clear, however, how much of this was a problem with the optical figure, and how much was due to the effects of the varnish and the limited observational experience with large instruments possessed by Ellery and Le Sueur. Some observations were commenced in the latter half of 1869, but the Melbourne climate produced its share of frustrations. Le Sueur complained of "a long chapter of weary heart-breaking watchings, with an occasional half-hour's work". Sketches and visual spectroscopic observations were made of the great η Carinae complex, as well as a few other objects. By the time Ellery made his March 1870 report to the Board of Visitors of the Observatory, he was cautiously optimistic about the future.

FURTHER OPERATION

Unfortunately troubles rapidly returned. By May 1870 Le Sueur had resigned, apparently finding his position at the Observatory intolerable. He had returned to England by the end of the year, thereby leaving Ellery in an unenviable position in any mirror polishing operations. Ellery taught himself how to refit the mirrors, but lacked the means to carry out accurate tests on the figure. Once the mirrors had been polished it appears they did not perform well again. The imperfect optics, together with the problems of weather and wind vibration, meant that the high hopes that originally went with the planning of the instrument were never fully realized. In spite of the difficulties, observations with the instruments continued slowly and steadily and the first instalment of these was published in 1893. By the end of the century however, work with the telescope had essentially ceased. The poor performance of this instrument is said to have discouraged the adoption of further large reflecting telescopes for nearly a third of a century.

Following the closure of Melbourne Observatory in 1944, the Great Melbourne Telescope was purchased by the Commonwealth Observatory at Mt Stromlo for £500, a tenth of its original cost. After considerable modification, it was re-erected in a suitable dome on the Mt Stromlo site. A 50-inch aluminized glass mirror was installed and the telescope tube was shortened and closed in. Observations commenced with the instrument in its new form in the late 1950's and continued until the instrument was taken out of service only within the last couple of years. It is satisfying that one hundred years after its first use, the telescope was able to fulfill some of its designer's aspirations.
Part of the original north pier of the telescope stands as a commemorative stone at the Academy of Science building in Canberra. In spite of its problems, the Great Melbourne Telescope was a major landmark in the development of Australian science and it is fitting that it be so recognized.

ACKNOWLEDGEMENT
Access to the prints appearing in Figures 1 and 2 was by courtesy of J. Haneke of the Mt Stromlo and Siding Spring Observatory library, which now houses some material from the former Melbourne Observatory library.

REFERENCES
1. Correspondence concerning the Great Melbourne Telescope, printed for private circulation by the Royal Society, 1871. (Unreferenced quotations in the text are from this source.)

Figure 1. The 48-inch Cassegrain reflector installed at Melbourne Observatory. A rolling roof covered the instrument when not in use. The observer's eyepiece is visible at the extreme left behind the primary mirror cell. A chronometer is stationed next to the south pier, and the clock mechanism which drove the telescope about its polar axis when tracking celestial objects is located in a cavity behind the small door in this pier. Weighted weights attached to the southern pier were associated with levers designed to relieve pressures on the bearings supports of the massive instrument. The large wheel beside the north pier was used to slew the telescope about its polar axis. Photography was undertaken at prime focus and the 'photographic apparatus', which replaced the secondary mirror on these occasions, is seen resting on the roof of the small photographic laboratory behind the south pier. The 48-inch metal mirrors could be taken through the doorway on the right, behind which was located polishing machinery driven by a steam engine.

Conferences and Courses

Computers and Neutrons

The Neutron Scattering Group of the Institute of Physics and the Faraday Division of the Chemical Society will hold a meeting in Oxford on 3 – 4 April, 1978. The purpose of the meeting is to discuss those aspects of the physics and chemistry of condensed matter which can be studied both by neutron scattering and computational techniques.

The main emphasis will be on the comparison of the results of computer simulation and modelling studies with those of neutron scattering experiments. The principal topics will be – lattice dynamics, liquids and ultrasonic forces, defects and diffusion in solids, molecular and macromolecular conformation and dynamics.

Further details can be obtained from P. Schofield, Materials Physics Division, Building 521, Harwell, Didcot, Oxfordshire OX11 ORA.

Geophysical Assembly

The second U.K. Geophysical Assembly will be held on 10 – 13 April, 1978 at Liverpool University. Further information can be obtained from Dr. A. E. Mussett, Department of Geophysics, Liverpool University, Liverpool L69 3BX.

16th Annual European High Pressure Conference

This conference will be held at the J. J. Thomson Physical Laboratory of the University of Reading on 11 – 13 April, 1978. The theme of the conference will be solid state physics and instrumentation at high pressure. Information is available from Mrs. J. Griffin, J. J. Thomson Physical Laboratory, University of Reading, Whiteknights, Reading, RG6 2AH.

Third Australian Conference on Science Technology

This conference, organized by the S.A. Division of ANZAAS and the Australian Institute of Science Technology (with the assistance of the Canberra Branch of AIST) will be held at the Australian National University, Canberra from 15 to 17 May 1978. Enquiries should be addressed to Mrs. Rene Ellis, ANZAAS—SA, 141 Rundle Mall, Adelaide, S.A. 5000

The Physics of Semiconductors, 14th International Conference, 4-8 September, 1978, Edinburgh, Scotland.

The conference is organized by the Institute of Physics under the auspices of the IUPAP. The organizing committee is under the Chairmanship of Professors Sir Nevill Mott, F.R.S.

The conference will cover progress in all aspects of semiconductor physics and the program will feature Invited Reviews by distinguished speakers drawn from many countries. Contributed research papers are invited and the deadline for submission of abstracts will be 31 March, 1978.

The conference will be held in the Appleton Tower, University of Edinburgh and coincides with the third week of the Edinburgh Festival. It will be impossible to secure hotel rooms at short notice and those who wish to stay in hotel rooms should contact the Institute of Physics at once. Other accommodation in University Halls of Residence and family flats can be arranged.

Associated with the main conference will be three Satellite Conferences and a Summer School. The conference topics are: Recombination in Semiconductors (Southampton, 30 August – 1 September); Defects and radiation effects in semiconductors (Nice, France, 11 – 14 September) Application of high magnetic fields in semiconductor physics (Oxford, 11 – 15 September). The Summer School on “The metal/non-metal transition in disordered systems,” takes place at the University of St. Andrews from 6 – 26 August. Further information is available from The Meetings Officer, The Institute of Physics, 47 Belgrave Square, London SW1X 8QX.

Structural Aspects Common to Synthetic and Biological Macromolecules

The Institute of Physics is organizing on behalf of the Condensed Matter Division of the European Physical Society of the Eighth Europhysics Macromolecular Conference to be held at the University of Bristol from 19 – 22 September, 1978.

Those wishing to be placed on the mailing list for further details should write to The Meetings Officer, The Institute of Physics, 47 Belgrave Square, London, SW1X 8QX.
Sources of Friction
K. Rachel Makinson, Division of Textile Physics, C.S.I.R.O. Ryde, New South Wales

The subject of friction is not as simple as it is often assumed to be. The physics involved is simple, but difficulty arises from the multiplicity of possible causes of friction and the complexity of stress and strain distributions between sliding bodies. The subject was bedevilled for many years by the tacit assumption that there must be one, single cause of friction, so that "crucial" experiments, designed to discriminate between various postulated causes, led only to fruitless controversies. Realisation of the multiplicity of direct causes, with subsequent subsuming of these direct causes into a more general cause, has been the key to the understanding of frictional mechanisms that has developed over the last 30 years. Even now the subject is not tractable mathematically; for example, it is rarely possible to predict the coefficient of friction between sliding bodies, from a knowledge of their physical properties, to within a factor of from 3 to 5, although it is often possible to predict the form of the dependence of the coefficient on such parameters as sliding velocity, temperature, and macro and micro dimensions of the bodies.

Friction is the resistance to mutual sliding between two bodies. It is generally accepted now that this resistance most commonly arises from deformations imposed on the bodies by the forces applied in the experimental or practical situation. Other sources are usually unimportant. However, these deformations can be so complex that a fully generalised treatment, although possible, is not always useful. It is preferable to consider certain limiting types of deformation that occur in certain situations, and to call each one a separate source of friction. Even then a great many approximations have to be made in developing the theory. Also, an unfortunate consequence of this piecemeal approach is that the different theories sometimes appear to be mutually incompatible, because they are meant to be applied to different situations.

The first big division usually made is that between adhesion mechanisms and deformation mechanisms. They are not in fact strictly separable, since adhesion results from and leads to deformation, although deformation can occur without adhesion. Nevertheless, the separation is useful, since when adhesion occurs the friction is usually much greater than when it does not occur.

Adhesion Mechanisms

Under this heading will be grouped those mechanisms in which adhesion of the two sliding surfaces is an essential feature; one of them will be discussed here in detail, and another outlined briefly.

The classical theory of "the" adhesion mechanism was developed principally by Bowden and his co-workers (Leban, Tabor and many others) from the mid-30's onward (Bowden and Tabor, 1950). It is really a theory of repeated adhesion and fracture (adhesion itself having been considered in the eighteenth century by Vinci and Coulomb). The classical theory was developed for metals sliding on metals. Bowden et al. thought that an adhesion-and-fracture mechanism was necessary to explain Amontons' Laws (that frictional force is approximately proportional to the normal load between the surfaces and independent of the area of apparent contact) and to explain why sliding is often jerky ("stick-slip") rather than smooth. In this belief they were wrong. Nevertheless, they did successfully demonstrate the occurrence of this mechanism in the sliding of metals, by showing that, when one fairly smooth metal slides over another, material is plucked out of one or both surfaces and transferred to the other. The most important features of their argument were (i) the stress they placed on recognition of the fact that when two nominally smooth, flat surfaces are placed in contact they touch, as a rule, over only a small part of the area of apparent contact, at the tips of asperities on one or the other (Fig.1); (ii) their recognition that friction does not arise from the behaviour solely of the outermost one or two molecular layers of the surfaces (as many people believed at the time), but involves relatively gross deformation of the sliding bodies and consequently can in principle be related to their bulk mechanical properties.

The argument of the classical theory, for metals, runs as follows. When, as is usually the case, the two sliding surfaces touch only at the tips of asperities, the normal load N pressing them together (Fig.1) is concentrated on the small regions of real contact, over which the pressure becomes very high. In the absence of deformation, the pressure would exceed the yield pressure of metals even for quite small values of N. The asperities on the softer metals therefore flow plastically at their tips. This increases each elementary area of real

![Diagram](image-url)

Fig. 1. Diagrammatic representation of the small area of real contact between two extended bodies.

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contact. Also—and nowadays this is usually considered more important—it brings the surfaces closer together, so that, unless the area of apparent contact is very small, more regions of real contact are established. The overall result is usually that the number of regions of real contact is increased when the load is increased, but the mean area of each is little changed. However, the total area of real contact, $A_0$, is always increased by increasing the load, so that the local pressure between the surfaces is limited to $p$, according to the relation

$$N = A_0 p.$$

Another important concept in the classical theory was that the two metals became cold-welded together over the regions where plastic flow occurred. This concept has caused some controversy. Cold-welding appears to occur with many metals, but it is not essential to an adhesion-and-fracture mechanism.

Contact between the surfaces having been established, a tractive force is applied to the slider parallel to the mean common surface, and gradually increased from a low value until sliding begins. (Couples are ignored in the elementary treatment). This force has to be sufficient to shear the welded junctions at the points of real contact. Consequently sliding will begin when the tractive force reaches a value $T$ given by

$$T = A_0 s, \quad \text{(ii)}$$

where $s$ is the shear strength of the junctions. (This equation can be regarded as summarising the adhesion-and-fracture mechanism). Fracture in shear will occur at the weakest part of the junctions, which may be the actual interface between the metals, but more often is a zone inside the weaker metal, because the flow of material is often work-hardened locally. In this case $s$ is equal, at least approximately, to the shear strength of the bulk metal.

The frictional force $F$ is, by definition, equal and opposite to $T$. Hence the coefficient of friction $\mu$ is given by

$$\mu = F/N = N/p. \quad \text{(iii)}$$

Since $s$ and $p$ both measure mechanical properties of the softer metal, their ratio tends to stay fairly constant for different metals, which offers an explanation of the comparatively small range of values of $\mu$ observed under normal circumstances.

The argument above has been presented for static friction (for $\mu$), which is an ill-defined concept since it assumes absolute rigidity of the metals up to the point of fracture. A similar argument can be used for the better defined coefficient of kinetic or dynamic friction, $\mu_k$. To account for the usual observation that $\mu_k > \mu_s$, it is necessary to make the ad hoc assumption that $s$ and $p$ vary differently with the velocity of sliding, although there is no very sound basis for this assumption for metals over the range of sliding velocities normally used. In general, applying this theory one frequently has to make ad hoc assumptions; nevertheless, it represented a great advance in understanding at the time of its development.

The quantities $s$ and $p$ are engineering rather than physical parameters, so their values depend to some extent on how they are measured. For example, $s$ is likely to be higher under hydrostatic pressure, such as exists in the welded junctions, than it is in pure shear. Hence it is not surprising that the theory does not give good absolute values of $\mu$ (although they are of the right order).

It is obvious that Amonton's Laws follow from this theory. The coefficient of friction is independent of the normal load $N$ because the local pressure over the area of real contact is independent of $N$; it is simply equal to $p$. The coefficient of friction is independent of the area of contact—the real area $A_0$ or the apparent area $A$—because both $F$ and $N$ are proportional to $A_0$ and they are both independent of $A$.

A great deal of work has gone into refining the above theory and making it applicable to polymers. One refinement has been critically accepted and misapplied, particularly in the field with which the writer has been concerned (friction of wool fibres). In 1952 Lincoln, applying the theory to high polymers, pointed out that these highly elastic materials will not undergo plastic flow when they are pressed together. The deformation of the asperities will be elastic under all practicable loads. It can be shown that the apparent area of contact of a sphere of polymer against a hard plane is $\propto \sqrt{2}$. Assuming that this applies to the contact of individual asperities (assumed spherical), the total area of real contact $A_0$ between two highly elastic bodies would also be $\propto \sqrt{2}$. Hence, if $F = A_0 s$, $F \propto \sqrt{2}/N$, and $\mu \propto N^{-1/2}$. It appeared that a study of the relation between $F$ and $N$ (or $\mu$ and $N$) would indicate whether the deformation of the asperities was elastic ($F \propto N$), plastic ($F \propto N^{2/3}$) or in between (index between 2/3 and unity). There was a flurry of activity along these lines. However, even as early as 1953, Lincoln himself, and Archard, separately showed that this conclusion was valid only when the area of apparent contact $A$ was so small that it included only a few regions of real contact, as for example, in the contact between two mutually perpendicular circular cylinders. (A Russian, Zhuravlev, had shown this in 1940, but his work was not known in the west). In general $A$ includes many regions of real contact. Because asperities are not all of the same height, increasing the load increases the total number of contacts but not their mean elementary area, the appearance of new, small, ones counterbalancing the growth of the older ones. A number of people showed, for various model situations, that the result would be that the index $n$ in $F \propto N^n$ would be $> 2/3$ even for purely elastic deformation. The more complex the distribution of asperities, the closer the index would be to unity—and real asperities are very complex.

This subject has been comprehensively reviewed by Jones, Howells and Probert [1968]. It is unfortunate that in some fields the index criterion is still being misapplied.

The adhesion-and-fracture theory is, nevertheless, applicable to the friction of high polymers, with minor changes. Cold-welding still occurs, but adhesion may be strong enough to cause fracture in one or both of the sliding bodies. In such case the basic equation (ii) is directly applicable, but it has to be noted that the area of real contact $A_0$ increases with the length of time during which the surfaces have been in contact, because of the occurrence of viscoelastic flow under the normal load. Consequently the static frictional force ($F_s$) tends to increase with the duration of contact under load prior to application of the maximum tractive force $T$. Kinetic friction ($F_k$), on the other hand, should not, in a simple analysis, depend very much on the sliding velocity $v$, because $A_0$ will decrease as $v$ increases, while $s$ will increase. Experimentally, however, $F_k$ is found to show considerable dependence on $v$, often passing through a maximum at a particular value of $v$, Ludema and Tabor [1966]. We have introduced an important new concept to explain this. They pointed out that shear occurred in a very thin layer at the interface, so that the rate of strain was high even at quite low sliding speeds. Deformation under the normal load occurred throughout the much greater thickness of material, so that the rate of strain for this deformation was much less. A shift of 5 decades between the two strain rates appeared to give very good agreement between theory and experiment for rubber sliding on glass, and reasonable agreement for a number of other systems.

There is one major difficulty in the way of accepting this explanation, viz. that there is no transfer of material, no fracture, when rubber slides on glass, although there is in the case of most other polymers. The difficulty has not yet been satisfactorily resolved. It appears to the present author that a
different mechanism of friction is operative here, but one to which Ludema and Tabor's concept is still applicable. The mechanism, postulated by Bulgin, Hubbard and Walters [1962], may be called adhesion with tangential dragging. At any elementary region where real contact is established between the rubber and glass, the tangential stress is required to break the interfacial van der Waals bonds will also shear the subsurface layers of the materials, even although it is not high enough to fracture them. Energy will be lost by viscoelastic mechanisms (cf. next section) in each elementary strained volume, i.e., there will be a frictional resistance to sliding.

Other adhesion theories of elastomeric friction have been developed by a number of authors; comprehensive reviews have been given recently by Moore and Geyer [1972], and by Moore [1972].

Deformation Mechanisms

There are also mechanisms of friction for which adhesion is not essential, although it may occur and if it does occur will usually affect the magnitude of the friction. These are generally called deformation mechanisms although, as has been seen, deformation (including adhesion up to fracture) is fundamental even to the so-called adhesion mechanisms.

There is an infinity of possible modes of deformation of two mutually sliding bodies. Its nature will be determined by the macro and micro geometry of the surfaces and the mechanical properties of the bodies. The practical approach to the problem is to isolate certain extreme types of deformation for consideration. Each of these is regarded as generating a separate mechanism of friction.

A well-known deformation mechanism (examined by Bowden and his colleagues at the same time as they developed their adhesion theory) is ploughing, illustrated in Figure 2 for the case of a hard, spherical or cylindrical body sliding over the larger and flatter surface of a softer metal. The mechanism is one of gross, irreversible pushing aside of the material of the softer metal by the slider. Consequently the existence of asperities can be ignored in the discussion. The displacement occurs by plastic flow (including actual cutting). In the example illustrated, with a spherical or circular cylindrical slider, it has been shown [Bowden and Tabor, 1950] that the component of frictional force due to ploughing is approximately equal to $dP/12r$, where $d$ is the width of the groove produced by the slider and $r$ is the radius of the slider.

Ploughing can also occur on a microscopic scale, if a relatively hard body with steep asperities slides over a softer body. Steep asperities are uncommon, but occur, for example, on wool fibres, where the tips of the cuticular scales have been observed to cut chips out of polytetrafluoroethylene as the fibre slide over it.

A second deformation mechanism depends on bulk viscoelastic deformation of one or the other sliding body. When two bodies are pressed together bulk deformation is produced around the region of apparent contact. As the bodies slide over each other, this deformation travels with the region of contact. Unless the bodies are perfectly elastic this causes absorption of energy, which is manifested as frictional resistance to sliding. This mechanism can be isolated to a considerable extent from the adhesion mechanism by studying lubricated sliding; it can be isolated even more by studying rolling friction instead of sliding friction, as adhesion usually makes little contribution to rolling friction, while there is very little difference between the bulk deformations produced in the two cases. (However, if both surfaces are smooth, adhesion may become important even in rolling.)

The bulk deformation mechanism has most often been studied experimentally and theoretically, in the case of flat slabs of high polymers deformed by hard balls or cylinders rolling over them, but very similar results are obtained when balls or cylinders of the polymers roll between hard, flat surfaces. It has been found that the coefficient of friction depends on the temperature and on the sliding or rolling velocity in much the same way as the viscoelastic loss factor does [Flom and Bueche, 1959; Grosh, 1963a, 1963b; Ludema and Tabor, 1966].

Because the stresses and strains are complex and difficult to handle mathematically, a number of simplified models have been advanced. Although none of these gives satisfactory quantitative results, each is qualitatively useful in illustrating a particular way in which energy is absorbed.

In an early model the polymer is considered to be perfectly elastic except for exhibiting hysteresis [Bowden and Tabor, 1964]. Each part over which the slider slides or rolls undergoes a closed hysteresis loop of deformation and recovery, the energy imparted to the polymer at the front of the slider being returned by the polymer to the slider at the rear, except for the hysteretic loss. It is, of course, impossible for a polymer to undergo a closed hysteresis loop unless there is some adhesion to take it into tension for a short period, so this model can be approximately correct only when the hysteretic loss is small. It is also unrealistic to consider the polymer as perfectly elastic except for exhibiting hysteresis; there would have to be time-dependence of the mechanical properties, so that the apparent hysteretic loss would depend on such factors as the velocity of sliding or rolling.

In a later model the polymer, more realistically, is considered to be viscoelastic but the strains are analysed by the unrealistic method of treating the slab of polymer as composed of parallel columns, each of which goes into compression as the slider slides or rolls over it. Shear strains being ignored [Flom and Bueche, 1959; May, Morris and Atack, 1959; Halaunbrenner, 1965]. Because viscoelastic materials have finite relaxation times, the pressure exerted on the slider by the polymer is less over the trailing half of the region of contact, where the polymer is recovering from deformation, than it is over the front half, where the polymer is undergoing deformation; the surfaces will, in fact, lose contact over some part of the trailing half (Figure 3). Consequently, not all of the deformation energy stored in the polymer can be returned to the slider, the part which is not returned being eventually dissipated as heat. A tractive force is therefore needed to maintain sliding or rolling, i.e., there is an opposing frictional force.

A better approximation has been made by a number of authors who have treated the polymer as a continuum in
which shear strains occur as well as compressive strains [May, 1960; Hunter, 1961; Morland, 1962]. The analyses are comprehensive but mathematically complicated, so that for non-specialists the simpler, less accurate models may provide more insight into the mechanisms involved.

A third deformation mechanism of friction is one of deformation of asperities caused by tangential pressure between them. This mechanism is usually unimportant, but can contribute significantly to the friction between surfaces which have roughly matching, steep asperities capable of engaging with each other so as to oppose sliding. If they are steep enough no force, however great, applied parallel to the mean macroscopic interface can cause rigid asperities to slide over each other, so that macroscopic sliding can only proceed by deformation of the asperities on one or both surfaces under the applied tractive force (the term deformation including, of course, fracture). The necessary inclination of the asperities to the macroscopic interface is given by

$$\theta = \frac{\mu}{1 + \mu^*}$$

where \(\lambda = \tan^{-1} \mu^*\) and \(\mu^*\) is the coefficient of friction due to sources other than that under consideration, i.e. \(\mu^* = \tan \theta = \frac{\mu}{1 + \mu^*}\) and \(\mu^*\) is the coefficient of friction on the flank of an asperity [Makinson, 1948]. The mechanism of loss of energy is that each individual asperity is repeatedly bent by the passage of an opposing asperity over it, and the deformation energy cannot all be returned to the source, both because of viscous effects similar to those already discussed and because the geometry of the surfaces provides no opportunity for complete return of the energy, even from a perfectly elastic asperity.

It is rare for surfaces that are commonly encountered to have asperities steep enough for this mechanism to be operative, but they are found in particular cases, e.g. on wool fibres, where they are asymmetrical (saw-toothed), contribute substantially to the friction in one direction, and are responsible for the felt properties of wool.

This mechanism is quite distinct from micro-ploughing, as it does not require the asperities on one surface to be harder than the other surface or to dig into the other surface, but does require two sets of asperities of approximately the same dimensions, one set on each surface.

Deformation mechanisms of friction have been reviewed recently by Moore and Geyer [1972] and by Moore and Geyer [1974].

Other Suggested Mechanisms

Brief reference will be made to three other suggested mechanisms of friction. The first is due to Coulomb, and is to be found in most textbooks that mention friction. Coulomb, after considering an adhesion mechanism, concluded that friction was due to the presence of asperities on the sliding surfaces; he suggested that it resulted from "an interlocking of the roughness of the surfaces, which cannot be separated unless they yield or break or are lifted over the tops of one another" [Coulomb, 1779]. The first two of these possibilities together constitute the deformation mechanism discussed immediately above; it is the third that is usually referred to as "Coulomb's mechanism", and for explicitness it is often called the hill-and-dale mechanism. Examination of this theory reveals a number of conceptual difficulties which make it improbable that the mechanism is important except for rather unusual surfaces. The principal one is that if the surfaces are extensive enough to include many asperities they will ride relatively level over each other, with very little lifting up and down. If, on the other hand, they are so small as to include only a few asperities, these few will be greatly flattened even under low loads, and again the surfaces will tend to ride level over each other. The mechanism could perhaps contribute to the friction under high loads of surfaces with fairly regular asperities, which would permit different asperities to rise and fall together.

A group of theories of the friction of elastomers, collectively known as molecular-kinetic theories, were extensively developed in the 50's and 60's (reviewed by Moore and Geyer [1972] and by Moore [1972]). These are adhesion theories, with adhesion regarded as a thermally activated stick-slip process on the molecular scale, local physical bonds between the surfaces being continually formed and broken during sliding. The lifetime of any particular bond depends on its activation energy and the temperature.

This leads to a typically viscoelastic dependence of the friction on sliding velocity and temperature, which fits some experimental data well but makes it difficult to decide between molecular-kinetic and grosser viscoelastic-deformation mechanisms except by direct observation of the interface. Even with rubber, for which some of these theories were developed, such observation has revealed deformations on a larger than molecular scale. The theories originally treated the subject as though frictional absorption of energy would only concern the outermost molecular layers of the surfaces. In most cases this could not account for the absolute value of the friction observed, although it could account for its dependence on various parameters. The theories have since been modified to allow for viscoelastic deformations on a larger scale (see Moore and Geyer [1972]).

An electrostatic mechanism was proposed by Schnurman [1942, 1949]. There is no doubt that charges on the surfaces will affect the friction by changing the value of the normal load between them from its nominal value, but Schnurman suggested a more direct effect, arising from almost tangential forces between opposite charges in the sliding surfaces. The exact mechanism has not been worked out and it is difficult to see how the principle could apply to extended surfaces. The hypothesis has been discussed critically by Barwell [1962].

Summary

Friction is a physically simple phenomenon but has a multiplicity of immediate causes and is difficult to calculate mathematically because of the complexity of stress and strain distributions between sliding bodies. Most of the mechanisms responsible for friction involve loss of energy in the process of deformation and recovery of surface and subsurface layers during sliding. Deformation may sometimes proceed to fracture. Adhesion is not essential for the development of friction but its occurrence usually considerably increases the magnitude of the friction. A number of specific mechanisms are discussed.

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References
Moore, D. F. (1972). The Friction and Lubrication of Elastomers, (Oxford, Pergamon). (An abridged account of this subject can be found in Moore [1975].)

6th. Australian Vacuum Conference
PERTH, W.A. 16-19 MAY 1978 - W.A.I.T.

The Western Australian Branch of the Vacuum Physics Group of the Australian Institute of Physics is organising the sixth conference in what has become a biennial series of vacuum conferences in Australia. The conference will be preceded by a course on vacuum technology aimed primarily at industrial applications.

Vacuum Technology Course
This course will be held on the 16th and 17th May 1978. It will start from first principles and the emphasis will be on practical applications rather than theory. It should be suitable for all those who need to use vacuum equipment, or make decisions about its use, but who are not well versed in its technology.

National Vacuum Conference
This conference will be held on the 18th and 19th May 1978. The topics to be covered are vacuum technology, vacuum pumping and gauging, vacuum processes in industry and medicine, teaching vacuum techniques, and research carried out in the medium and high vacuum range.

Trade Exhibition
A trade exhibition will be organised in conjunction with the 1978 course and conference. It will include equipment used in heavy and light industry and in the refrigeration and medical fields.

Registration, Fees and Call for Papers
People contemplating attendance at either the course or conference are requested to signify their interest as soon as possible to the Conference Secretary (address below) who will supply registration forms and further information.

The fee for the course (including attendance at the conference) is $50, and rebates for students and apprentices will be considered. The fee for the conference is $25, with a rebate of $7 for members of the Vacuum Physics Group.

The deadline for abstracts of contributed papers to the conference will be 24th March 1978.

Travel and Accommodation
It is hoped that Ansett Airlines will be able to arrange package deals on air tickets and accommodation.

Further Information and Registration Brochures
Please contact: Dr. K. W. Terry, Conference Secretary, 6th A.V.C. & V.T.C., Physics Department, W.A. Institute of Technology, Bentley, W.A. 6102. [Telephone (09) 350 7544].
Solar Research

GRANTS FOR SOLAR RESEARCH

The Minister for Science has announced details of the 16 solar energy research projects which will receive funds under the Australian Research Grants Scheme during 1978. The solar energy projects are among a record 1,300 research projects which will receive a total of $11 million under the Australian Research Grants Scheme during 1978.

The 16 solar energy research projects are as follows:

Professor L. W. Davies and Dr M. A. Green, University of New South Wales, to work on photovoltaic conversion of solar energy to electricity ($62,729).

Professor L. E. Lyons, University of Queensland, to work on solar energy conversion to electrical and chemical energy ($49,890).

Dr G. S. Laurence, University of Adelaide, to work on electron transfer reactions of CT excited states of transition metal complexes ($20,562).

Dr G. H. Derrick, University of Sydney, to work on crossed gratings as selective solar absorbers ($16,630).

Dr B. Window and Dr G. H. Derrick, University of Sydney, to work on selective surfaces as solar energy absorbers ($16,606).

Dr G. D. Smith, Australian National University, to work on a study of hydrogen gas production by microorganisms ($11,640).

Mr J. A. Ballinger and Ms N. C. Rodgers, University of New South Wales, to work on beam daylighting - direct use of solar energy for interior lighting ($10,300).

Dr K. Landecker, University of New England, to work on utilisation of solar energy by means of the thermoelectric effect ($9,923).

Mr C. W. Ambrose, Monash University, to work on comparison models of regenerative dehumidifiers in solar air conditioning applications ($4,300).

Professor H. A. Blevin and Dr E. L. Murray, Flinders University of South Australia, to work on collection of solar energy ($7,000).

Professor J. O'M. Bockris, Flinders University of South Australia, to work on chemical aspects of a solar hydrogen economy ($5,250).

Professor J. O'M. Bockris, Flinders University of South Australia, to work on photo-production of hydrogen ($4,600).

Dr M. D. Waterworth and Dr R. D. Watson, University of Tasmania, to work on diffraction grating studies ($6,600).

Dr J. Gutiurich, University of New South Wales, to work on a wedge shaped refracting concentrator system suitable for heating and for use with photovoltaic devices ($4,000).

Associate Professor D. Haneman and Associate Professor E. R. McCartney, University of New South Wales, to work on solar energy conversion ($8,890).

Dr G. L. Morrison, University of New South Wales, to work on dynamic characteristics of stratified thermosyphon flows ($4,039).

Among other new projects to receive grants this year are:

Professor M. H. Brennan, Flinders University, for work on waves in current-carrying plasmas ($10,657).

Professor J. Holmes, Flinders University for work on isotopic techniques for the study of water resources.

SOLAR HOUSING

The University of Queensland is co-operating in the instruction of what is believed to be Australia's first prototype solar house. It is to be built by a firm of private developers 35km south of Brisbane in a new estate called Solar City.

The prototype solar house is expected to be built by the end of this year. Initially it will have an independent solar hot water heating system, a solar air-conditioning and heating system, a built-in solar barbeque, solar screening to reduce summer heat and insulation to retain winter warmth.

The University is incorporating a limited solar electrical system which will power small electrical appliances, for example a TV set or fan, for research and demonstration purposes.

It is expected that all homes built at the Solar City estate will take advantage of developments in solar research. Initially, solar heating will be used for water heating in all houses built.

The prototype solar home has been designed under the direction of Mr. S. Szokolay, Director of the Architectural Science Unit at the University of Queensland's Department of Architecture. The estate is being managed by the West Coast Group of Companies. - University News, November 97, October 19, 1977.

ANU staff request support for solar energy project

Thirteen members of the staff of the Australian National University have asked their Vice-Chancellor to investigate ways of continuing ANU support of the solar energy project in the Department of Engineering Physics.

Professor Low has replied that "a good deal of effort" is going towards interesting outside companies in contemplating the construction of a prototype solar energy power plant, and he hopes "that before very long some response of real promise along these lines will be forthcoming." - ANU Reporter, Vol. 8, No. 15, 1977

Correction to November Issue, page 162

AUSTRALIAN CONFERENCE ON ELECTRON SPECTROSCOPY.

Conference Secretary: Dr. R. Leckey, Physics Department, La Trobe University, Bundoora, Victoria 3083.

The Australian Physicist, December 1977 191

Reviewed by R. J. Dewar, Research School of Physical Sciences, Australian National University, Canberra.

There is a growing realization that substances such as porous media, suspensions (e.g. blood), polymeric substances, solids with microcracks and dislocations, fluids in a state of turbulence, etc., all have internal structures, which must be accounted for by adding extra degrees of freedom to the continuum description and by taking into account nonlocal effects. These effects can be important, for example, in the propagation of short wavelength waves. Ultimately, one hopes, the continuum description will link up with microscopic many body theory.

In the first section of this book Eringen develops his theory of micropolar materials (in which the internal structures can rigidly rotate with respect to the surrounding medium), and micromorphic materials (which allow internal deformations also), and in the third section he treats a nonlocal extension of this theory. In the middle section D. G. B. Eddel is given a general discussion of nonlocal theories and the point of view of global balance laws and variational formulations.

The style of the book is highly formal and mathematical, with very practical examples (although the references are given to some of these). The authors are concerned with only the general properties of the constitutive equations, subject to conservation of mass, momentum, angular momentum, energy, and to thermodynamic constraints. Familiarity with the tensor notation developed in Eringen's books on continuum mechanics is assumed. Nevertheless the presentation is reasonably clear, and the production is excellent. Researchers in applied mathematics, fluid dynamics, geophysics, biophysics and solid state physics may find material of interest to them here.


Reviewed by J. F. McConnell, School of Physics, The University of New South Wales.

So many exciting developments in optics have taken place in recent years, and so many good books on the subject have appeared that the inspection of the 3rd edition of Ditchburn's "Light" was awaited with enthusiasm. The present work is available in two volumes paperback or in hard cover edition in one volume. Volume 1 is intended basically as an undergraduate test, and Volume 2 has as its principal objective the introduction of postgraduate to new developments and research trends.

It came as a disappointment to the reviewer that it appeared unsatisfactory on both counts. The interest of today's undergraduates in optics cannot be maintained without some excursions into modern developments; and discussion of some currently developing topics is either omitted or treated inadequately. Such topics include spatial filtering, holography, recent laser developments and the use of matrix methods. It is also disappointing that the treatment of crystal optics is confined to the wave-surface approach.

Notwithstanding the above criticisms there is much of merit in the book. The treatment of the more classical sections of optics is still very sound, even if such things as the Fourier Transform approach and the Fresnel Integral have been relegated to appendices, which are sprinkled very liberally throughout the book. A very good set of references has been included in each chapter, which makes it easy for the more serious student to follow the criticism of the last paragraph.

Finally, it is strange that in a book published in 1976 that units such as cm, Angstroms, dynes-cm and oersteds should appear. The designated units for Vol. 2 are MKS (SI units are not mentioned) but some traces of the units of older editions still appear, such as a "c" in equation 16 (14). This appears on the next line, so the error is not progressive. Also some inconstancy in symbols betrays the amended nature of the classical sections. The exposition is generally written in the conventional way as W., but in Appendix A it appears in Green's Theorem and the Helmholtz relation as W.

The book will doubtless form an essential reference text for most undergraduate and graduate students in optics. It is difficult to imagine it being a prescribed student text at the Australian price of $19.50 each for paper back Vol 1 and Vol 2. of $53.50 for the hard cover combined volume.


Reviewed by J. S. Dryden, National Measurement Laboratory, Chippendale NSW.

Several Laboratories in Japan have been very active in their study of ferroelectricity. The appearance of this translation of a book published originally in 1969, therefore makes a welcome addition to the texts available on the subject. This translation contains an extra appendix in the form of bibliography of papers on ferroelectric phase transitions published since the Japanese original. The emphasis in this book is on ferroelectric phase transitions and the authors have succeeded in their endeavour to present ferroelectricity in a systematic way. The derivation of many of the formulæ is more detailed than is to be found in other texts on the subject.

A slightly annoying feature of the method of printing is the difficulty of separating figure captions from the text.


Reviewed by J. S. Falcotter, School of Physics, University of Sydney.

The recent evolution of the dye laser from a difficult-to-use research laboratory curiosity to a reliable source of tunable light has made possible many new investigations involving atomic systems. One class of such experiments concerns the resonant and near-resonant interaction of coherent light with atoms. Some of the phenomena observed optical selection, free induction decay and photon echoes are analogous to NRM and ESR phenomena, while others - pulse compression, self induced transparency and superradiance are characteristic of systems where the wavelength is smaller than the dimensions of the interaction medium.

The theory of these phenomena is developed in this book for the case where only two atomic levels need to be taken into account. After an introduction to the classical interaction of an electromagnetic wave with a collection of dipole oscillators the Bloch equations, the equations of motion of "pseudoatomic" vectors related to the electric dipole moment are developed. The bulk of this book is concerned with the solution of these equations and Maxwell's equations near resonance. Later chapters extend this semiclassical picture to take account of quantization of the radiation field which is necessary to describe superresonance.

This brief but balanced summary relates theoretical conclusions to the relevant experiments and clearly specifies the significance of the various approximations made in theoretical derivations. This excellent book would be of interest only to specialists working in this field.


Reviewed by R. J. Dewar, Research School of Physical Sciences, Australian National University, Canberra.

There is a growing realization that substances such as porous media, suspensions (e.g. blood), polymeric substances, solids with microcracks and dislocations, fluids in a state of turbulence, etc., all have internal structures, which must be accounted for by adding extra degrees of freedom to the continuum description and by taking into account nonlocal effects. These effects can be important, for example, in the propagation of short wavelength waves. Ultimately, one hopes, the continuum description will link up with microscopic many body theory.

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INTRODUCTION

Many changes took place within the Australian Institute of Physics during 1977. The transfer of administration from Melbourne to Sydney was accompanied by the appointment of a new Executive and an almost complete change in Branch Chairmen and hence in the membership of Council. Many new initiatives were adopted to develop the role of the Institute within the community and to encourage wider participation by members while at the same time holding down costs.

NATIONAL ACTIVITIES

COUNCIL

Only one Council meeting was held during 1977, with decisions on a number of topics being decided by postal votes during the year. Council determined to make no increase in subscriptions for 1978 but nevertheless were able to budget for a number of new activities.

Physics events sponsored by the Institute during 1977 included a very successful meeting on Solid State Physics at Wagga in February and the Pavis Memorial Lecture held in Melbourne where a large audience heard Prof. G.R.A. Ellis (University of Tasmania) lecture on 'Exploration of the Solar System'.

Other conferences were organised by AIP Groups and Council approved support for a number of important conferences in 1978. The third AIP National Congress is to be held in Perth in January 1979. Conference Guidelines were adopted by Council and published in The Australian Physicist in October 1977.

In an imaginative program to bring physics to a wider audience, investigations were commenced into the possibility of holding a Summer School on Energy and a major exhibition on the science of the Earth and the Planets. A number of Special Awards were offered for articles judged to make the most helpful contribution to the public understanding of the nuclear debate.

Council amended By-Laws 26 and 30 to extend retirement and concession advantages to non-corporate members and also approved a special concession rate for members of Science Teachers Associations who take up non-corporate membership of the Institute.

SCIENCE POLICY

Activity continued to expand in the area of science policy and papers were prepared on the following topics:
- Inquiry into the CSIRO
- Review of Bureau of Mineral Resources
- Inquiry into Industrial R & D
- Questions and Answers on Uranium
- Energy Policy
- Fundamental Research in Australia

The Science Policy Committee was expanded during the year to cope with the work to be done. Council also decided to encourage the formation of science policy sub-committees associated with Branch Committees so that more members can participate in this important area.

EDUCATION

The Education Committee of Council prepared a submission to the Inquiry into Education and Training. It also commenced collecting information on the number of students studying physics at various educational levels and the subsequent use of physics they have learned.

Council adopted a recommendation that ways be sought to increase interaction with physics teachers in secondary schools.

EMPLOYMENT

The Employment Committee of Council has been active on matters of employment anomalies and employment statistics. Anomalies being investigated include the employment of hospital physicists, discrimination against physicists in public service positions, retraining conditions and problems of unemployment.

Statistics are being sought from physics departments concerning the employment history of their graduates and from AIP members via a follow-up survey issued with the 1978 subscription notice. Council agreed to allow the position of Industry Liaison Officer to lapse for the time being and to concentrate on the work of the Employment Committee.

THE AUSTRALIAN PHYSICIST

During 1977, emphasis has been placed on the rapid publication of news and informative articles with the aim of promoting interaction between physicists and to help them identify with the activities within their profession. This important activity of the Institute has been promoted very effectively by the Committee in Adelaide under the Editorship of Mr Bill Boudry. The ever-present problem of rising costs has been offset to some extent by use of cheaper materials.

ADMINISTRATION

In the absence overseas, of the Vice-President, Prof. R.C. Bolton, four members of the Executive have met monthly. Early in 1977, Mr David Ellyard was appointed Hon. Assistant Sec. to assist the Executive in investigating possible new activities to stimulate interest in and within the Institute.

Following the transfer of administration to Sydney in February 1977, the 1976 members of the Executive supervised the closure of the Melbourne Office, the transfer of pre-1974 records to the Adolph Besser Library in Canberra, and the transfer of the remaining material to Sydney.

The Australian Physicist, December 1977 193
A new style of operation has been established in Sydney involving the use of secretarial services provided by The Science Centre, 35-43 Clarence St. The Registered Office of the Institute remains at Clunies Ross House in Melbourne with the records required by the Victorian Companies Act being maintained by Mrs E.K. Williamson as Assistant Secretary.

The staff of The Science Centre have provided excellent support for the administration of the Institute and have helped to streamline the procedures used. As a result, costs are being kept at a reduced level for 1977 and 1978.

BRANCH ACTIVITIES

Branches continue to explore avenues for supplementing the monthly scientific meeting which is now in competition with seminar activities held by most of the major scientific organizations. Some of the successful events in 1977 included:

- Queensland Youth Lectures given by Prof. L.W. Davies on "The Future of Semiconductors and Solid State Electronics".
- Victorian Youth Lectures presented by Dr G.F.J. Tronp on "The Use of Lasers in the Study of Biological Systems".
- New South Wales Ladies Evening addressed by Dr N. Betteridge on "Tokens and Forgeries: A Curator's Nightmare".
- ACT Visit to Department of Physics, Royal Military College, Duntroon.
- Visits by special Lecturers to North Queensland

and many others. Full reports are made independently to members of each Branch.

During 1977, the Uranium topic was much to the fore in Branch activities. Numerous lectures were given often in conjunction with other organizations, and in other ways physicists endeavoured to help clarify the issues involved on this topic.

Other Branch activities included the award of special prizes, for example in school's science contests or to successful physics students, and the support of postgraduate students wishing to attend conferences.

GROUP ACTIVITIES

NUCLEAR AND PARTICLE PHYSICS GROUP

A very successful Summer School was held at Jindabyne in February 1977. The special guest lecturer was Prof. T. Tombrullo (Caltech.) but a number of other overseas visitors were also in attendance. The next major event is the International Conference on Nuclear Interactions to be held in Canberra in August 1978. Australian Academy of Science and IUAP support has been given to this conference which is being organized by a Canberra committee with an International Advisory Committee.

VACUUM PHYSICS GROUP

The next Vacuum Physics Conference is to be held in Perth in 1978 and the Group Secretariat is being transferred to WA to organize this event.

BIOPHYSICS GROUP

The 17th Annual Conference on Physics and Engineering in Medicine and Biology was held in Brisbane in August 1977. During the Conference arrangements were completed for the formation of a new Australasian College of Physical Scientists in Medicine. This will supersede the IPA Australasian Regional Group and the AIP Biophysics Group which was disbanded in December 1977.

The main objective of the College will be to further the development of sciences of physics, engineering, mathematics and computing as applied to medicine. An Association was also formed with membership open to any person interested in this field. The Bulletin published by the College will be available to members of the AIP. The AIP Council expressed their best wishes to the new College for its future success.

OTHER ORGANIZATIONS

The Institute has reciprocal arrangements with:

- The Institute of Physics, London
- The American Institute of Physics
- The Canadian Association of Physicists
- The European Physical Society
- The Institute of Physics, Singapore
- The Physical Society of Japan
- The South African Institute of Physics

A member of one society visiting the other's country can be helped in establishing contacts with other physicists and enjoy most of the benefits of the other society (without subscription but without voting rights).

The Institute values its association with the following organizations and the service of the members who represented the Institute during 1977:

Conference of Allied Societies (Dr J.C. Campbell, Prof. K.D. Cole)
Australian Journal of Physics Advisory Committee (Dr R.W. Crompton)
National Association of Testing Authorities (Prof. L.M. Davies)
Australian National Committee on Illumination (Dr A.J.D. Porter)
Australian Academy of Science, National Committee for Physics (Dr F.J. Jacke)
Australian Institute of Radiography (Dr R.J. de Groot)
Acoustic Standards Committee of SAM (Prof. H.F. Pollard)

MEMBERSHIP

The Institute records with regret the death of Dr J.S. Rogers Hon. FAIP (Vic).
The membership figures at 30 November, 1977, are shown in Table 1. They are based on a complete count of the Register in June 1977 plus incremental changes since then. During the year 70 persons have been admitted to the Institute in all grades and 116 have been removed from the Register, a net loss of 44 members. Of the 116 removals, 43 were by resignation and 70 by Resolution of Council under Clause 13 of the Articles for non-payment of 1976 subscriptions. The names of these 70 persons will be published in the Australian Physicist.

Since the formation of the Institute in 1964 the total membership has followed quite closely a population curve which is exponentially approaching saturation at about 2000 members after 5 years. This model indicates an expected increase of about 20 members in 1977, in contrast to an actual loss of 44. About 80% of the loss has been for economic reasons, members being unwilling or unable to pay the fees at the levels set.

In November 1977 the Institute commenced a recruiting drive, which will continue throughout 1978. The early response is encouraging, and all members are urged to assist by bringing the Institute and its activities to the notice of colleagues and students who are not yet members.

There has been no change in the qualifications at present acceptable for Graduateship. These are as listed in the 14th Annual Report published in the December 1976 issue of The Australian Physicist. During the year the Membership Committee has assessed four overseas qualifications not previously submitted to the Institute for corporate membership.

### TABLE 1 - MEMBERSHIP AT 30 NOVEMBER 1977

<table>
<thead>
<tr>
<th>ACT</th>
<th>NSW</th>
<th>Qld</th>
<th>SA</th>
<th>TAS</th>
<th>VIC</th>
<th>WA</th>
<th>OS</th>
<th>TOTAL</th>
<th>UN*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nom. Fellow</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>1</td>
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</tr>
<tr>
<td>Fellow</td>
<td>22</td>
<td>88</td>
<td>16</td>
<td>27</td>
<td>8</td>
<td>55</td>
<td>21</td>
<td>284</td>
<td>3</td>
</tr>
<tr>
<td>Member</td>
<td>51</td>
<td>171</td>
<td>57</td>
<td>72</td>
<td>15</td>
<td>183</td>
<td>41</td>
<td>628</td>
<td>4</td>
</tr>
<tr>
<td>Graduate</td>
<td>51</td>
<td>177</td>
<td>60</td>
<td>6</td>
<td>11</td>
<td>183</td>
<td>58</td>
<td>620</td>
<td>3</td>
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<tr>
<td>Total Members</td>
<td>125</td>
<td>438</td>
<td>112</td>
<td>159</td>
<td>34</td>
<td>452</td>
<td>118</td>
<td>1537</td>
<td>10</td>
</tr>
<tr>
<td>Associate</td>
<td>7</td>
<td>14</td>
<td>3</td>
<td>1</td>
<td>12</td>
<td>6</td>
<td>-</td>
<td>43</td>
<td>-</td>
</tr>
<tr>
<td>Student</td>
<td>3</td>
<td>19</td>
<td>13</td>
<td>7</td>
<td>4</td>
<td>33</td>
<td>13</td>
<td>95</td>
<td>2</td>
</tr>
<tr>
<td>Subscriber</td>
<td>9</td>
<td>16</td>
<td>5</td>
<td>-</td>
<td>14</td>
<td>4</td>
<td>48</td>
<td>145</td>
<td>1</td>
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<tr>
<td>Grand Total</td>
<td>137</td>
<td>480</td>
<td>139</td>
<td>174</td>
<td>39</td>
<td>513</td>
<td>161</td>
<td>1723</td>
<td>13</td>
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<tr>
<td>Company</td>
<td>1</td>
<td>8</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Company Nominee</td>
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<td>2</td>
<td>8</td>
<td>-</td>
<td>14</td>
<td>-</td>
<td>33</td>
<td>-</td>
</tr>
</tbody>
</table>

*UN = Unattached, whereabouts unknown

### FINANCE

The accounts for the year ended 30th September 1977 are presented in essentially the same form as last year. The consolidated accounts comprise the individual accounts of the Branches, Groups, Council Funds and the Australian Physicist. The Benevolent Fund is independent from the Institute Funds and is reported separately. Members should have received financial statements from the Branches and Groups to which they belong.

The consolidated Institute accounts show a surplus of $8422 which result from a surplus of $3511 in Branch and Group funds, a surplus of $1800 for the Australian Physicist, and a surplus of $3511 for the Council controlled funds. Table 11 shows in summary how the accumulated funds of the Institute are distributed.

Table 11 shows how the income was disbursed for the year ending 30th September 1977 and how it is expected to be disbursed for the succeeding year 1978. Income received in 1977, which is predominantly from members' subscriptions, was close to the budget estimate. Administrative costs were higher in 1977 than in 1976, due to the special costs associated with the transfer of the office from Melbourne to Sydney. Nevertheless, the total expenditure was contained within the budget estimate. The net result was a useful surplus. The 1978 budget envisages a real reduction in administrative costs, a reduction in the cost of legislative activities to be achieved by holding only one Council meeting in the 1978 financial year, and increased spending on National, Branch and Group activities.

### TABLE 11 - ACCUMULATED FUNDS

<table>
<thead>
<tr>
<th></th>
<th>1976</th>
<th>1977</th>
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</thead>
<tbody>
<tr>
<td>19458</td>
<td>Branches</td>
<td>21809</td>
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<tr>
<td>3842</td>
<td>Groups</td>
<td>5002</td>
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<tr>
<td>2385</td>
<td>Australian Physicist</td>
<td>3785</td>
</tr>
<tr>
<td>2332</td>
<td>Council Funds</td>
<td>5843</td>
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<tr>
<td>28017</td>
<td>*Sub-Total</td>
<td>36439</td>
</tr>
<tr>
<td>400</td>
<td>Special Reserves</td>
<td>-</td>
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<tr>
<td>28417</td>
<td>Grand Total</td>
<td>36439</td>
</tr>
</tbody>
</table>

*The subtotal corresponds to the statement of accumulated funds on the consolidated balance sheet.

The Australian Physicist, December 1977 195
TABLE III  - FINANCIAL SUMMARY

<table>
<thead>
<tr>
<th>1976</th>
<th>1977</th>
<th>$</th>
<th>1978</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>Legislative Activities</td>
<td>10%</td>
<td>4765</td>
<td>8%</td>
</tr>
<tr>
<td>29%</td>
<td>Publishing Activities</td>
<td>31%</td>
<td>15000</td>
<td>30%</td>
</tr>
<tr>
<td>24%</td>
<td>National, Branch and Group Activities</td>
<td>20%</td>
<td>9506</td>
<td>29%</td>
</tr>
<tr>
<td>4%</td>
<td>Interest to Branches and Groups</td>
<td>3%</td>
<td>1628</td>
<td>4%</td>
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</tbody>
</table>

Administrative Activities

<table>
<thead>
<tr>
<th>25%</th>
<th>Office</th>
<th>26%</th>
<th>12281</th>
<th>18%</th>
<th>9100</th>
</tr>
</thead>
<tbody>
<tr>
<td>8%</td>
<td>Other</td>
<td>10%</td>
<td>4775</td>
<td>11%</td>
<td>5500</td>
</tr>
</tbody>
</table>

Total Disbursed: 47955, 49600
Surplus: 3511, 1100
Gross Income: 51466, 50700

MEMBERSHIP OF COMMITTEES

COUNCIL

The following members of the Executive:

President: Prof. T.M. Sabine
Vice-President: Prof. H.C. Bolton
Hon. Secretary: Dr J.R. Bird
Hon. Treasurer: Dr C.J. Howard
Hon. Registrar: Dr J.G. Collins

and Immediate Past President: Dr J.G. Campbell
Chairman as listed below

OFFICERS

In addition to the Executive:

Asst. Secretary: Mrs E.K. Williamson
Hon. Asst Secretary: Mr D.G. Ellyard
Auditor: F.J. Morton
Returning Officer: Prof. B.M. Spencer

Editorial Committee: Mr W.S. Boundy (Editor), Dr E.R. Sanderson (Aset Editor), Mr J.A. Westphalen (Hon. Sec.), Dr R.D. Campbell (Hon. Treas.), Dr B.J. Possingham, Dr C.B. Robertson, Mr G.A. Bell.

Associate Editors: Mr F.W. Brown (ACT), Dr N. Bignell (NSW), Prof. E.C. Webster (QLD), Dr G.B. Robertson (SA), Dr P.N. McCulloch (TAS), Dr J.D. Cashion (VIG), Dr J.R. de Lauter (WA).

Membership Committee: Dr J.G. Collins (Chairman), Prof. H.J. Goldsmit, Dr W.R. Elyea, Dr R.E. Collins.

Finance Advisory Committee: Dr C.J. Howard (Chairman), Hon. Treasurers of Branch Committees as listed below.

Trustees for Benevolent Fund: Dr C.J. Howard (Chairman), Prof. H.C. Bolton, Dr R.M. Crompton, Prof. T.M. Sabine, Dr J.G. Campbell.

Saliene Policy Committee: Prof. T.M. Sabine, (Convenor), Prof. B. Hancman

(Hon. Secretary), Dr J.R. Bird, Prof. H.C. Bolton, Dr R.E. Collins, Dr J.S. Dryden, Dr L.S. Falconer, Dr C.J. Howard.

Education Committee (to September 1977): Prof. B. Hainsbridge (Conv.), Prof. V.E. Clark (Hon. Secretary), Prof. J.P. Prescott, Dr G.C. Fletcher, Dr A.J. Graham, Dr R.M. Green, Dr J.R. de Lauter, Dr R.I. Macdonald, Dr B.I.H. Possingham.

Education Committee (from September 1977): Prof. G.I. Opat, Prof. W.A. Rakhinger, Dr P.K. Clark, Dr G.C. Fletcher, Dr E.G. Barlow, Dr B.I.H. Possingham, Dr D.T. Dobney, Dr I.A. Newman, (Prof. B. Hainsbridge).

Employment Committee: Dr R.M. Green (Conv.), Prof. T.M. Sabine, Dr I.C. Maclean, Prof. D.H. Morton.

BRANCH AND GROUP COMMITTEES

ACT BRANCH: Mr G.E. Barlow (Chairman), Prof. G.V.H. Wilson (Vice-Chairman), Dr W.J. Barton (Hon. Sec.), Mrs E.M. Richardson (Hon. Treas.), Mr P.W. Brown, Dr D.H. Chaplin, Mr D.H. Finlayson, Mr J.P. Lomberg, Dr R.V. McKenna, Dr G.S. Newton, Dr A.E. Nicholson, Dr G.J. Raymond, Dr R.J. Sandeman, Dr P.B. Treacy.

NSW BRANCH: Assoc. Prof. D.H. Norton (Chairman), Dr R.E. Collins (Vice-Chairman), Prof. K.N.R. Taylor (Hon. Sec.), Dr T.E. Freeman (Hon. Treas.), Dr R.E. Beavers, Dr M. Bignell, Dr G.H. Burton, Prof. G.D. Ellyett, Dr J.J. Falconer, Prof. P. Fisher, Dr P.M. Kelly, Dr A.R. Moon, Dr B. Window.

QLD BRANCH: Dr R.B. Gardiner (Chairman), Prof. P.D. Stacey (Vice-Chairman), Dr P.S. Turner (Hon. Sec.), Dr D.W. Field (Hon. Treas.), Mr R.E. Dunlop, Mr R.S. Fitzsimons.

TAS BRANCH: Dr W.D. Parkinson (Chairman), Dr R. Underwood (Vice-Chairman), Dr L.A. Newman (Hon. Sec./Treas.), Dr J.E. Hubble.

VIC BRANCH: Prof. K.D. Cole (Chairman), Prof. T.P. Smith (Vice-Chairman), Dr F. Rannof (Hon. Sec.), Dr J.G. Cree (Hon. Sec.).
NOTICE OF MEETING

NOTICE is hereby given that the 15th Annual General Meeting of the Australian Institute of Physics will be held at 7.30 p.m. on Tuesday, 14th March, 1978 at the School of Physics, University of Sydney.

AGENDA

1. Apologies and Declaration of Proxies
2. Minutes of the 14th Annual General Meeting
3. Business arising from the Minutes
4. 15th Annual Report and Financial Statement
5. Appointment of Auditor
6. Other Business

J.R. BIRD
Honorary Secretary

CONSOLIDATED BALANCE SHEET AS AT 30TH SEPTEMBER, 1977

<table>
<thead>
<tr>
<th></th>
<th>1976</th>
<th>1977</th>
<th>1976</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACCUMULATED FUNDS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28017 Balance as at 30th September 1977</td>
<td>36439</td>
<td></td>
<td></td>
</tr>
<tr>
<td>See Table II in Report</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CURRENT LIABILITIES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accounts Payable</td>
<td>2072</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subscriptions in Advance</td>
<td>234</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4619</td>
<td>2306</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CURRENT ASSETS</strong></td>
<td>9270</td>
<td></td>
<td>9091</td>
</tr>
<tr>
<td>Cash in Hand</td>
<td>773</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash at Bank</td>
<td>6500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accounts Receivable</td>
<td>1013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stock on Hand at Cost</td>
<td>1305</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INVESTMENTS - at Cost</strong></td>
<td></td>
<td></td>
<td>24989</td>
</tr>
<tr>
<td>Debentures etc. as listed in accompanying table</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Society</td>
<td>2055</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Credit Union</td>
<td>1905</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FIXED ASSETS</strong></td>
<td>22133</td>
<td>28949</td>
<td></td>
</tr>
<tr>
<td>Furniture and Fittings</td>
<td>2249</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lease Depreciation</td>
<td>1544</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1233</td>
<td>705</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL CURRENT</strong></td>
<td>32636</td>
<td>38745</td>
<td>32636</td>
</tr>
<tr>
<td><strong>TOTAL ASSETS</strong></td>
<td>38745</td>
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<td></td>
</tr>
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</table>

COUNCIL FUNDS - BALANCE SHEET AS AT 30TH SEPTEMBER 1977

<table>
<thead>
<tr>
<th></th>
<th>1976</th>
<th>1977</th>
<th>1977</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIABILITIES</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2332 ACCUMULATED FUNDS</td>
<td></td>
<td></td>
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<tr>
<td>Balance 30th September 1976</td>
<td>5843</td>
<td>3129</td>
<td></td>
</tr>
<tr>
<td>Add Surplus for year</td>
<td>3511</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5843</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CURRENT ASSETS</strong></td>
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<td></td>
<td>1773</td>
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<tr>
<td>Cash on Hand</td>
<td>44</td>
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<tr>
<td>Cash in Bank</td>
<td>1335</td>
<td></td>
<td></td>
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<tr>
<td>Stock on Hand At Cost</td>
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<td></td>
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<tr>
<td><strong>TOTAL ASSETS</strong></td>
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<td>1773</td>
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</tbody>
</table>

The Australian Physicist, December 1977
### 1976 LIABILITIES

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<th>22071</th>
<th>CURRENT LIABILITIES</th>
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<td>Sundry Creditors</td>
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<tr>
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<td>Due to Benevolent Fund</td>
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<tr>
<td></td>
<td>At Call</td>
<td>20057</td>
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<tr>
<td></td>
<td>Funds held on behalf of Branches</td>
<td>21624</td>
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<tr>
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<td>1233</td>
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### 1977 ASSETS

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<tr>
<th>20041</th>
<th>INVESTMENTS At Cost</th>
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<td></td>
<td>Debentures etc. as listed in accompanying table</td>
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### FIXED ASSETS

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<tr>
<th>705</th>
<th>Cost</th>
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<tr>
<td></td>
<td>Less Depreciation and Sale of Furniture</td>
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</table>

### FUNDS HELD ON BEHALF OF THE BRANCHES AND GROUPS

<table>
<thead>
<tr>
<th>Balance at 1.10.76</th>
<th>Deduct Withdrawals</th>
<th>Add Undrawn Grants</th>
<th>Surplus from Activities</th>
<th>Annual Interest</th>
<th>Balance at 30.9.77</th>
</tr>
</thead>
</table>

#### BRANCHES

<table>
<thead>
<tr>
<th>ACT</th>
<th>907</th>
<th>-</th>
<th>-</th>
<th>-</th>
<th>82</th>
<th>989</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW</td>
<td>4025</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>363</td>
<td>4388</td>
</tr>
<tr>
<td>QLD</td>
<td>1288</td>
<td>-</td>
<td>150</td>
<td>-</td>
<td>116</td>
<td>1554</td>
</tr>
<tr>
<td>SA</td>
<td>3369</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>322</td>
<td>3891</td>
</tr>
<tr>
<td>TAS</td>
<td>343</td>
<td>-</td>
<td>265</td>
<td>-</td>
<td>31</td>
<td>639</td>
</tr>
<tr>
<td>VIC</td>
<td>5126</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>462</td>
<td>5586</td>
</tr>
<tr>
<td>WA</td>
<td>1597</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>144</td>
<td>1741</td>
</tr>
</tbody>
</table>

#### GROUPS

| Biophysics | 3 | -  | 12 | -  | 15 |
| Education | 437 | 437 (Round up 31.12.76. These funds returned to Council) | -  | -  | -  |
| Nuc. & Part Phys. | - | -  | 9  | -  | 9  |
| Vacuum Phys. | 1136 | -  | 6  | -  | 103 | 1245 |
|              | 18429 | 437 | 442| -  | 1623 | 20057 |

### INVESTMENTS AT COST AS AT 30TH SEPTEMBER, 1977

<table>
<thead>
<tr>
<th>(Nom.)</th>
<th>% Due</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>788</td>
<td>(800)</td>
<td>C.U.B. Ltd</td>
</tr>
<tr>
<td>2,752</td>
<td>(1,000)</td>
<td>B.P. Aust. Ltd</td>
</tr>
<tr>
<td>1,012</td>
<td>(1,000)</td>
<td>Ford Motor Co. Pty Ltd</td>
</tr>
<tr>
<td>3,000</td>
<td>(3,000)</td>
<td>Associated Securities Ltd</td>
</tr>
<tr>
<td>2,000</td>
<td>(2,000)</td>
<td>ESANDA Ltd</td>
</tr>
<tr>
<td>780</td>
<td>(800)</td>
<td>I.C.I. Ltd</td>
</tr>
<tr>
<td>1,936</td>
<td>(2,000)</td>
<td>ESOS Pty Ltd</td>
</tr>
<tr>
<td>1,005</td>
<td>(1,000)</td>
<td>ESANDA Ltd</td>
</tr>
<tr>
<td>808</td>
<td>(800)</td>
<td>Finance Corp. of Aust. Ltd</td>
</tr>
<tr>
<td>2,000</td>
<td>(2,000)</td>
<td>Alliance Holdings Ltd</td>
</tr>
<tr>
<td>1,640</td>
<td>(1,700)</td>
<td>B.H.P. Ltd</td>
</tr>
<tr>
<td>1,030</td>
<td>(1,000)</td>
<td>I.C.I. Ltd</td>
</tr>
<tr>
<td>290</td>
<td>(300)</td>
<td>B.H.P. Ltd</td>
</tr>
<tr>
<td>20,041</td>
<td>(3,000)</td>
<td>CMAC Ltd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Australian Savings Bonds</td>
</tr>
</tbody>
</table>

198 The Australian Physicist, December 1977
CONSORTIUM STATEMENT OF INCOME & EXPENDITURE FOR THE YEAR
ENDED 30TH SEPTEMBER 1977

<table>
<thead>
<tr>
<th>1976</th>
<th></th>
<th>1977</th>
</tr>
</thead>
<tbody>
<tr>
<td>3890</td>
<td>Surplus from normal years activities after making the following charges and provisions</td>
<td>8422</td>
</tr>
<tr>
<td></td>
<td>1034 Audit Fees</td>
<td>1034</td>
</tr>
<tr>
<td></td>
<td>100 Depreciation of Fixed Assets</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>- Directors Remuneration and Remuneration</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1134</td>
<td>1112</td>
</tr>
<tr>
<td></td>
<td>28017</td>
<td>28017</td>
</tr>
<tr>
<td></td>
<td>36439</td>
<td>36439</td>
</tr>
</tbody>
</table>

COUNCIL FUNDS - INCOME & EXPENDITURE ACCOUNT FOR YEAR ENDED 30TH SEPTEMBER 1977

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>40990</td>
<td>Income from Normal Sources</td>
<td>48394</td>
<td>4427</td>
<td>Legislative</td>
<td>4765</td>
</tr>
<tr>
<td>502</td>
<td>Members Subscriptions</td>
<td>655</td>
<td>-</td>
<td>Council Meeting &amp; Executive Expenses</td>
<td>-</td>
</tr>
<tr>
<td>2226</td>
<td>Bank and Investment Income</td>
<td>1882</td>
<td>-</td>
<td>Publishing</td>
<td>15000</td>
</tr>
<tr>
<td>80</td>
<td>Exhibitions and Summer Schools</td>
<td>-</td>
<td>12500</td>
<td>&quot;The Australian Physicist&quot;</td>
<td>-</td>
</tr>
<tr>
<td>397</td>
<td>Sundry Groups and Lectures</td>
<td>235</td>
<td>500</td>
<td>Branch and Group Activities</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Second National Congress</td>
<td>7962</td>
<td>1292</td>
<td>Branch and Group Grants</td>
<td>7505</td>
</tr>
<tr>
<td></td>
<td>Extraordinary Income</td>
<td>-</td>
<td>1240</td>
<td>Visiting Lecturers Grants</td>
<td>1149</td>
</tr>
<tr>
<td>100</td>
<td>Transfer from provision for Long Service Leave</td>
<td>-</td>
<td>1570</td>
<td>Conferences and Lectures</td>
<td>852</td>
</tr>
<tr>
<td></td>
<td>DEFICIT FOR YEAR</td>
<td>11134</td>
<td>1570</td>
<td>Interest Due to Branches</td>
<td>1620</td>
</tr>
<tr>
<td>754</td>
<td></td>
<td></td>
<td></td>
<td>Administrative</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Salaries</td>
<td>10194</td>
<td>1247</td>
<td>Budget &amp; Administration</td>
<td>5157</td>
</tr>
<tr>
<td></td>
<td>Rent and Cleaning</td>
<td>751</td>
<td>374</td>
<td>-</td>
<td>374</td>
</tr>
<tr>
<td></td>
<td>Science House Fees</td>
<td>1483</td>
<td>6750</td>
<td>-</td>
<td>6750</td>
</tr>
<tr>
<td></td>
<td>Printing, Stationery &amp; Insurance</td>
<td>1144</td>
<td>1247</td>
<td>-</td>
<td>1247</td>
</tr>
<tr>
<td></td>
<td>Postage and Telephone</td>
<td>100</td>
<td>38</td>
<td>Depreciation</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>286 Sundry and Bank Fees</td>
<td>1600</td>
<td>600</td>
<td>Audit &amp; Accountancy</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>- Office Removal</td>
<td>286</td>
<td>262</td>
<td>-</td>
<td>262</td>
</tr>
<tr>
<td></td>
<td>- Donations</td>
<td>-</td>
<td>392</td>
<td>-</td>
<td>392</td>
</tr>
<tr>
<td></td>
<td>- ANZI Membership</td>
<td>-</td>
<td>297</td>
<td>-</td>
<td>297</td>
</tr>
<tr>
<td></td>
<td>Extraordinary Expenditure</td>
<td>1500</td>
<td>-</td>
<td>Transfer of Funds to &quot;The Australian Physicist&quot;</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>SURPLUS FOR YEAR</td>
<td>-</td>
<td>3511</td>
<td>-</td>
<td>3511</td>
</tr>
</tbody>
</table>

The Australian Physicist, December 1977 199
# THE AUSTRALIAN PHYSICIST

## INCOME & EXPENDITURE ACCOUNT FOR THE YEAR ENDED 30TH SEPTEMBER 1977

<table>
<thead>
<tr>
<th>Year</th>
<th>Income</th>
<th>Expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>$12,500</td>
<td>$9,836</td>
</tr>
</tbody>
</table>

## Income Sources
- **Grant from Australian Institute of Physics**: $15,000
- **Advertising**: $2,079
- **Subscriptions**: $13,600
- **Sales of Publications & Reprints**: $1,699
- **Interest**: $144
- **Extra-ordinary Income**: $4,610

## Expenditure Categorizations
- **Publication Costs**: $11,329
- **Printing**: $6,718
- **Typenetting**: $3,058
- **Graphics**: $1,797
- **Advertising Costs**: $427
- **Loss Reimbursements**: $671 (254)
- **Distribution Costs**: $5,202
- **Mailing**: $1,780
- **Mailing List**: $273
- **Postage**: $2,403
- **Stationery**: $746

## Other Costs
- **Accountancy & Clerical**: $50
- **Secretarial**: $75
- **Ten Year Index**: $-
- **Book Reviews**: $23
- **Advertising Commission**: $301
- **Audit**: $150
- **Telephone**: $37
- **Travel**: $199
- **Sundries**: $6

## Net Surplus for the Year
- **Income**: $13,567
- **Expenditure**: $9,836
- **Net Surplus**: $3,731

## BALANCE SHEET AS AT 30TH SEPTEMBER 1977

<table>
<thead>
<tr>
<th>1976</th>
<th>1976</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accumulated Funds</td>
<td>$2,385</td>
</tr>
<tr>
<td>Surplus for year</td>
<td>$1,600</td>
</tr>
<tr>
<td>Stock on hand, at cost</td>
<td>$931</td>
</tr>
<tr>
<td>Deposit at Call, - Building Society</td>
<td>$2055</td>
</tr>
<tr>
<td>Cash at Bank</td>
<td>$232</td>
</tr>
<tr>
<td>Accounts Receivable</td>
<td>$853</td>
</tr>
<tr>
<td>Subscriptions Receivable</td>
<td>$66</td>
</tr>
</tbody>
</table>

## Current Liabilities
- **Accounts Payable**: $352

## Benevolent Fund Investment at Cost

<table>
<thead>
<tr>
<th>Year</th>
<th>Nom.</th>
<th>% Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>1300</td>
<td>1300</td>
</tr>
<tr>
<td>186</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>782</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>

200 The Australian Physicist, December 1977
BALANCE SHEET OF BENEVOLENT FUND AS AT 30TH SEPTEMBER, 1977

ACCUMULATED FUNDS

Balance at 1st October, 1976
Add Members contributions and interest
less payments
Held as follows:
Bank Account
AIF General Account
Investment at cost

Total Funds 6272

Your Councillors submit here with the following audited financial statements:

Income and Expenditure Account made up for the year ended 20th September, 1977.
Balance Sheet as at the end of the financial year then ended.

Your Councillors report that:

1. The net surplus of the Institute for the financial year amounted to $8622.

2. Prior to the making out of the Income & Expenditure Account and the Balance Sheet your Councillors took reasonable steps to ascertain what action had been taken in relation to the writing off of bad debts where necessary in the making of provision for doubtful debts and are satisfied that there are no known bad debts to be written off and no provision is considered necessary for doubtful debts.

3. At the date of this report your Councillors are not aware of any circumstances which would render the position as regards accounts receivable as stated above inadequate to any substantial extent.

4. At the date of this report your Councillors are not aware of any circumstances which would render the values attributed to current assets in the accounts misleading.

5. At the date of this report no charge on the assets of the Institute has arisen since the end of the financial year which secures the liabilities of any other person; and no contingent liability has arisen since the end of the financial year.

6. No contingent or other liability has become enforceable or is likely to become enforceable within the period of twelve months after the end of the financial year which in the opinion of your Councillors will or may affect the ability of the Institute to meet its obligations when they fall due.

7. The result of the Institute's operations during the financial year were, in the opinion of your Councillors, not substantially affected by any item, transaction or event of a material and unusual nature.

8. There has not arisen in the interval between the end of the financial year and the date of the report any item, transaction or event of a material and unusual nature likely, in the opinion of your Councillors to affect substantially the results of the Institute's operations for the next succeeding financial year.

9. Since the end of the previous financial year no Councillor has received or become entitled to receive any benefit not disclosed in the accounts by reason of a contract made by the Institute with the Councillor, or with a firm of which he is a member, or with a company in which he has a substantial financial interest.

Signed on behalf and in accordance with a resolution of the Councillors dated 29th November 1977.
This 29th day of November, 1977.

C.J. Howard
J.R. Bird

STATEMENT OF COUNCILLORS

We, Christopher John Howard and John Roger Bird being two Councillors of THE AUSTRALIAN INSTITUTE OF PHYSICS state in the opinion of the Councillors -

(a) The Income and Expenditure Account is drawn up so as to give a true and fair view of the surplus of the Institute for the financial year ended 30th September, 1977, and;

(b) The Balance Sheet is drawn up so as to give a true and fair view of the state of affairs of the Institute as at the end of the financial year ended 30th September, 1977.

Signed on behalf of and in accordance with a resolution of the Councillors dated 29th November, 1977.
This 29th date of November, 1977.

C.J. Howard
J.R. Bird

STATEMENT OF PRINCIPAL ACCOUNTING OFFICER

I, Christopher John Howard being the principal accounting officer of THE AUSTRALIAN INSTITUTE OF PHYSICS state that, to the best of my knowledge and belief, the accounts give a true and fair view of the matters required by Section 162 of the Companies Act 1961, to be dealt with in the accounts.
This 29th day of November, 1977.

C.J. Howard

AUDITOR'S REPORT

To: The Members of THE AUSTRALIAN INSTITUTE OF PHYSICS

As required by the Companies Act 1961, I report as follows:

I have accepted without qualification the Accounts and Balance Sheets of the various Branches and Groups for the past financial year. I report that the returns from the Branches and Groups appear to be in form and content appropriate and proper for the purposes of the preparation of the attached Balance Sheet and supporting accounts of the Institute.

In my opinion:

(a) The attached accounts are properly drawn up:

(i) so as to give a true and fair view of the matters required by Section 162 to be dealt with in the accounts, and;

(ii) in accordance with provisions of that Act.

(b) The accounting and other records and the registers, required by the Act to be kept by the Institute have been properly kept in accordance with the provisions of the Act.

F.J. DOROTHY

Registered under the Public Accountants Registration Act, 1945, as amended.
1978 NUPP Theoretical Physics Summer School

This is intended to be a 'working' Summer School providing an opportunity for physicists to obtain detailed knowledge about specialized topics in particle physics and statistical mechanics.

Speakers:
Dr M. Barber — Renormalization Group Techniques in Statistical Mechanics and Lattice Gauge Theory.
Dr R. Cahill — Functional Methods in Quantum Mechanics.
Professor R. Delbourgo — Gauge Field Theory.

Cost and Registration Fee:
The Registration fee is $5.00. Bed and breakfast is available at Janet Clark Hall for approx. $14 per day. Student members of Australian Institute of physics may apply to the Hon. Secretary of their local Branch for financial assistance.

Information and Application Forms:
May be obtained from — Ms Eve Kovacs, Department of Physics, Melbourne University, Parkville, Vic. 3052.

Applications close on Friday, 13th January, 1978.

CSIRO
Experimental Officer
Division of Chemical Physics, Clayton, Vic.

FIELD: Reaction bonding.

DUTIES: The appointee will be involved in the technical development of a patented ceramic-metal reaction bonding process. A major portion of the duties involve the use of high-temperature furnaces and ancillary equipment together with the operation of physical equipment. Experience in these activities would prove an advantage.

QUALIFICATIONS: A degree or recognized diploma in Science or equivalent qualification. Experience in the physics and chemistry of materials is desirable.

SALARY: Experimental Officer Class I or 2: $9779-$15808 p.a.

TENURE: Indefinite with superannuation.

Applications stating full personal and professional details, the names of at least three referees and quoting reference number 582/141 should reach:
The Chief, Division of Chemical Physics, CSIRO, P.O. Box 160, CLAYTON. VIC. 3168 by 16th January 1978.