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Radioisotope Standardization

G. C. Lowenthal, A.A.I.P.
A.A.E.C. Research Establishment, Lucas Heights, N.S.W.

An account is given of problems in radioisotope standardization as carried out within the Radioisotope Standards Group of General Physics Section, A.A.E.C.R.E. General Physics Section is concerned with research on nuclear detection processes and with nuclear instrumentation in general.

During 1960 work was started at Lucas Heights to establish absolute counting techniques which were required for many aspects of the Commission's research programme and also for the absolute standardization of the activities of radioisotopes produced in the research reactor HIFAR (Urquhart 1964).

The activity of a radionuclide is defined as the number of nuclear disintegrations per unit time occurring in the nuclide. The unit of activity is the curie (1 C = 3.7 x 10¹⁰ nuclear disintegrations per second, (dps) exact). Thus counting is the only absolute method of measuring radioactivity (see U.S. National Bureau of Standards Handbook No. 86, 1963).

To standardize a radionuclide, it is normally first dissolved; the specific activity of the solution (dps/g) is then determined by counting a known fraction which had been placed on a metallized plastic counting foil and evaporated to dryness. To date, other procedures such as liquid scintillation counting and gas counting have not been used at the A.A.E.C. Research Establishment for absolute measurements.

To perform accurate counting one must know the decay characteristics of the nuclide concerned and no two nuclides are alike in that respect. The response of the counting equipment to these decay products, and preferably all physical and chemical characteristics of the source material that could affect the source-making process, must be known.

These demands arise mainly for two reasons. Firstly, absolute counting requires more than just the detection of disintegration products. It is necessary to relate the number of counts in the detectors to the true rate of nuclear disintegrations within the source. Most nuclides decay with the simultaneous emission of several decay products: alpha or beta particles, gamma rays, X-rays, conversion electrons, and Auger electrons. It is then necessary not only to know exactly what radiations to expect, a knowledge provided by the decay scheme, but also how to interpret the recorded count rates, which at times can only be done with quite low accuracies—five per cent. or even less.

Secondly, the energy of decay products is often so low that a substantial fraction is absorbed in the source itself and in the source support. Correct estimation of self absorption is notoriously difficult (Yaffe 1962) and it is best, therefore, to minimize absorption effects by making the thinnest possible supports on the thinnest possible supports.

The present work at Lucas Heights centres around the following activities:
(1) 4π proportional gas flow counting with the main emphasis on source preparation techniques.
(2) Coincidence counting of nuclides emitting gamma radiation in coincidence with particles and/or X-rays.
(3) Measurements by micro-calorimetry.
(4) Secondary standardization on a routine basis mainly by means of 4π ion chamber measurements.

Most research work is concentrated under (1) and (2) and its salient points are as follows:
(a) Techniques have been developed to reduce considerably the thickness of counting foils while retaining the required degree of mechanical strength and electrical conductivity (Lowenthal and Smith 1964).
(b) The nucleation and precipitation of solids during the evaporation of dilute solutions, containing at most a few micrograms of solids per gram of solvent are being studied.
The aim is to produce very thin and uniformly distributed sources in order to minimize the absorption of decay products in the active material. Uniformly thin sources can be made, e.g., by electrolysis or electrospaying (Yaffe 1962) but the fraction deposited is then generally not known with sufficient accuracy.

(c) The polyvinylchloride-acetate (VYNS) foils used for the making of source supports are treated with various surface active agents, chosen as likely to create a supporting surface more favourable to uniform source deposition than untreated VYNS.

Following Campion's (1958) pioneer work on $4\pi \beta-\gamma$ coincidence counting, accuracies attained with this technique have been improved to better than 0.5 per cent. for a few nuclides. Further progress is limited (a) by a few small correction terms which are becoming significant now that accuracies are increasing; and (b) by counting statistics.

To standardize a solution of 1 per cent. may require the accumulation of up to $1 \times 10^5$ counts and each further doubling of the statistical accuracy of counting requires another fourfold increase at least in the accumulated count number. Counting speeds must then also be increased to avoid delays and the tying-up of costly equipment.

To solve problems such as these requires improved or more specialized instruments and some of these have been or are now being designed by other groups within the General Physics Section. For example, small volume (a few millilitres) $4\pi$ gas flow counters have been designed to minimize the spread of pulse collection times since, by reducing this spread, shorter coincidence resolving times may be used without danger of losing coincidence counts. An amplifier is under test with a dead time matching that of the proportional counter ($\sim 1 \mu s$) and yet satisfying the stringent overload recovery characteristics required for absolute beta counting. Use of this amplifier will permit an increase in count rates from the present maximum of about 8000 counts/sec to between 30,000 and 40,000 counts/sec without creating difficulties resulting from overshoot or to uncertain dead time corrections. More specialized instruments include an auxiliary counter which has been constructed to determine directly the gamma efficiency of the proportional counters. This is a correction term required especially for the coincidence counting of electron capture nuclides such as Cr-51 and Mn-54 which emit X-rays and Auger electrons instead of beta particles and yield relatively low efficiencies in the $4\pi$ counter.

To enable standards laboratories to compare the quality of their work, the International Bureau of Weights and Measures (B.I.P.M.), Paris, has been organizing international intercomparisons of radioactivity measurements. So far the only nuclides selected for intercomparisons have been those whose calibration offers no serious difficulties. Otherwise few laboratories would have been in a position to submit useful results. The procedure is to circulate a representative sample of a master solution to every participant, now comprising between 20 and 30 laboratories, representing nearly as many countries. Each participating laboratory measures the specific activity of its sample and reports the result together with all relevant information on the measurements. These reports are collated and published and used to judge the level of confidence that can be attached to a standardization of the given radionuclide or of nuclides with sufficiently similar properties. Moreover, most participants obtain useful information from a study of the procedures reported by their colleagues in other countries.

The A.A.E.C. Research Establishment's participation in international intercomparisons started in 1962. Since then four intercomparisons have taken place; for Tl-204, Co-60, Am-241 and Sr-90. The information in Table 1 was taken from reports on these intercomparisons published by the B.I.P.M. and circulated to participants. The mean result for all participants is followed by the standard deviation from the mean and, in brackets, by the overall spread, that is, the difference between the highest and lowest result expressed as a percentage of the mean. In all cases the spread could have been more than halved by eliminating at most four of the results. The A.A.E.C. Research Establishment results are shown with their estimated error except that for Sr-90 there was an additional $\pm 1.2\%$ error in the self-absorption correction.

The large error assigned to our Tl-204 results reflected not only our uncertainty regarding self-absorption but also uncertainties regarding other aspects of our source preparation techniques at that time. Since then these techniques have been substantially improved. Of the four nuclides listed in Table 1, only Co-60 had been the subject of a previous intercomparison in conditions similar to those applying at present. This was during December, 1961, when the overall spread of results was nearly 8 per cent. and the standard deviation was 1.8%. This and other evidence points to definite improvements in the consistency of standardizations for which international intercomparisons can claim a fair share of credit.

(Continued on page 85)
The late J. L. Pawsey did as much as any scientist to initiate the work on Radio Astronomy in Australia and the country owes as much to him as to any man for having given Australia the undisputed place of leadership in the field in the world. It was tragic that he should have died at far too young an age, just when he was reaching his pinnacle of performance. It is fitting that his colleagues should have established the Annual Pawsey Lecture to be delivered under the auspices of the Australian Institute of Physics.

Dr. Pawsey was first of all a physicist in the fullest sense of the word. He was a man who knew how to apply to greatest advantage his profound knowledge of electronics and astronomy and use these in the development of the new science of Radio Astronomy. He was in a very special sense a great teacher and research director. It was he, more than anyone else, who guided the work of the remarkable group of young radio astronomers brought to Sydney and the C.S.I.R.O. under the joint direction of Dr. E. G. Bowen and himself. I need to mention here only a few: W. N. Christiansen, B. Y. Mills, J. P. Wild, J. G. Bolton, F. J. Kerr. There are at least a dozen more. Dr. Pawsey was their critical friend and guided their work. Without asking for credit, he advised them in the early stages of the planning of their researches, he followed their progress critically during the construction of equipment, communicated his ideas freely and read with care the first and subsequent drafts of their scientific papers. He brought to the Radio-physics Laboratory many of the younger radio astronomers who now flourish at the C.S.I.R.O., at Sydney University and elsewhere. He retained his interest in people and in research during his tragic illness. During my last visit with him, a short time before his death, he and I talked at length about the new and wonderful studies on Faraday Rotation, which he had helped to initiate. He was a good friend and a great man.

At the age of fifty, he had achieved a fine reputation overseas. A Fellow of the Royal Society, a recipient of several of the world's most coveted medals, the First President of the Commission on Radio Astronomy of the International Astronomical Union, the recipient of one of the first Honorary Degrees awarded by the Australian National University—all of these were his at an age much younger than at which scientists of high distinction generally receive such awards. He was much sought after as a speaker and leader at international meetings and symposia and his colleagues here and overseas listened whenever he spoke. He was a great Australian and a great scientist, whose name will long be remembered.

The Eta Carinae Nebula in Red Light. This photograph was taken with the Uppsala Schmidt Telescope and covers a region of close to 4 x 4 degrees of the sky.
Dr. Pawsey was always thinking and planning for the future and that is why I have chosen 'The Future of Galactic Research' as the topic of my lecture. The band of the Milky Way, so beautifully seen from our southern latitudes, outlines the central plane of the vast Milky Way system, the Galaxy, of which our sun and the earth are a part. If we undertake to look into the likely future developments of research on our Galaxy, we do well to examine first the past history of research in the field and list the places where the major breakthroughs have occurred over the past fifty years. I select the fourteen that follow as of greatest significance:

1. The discovery by Harlow Shapley in 1915-18 that our sun holds a position in our Galaxy near its central plane, but at a distance of about 35 thousand light years from its centre, the overall major diameter of our system being approximately 100 thousand light years.

2. The discovery by J. H. Oort and by Bertil Lindblad (1927) that our flattened Milky Way system rotates around the distant centre in Sagittarius, that the speed of the sun's rotation around the galactic centre is of the order of 180 miles per second and that our sun and earth complete one revolution around the centre of our Galaxy in 200 million years.

3. The discovery by R. J. Trumpler (1930) of the general absorption of light in our Galaxy, the density of the cosmic dust that produces this absorption being sufficient to dim the light of stars 5 thousand light years away by as much as one full magnitude of stellar brightness appreciably reddening the light from the distant stars in the bargain.

4. The detection, first by Karl G. Jansky (1932), then by Grote Reber, of the radio radiation that reaches us from the centre and from other parts of our Galaxy, especially from the gas clouds of interstellar space.

5. The recognition by Walter Baade (1944) of the existence of two Stellar Populations and the consequent general acceptance of the notion that there exist many stars two or three times as old as the sun and earth, others that have probable ages since formation from the interstellar gas and dust of less than one percent of the age of the sun and earth.

6. The discovery by H. I. Ewen and E. M. Purcell at Harvard University, confirmed almost immediately by radio astronomers in Sydney and in Leiden, of the 21 centimetre line of neutral atomic hydrogen, which first gave astronomers an opportunity to study the physics and arrangement of the interstellar clouds of the most common gas, hydrogen, in its most common, neutral, form in our Galaxy.

7. The first proof for the presence of spiral structure in our Galaxy by W. W. Morgan and associates (1951) from optical studies of the distribution of the gas clouds and of the young star clusters in our Galaxy.

8. The radio studies of the spiral structure as revealed by the 21 centimetre line of neutral atomic hydrogen, begun in Sydney and in Leiden early in 1952, which show our Galaxy to be a closely wound spiral system.

9. The discovery by J. S. Hall and W. A. Hiltner (1953) of optical polarization in the light of distant stars, and the subsequent discovery of Faraday Rotation at radio wave lengths. All these observations show the importance to our Galaxy of large-scale magnetic fields.

10. Radio studies of the central regions of our Galaxy (Sydney, Leiden, Green Bank, Pulkova), which show a very complex structure and which are indicative of the role played by the central regions of our Galaxy (and of other galaxies) in controlling and initiating the major phenomena observed in the outer parts.

11. The discovery of the OH molecule by radio techniques (U.S.A.) followed by its location in great abundance (Parkes Radio Telescope, Leiden, Great Britain) in the central regions of our Galaxy.

12. The recognition that cosmic rays observed to possess very high energies are probably formed within our Galaxy and are contained in it by the large-scale magnetic fields which may prevail even in the thin outer corona of our Galaxy.

13. The discovery of supernovae in our own and other galaxies and the general recognition that these and other violent events, like those observed in the quasi-stellar nuclei of other galaxies, may be critical factors controlling the overall development of a galaxy and the birth and evolution of the stars therein.

14. The increasing emphasis on studies relating to the chemical composition of stars and of the interstellar gas as an indication of age and of the cosmic history of the stars and gas clouds from which this composition can be determined. Comparative kinematical studies of stars with different chemical compositions in their atmospheres make it possible to suggest probable places of origin for stars with well-defined properties.

It is not difficult to list some of the areas in which we may expect considerable advances in the years to come.

I place at the head of my list the detection of molecular hydrogen in interstellar space. The simple hydrogen molecule will certainly be present in abundance in some of the gas clouds of our Galaxy, but no one knows how much there is and where the greatest concentrations are. It seems unlikely
that the detection of the \( \text{H}_2 \) molecule will come from studies in the normal visual or photographic spectrum, for there the search has already been pressed to the limit. My personal guess is that the spectrographs that will soon go into orbit aboard space vehicles, or mounted on space platforms, will produce tell-tale interstellar features in the ultra-violet that will be identified as arising from interstellar hydrogen molecules. The place to look in the spectrum seems to be near 1100 Angstroms, hence in the region well below the 3000 Angstrom limit set by our atmosphere for studies in the near ultra-violet. This is at greater wavelengths than the limit of 912 Angstroms, where galactic interstellar space may become ‘foggy’ because of the absorption of light produced by the single neutral hydrogen atom. There is a possibility that the detection will be made in the far infra-red end of the spec-
The Association I Scorpii. An Uppsala Schmidt photograph of the extensive young star Association, I Scorpii, which has the open star cluster, NGC 6231, at its centre. The field measures approximately 4 degrees across.

The chances seem rather slim, even for equipment carried outside the earth's atmosphere by space vehicles. On the whole, the chances of discovery by radio astronomical techniques seem to run a poor third, but it would be rash to predict with confidence which horse will come in ahead!

Once the hydrogen molecule has been discovered, the detection technique will certainly figure prominently as a major tool of Milky Way research in the years to follow. We shall all want to know how much molecular hydrogen is present in the regions of our Galaxy within a few hundred light years of the sun and earth—and presently where and under what physical conditions these molecules are found. There have been suggestions from purely gravitational arguments that we have accounted to date for only 70 percent of the matter in the galactic plane for the regions near the sun. What is the unknown and unaccounted 30 percent? Is it made up of dark stars, or sub-luminous stars, or giant planets? Or, is it interstellar hydrogen found in the elusive and yet so simple hydrogen mole-
cule? And, if the hydrogen molecule is found in our vicinity, what role does it play in the formation of cosmic dust and in the formation of stars from the interstellar gas?

In a way even more interesting are the problems posed by the probable presence and abundance of molecular hydrogen in the central regions of our Galaxy. The terrific abundance of the OH molecule revealed by the Parkes Radio Telescope suggests that the conditions for the formation of the simple two-atom hydrogen molecule may be favourable in and near the galactic centre. And, finally, we must know the abundance of the hydrogen molecule in intergalactic space, for it is not outside the realm of possibilities that our Galaxy floats in a medium of mostly molecular hydrogen. While the formation of molecular hydrogen under the conditions prevailing in space seems like an unlikely process to take place, the destruction of such a molecule once formed seems even less likely.

Spectral studies in the far ultra-violet, and to a lesser extent in the far infra-red, offer great opportunities for advancing our knowledge of matter in the gas clouds of interstellar space. Many absorption lines of interstellar origin await discovery in the range of wavelengths between 900 and 3000 Angstroms. Our views on the chemical composition and physical conditions—and variations thereof—in the interstellar gas stand to be modified considerably during the next decade by studies from space vehicles.

Another major area of future research lies in the study of the chemical composition of stars themselves and in the tracing of the past histories of the stars exhibiting certain characteristics. On the whole, the older stars, especially those that appear from their motions to have originated in or near the central regions of our Galaxy, are much richer in hydrogen, or, better said, they lack heavy elements, when compared to the younger stars formed in the regions far from the galactic centre such as the section of the Milky Way where the sun is found. Was our universe in the postulated pre-galaxy phase composed of almost pure hydrogen, or was there already an admixture of the heavier elements in these early stages? There are some indications that a fair percentage of the heavier elements was present at the pre-galaxy stage, but we must know for certain before we can proceed with soundly based studies of the chemical and kinematical evolution of our own and other galaxies.

The Large and the Small Magellanic Cloud are beginning to provide important clues in relation to both the younger and the older stars. Until the establishment of full-fledged observatories beyond the earth's atmosphere—which may still be half a century away—the astronomers of the Southern Hemisphere are the privileged few to have access to the key sections of the southern Milky Way and to the Magellanic Clouds. Hence the establishment of major Southern Hemisphere telescopes, with apertures of 150 to 200 inches, is a must for the proper study of the heavens. Australia cannot afford to fall behind in these developments.

A problem to which continuing attention must be paid relates to the study of the spiral structure of our own and neighbouring galaxies. Here we require continuing progress in the delineation of the spiral arms, which, as far as we can tell now, are composed wholly of interstellar gas and dust and of stars that are very young on the cosmic scale. Even with the most favourable conditions in galactic magnetic fields, we know of no mechanism that will hold a gaseous spiral arm intact for more than two galactic revolutions. This represents only about 10 percent of the age of the sun and earth.

Are these arms being constantly formed and reformed? Do they—as some radio observations suggest—come as smoke rings blown from the central regions of our own and other galaxies? And, if so, how are they drawn out from smoke rings into the beautiful spiral features? And, from where does the interstellar gas come that would presumably be expelled by the galactic nuclei? When one surveys the proliferation of plausible theories now on the astronomical market, one distinctly gains the impression that we have not yet begun to understand the origin and behaviour of spiral arms. What we need is not new and more observations, nor new and more indications as to basic patterns, but, above all, we need new ideas and new approaches to the basic theory of spiral structure in galaxies. I expect that 10 or 15 years hence our present-day theories of spiral structure will seem even more out of date than our present-day observations.

It may well be that the key to the solution of many of the problems of galactic research will have been found when we begin to understand the origin of cosmic rays. As we noted earlier, the cosmic rays are probably atomic particles of great energy from within our Galaxy, held there by the presence of extended weak magnetic fields. We have as yet no way of knowing from where and how they originate. They carry with them a sizeable fraction of the total energy of our Galaxy, possibly close to one-third of this total. The electromagnetic forces that keep these particles within our Galaxy also assist in the production of the radio waves of larger wavelengths—the synchrotron radiation—that are detected by our large radio telescopes, such as the 210-foot radio telescope at Parkes. It will be possible to study these radio sources with very high angular resolution with the Sydney University Mills Cross now approaching completion near Hobart-town.

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Constellation 1 in the Large Magellanic Cloud. This is one of the finest groupings of young and very luminous blue-white stars in the Large Magellanic Cloud. The field shown measures less than one degree across in the sky, which at the distance of the Large Magellanic Cloud represents approximately three thousand light years.
If I had to select two future breakthroughs that will contribute most to the understanding of our Galaxy and the Universe of which we are a part, I would not hesitate to name:

1. Cosmic Rays,
2. Violent events in galactic nuclei.

I have already indicated the importance of the first and will in conclusion speak briefly about the second area of research.

In a violent event observed in the nucleus of a galaxy, radio and optical observations show that tremendous amounts of energy are released during one of these outbursts. The observations show furthermore that these outbursts are initially confined to volumes of space that are very small on the cosmic scale—hence the term 'quasi-stars'. Their effects on the galaxies in which they take place must be tremendous, and it is worthy of note that these kinds of events have been observed in more than one of the nearer neighbours of the Milky Way system. Hence, offhand, it does not seem unlikely that some time during the next two or three galactic revolutions our Galaxy will be subjected to such an outburst. Will this be the time of major atom-building? Or the time at which fresh interstellar matter will be expelled into the outer reaches of our Galaxy? And why, if this is the case, does the gas flow mostly in the galactic plane rather than being expelled more or less equally in all directions?

If such a gigantic explosion were to take place in our Galaxy, it would probably produce pressure waves of unprecedented dimension and it is not difficult to imagine that conditions may exist for cosmically brief periods and on such a vast scale for the production of new stars from the interstellar gas. Hence, the whole range of problems of star birth may be intimately connected with the occurrences of violent events in the nuclei of galaxies.

The future of galactic research looks complex, yet wonderful. With our new and improved techniques, and with new tools for earthbound studies in optical and radio astronomy—and with the advent of space research—we are on the threshold of magnificent new discoveries. But, even more than new techniques, new tools and new discoveries, we shall need new ideas and fresh approaches to old problems if we are to realise the full benefits of the promise of our bright future for increased understanding of the Galaxy in which we live.

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**Radioisotope Standardization (Continued)**

**REFERENCES:**


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**TABLE 1**

**SUMMARY OF RESULTS OF INTERNATIONAL INTERCOMPARISONS MADE WITH A.A.E.C. RESEARCH ESTABLISHMENT PARTICIPATION**

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Date</th>
<th>No. of Participants</th>
<th>Results (10² dps/mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean for all participants</td>
</tr>
<tr>
<td>Tl-204</td>
<td>1962</td>
<td>29</td>
<td>37.5 ± 3.3% (14 %)</td>
</tr>
<tr>
<td>Co-60 (**)</td>
<td>1963</td>
<td>20</td>
<td>15.22 ± 0.9% (4.6 %)</td>
</tr>
<tr>
<td></td>
<td>1963</td>
<td>29</td>
<td>0.1129 ± 0.9% (4.3 %)</td>
</tr>
<tr>
<td></td>
<td>1964</td>
<td>24</td>
<td>10.95 ± 0.7% (3.0 %)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.732 ± 1.3% (3.0 %)</td>
</tr>
</tbody>
</table>

(*) An A.A.E.C. report on these intercomparisons is in preparation.

(**) Solid Co-60 sources were also circulated. The counting results for these sources were more than twice as consistent than the counting results from the sources prepared from the solutions. This improvement is probably due to the avoidance of errors arising during source preparation.

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A PHYSICS RESEARCH REGISTER FOR AUSTRALIA

Sir,—Communication is a central problem in scientific research in Australia. There seems to be a great need for some sort of register of current scientific research in all fields and most certainly in Physics. Whenever I have discussed this subject with other scientists they have reinforced my view. Very often one learns with surprise that someone in Perth or Brisbane is working on a similar field, and perhaps has been for a number of years. Of course, there is not so much excuse for ignorance after the work is published, but allowing about two years from the commencement of the work to the submission of the first manuscript, and another year for refereeing, printing, mail delivery and library routing, it can well be three years from the start of a project to the interstate awareness of it, and of the people involved.

The direct physicist-physicist communication problem is bad enough, but it becomes worse when one considers the peripheral fields in which physicists operate. Research in physics can well be disguised in laboratories labelled Engineering, Chemistry, Geology, Mathematics, Medicine or Meteorology to name an incomplete list. The paucity of local formal and informal conferences which involve interstate groups, as a result of distance, finance and time, together with the low density of scientists across the face of Australia, makes our problem perhaps unique.

All the above is probably a string of truisms to most Australian scientists. What I propose is that the Australian Institute of Physics should sponsor a register of current research in physics which would be compiled initially with the co-operation of our membership, and revised annually. It could be quite a modest affair to start with, roneoed or off-set printed, and need not cost much in time, effort and money. On the other hand, we should aim to expand its scope and interest other professional bodies in joining us in this annual register of research. Our hope should be to produce ultimately a handbook which takes its place beside university calendars in libraries. Not only would it form a register of research activity, but also of personnel.

We might aim, even from the start, to interest other bodies with bulkier purses to finance the project. The Universities Commission, C.S.I.R.O., the Department of Supply, the Australian Academy of Science, the Clunies Ross Foundation, and others could have sufficient interest to finance the project in a more satisfactory form.

Of course, there are already in existence a number of annual reports, research reports and so on issued by individual bodies such as C.S.I.R.O., A.A.E.C., and various universities. While these are too detailed and wordy for a comprehensive register as they stand, they could form the basis for briefer statements.

The proposed register could be of great value to individual research workers in the stimulation of direct communication. However, it would also be an invaluable guide to Industry in indicating the body or man who might be consulted about particular industrial problems or processes. The absence of commercial research contract bodies in Australia has meant that universities and government laboratories have become the entrepreneurs of current research to industrial firms, excepting of course those large enough to employ their own scientists. More direct liaison and less time-wasting might occur if a research register were available.

There are snags to be seen. Some people might not be prepared to reveal their current activities. Defence and industrial secrecy and reticence might inhibit some entries. Some might believe such a scheme to be impractical — whether anything like it has been tried and failed (or succeeded) in other countries is irrelevant. Ours are special problems and our numbers are small enough to make the project at the same time both possible and necessary.

Not the least in importance would be the publicity value of the project to the A.I.P. I was shocked recently when I learned that the organizers of the Clunies Ross Foundation Scientists Club in Melbourne had not circularized A.I.P. members as they thought our numbers were too small! So much for our present impact on other scientists, let alone the public!

I am proposing this project via your columns, Sir, to canvass general opinion, but I hope that the Council of the A.I.P. will consider it in due course.

C. K. COOGAN.

15 Irribarr Road, Canterbury, Vic.
April 18, 1965.

Comments on such topics as these would be welcome, as will any other exchange of views.—Ed.

Reviewed by H. F. Pollard, University of New South Wales.

It is no longer a novelty to be reminded, rather forcibly of the rapid growth of scientific subjects. In 1958 the essential basic principles on which a working knowledge of Physical Acoustics could be based was contained in a single volume of some 400 pages written by Dr. W. P. Mason. Now, during 1964, Dr. Mason appears as the editor of a set of 6 books devoted to the principles and methods of Physical Acoustics.

Two books, labelled Vol. 1 Pt. A and Pt. B, are devoted to Methods and Devices; Vol. 2 Pt. A to Properties of Gases, Liquids and Solutions; Vol. 2 Pt. B to Properties of Polymers and Nonlinear Acoustics; Vol. 3 to Applications to the Study of Imperfections and Lattice Dynamics; Vol. 4 to Applications to Quantum and Solid State Physics. Each volume contains a number of chapters and involves the work of several authors.

In Vol. 1 Part A, four chapters deal with fundamental matters such as wave propagation in infinite and finite media, transducer theory and measurement methods while three chapters are concerned with applications to filter design and delay lines.

Chapter 1—Wave Propagation in Fluids and Normal Solids by R. N. Thurston—is a very thorough and fairly advanced treatment of 110 pages dealing with basic elastic, thermoelastic and viscoelastic theory together with a useful section on small-amplitude waves in strained elastic crystals and the determination of third-order elastic constants.


Chapter 3—Piezoelectric and Piezomagnetic Materials and their function in Transducers by D. A. Berlincourt, D. B. Curran and H. Jaffe—is again a quite extensive (102 pages) account in which is included all fundamental definitions, equations and numerous tables of data. A full treatment is given of ceramic ferroelectric materials and the various vibration modes of transducers is more complete than usual.

Chapter 4—Ultrasonic Methods for Measuring the Mechanical Properties of Liquids and Solids by H. J. McSkimin—covers the essentials of many of the methods that have been reported. However, the depth of treatment is introductory in character and will probably serve mainly as a guide to the many references quoted. It is a pity that the excellent and extensive work carried out by Bradfield at N.P.L. does not receive more consideration.

In Chapter 5—Use of Piezoelectric Crystals and Mechanical Resonators in Filters and Oscillators by W. P. Mason—there is much useful information concerning the choice and properties of various crystal cuts and the application of analogous electrical circuits and transmission line theory to filter design, a subject that has been pioneered by Dr. Mason.

Chapter 6—Guided Wave Ultrasonic Delay Lines by J. E. May, Jr.—includes detailed discussion of both non-dispersive and dispersive lines using longitudinal modes in wires, shear waves in plates and strips, longitudinal modes in wires and piezoelectric lines, etc.

Chapter 7—Multiple Reflection Ultrasonic Delay Lines by W. P. Mason—differs from previous chapters in that it consists of a brief summary of well-known facts concerning sound waves in solids together with an equally brief discussion of straight and folded solid delay lines.

Apart from Chapter 7, the various treatments in the book are carried out to a considerable depth, making the book an indispensable one for workers in this field as well as a valuable source of material for advanced courses in physics and engineering.


This book considers various approaches to solving the problem of determining parameters which connect intuitive trial functions to give an estimate of the solution of a given equation. The method is formulated in general terms and embraces nonlinear, constrained and non-self-adjoint problems. A least-squares variational technique is developed, and although it tends to complicate the analysis, it removes the need to supply adjoint trial functions which are frequently not intuitively available.

Constrained variation is tackled in such a way that the procedure is still tractable. An example which has great importance in reactor physics is given in detail to illustrate the potential of the least-squares variational technique. This example is the burn up of fuel in a nuclear reactor with the governing equations reduced to a simple form (one space variable, one neutron energy group and one fuel nuclide). Other simple examples are given to show the reader the power of the various methods. More examples could have been given, however, to illustrate the manipulative requirement of the procedure and this failing makes the book hard going for an engineer or scientist interested mainly in using the ideas for a specific study of his own.


Reviewed by Professor R. Street, Monash University.

During the last twenty years our knowledge of the magnetic properties of materials has broadened considerably. This expansion has been due, firstly, to the availability and application of new experimental and theoretical techniques of investigation and, secondly, to the demand for specialised magnetic materials in a wide range of technological applications. A number of books have been written in which the problems of selection of the vast amount of available information have been tackled in different ways. Professor Chiharaumi's book is, frankly, a textbook in the sense that there are relatively few references to original work and limited numbers of problems are appended to some chapters. The overriding emphasis is on the properties of ferromagnetic materials. The main body of the book is in four parts on Magnetic Phenomena, Intrinsic Magnetization, Magnetic Domain Structure, and The Magnetization Process. All the arguments are carefully and clearly developed and provide an excellent introduction to the phenomenology of ferromagnetism. Part 5 is concerned with a number of Special Topics, again mostly in ferromagnetism, in which, of necessity, some important modern work using Neutron Diffraction, NMR and the Mössbauer Effect are only briefly mentioned. The final brief section is on Engineering Applications of Magnetic Materials.

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In summary, Professor Chihara's ability to emphasize underlying physical principles makes his book an admirable introduction to more advanced work on ferromagnetism. As such, the book will be of value both at the undergraduate and postgraduate levels.


Reviewed by J. C. Kelly, University of New South Wales.

The level of the book is about first year University and starts off assuming some knowledge of particle dynamics and Newton's equations of motion.

Chapter I starts with rotation about a fixed axis and goes on to develop the idea of moment of inertia. The moments of inertia of the basic regular bodies are derived and the usual axis theorems illustrated with examples. The chapter ends with the Gyroscope and Rolling motion.

The second chapter deals with general motion in a plane, the third with frictional problems such as the Efficiency of Belt Transmission. Chapters four and five discuss oscillatory motion including cent of percussion, the effects of damping and forced oscillations.

The last of the six chapters deals with Gravitation and is perhaps the best chapter in the book. The use of Gauss' Law to solve problems of gravitational attraction is not often enough seen in elementary books and its use here is to be applauded.

Each chapter is followed by some twenty problems for which answers are supplied. The problems are, unfortunately, mostly of a numerical kind and with a few exceptions use engineering units of feet, pounds, horsepower, etc., rather than a little conversion to find friction expressed in lb. ton in problem 23 of the first chapter.

The author has achieved his aim of giving a good concise treatment of some topics in plane rigid body dynamics at a first year University level. The book will probably appeal more to the Engineering student than to students of Mathematics and Physics.


Reviewed by J. C. Kelly, University of New South Wales.

The literature on glass surfaces is spread over a very large number of journals devoted to Physics, Chemistry, Vacuum Technology, Astronomy, Engineering and other subjects. There is therefore no doubt that a real need exists for a book which gathers together all these loose strands.

The author has for many years worked as a vacuum physicist and it is from his interest in solid thin films that this book stems. The coverage, however, is considerably wider than that needed to prepare a glass surface for successful vacuum evaporation as a list of the chapters shows.


The fact that the basic generalisations are made is a reflection on the nature of the glass surface. The book contains, however, a wealth of experimental information and tabulated data ranging from the contact angles of organic fluids on glass to the dielectric loss of various glasses as a function of frequency. The chapter on glass cleaning contains specific practical advice which should be read by anybody preparing thin films by vacuum evaporation.

The coverage of the dispersed literature on the subject is good and one cannot grumble at minor errors such as the omission from the list of references of the paper by Todd mentioned on P. 254. (The missing reference is Todd et al. (1960), J. Appl. Phys. 31, 51.)

The section on the adhesion of synthetic resins to glass gives information of which most physicists would be unaware. Although mainly gathered for fibreglass construction work, the details of bond strengths will be a help to experimenters attaching equipment to glass. It could have been even more useful for physicists using vacuum systems had some of the extensive information on the vapour pressure of the polymers been included.

The book fills a need and does it well. A copy should be available to anybody working with glass or doing experiments in glass apparatus.


Reviewed by S. R. Taylor, Department of Geophysics and Geochemistry, Australian National University.

The origin and evolution of planetary atmospheres and oceans is a subject well suited to modern geophysical and geochemical investigation, and there are excellent reasons for the publication of a book on this important and splendid subject. It is therefore noted with regret that the book under discussion falls short of the promise of its title. It is another example of that, now ungenerally called, 'publication of a report of a conference'. This was held in April, 1963. The editors' preface is dated August, 1964, and the book was received for review in December, 1964. The publication delay of over 18 months is unfortunate in an active subject. The spate of similar conference reports in book form has led to much unfavourable comment by reviewers. Without doubt, the rapid issue of cheaply produced proceedings would be a more useful service to scientists than the delayed appearance of a permanent printed record.

A serious criticism of the book is that, of a total of 306 pages of text, 118 or 38.6 percent has been published previously including Rubey's classic 'Geophysical history of the sea' which appeared fourteen years ago (Bull. Geol. Soc. Amer., Vol. 62, p. 3111, 1951). A price of 125/- thus appears excessive for 188 pages which includes about 16 pages of discussions, following the individual papers. These are interesting, but of doubtful permanent value, except for a contribution by Gold noted later. The discussions are reported apparently verbatim and include contributions from 'a voice', not otherwise identified, but whose comments seem to be of value.

The book comprises 17 chapters. These are the usual disconnected series of papers of variable length and quality. The first is the reprint of Rubey's paper. His thesis that the oceans were derived by degassing of the interior of the earth during geological time is now rather generally accepted. Turekian, Wasserburg and Brancaccio discuss outgassing of the earth. Turekian shows that the $^{10}$ content of the atmosphere can be adequately accounted for by radioactivity from terrestrial $^{8}$ K. One of the better chapters in the book is by Hollard, who discusses the chemical evolution of the atmospheres of the earth and Venus. He reminds us that the oceans constitute 0.024 percent of the atmosphere only 0.00009 percent of the mass of the earth. He suggests that oxygen began to be an important component of the earth's atmosphere about $2 \times 10^{9}$ years ago, about half way through earth history. Berliner and Merrill discuss the biochemical production of oxygen. MacDonald's extensive discussion (55 pages) of the escape of helium from the earth's atmosphere has already appeared in Reviews of Geophysics. Vol. 1, p. 305.
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The unit is 5 inches in height and 17 inches wide.

On Walkabout

Dr. D. W. Posner of the Division of Applied Physics, C.S.I.R.O., has been seconded for a year to the Commonwealth Directorate of Civil Defence where he will act as a Scientific Adviser to the Director.

Professor J. M. Cowley, Physics Department of the Melbourne University, has been overseas during March and April. Professor Cowley attended the Executive meetings of the International Union of Crystallography in London primarily though he also visited universities in the U.S.A. en route.

Dr. James Campbell has been appointed Director of the Australian Wool Testing Authority. Dr. Campbell graduated in physics at Melbourne University and continued his researches there in nuclear physics. After the award of his Ph.D. at Melbourne University, he joined the research laboratory of A.P.M. to work on problems of paper-making using Australian woods. For a few years he forsook the laboratory and was drawn into the production side of A.P.M.’s activities. He will bring a wide knowledge of research and production to his new job of directing the development of methods of testing wool.

Dr. J. C. Duggleby, formerly with Health and Safety Division of the A.A.E.C. Research Establishment, has been appointed to a post with the Commonwealth X-ray and Radium Laboratory in Melbourne.

Books Received


PROFILE OF A PHYSICS DEPARTMENT
ROYAL MILITARY COLLEGE—DUNTRUON

The Royal Military College of Australia was established at Duntroon, on the outskirts of Canberra, in 1911. Its role is to educate and train young officers for the Regular Army. The curriculum, presented over four years, has a large academic content as well as specific vocation elements. The academic work of the College is presented by civilian lecturing staff employed by the Department of the Army, while professional elements are presented by military staff. The professors, senior lecturers and lecturers form an academic body about thirty strong.

Physics has been a subject of the course since the college opened. Before 1948, a common course was studied by all cadets, irrespective of their aptitudes in various disciplines and irrespective of their ultimate role in the Army. From 1948 to 1963, three separate courses, containing vastly different syllabuses in Physics, have been developed in Arts, Science and Engineering. In this period, the major Physics commitment rested in the provision of a three-year sequence as part of the Engineering course aimed at preparing students for entry to the third year of Engineering courses in the Australian Universities.

The beginning of 1964 saw a major step in the evolution of the courses at R.M.C. All students entered the college with the matriculation requirements of their home State (for several years previous to this, some eighty per cent. of the entrants were matriculated). Three courses of study are available—Arts, Applied Science, Engineering— which are designed to complete at Duntroon the academic training of the young army officer to the level of a pass degree or a diploma, depending on the ability and application of the student. Apart from presenting terminal subjects in the Arts and Engineering courses, the largest objective of the Physics department is a three-year sequence composed of a fairly conventional Physics I followed by two years of Applied Physics. The syllabus of these two years of Applied Physics has been designed to give treatment of relevant principles interlaced with applications of importance to the Army and to the modern world. Accordingly, one finds four main topics named for their best known applications: for example, Solid State Science embraces the principles and methods of solid state physics, quantum mechanics, spectroscopy, while leading to applications in these fields, and communications and computations lead from the principles and methods of electricity and electromagnetism, acoustics, electrical circuitry to techniques in radio, radar, analogue and digital computing.

Teaching staff consists at present of a professor and four lecturers. It is hoped to add this year an additional lecturer or senior lecturer preferably with teaching and research experience in Solid State Physics. Salaries of lecturers and senior lecturers are those of their university equivalents. Teaching loads are designed to allow time for research. We are fortunate that close proximity to the Australian National University permits attendance at seminars and the benefit of discussions with other physicists.

Acquisition of equipment essential for teaching and research has continued at an increased rate for some years past, but the requirements of the new courses have accelerated this somewhat. An Hitachi electron microscope of 8 A resolution arrives in March, 1965. Some of the equipment being considered includes a neutron generator, an X-ray spectrometer and accessories, multichannel analyser and teaching equipment for analogue and digital computing.

Research is encouraged by the college and supported by Army funds. Staff research projects are generally of an individual nature. At present, two of the staff are working in the field of electrical discharges in gases, one in the study and development of solid state alpha particle detectors, and another in the study of U.V.-induced conductivity, and of the dielectric relaxation, of polyethylene films. With the availability of an electron microscope, X-ray equipment and a neutron generator, it is expected that research in the future may move more towards a group interest in the solid state field and perhaps in work on thin films. However, staff members are free to choose their individual projects.

Maintenance of standards is dear to the hearts of all physicists. It is therefore pertinent to make clear in conclusion that the development and evolution of the courses at Duntroon has been by no means a haphazard or "wildcat" venture. Design of courses over the past thirteen years has been vested in the Standing Committee, a body composed of university professors and senior military men, acting more and more like a governing council. Design of the new syllabuses has been the task of the Advisory Board, a body composed of university professors and the heads of the local departments, acting over the past eighteen months as a composite faculty. To ensure that the examining and marking meet university standards, the Advisory Board appoints External Examiners (experienced university examiners) in the various sub-
jects, who criticize the papers set by the local staff and who, by sampling final examination scripts, check the marking standards. It is interesting to note that on these three bodies all except three Australian universities are represented. By these means, it is intended that the best of our students should reach, before they leave Dunrobin, the standard of a good pass degree in one of the three courses offered. One of the most encouraging facets in this advisory structure is the interest, enthusiasm and effort shown by the academics from the universities, who are engaged in this co-operative venture.

—D. E. Swan.

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three new Keithley solid state picoammeters

HIGH SPEED
Models 417/416
provide a ten-fold increase in speed of response over other instruments. Speed is maintained by the unique plunger design which allows the amplifier input to be located up to 100 feet from the instrument chassis. Rise times may be adjusted with a front panel damping control. Both models are identical except the 417 provides calibrated current suppression from 10^-6 to 10^-11 amperes. Applications include use in mass spectrometry, vacuum studies and giantics physics studies.

- Ranges: 10^-6 to 3 x 10^-4 amperes fs
- Accuracy: 2% FS to 10^-4 amperes; 1% beyond
- Zero Drift: less than 1% per 6 hours, with zero volt source
- Outputs: ±3 volts for 16 meter deflection
- Rise Time: 30 milliseconds on 10^-11 amperes range at critical damping

Model 417 High Speed Picoammeter
Model 416 High Speed Picoammeter

LOW ZERO DRIFT
Model 409
allows long term measurements of currents as low as 10^-11 ampere. Circuitry is completely solid state, except for electrometer tube input, assuring reliability and low power consumption. Zero check switch permits zeroing the meter without disturbing the circuit. Applications include use with photocells, photo-multipliers, and ion chambers. With the Model 4103 Electronic Trip, the 409 is excellent for nuclear reactor control.

- Ranges: 3 x 10^-11 to 10^-3 amperes fs
- Accuracy: 1.2% FS to 10^-4 amperes; 0.7% beyond
- Zero Drift: less than 1.5% per 24 hours, with zero volt source
- Outputs: ±3 volts for 16 meter deflection
- Rise Time: 1.5 seconds on 10^-11 amperes range

Model 409 Low Zero Drift Picoammeter
Model 4103 Electronic Trip (installed)

Send for Engineering Notes on New Picoammeters

OTHER KEITHLEY PICOAMMETERS
Model 410—high sensitivity, 20 linear ranges
Model 411—telescopic deflection, 15 linear ranges
Model 412—log n amplifier, 6 decade span
Model 413A—high frequency 12 decade span
Model 414—high performance over 17 linear ranges
Models 420A/421—log n period amplifiers

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dc microvoltmeters • differential voltmeters • wideband voltmeters

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