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The original typescript and one copy should be forwarded. Original drawings should be submitted but, where possible, photographic copies, Xerox, or blueprints of the originals should also be submitted. Half-tone illustrations should only be included if essential, they should be on white glossy paper and show a full range of tones with good contrast.


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THE NINTH ANNUAL MEETING OF PHYSICS IN MEDICINE AND BIOLOGY

K. H. Clarke and R. J. de Groot
Cancer Institute, Melbourne

The Ninth Annual Meeting of Physics in Medicine and Biology was the first such meeting to be held in Perth and the organizers are to be commended on staging a very interesting and successful programme. It was held from 25 to 29 August 1969, in the Engineering School of the University of Western Australia, except for one session which was held in the School of Physics in the new Western Australian Institute of Technology. Thirty-eight delegates attended, twenty of whom came from interstate. Altogether thirty-three papers were presented.

For the first time the programme included a session on bio-engineering in which the role of the bio-engineer in a hospital was discussed, and some practical applications of engineering principles were presented. For some time there has been discussion amongst members about broadening the scope of these annual meetings to include the application of all the physical sciences to medicine and biology, and the success of this session on bio-engineering gave great support for this idea. This was discussed later in the week and a motion, that 'an approach be made to the professional bio-engineers to see what can be done to co-ordinate activities' was passed.

The session on imaging devices included radio-nuclide and ultrasonic techniques and covered the determination of the rate and pattern of flow of cerebrospinal fluid, flow studies with a gamma camera modified for regional digital read-out, subtraction techniques involving scanning with two radionuclides simultaneously, a comparison of ultrasonic and isotope lung scans, and other ultrasonic studies involving the pregnant uterus, eye, breast, brain, and heart.

Studies of the rhythmic (circadian) leaf movements in clover were presented in relation to the electrochemical properties of the pulvinal cells at the base of the leaf, the membrane potential difference, and changes in ion and water concentration in these cells.

Other papers included studies of membrane biophysics, the use of the Mössbauer effect to study acoustic vibrations, $X$-ray spectrophotometry in biological systems, the hazards of lasers, radiation dosimetry, the application of computer techniques to clinical dosimetry and radiation monitoring problems, and the training and organization of medical physics.

The final scientific session was a very interesting and stimulating symposium on the Hazards of Peaceful Uses of Nuclear Energy in which the radiation protection problems and economic advantages associated with certain nuclear ploughshare projects were presented and discussed.

The annual dinner was held at University House and was a most enjoyable social evening. The meeting concluded on a very informal and relaxed note with a visit to the Valencia vineyards, a very well attended session.

The meeting was very successful from the points of view of breadth of coverage, presentation of new material and excellent organization; furthermore, Perth turned on a week of wonderful weather which added to the overall success. The interstate visitors were given overwhelming hospitality by the Western Australians, and Perth is now a lot closer to the Eastern States than it was before the meeting. Special thanks are due to the principal members of the organizing team, Messrs R. F. Fleay, P. W. Henson, W. K. Jones, L. Munslow-Davies, and R. W. Stanford, whose efforts were greatly appreciated.

Summaries of some of the papers are given.

### Attendance at Ninth Annual Meeting of Physics in Medicine and Biology

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The Australian Physicist, April 1970
A Muscle-like Pneumatic Actuator with Possible Prosthetic Application—D. Macey, Department of Mechanical Engineering, University of Western Australia

In this paper the characteristics and properties of a simple type of pneumatic actuator are described, and reasons for its possible application in prosthetic and orthotic devices suggested.

The actuator consists of a Silastic tube reinforced in the axial direction with glass fibres within the walls. Since the length, measured along the wall, cannot change, any inflation must be accompanied by an endwise contraction. High forces of contraction are available for small displacements.

The reason for suggesting medical applications is that a similar device, known as the McKibben muscle, has been used on prosthetic and orthotic devices with some success. It consists of a rubber tube reinforced with a helical-weave glass-mesh sheath. The axially reinforced tube should offer the advantages of higher operating force and greater durability over the McKibben muscle.

Both of these ‘muscle-like’ devices compete among pneumatic systems with the piston-and-cylinder, and the bellows. All of these devices compete for application with electrical systems.

Ultimately, the success or failure of this actuator can only be judged by the patient who uses it, but the author feels that it offers promise due to its simplicity, low weight, and potential reliability.

Modification of the Scintillation Camera for Digital Dynamic Studies with Radionuclides—P. Ronai, Institute of Medical and Veterinary Science, Adelaide

An instrument for imaging radionuclide distribution, which has become commercially available recently, is the scintillation camera. This instrument originally developed in 1958 by Anger at the University of California, Berkeley, differs from previous devices in that it does not scan the patient mechanically. A large (114-inch diameter) sodium iodide crystal views the area of interest continuously and information on radionuclide distribution is electronically derived from the distribution of scintillations in the crystal. Since this device is very sensitive and views the whole field continuously, it is not limited to imaging radionuclides whose distribution is static. Dynamic studies of organ blood flow, for example, can be performed and serial pictures with exposures of as little as one second can be taken. Such analogue information is, however, limited in that quantitative results cannot readily be obtained from serial photographs.

One of the two scintillation cameras at the Institute of Medical and Veterinary Science in Adelaide has been modified for digital studies in the following way. X- and Y-positioning information for all scintillations passed by the pulse-height analyser of the camera is fed into dual analogue-to-digital converters. These digitize the amplitudes of X and Y pulses allowing positioning of each event within a 40 × 40 matrix of addresses in a 1600 word memory. Interfaced with the memory is an Ampex magnetic-tape unit which allows rapid readout of data from the memory in computer-compatible format. By using automatic store-read cycling, data can be stored in the memory for short intervals and automatically dumped onto the tape. At the end of the study the tape can be replayed into the memory and regions of interest selected on the memory oscilloscope display. A data processor is used to sum counts within each region of interest. In this way multiple data points can be plotted to construct a perfusion curve for the selected regions of interest. This can be done simultaneously for two regions of interest. Computer processing can be used to facilitate computations or if more than two regions of interest are to be selected.

Preliminary clinical experience involving the use of this equipment in cerebral blood-flow studies were presented.

Comparison of Isotope and Ultrasonic Scans of Lung—L. Collins and J. Myhill, Royal North Shore Hospital, and University of Sydney

Pulmonary embolism is one of the most common causes of hospital death. Of the diagnostic tests for this illness, the radionuclide scan is the most successful. However, it has two main disadvantages: firstly, the patient’s condition may preclude a scan, and secondly, the limited spatial resolution of scanning techniques gives only broad information regarding pulmonary blood flow.

Equipment for an ultrasonic investigation of the lung, which promises to overcome these disadvantages, has been constructed by the Commonwealth Acoustic Laboratories and has been used experimentally and clinically at the Royal North Shore Hospital of Sydney.

Ultrasonic waves travel through a uniform medium unchanged. When a change in acoustic impedance is encountered part of the energy of the wave is reflected. Thus changes in lung density or elasticity due to ischaemia, etc., can be detected.

Thirty-one patients have been studied, all having isotope and ultrasonic investigations. The ultrasonic test was found to be reliable, and the portability of the instrument a real advantage. The technique is versatile, in that pleural effusions can also be detected, and the abnormality is accurately localized. The technique is now in routine use as a complement to isotope, X-ray, and angiographic investigations.

X-Ray Spectrophotometry—L. Collins and J. Myhill, Royal North Shore Hospital and University of Sydney

In a system in which a substance of interest, the tracer, undergoes various physical and chemical processes, information is often required about quantities and movements of the tracer involved. This is achieved by observation of a similar, easily detected substance—called the tracer.
Classical tracer kinetics was developed as a means for interpreting the dynamic state of chemical and other simple systems. A new theory was recently developed by Bergner for biological systems, using fewer assumptions, which enables tracer determination of the inhomogeneous organ content of a trace.

The present research is aimed towards testing this theory. Bergner has dispensed with the need for assuming homogeneity of the organ concerned, since in a biological system all compartments are chemically and physically inhomogeneous. It is the effect of this possible source of error which is to be investigated. The technique of X-ray-absorption spectrophotometric analysis is used to measure directly the organ concentration, for comparison with the isotope-tracer method. The basic techniques have been presented previously, and this paper discusses a further technique, the use of isotopic sources of primary photons, and also the application of the method to testing tracer kinetics, measurement of bone-mineral content, and other tracer processes.

Developments in Ultrasonic Diagnosis—D. E. Robinson, Commonwealth Acoustic Laboratory, Sydney

Pulsed ultrasonic may be used to obtain a cross-section of the human body in a manner similar to sonar and radar. The technique has been used in the pregnant uterus, abdomen, eye, and breast. The resolution along the beam is approximately two wavelengths and across the beam 20 to 25 wavelengths. Improvement in effective beamwidth can be achieved by comparing each echo with the echo at the same delay from the previous pulse when the beam is scanning across the target, by the use of a delay line. If the amplitudes are different, it is assumed that the echoes are obtained when the target is at the edge of the beam, and the receiver is gated off.

Transducers slightly displaced from the line of sight can be used to extend the aperture of the receiving transducer but the ideal position of these is different for different depths of penetration and the resolution suffers. A much wider catching array can be used if the interface position is calculated from the echo delay, using the known system geometry and an on-line computer to compute the correct interface position. A composite signal of one line of scan can be obtained with normal and inclined structures appearing at the correct delay and this could then be displayed in the normal way. The dynamic range of received echoes is far greater than that of the display system. A computer may be used to store the picture as it is formed with far greater dynamic range. The memory requirement for storing an actual picture is 16,000 words. To store the entire echogram echo by echo would require a memory of approximately $2 \times 10^4$ words, which can be achieved only by a tape or disc unit at this stage. However, considerable processing can be achieved at the line and picture stage without examining individual echoes.

Mössbauer-effect Studies of the Ear—B. M. Johnstone and K. J. Taylor, Department of Physiology, University of Western Australia

Techniques and Applications to Basilar Membrane Motion (presented by K. J. Taylor)

Techniques have been developed for employing the Mössbauer effect to study acoustic vibrations with amplitudes in the range 1 Å to 1μm in the ear. The frequency response of points about 2mm from the stapes end of the basilar membrane of the guinea pig has been measured. The tuning peak of 18 kHz has been found and this has a slope of 12 dB/octave on the low-frequency side and 95 dB/octave on the high-frequency side. The local frequency gradient is 2.5 kHz for a 0.5 mm length of the membrane. The phase of the motion for a point on the membrane with respect to the stapes has been measured for frequencies above and below its resonant frequency.

Middle Ear Characteristics and a Consideration of Energetics (presented by B. M. Johnstone)

Transmission characteristics have been measured for the middle ears of cats, guinea pigs, and frogs. These show a pronounced similarity which suggests that the detail of the structure is unimportant in determining the characteristics. A large part of the energy available to the ear is lost in resistive and viscous damping, so a prosthesis to replace the middle-ear ossicles could be designed to have a better transmission than the normal ear. At the threshold of hearing the amplitude of vibration in both the middle ear and the basilar membrane is of the order $10^{-18}$ Å. The transmission process must be sensitive to these amplitudes and thermal vibrations must be smaller than this.

Studies of Rhythmic Leaf Movements in Clover and Their Causes at the Cellular Level—B. I. H. Scott, University of Tasmania

Diurnal leaf movements in clover (Trifolium repens) are due to changes in the pulvinal cells at the base of the leaf. As they swell and contract, they pivot the leaf back and forth. The cells appear to have special properties at the electrochemical level. The swollen cells on the convex side of the pulvinus always contain potassium and sodium at higher concentrations than on the concave side, suggesting that a primary cause of the leaf movements is a periodic ion pump, water moving in and out of the cells passively due to resulting osmotic changes. These conclusions are supported from observations of changes in potential difference across the cellular membrane.

Although movements are primarily controlled by an internal oscillator ('biological clock'), they can be driven at various frequencies by environmental oscillations of light and temperature. Responses of the leaf to various forcing oscillations support the hypothesis that feedback processes within the pulvinus are responsible for the internal oscillations and the time sense of the plant.
The Crystal Structure of n-acetyl Neuraminic Acid Methyl Ester Mono-hydrate—A. M. O’Connell, Physics Department, University of Western Australia

Sialic acids are an important group of compounds of biological origin. In nature they occur as n-acetylated and o-substituted neuraminic acids. In order to directly determine details of the molecular geometry and stereochemistry a single-crystal X-ray structure analysis has been performed on the methyl ester of n-acetyl neuraminic acid.

The crystals are orthorhombic, spacegroup P2₁2₁2₁, with unit-cell constants a = 7.954, b = 11.675, c = 16.974. The intensities of 2081 Bragg reflections were measured on a Picker X-ray diffractrometer with Mo Kα radiation. The structure was solved using the tangent formula and refined to an R index of 0.042. The carbon, nitrogen, and oxygen valence-electron populations were included in the final stages of refinement.

The pyranose ring has the normal chair conformation. The n-acetyl, the glycerol, and the methyl-ester groups are all bonded equatorially to the ring and the hydroxyl group at the anomeric carbon atom is in the axial position. All available hydrogen atoms are used in an extensive system of one intra- and seven inter-molecular hydrogen bonds which hold the molecules quite rigidly in the crystal lattice resulting in an average overall isotropic temperature factor coefficient of only 2.5Å². The coordination of the intra and inter-molecularly bonded hydrogen atoms about the water molecule is tetrahedral. The carbonyl oxygen of the n-acetyl group is involved in three acceptor hydrogen bonds, one of which is intra-molecular, in tetrahedral coordination. The refinement of the valence-electron population parameters indicates an excess of electrons at this oxygen atom.

Intercomparison of Methods of ⁸⁶Sr Dosimetry—R. M. Millar, Physics Department, Cancer Institute, Melbourne

When ⁸⁶Sr plates are used for treatment, they are usually placed 8 mm above the skin surface, because the treated area may be sore and perhaps even ulcerating. As the plates are calibrated on their central axis with the plate lying on skin surface, it is important to know the relationship between the skin surface dose and the height of the plate above skin surface. It is also important to know the dose at depth with the plates at different heights above skin surface.

These measurements were originally done using a film method; however, when these results were checked using a scintillation technique, some considerable differences were found. It was proposed that the film method was in error due to its variation in sensitivity with angle of incidence of beta rays. When some of these results were checked using an extrapolation ionization chamber, it agreed with the scintillation measurements, thus supporting the theory that the film method was in error.

Radionuclide Standards for Instrument Calibration—D. K. B. Sewell, Commonwealth X-Ray and Radium Laboratory, Melbourne

A radionuclide standardisation laboratory has recently been established within the Commonwealth X-ray and Radium Laboratory. Absolute standardization methods currently in use are:

A. The coincidence method using a 4π gas-flow proportional counter and two sodium iodide crystal detectors.
B. The extrapolation method using a single bi-alkali photomultiplier tube that operates at room temperature. Aluminium optics are used and butyl PBD is the liquid scintillant used.
C. 4π gasflow proportional counting using sources precipitated on gold-coated thin plastic films of 50 microgram per square centimetre.

Comparative methods used for measuring radionuclide activity are:

A. A five litre re-entrant ionization chamber filled with argon at 20 atmospheres pressure, together with an electrometer and digital voltmeter.
B. A 3-in diameter by 3 in sodium iodide crystal in a large lead cave in conjunction with a 512-channel analyser.

The accuracy of some radioactive standards measured at this laboratory have been checked against radioactive standards issued by an overseas laboratory and results are to-date very satisfactory.

Two-compartment Models Defined by Data from Three-compartment Systems—J. Myhill, University of Sydney and Royal North Shore Hospital

Data were simulated from sums of three exponentials,

\[ f(t) = N_1 \exp \left(-\lambda_1 t\right) + N_2 \exp \left(-\lambda_2 t\right) + N_3 \exp \left(-\lambda_3 t\right), \]

which were solutions for the time course of tracer concentration in one compartment of a three-compartment open system, until the numerical value of the data declined to one per cent of the initial value. Two per cent independent random normal error was added at each simulated point. The four cases where \( \lambda_1: \lambda_2: \lambda_3 \) was 100:10:1, 36:6:1, 16:4:1, and 4:2:1 were considered in association with the same ratios for \( N_1:N_2:N_3 \) or, in separate simulations, the condition \( N_1 = N_2 = N_3 \).

Let \( r = \lambda_1/\lambda_2 = \lambda_2/\lambda_3 \) and \( s = N_1/N_2 = N_3/N_2 \).

Each of the sets of simulated data was fitted to a sum of two exponentials using a non-linear least-squares computer program. This defined two-compartment models consistent with the data.

It was found that the two-compartment model consistently underestimated the fractional loss of tracer from the system. The fraction of tracer in the first compartment moving to other compartments was poorly estimated. The fraction of total system turnover of trace (mass/time) which participates in interchange within the system was grossly overestimated.
The ratio of compartment sizes (masses) given by the two-compartment fit was not a suitably weighted average of the ratios obtaining in the three-compartment system. Only when \( r = s = 6 \) or \( r = s = 4 \) could the fitted two-compartment solution be demonstrated to be different from the simulated three-compartment data by a statistical significance test. Thus two-compartment models do not provide a useful approximation to three-compartment systems.

**The Assessment of Film-Badge Exposure using a Computer—N. J. Hargrave and N. T. Wilson, Commonwealth X-ray and Radium Laboratory, Melbourne**

The determination of a radiation worker's occupational exposure by monitoring film can be inaccurate owing to subjective decisions made by the assessor regarding the type of radiation used by the worker, based on the film's appearance. Digital-computer techniques have been developed in the UK to perform these calculations and decisions.

An outline of the assessment procedure at the laboratory is given. It is stated that if various simplifying assumptions are made, the density above fog of a film \( (D') \) may be related to its exposure \( X' \) by the relation \( X' = Q \ln(1 - kD') \) where \( Q \) and \( K \) are suitable constants dependent on the developing conditions. These constants are varied to take account of variations in developing conditions.

A method using an analogue computer to perform these calculations and those required by the UK assessment procedure is outlined for use with the RPS/AERE film holder and a holder based on a design of Spiegel and Davis when US Kodak Personal Monitoring Film, Type 2, or UK Ilford X-ray Film, Type 1 is used. The accuracy and reproducibility of the system are such that photon-assessment reliable to within thirty per cent. is normally attained.

**A Computer System for Handling Radiation-Monitoring Film-badge Data—P. W. Henson, Department of Medical Physics, Royal Perth Hospital**

A computer system has been devised to file, analyse, and report on the routine radiation-monitoring records arising from approximately 250 people wearing film badges for monthly periods. The data are stored on a magnetic-tape master file which is processed at three-monthly intervals in a computer run consisting of four automatically linked programmes, three of which are written in Fortran IV, the fourth being a generated-assembly language-sort programme. The input to the run consists of collected monthly-dose records on punched cards, selected fields of which are validated by the computer before the data are used to produce a number of printed outputs, including: (i) quarterly dose reports which are sent to the department concerned, (ii) an analysis of the dose distribution within a department for the time specified on input, the average dose/person-month also being calculated, and (iii) records of persons who have resigned, etc. An updated master file is also produced during processing.


Studies have been made of the yield, dose kinetics, dose rate, and fractionation effects for the induction of chromosome aberrations following in vitro irradiation of human blood with neutrons and X-rays. The results confirm previous observations that dicentric aberration production shows promise for use as a biological dosimeter under radiological-accident conditions. Sample preparation, culture conditions, and scoring criteria were briefly discussed and the adoption of standard procedures strongly recommended. Some recent in vitro results following relatively low-level doses arising from accidental whole-body gamma irradiation were presented.

**Status of and Training for Medical Physics—K. H. Clarke, Physics Department, Cancer Institute, Melbourne**

Many branches of medicine must be regarded as multidisciplinary activities in which the physicist has a vital role to play in the understanding of body functions and in the development of instrumentation to measure or monitor body-function parameters. But in order to get the best contribution to medicine from science and technology there must be increasing co-operation and understanding between medical and non-medical scientists and there must grow up a greater sense of inter-dependence between them.

There is need to establish physics departments in all large general hospitals, not only having responsibilities to provide a clinical physics service to special units but also having facilities and opportunities for research. It is important to encourage the research activities both for the training and development of the individual physicist and for the advance of medical physics. Furthermore, because of the multidisciplinary nature of the work, serious attempts should be made to give physicists in this field some formal training in the biological sciences in order that they can understand the problems better.
PERFORMANCE OF FIRST-YEAR PHYSICS STUDENTS
AT THE ANU IN 1969

A. J. Mortlock
Australian National University, Canberra

Introduction

This paper is an analysis of the performance of first-year students in physics at the Australian National University in 1969. Particular interest attaches to such an analysis because of the generally poor performance of first-year physics and chemistry students in New South Wales and the Australian Capital Territory in 1968. That year the universities in this area took in their first intake of high-school students who had been trained under the Wyndham scheme of integrated science education. A brief description of this scheme and an analysis of the performance of first-year physics students at the ANU that year has been given by Aitchison [1969]. This analysis indicated that those who had been trained at school outside the NSW/ACT system tended to do better at the university than those trained under the Wyndham scheme.

Because of the possibility of repetition of the poor performance of 1968 some corrective procedures were clearly necessary in 1969 at the first-year level.

New Teaching Arrangements

A deliberate decision was made in the Physics Department at the ANU at the beginning of 1969 not to lower standards to meet the situation, but to endeavour to raise any weaker students to the normal level by a new scheme of intensive teaching.

The arrangements that were introduced increased the emphasis on course work throughout the year by attaching 25 per cent. of the total possible credit for the year to this. The remaining 75 per cent. of the possible credit continued to be attracted by the end-of-year examination. The course work itself consisted of laboratory practical work, written assignment problems, and two one-hour written term examinations. The assignment problems had to be handed in for marking at the rate of one problem per student per week. These problems, together with others, were solved with the students during subsequent periods with tutors. The overall aim of this arrangement was to decrease the stress of the written end-of-year examination and, at the same time, train the Wyndham students particularly towards being better able to cope with normal university-examination methods. It was strongly felt that the direction of this training was in a basic way very desirable anyway as, unless a student can solve numerical problems in physics, then he simply does not understand the subject in the way a physicist ought to understand it.

Results

Before setting down the results obtained under these conditions it is necessary to define the two levels at which first-year physics is taught at the ANU. Physics I is a course intended for those who wish to go on in the subject and intake is restricted to 1F or 2F in the Wyndham scheme; General Physics on the other hand is a lower-level non-calculus course mainly intended for those who wish to take the subject for one year only.

Figures 1 and 2 show how the overall pass rates in Physics I and General Physics have varied over the years. The sharp dip corresponding to the relatively poor performance in 1968 is clearly evident. In 1969 it is pleasing to be able to report that there was a general recovery, as is evident from the figures. The overall pass rate in 1969 for Physics I was 73 per cent. and 68 per cent. for General Physics.
If these figures are broken down further to take account of the origin of the students the following picture emerges:

<table>
<thead>
<tr>
<th>Physics I</th>
<th>Pass Rate</th>
<th>General Physics</th>
<th>Pass Rate</th>
<th>Wyndham Students (35)</th>
<th>66%</th>
<th>Non-Wyndham Students (17)</th>
<th>88%</th>
</tr>
</thead>
</table>

If those students who are repeating are excluded from these data the pass rates are altered as below:

<table>
<thead>
<tr>
<th>Physics I</th>
<th>Pass Rate</th>
<th>General Physics</th>
<th>Pass Rate</th>
<th>Wyndham Students (39)</th>
<th>67%</th>
<th>Non-Wyndham Students (11)</th>
<th>73%</th>
</tr>
</thead>
</table>

The figures in parentheses are the number of students in each category.

**Discussion**

Because of the small numbers of students taking physics at the ANU, any general deductions which might be made from the results set out above have to be treated with great caution. For this reason it would be of great interest to hear of the results for 1969 at the larger universities in New South Wales.

Apart from noting the general improvement in pass rates the most important deduction to be made (subject to the reservation just mentioned) relates to the relative performance of students fresh to the University in 1969. Superficially it might seem that there is no real difference between Wyndham and non-Wyndham students at the General-Physics level but that there may be a small but significant difference at the Physics-I level, the non-Wyndham students being somewhat better than the Wyndham students. The picture becomes clearer, however, if the average marks achieved by these particular students for the year are examined. These marks are set out below, the errors quoted being standard errors:

<table>
<thead>
<tr>
<th>Physics I</th>
<th>Mark (%)</th>
<th>General Physics</th>
<th>Mark (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyndham (29)</td>
<td>58.7 ± 4</td>
<td>Non-Wyndham (12)</td>
<td>65.6 ± 4</td>
</tr>
<tr>
<td>Non-Wyndham (34)</td>
<td>54.4 ± 3</td>
<td>Non-Wyndham (6)</td>
<td>54.7 ± 9</td>
</tr>
</tbody>
</table>

Without resorting to small sample statistics it is evident that there is little difference in quality between Wyndham and non-Wyndham students at the Physics I level and no significant difference at the General Physics level.

**Conclusions**

(i) In 1969 the performance of first year physics students as a whole at the ANU was considerably improved relative to 1968. In fact the pass rates were generally back to the levels which operated prior to 1968. As to whether the improvement was due to the changed teaching methods introduced in 1969 or whether it would have been observed anyway it is not possible to say. (However, the staff of the Physics Department like to think the new teaching arrangements helped.)

(ii) The performance of students trained under the Wyndham scheme and entering the University for the first time in 1969 was overall only marginally worse than that of similar students trained elsewhere.

**Reference**


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**PHYSICS FOR PROFIT**

D. H. Morton
Physics Group Leader, APM Ltd, Research Division, Melbourne

Article based on an address delivered to the 1969 ANZAAS Symposium in Adelaide.

A survey carried out last year by the Department of Labour and National Service showed that only 4.5 per cent. of physicists working in Australia are employed in industry [Argy 1969]. My purpose here is to examine the role of a physicist employed in manufacturing industry and to try to discover whether he fulfils a useful and a proper purpose in the context of a modern company. I believe that this will show that there is a strong case for increasing the extent to which physicists have been able to penetrate Australian industry.

Firstly let us consider some of the activities undertaken by manufacturing industry:

- Dairy Produce
- Synthetic Fibres
- Leather
- Lubricants
- Ceramics
- Road-building
- Concrete and Masonry, etc.

Secondly let us consider some of the activities undertaken by manufacturing industry:

- Timber
- Plastics
- Printing and Packaging
- Paper and Board
- Baking and Confectionery
- Paint

This list, which is not intended to be comprehensive, illustrates the diversity of industries in which either the processes employed depend on the physical properties of the materials being processed, or the quality of the final product is judged by its physical properties, or sometimes both. There therefore seems to be a *prima facie* case for believing that persons trained in
the disciplines of physics should be able to play a part in the activities of all such industries.

Let us now look at where in a manufacturing organization a physicist may fit and contribute to profitability. There are many fields in which a background of physics makes as good a starting point as any other but does not have any special virtues. Quality control, product development, production management, instrumentation, and marketing are all within the scope of physicists but the most obvious niche is in research and development and it is on this field that I wish to concentrate.

I believe that many people outside industry have a distorted idea of what industrial R & D involves. If it is not thought of as a dreary round of trivial troubleshooting it is regarded as some second-rate study which is only undertaken as a window-dressing tax dodge and would in any case be better done in a university department. Undoubtedly this can be true and sometimes is, but a good industrial laboratory can be a stimulating place to work and can be one of the best profit-generating investments a company can make.

Directors of any company will be naturally and properly reluctant to employ anyone whose activities cannot be shown sooner or later to be profitable to the organization. That research activities are profitable is not necessarily obvious when one comes to analyse their merits by some form of economic measure. Thus over a broad range of Australian companies there is no correlation between research intensity and company success [Stubbs, 1968]. Some Australian companies buy and employ overseas technology very successfully, whilst others such as the wood pulp industry owe their very origin to R & D carried out in Australia.

The point I wish to emphasize is that I have observed among physicists not employed in industry a vague feeling that it must in some way be 'good for industry' for it to employ more physicists and do more R & D. It is not so obvious to those whose responsibility it is to spend other people's money wisely. Many industrial managers believe that such investment can be very profitable but it has to compete with other demands for capital and the value of research, particularly physical research, has to be continually reiterated for the long-term technological health of this community.

Whilst in Australia the picture is confused by the effects of tariffs, licence agreements, and the import of technology, it is reasonable to expect that, other things being equal, the profitability of a company will be related to the rate at which it is able to introduce innovations in products or processes, which in turn will be related to its R & D effort. Let me now point to some examples of profitable research studies in various industries in which I have to some extent been personally involved:

Textiles

In a medium-sized yarn-dyeing works 5 people were employed doing nothing else but trial dyeings to match the thousands of customer shades that were needed. Application of the principles of tristimulus colorimetry in a modified form showed that calculation of dye recipes should be possible but the equations were intractable and explicit solutions could not be obtained. This was before the days of ready availability of cheap digital computing capacity. The answer was a small specialized analogue calculator which permitted the dyer to set in the spectral properties of the dyes he had chosen and to vary their proportions by adjusting electrical components until the predicted colour matched the desired shade. A single confirmatory trial dyeing was then usually enough.

This enabled the dye-house largely to dispense with its matching laboratory, saving the costs of employing several assistants and reducing the time needed to find a match from many hours to a few minutes. The computer paid for itself within two years and the rest was profit.

Plastics

Development of a new kind of plastic film was impeded by distortion due to its tightening on the roll onto which it was wound after emerging from a heated coating tower. This was thought to be due to cooling and contraction of the film but pre-cooling the film in a relaxation zone seemed to make things worse. Investigation showed that, unlike materials the engineers had handled before, the plastic film had a temperature-sensitive delayed elastic response to stress. The answer was to heat the film in the relaxation zone so as to accelerate the elastic recovery before winding.

The work involved took only about a week but as a result a project on the verge of failure was completed and a profit-earning product brought to the market.

Paper

In making a corrugated fibre-board box the composite structure, which is quite complex has to be bent at the corners. To allow this the surface layers have to have sufficient strength and elasticity to take the strain when bent either along or across the corrugations.

The machines my company uses to make these boards allow us to vary the contributions of strength from the various components of the structure and to vary the relative strengths along and across the machine. The whole project, extending over two years, involved many departments of the company in a co-operative effort and showed that by quite small adjustments to the running of our machines we could achieve substantial improvements in uniformity of our product and major reductions in the amount of board liable to be rejected by our quality-control system, with consequent gains to ourselves and to our customers in improved quality.

The sort of work a physicist may find himself doing in such a project is varied both in nature and academic content. My group has for instance been involved in making quite fundamental studies of the rheology and fracture mechanics of inhomogeneous anisotropic nonlinear viscoelastic materials. Equally we have been virtually running a corrugating box-making machine, wading through hundreds of boxes to evaluate subjectively the quality of their corners, and making thousands of measurements of mechanical properties of products of our experiments on paperboard machines.
Although varying in nature, depth and extent, these examples typify most industrial R & D projects. They involve:

(a) *Recognition* of the fact that a problem exists. This is often obvious, like our mis-shapen plastic film, but not always so.

(b) *Identification* of the true nature of the problem. This may be the most critical part of the whole investigation. There is little virtue in an elegant solution to a situation which is not the simplest and most economical way of achieving the desired end-result.

(c) *Investigation*, experimentation, hypothesis, and test; the classical methods of scientific work, which must go as far into the fundamental studies of the product or process as is needed to provide a solution.

(d) *Application* of the results. A successful industrial researcher should be ready to try out a possible solution well before he has completed all the basic work he had planned.

It will be noted that in this procedure there is no room for a study just because it is felt that it would be 'useful' to know more about a subject, no matter how important it may be to the company's operations unless the information is really needed, as it might be for a major investment decision, where it becomes part of R & D functions to anticipate the needs of management. Such information as is otherwise acquired tends to be built up from a more or less disconnected series of investigations. This can be frustrating at times when a worker becomes interested in a basic investigation, which has to be stopped because enough is known to solve the problem at hand and no further applications can be seen or something more urgent is calling for attention.

This situation is hard to avoid in industries of modest size such as we have in Australia. Even in big UK companies the trend is away from long-term basic research. At a recent seminar on training and employment of physicists [McNeill, 1969] some outstanding examples were given of pure non-oriented research which had resulted in developments of major profit-eating importance. Even though such cases do occur and are given deserved publicity, I doubt whether there are more than a handful of companies outside the USA with the resources of both capital and management versatility needed to sustain and exploit work of this kind.

Our need is more to be able to exploit any worthwhile discoveries which may emerge from research supported co-operatively such as those of the CSIRO, universities, and governmental laboratories. To allow this, two conditions are possible:

(a) that persons working in these places should themselves be fully aware of the needs of the marketplace. This is a serious problem but not one which space permits me to deal with here.

(b) that individual companies should have on their staff personnel of the appropriate disciplines and experience to be able to appreciate the significance and applicability of discoveries in their own fields as soon as these become public knowledge. To be effective in this way a company's scientific staff must keep itself in the 'main-stream' of thought and in their own specialities. This way they can often pick up ideas and techniques even before they are formally published. They thus have a need to participate in the affairs of learned societies, to attend conferences and to publish papers. Not all follow this course. Industrial secrecy is not such an impediment to publication as is sometimes thought but there is rarely any tangible reward for such activity even when the difficulties of incomplete work referred to above have been overcome. Hence the industrial researcher may well feel that there are more immediately useful things to which to devote his efforts than writing up a piece of past history.

How then does it come about that so few physicists are employed by Australian industry? How are we to generate the necessary mutual respect for the interests and abilities of the parties to bring industry and physicists together? The problem is one of mutual disinterest rather than distaste. I have shown that physicists can and do make contributions to profitability. To do this they need to be, in addition to the usual formal requirements, adaptable both intellectually and personally. It does not do for instance to be too fastidious—I sometimes need to get very dirty working on some parts of a paper machine, but it is necessary to experience personally any problems which proposals may involve for the operators of a process.

Further it is essential that industrial physicists have a sound grounding in classical physics. These things have been widely discussed [e.g. Milner, 1969] but can not be reiterated too often. Perhaps what is most required can be best described as a 'feeling' or a 'sensitivity' to the realities of the material world—the 'non-linear world where friction exists'. This can only be obtained by prolonged exposure to real substances and complex phenomena.

Insofar as its value for industrial work is concerned, opinions differ as to the merits of post-graduate study and many industrial managers consider a PhD as over-trained. Certainly such a degree is an indicator that those who possess it are able persons capable of independent work and study in depth but they will have spent four years in a highly formative and productive period of their lives in a way that bears little relation to the functions they might perform in industry in any other than a research department. The reluctance often shown by new post-graduate physicists to leave the secure base of their accumulated experience and venture into new fields contributes significantly to the disinterest shown by potential industrial employers to physicists. Any new physics graduate who is not sure that he wants to spend the next ten years or so of his career in a research or development function would be well advised to consider following a course of economics, business studies, or accountancy.
What now of the Bachelor-degree man? Whilst he may have gained much of the basic knowledge he needs to carry out useful work, he still needs to acquire the skills needed for his particular application. Quality control for instance has its own literature, professional societies, and technical study groups and could be regarded as a post-graduate subject in its own right. If a new bachelor is to enter a research department he still has to learn how to work independently of supervision, to find his own sources of information, to find how to communicate, how to adapt to being part of a multi-disciplinary team, how to build and procure apparatus, and how to write a useful report. The big industrial laboratories of the UK and USA are capable of providing this training and at the same time getting some value from their recruit. Because of their limited size and scope I doubt if there are any industrial laboratories in Australia which can perform this function for physicists without some form of outside help.

There is thus a need for greater co-operation between industrial and university research departments. It would benefit everyone if we were able to cultivate a flexibility of interchange of staff and students and enable the latter to qualify more easily for post-graduate degrees by research work in industry. I am sure the barrier which restricts a man who goes into industry from going back into academic life is one which deters many good men from trying their abilities on industrial problems and I would like to see the barrier lowered. One way or another industry and the universities will have to learn to adapt to one another if we are to keep our output of expensively trained PhD's in Australia. Only 5 per cent. of them go into industry compared with 70 per cent. in the USA. Some physics departments are well aware of the change in attitudes that will be needed on their part, but not all universities seem even to be aware that the problem exists. A hopeful sign is that one university is setting up to offer a degree in Applied Physics with the object of producing physicists with a bias towards industry, but is it not a sad commentary on the state of our profession when we need to use such administrative tricks to remind ourselves and the community that physics is an applied science? What would Archimedes, Newton, or Faraday have thought?

Personalities can be an important factor in industrial problems, particularly in the final stages of application. No change or development can possibly succeed without the help of the production staff whose job it is to operate the ideas, and the co-operation of sales staff with their ability to point to needs and deficiencies is of great value in directing work in a profitable direction. These people who may have spent a lifetime in the industry but have no formal training must not be under-rated. The acuity of their observation and the depth of their knowledge and insight may surprise an unwaried newcomer. Understanding and sensitivity to other people's problems are an essential attribute of a successful industrial problem-solver. Nothing leads to failure in application more surely than intellectual arrogance on the part of the researcher.

In conclusion, let me assure all those who wonder what satisfaction can be achieved in work of this kind that there are few things more gratifying than to stand back and look at something real, something solid and tangible, some new product or process which is just that much better as a result of your own labours.

Acknowledgement

Thanks are due to the Directors of Australian Paper Manufacturers Limited for permission to publish this paper.

References


NOTES AND NEWS

Physics in Medicine and Biology

The Tenth Conference of Physics in Medicine and Biology will be held in Melbourne on 24-28 August, 1970. The venue will be the Clunies Ross National Science Centre, and a Scientific Trade Exhibition will be held in conjunction with the Conference.

The subjects covered will include Biophysics, Physics of Nuclear Medicine and other Diagnostic Techniques, Bio-engineering, Health Physics, Radiation Physics, Automatic Data Processing, and Other Applications of Physics to General Medical Problems. Further information from Mr. K. H. Clarke, Physics Department, Cancer Institute, 278 William Street, Melbourne, Vic. 3000.

Transport Conference

The NSW Branch of the Australian Institute of Physics is organizing an International Conference on Transport Properties of Solids in Sydney on 27-29 August 1970. The Conference is being arranged as a satellite meeting prior to the 12th International Conference on Low Temperature Physics (LT12) in Kyoto, Japan, on 4-10 September 1970.

The Conference will cover the conduction of heat and electricity in solids at all temperatures and the associated
property of thermoelectricity. Particular emphasis will be placed on the interactions between electrons and phonons in 'normal' metals, and on the effects of new knowledge of band structure and lattice spectra on the understanding of scattering processes.

Invited papers will include the following: *Electrical and thermal resistivity of 'normal' metals*, Prof. J. S. Dugdale (Leeds); *Electrical and thermal resistivity of transition metals*, Prof. B. R. Coles (Imperial College); *Transport properties in ferromagnetic metals*, Dr I. A. Campbell (Oxford); *Phonon-phonon interactions and lattice thermal conductivity*, Prof. R. O. Pohl (Cornell); *Electron-phonon interactions*, Prof. N. W. Ashcroft (Cornell); *Thermal conductivity in disordered solids*, Prof. P. G. Klemens (Connecticut); *Thermoelectricity in metals and alloys*, Prof. F. J. Blatt (Michigan State). Further reviews are being arranged on electron-electron interactions and the metal-insulator transition. About thirty contributed papers will also be presented.

All inquiries about the Conference should be addressed to: AIP Transport Conference, c/o National Standards Laboratory, Chippendale, NSW 2008, Australia.

**APS-AAPT Winter Meeting**

The APS–AAPT Winter Meeting was held in Palmer House, Chicago from 24–29 January 1970. The APS research-oriented programme and the AAPT educational programme will not be discussed as they will be published in American Institute of Physics Journals. Two interesting features of the meeting will be discussed in this brief report.

The first feature was the significant amount of 'political' material distributed at the meeting. The material varied from support of the GE strikers to the formation of a new organization, the APS '70 Coalition. One pamphlet suggested an amendment to the APS constitution. Article II states 'The object of the Society shall be the advancement and diffusion of the knowledge of physics.' The suggested amendment read as follows and concern for the application of this knowledge to the welfare of mankind'. Other literature included a suggestion for the exclusion from professional discourse of all those physicists working or consulting for Los Alamos, Livermore, and Fort Detrick.

The above reactions may have been in part due to the employment situation. There are at least ten PhD students for each vacant employment position. The AIP Division of Education and Manpower has been investigating this problem. A survey of employers and the associate corporate members of the APS suggested that physics PhD's are too specialized, that engineers are more willing to undertake developmental work than are physics PhD's, and that PhD supervisors instill in PhD students attitudes which are unfavourable towards industrial research and development.—E. R. Sandercock.

**Computers in Education**

A conference on Computers in Undergraduate Science Education is to be held at the Illinois Institute of Technology, Chicago, 17-21 August 1970. Inquiries should be sent to Ronald Stift, Information Science Center, IIT, Chicago, Illinois 60616.

**Colloque Ampère**

The sixteenth Colloque Ampère entitled 'Magnetic resonances and related phenomena' will take place in Bucharest, Rumania, 1 to 5 September 1970. Further information can be obtained from Dr V. Lukej, Institut de Fizica Atomica, C.P. 35, Bucharest.

**Second National Vacuum Symposium and Exhibition**

Those intending to present a paper(s) at this Symposium (Sydney, August 24-26, 1970) are reminded that abstracts of about 150 words, double spaced and with carbon copy should be sent now to Dr J. W. Kelly, Hon. Secretary, Vacuum Physics Group, C/o AAEC Research Establishment, Private Mail Bag, Sutherland, NSW 2232. It would also facilitate booking arrangements if interstate visitors would make known their intentions as soon as possible.

**Formation of Mass Spectrometer Users' Group**

The formation of such a group, either as a separate body or, depending on numbers, attached to an existing AIP or RACI group has been suggested. Anyone interested in this proposal should make known his interest and preferred grouping by writing to Dr J. W. Kelly, AAEC Research Establishment not later than the 1 May 1970.

**THE CALENDAR**

**May**

12 *Forensic Applications of Physics (SA-AIP),
Observatory Lecture Theatre, Un. of Adelaide; Detect. R. Harbrow, SA Police Force.*

14 (NSW-AIP); Dr K. Hart, NRC Canada.

**June**

9 *SUS for the Layman (SA-AIP);
Prof. A. Hurst*

16 *Australian Antarctic Physics (NSW-AIP);
Dr J. F. Jacka*
THE REGISTER

CHANGES IN MEMBERSHIP FROM 9 FEBRUARY 1970 TO
13 MARCH 1970

FELLOWSHIP
(a) New Election
De Laeter, J. R., Western Australian Institute of Technology.
(b) Deceased
Martin, D. F. (NSW).

ASSOCIATESHIP
(a) New Elections
Bagchi, R. N., National Standards Laboratory, NSW.
Brettell, J. M., University of New England, Armidale, NSW.
Doolan, A. L., University of Queensland.
Howard, C., J., Australian Atomic Energy Commission, Sutherland, NSW.
Kaye, A. S., Aeronautical Research Laboratories, Vic.
Towson, J. E., Royal Prince Alfred Hospital, Sydney, NSW.
(b) Transfers
Fleischmann, A. W., Department of Public Health, Lidcombe, NSW.
Maloney, J. E., University of Melbourne, Vic.
Paul, G. L., University of New South Wales.
Stevens, L. W., Royal Melbourne Hospital, Parkville, Vic.
Uren, N. F., Western Australian Institute of Technology.

GRADUATESHIP
(a) New Elections
Burns, P. A., Commonwealth X-Ray and Radium Laboratory, Melbourne, Vic.
Denton, R. E., University of Adelaide, SA.
McCue, K. F., Bureau of Mineral Resources, Canberra, ACT.
Molde, T. A., Gawler High School, SA.
Quinlan, C., Marist High School, Parramatta, NSW.
(b) Transfers
Bennett, I. W., United Kingdom Atomic Energy Authority, Dorchester, England.
Carse, G. D., University of Melbourne, Vic.
Harwood, K., University of Adelaide, SA.
Kery, R. T., Sydney University, NSW.
Magennis, C. W., Education Department of WA.
Rennie, J. E., Education Department of WA.
(c) Resignations
Melton, L. R. A. (Vic.)
Young, M. J. (SA)

STUDENTS
(a) New Elections
Kumar, Y. (NSW)
Mitchell, I. W. (Vic.)
(b) Resignations
Mero, R. P. (Vic.)

ADDRESS UNKNOWN
Mr J. L. Atchison (ST-Vic.)
Mr P. G. Browne (ST-Queensland (G-Vic.)
Mr E. J. Clayton (ST-Vic.)
Mr C. G. Don (G-Vic.)
Mr G. L. Evenhuis (ST-Vic.)
Mr I. R. Forrest (ST-Vic.)
Mr H. H. Hau (G-Vic.)
Mr A. S. Kent (G-Vic.)
Mr R. G. Milne (ST-Vic.)
Mr G. G. O'Connor (G-SA)
Mr W. H. Shorter (ST-SA)
Mr H. J. Walsh (ST-Vic.)
Mr B. M. Bartlett (G-SA)

BOOK REVIEWS


This volume is packed full of information but, even with two more to follow it cannot fulfil the claim
in the foreword, that it is a 'comprehensive review of the status of the entire field' of nuclear and fundamental
particle physics. The chapter headings are much the same as in any other text on radioactivity and nuclear
physics, but the weighting of various topics and the approach is usually different. For example, 110 pages
are devoted to a particularly thorough treatment of the passage of ionizing radiation through matter, but the
75 pages used for the fundamental characteristics of nuclear reactions leaves many aspects of this topic
untouched.

The emphasis throughout the book is on explanation of the phenomena discussed and its main value
is in the wide-ranging approach which provides many valuable insights and lucid explanations. Thus although much
useful experimental information is presented it is to be regarded much more as an instructive text than as a
handbook and if the later volumes continue the standard set, they will provide an important contribution to the
literature in this field.

Press, 1969. xi + 206 pp. 18/-.


The text contains material for a first course in statistical methods for undergraduates. Mathematical
results are stated and a few involving rudimentary procedures are derived: about a dozen integral signs appear
in the book, mostly in the tables or the miscellaneous exercises; use of the process of differentiation is ex-
ceedingly sparing.

Within its limitations the book clearly achieves its purpose. Not intended as an exposition of the
theory, it must be judged purely as a description of methods familiar to statisticians for reducing data and testing significance. The selection of topics discussed and the depth of the treatment is appropriate to the readers the author has in mind but not in general for a wider audience. Research workers would not find in it a compendium of statistical methods; students in almost any first-methods course (agriculture, biology, engineering) would cover the material of the book.

The coverage is as follows: Probability (including binomial and poisson distributions), Normal distribution, $x^2$ goodness-of-fit (including $2 \times 2$ tables), use of the $t$-distribution, quality control, simple regression, rank correlation, analysis of variance (one- and two-factor experiments).

A pleasing feature of the book for home-study students is the large number of examples drawn from extremely wide areas of application; these are both worked in the text and set as exercises (with answers). Normal, $x^2$, $t$, $F$ and exponential tables are given. A useful glossary of about 50 statistical terms occupies 8 pages. There appear to be few misprints.

For first course students, and as a back-up for teachers in elementary courses, this book is to be recommended.


Reviewed by A. J. Mortlock, Department of Physics, Australian National University, Canberra.

This volume is published to honour the 60th birthday of Professor Suri Bhagavantam, since 1962 Scientific Advisor to the Indian Minister of Defence. Professor Bhagavantam has also been for many years a practising physicist of some renown in the fields of optics, ultrasonics, crystal physics, and geophysics. For a long time this has largely been on the theoretical side. The present volume contains twenty-nine papers in the field of solid-state physics by authors such as (Kathleen) Lonsdale, Jain, Nowick, Bloembergen, and (our own) Professor Bullen. These papers have links with Professor Bhagavantam’s researches and focus attention on current trends in these areas.

It is obviously impossible to review all the papers which are presented, but some stand out sufficiently to warrant separate mention. For example, Jain and Khan’s review entitled ‘Defects in Alkali Halides’ sets out the properties of these defects in a comprehensive and very readable way. Again Lonsdale’s paper on the ‘Geometry of Chemical Reactions in Single Crystals’ is a fascinating and beautifully illustrated account of what appears to be a new field of study; the use of X-ray techniques for studying changes in the structure of single crystals of simple organic compounds during the course of chemical change (e.g. room-temperature decomposition of anthracene peroxide during irradiation with X-rays).

Some of the other papers which are included are: ‘Antisymmetry’ by Shubnikov; ‘Mössbauer Effect and its Applications to Magnetism’ by Bliue; ‘Symmetry Properties of Non-linear Optical Susceptibilities’ by Bloembergen, and ‘Thermal Expansion of Crystals’ by Krishna Rao.

The volume is well produced and the papers are of generally high standard. However, it is rather too expensive for other than purchase by organizational libraries. Solid-state physicists are bound to learn much that is new by reading through it, and for this reason should encourage their libraries to add it to their collections.


Reviewed by R. E. B. Makinson, Macquarie University, Eastwood, New South Wales.

This book is well described in the preface as an account of current understanding of a number of aspects of the electron theory of metals, with particular reference to band structure, Fermi surfaces and transport properties.

That it reflects the particular interests, methods and outlook of the school associated with Bristol and Cambridge results from its original conception as a work in honour of the 60th birthday of Professor Sir Nevill Mott, the authors having all been associated at some time with him. They are Heine, Schoenberg, Pippard, Chambers, Ziman, Faber, Brown and Taylor, Friedel, each contributing a solid monograph on a single topic. Taking for granted the material in the usual introductory text books, it is intended for research workers and advanced students.

The editing, by Ziman, and the evident degree of collaboration give the book unity and coherence, with a limited range of topics in view. It is no conventional Festschrift.

The sections are: electronic structure of metals (Heine) built around the concept of pseudo-potentials; experimental results in the same area (Schoenberg); metallic electrons in a magnetic field (Pippard); transport properties (Ziman), surface and size effects (Chambers); transport properties of liquid metals (Faber); experimental studies of structures of metals and alloys (Brown and Taylor); transition metals, the role of the $d$ band in crystalline and magnetic structures (Friedel). Topics not touched upon include superconductivity.

Each section is thus by an author who has made many major contributions in that area. The style generally places emphasis on the physics and the mathematics is not too dominant or sophisticated, in the Mott tradition. Theory and experiment are well related.

The book is thus an essential for any research worker interested in metals and would be valuable as reference material in any courses in solid state physics above the introductory level.
It is interesting to note that no royalties go to the authors, being paid instead into a trust fund ‘to encourage study and expertise in foreign languages amongst professional scientists’. A second volume subtitled Defects is being edited by Professor P. B. Hirsch.


Reviewed by L. C. Robinson, University of Sydney.

Within the unifying theme of its title this volume deals with two physical topics: particle accelerator theory and plasma containment. Professor Lichtenberg brings to these topics a considerable range of experience and he succeeds well in his formulation.

The book begins with a brief but adequate survey of Hamiltonian mechanics, a treatment of integral invariants and phase-space conservation principles, and discussion of the application of these principles to oscillatory systems. Second-order differential equations with time-dependent driving terms, and periodic coefficients are discussed as well as nonlinear equations. In particular, these include the Mathieu and Hill’s equations (for later use in connection with accelerators), and perturbation techniques and asymptotic expansions for the handling of nonlinear equations.

The question of near-adiabatic invariance is treated with considerations of both asymptotic and iterative methods applied to the action integral. The application of these results to the important problem of adiabatic invariance of the dipole moment of a particle orbiting in a magnetic field is treated later in the book, but when this is done the treatment is extended to the conditions required for non-adiabatic behaviour also.

The middle chapters give an expert treatment of particle motion in accelerators: the alternating gradient principle, stability considerations, betatron oscillations, beam matching, etc. There have been several good books written on this subject in recent years, and this one maintains the high standards.

The latter part of the book deals with a phase-space outlook on plasma containment, trapping, and heating. It is somewhat more piece-meal than the structured development in the first and middle parts, but it is a useful contribution to the literature. It deals with trapping in a dipole field and the usual laboratory mirror, cusp, etc. configurations, and the methods used to change the dipole moment of trapped particles. The functioning of reciprocal and non-reciprocal transverse field perturbation mechanism is treated largely in review form and it may be necessary for the reader to seek out the original papers in order to get a satisfying understanding. When occasions such as this arise the reader is well guided to the relevant references by Dr Lichtenberg.
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