The Physics of Collagen and its Relation to Biology and Physiology—B. J. Rigby

Amendments to the By-Laws

Matriculation Results as an Indicator of Probable Success at University—W. A. Macky

Solid State Physics at the A.N.U.—A. J. Mortlock

Notes and News

Institute Affairs

On Walkabout

Book Reviews
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The Physics of Collagen and its Relation to Biology and Physiology

B. J. Rigby

Division of Textile Physics, C.S.I.R.O. Wool Research Laboratories, Ryde, Sydney.

Introduction
Collagen is one of the most abundant and widespread proteins in the animal kingdom. It is the basic fibrous constituent of tendon, skin, cartilage and bone, and occurs in practically every organ of the body. In each of these situations it is associated with small quantities of non-collagenous protein, e.g., elastin, and varying percentages of polysaccharides.

In its purest form, tendon, there is less than 1% by dry weight of polysaccharide but cartilage can contain up to 40% of polysaccharide. The collagen-polysaccharide complex is maintained in equilibrium with tissue fluids, the weight fraction of collagen in tendon being about 0.3 in this state. In this condition fibres show a Young's Modulus of about $10^n$ dyne cm$^{-2}$. Collagen is an extra cellular protein and once formed is metabolically stable in most sites; this is in contrast to other body proteins which show a continuous turnover of molecules.

Collagen is the supporting framework protein of the body and, since in humans it comprises about one third of the total mass of protein its importance in physiology and pathology is obvious. This short article lists briefly the major physical and chemical properties of collagen and indicates some of their biological and physiological consequences.

Collagen from the point of view of Chemical Physics
Collagen is a highly crystalline protein which gives characteristic X-ray diffraction diagrams. The important features are an arc on the meridian corresponding to 2.9Å spacing and a spot on the equator corresponding to a spacing between 10 and 16Å depending upon the hydration of the sample. At very low angles a number of meridional spots and arcs appear all of which are related to a single fundamental period of 640Å in a dry specimen.

The electron microscope shows a periodic band structure especially when the sample is suitably stained, which corresponds in period to the 640Å repeat observed in X-ray diffraction. (See Fig. 1).

Like all other proteins, collagen is made up of varying proportions of the 20 or so amino acid

![Collagen molecule](image)

The collagen molecule. (a) represents the molecule; it has approximate dimensions of 2800Å x 14Å; (b) represents an enlargement of a section of the molecule showing it to be composed of three distinct but intertwining polypeptide chains each in the shape of a helix. Two of the chains have a similar chemical composition but the third is different. (c) shows how each chain is made up of amino acid residues linked via the peptide link. The basic formula of an amino acid is given in (d) and R stands for any of the 20 or so different side groups which distinguish the amino acids.
residues. Among these the most prevalent is glycine which accounts for about 33% of the residues. Proline and hydroxyproline account for about 25% in mammalian collagen and while the glycine content is invariant through all species, the proline and hydroxyproline vary considerably. Their variation however, is not haphazard — generally there is a good correlation between the environmental temperature of the animal and the sum of proline and hydroxyproline. This point will be discussed again later.

The amino acid residues join up to form left handed helical polypeptide chains and it is generally agreed that the “molecule” of collagen consists of three of these helices wound together to form a right handed super helix. It is held together by hydrogen bonds inclined to the fibre axis and a very small number of ester bonds, approximately 3 or 4. Each of these molecules is about 2800Å long and about 14Å wide. The mean 640Å repeat observed in the native material comes about by a stacking of molecules overlapped by one-quarter of their length. The molecules stack in such a way because there are sequences of residues which may react to form bonds between different parts of adjacent molecules, e.g., ionic bonds, between charged groups. However, it has been shown on purely geometrical grounds that in fibrils of average size, only about 68% of the molecular contacts can be of this type. Thus there is quite a large part of the collagen fibre in which the packing is not of the most preferred type, but it is not known what significance this has for the general physical properties. The polysaccharide material also is situated between the molecules and/or fibrils in an unknown way. In some cases it is known to be co-valently bound to the collagen via ester bonds, but usually it appears to be only lightly bound and plays little part in the mechanical strength and thermal properties.

Properties of Collagen Molecules in Solution

A small fraction of native collagen can be broken down to the molecular level by weak acid and alkaline buffers, resulting in solutions of the long rod molecules described above. In fact, much of the information concerning molecular dimensions has been obtained by solution studies, using techniques such as viscometry, light scattering and optical rotation. When a solution of collagen is heated these techniques show that the molecule “melts”, i.e., the three-stranded rod dissociates into its constituent chains which then curl up into loose spherical forms. This happens at a well defined temperature, $T_n$, which varies with the source of collagen (the subscript D refers to denaturation). Thus mammalian collagens in solution at neutral pH melt at about 38°C while collagen, from a cold water fish such as Cod, melts at about 14°C. The melting temperature $T_D$ correlates with the sum of proline and hydroxyproline and Fig. 2 shows the close relation between $T_D$ and the total content of these two amino acids for a range of different collagens.

Properties of Native Collagen

A length of tendon may be extended in physiological saline without damage, by only 2–3% beyond its natural length. This is in accord with its function as a transmitter of muscular force and as a supporting tissue in the body. Much work has been done on the effect of large extensions on tendon, but the only result of interest here is that large extensions reduce the original thermal stability of the sample. The matter of thermal stability will now be discussed in some detail.

When a freely suspended specimen of collagen is heated in physiological saline no visible changes occur before the shrinkage temperature, $T_s$, at which the sample contracts and becomes rubbery. The values of $T_s$ are elevated by about 20°C above $T_D$ for each species, and $T_s$ shows the same correlation with total amino acid content as does $T_D$ (Fig. 2). The shrinkage phenomenon has been shown to result from a melting of crystalline fibres — $T_s$ is higher than $T_D$ because of the gain in stability obtained from the interaction of the close-packed, long rod-like molecules.

However, if sensitive volume expansion measurements are made changes can be seen to begin well below $T_s$. Fig. 3 shows the results of such an experiment. The small change in slope of the curve
as 40°C denotes a minor structural change while the large change at 60°C is characteristic of melting and, in fact, is equivalent to the Tₘ value obtained by simpler methods. The small structural change occurs at about the same temperature as the melting of the molecule of the same collagen in solution, that is Tₜₐₚ.

![Graph showing specific volume vs. temperature](image)

**Figure 3**

Thermal expansion of beef achilles tendon in physiological saline. The small change in slope at about 38°C represents the melting of collagen molecules in highly swollen regions of the tendon. The large change in slope at 58°C represents the melting of the bulk of the tendon where the collagen is in a much less swollen condition. The transition at 58°C is easily observed with the eye and is the effect well-known as thermal shrinkage. The temperature at which it takes place is denoted by Tₜₐₚ.

A number of simpler methods have been developed which allow the determination of this small transition temperature, and for a wide range of species the value obtained on the bulk material agrees with the corresponding value of Tₜₐₚ measured in solution. Because of this agreement we are led to conclude that this small transition which occurs in native collagen is due to the "melting of collagen molecules". This is reasonable when we consider that on purely statistical grounds a small percentage of molecules in native collagen will find themselves sufficiently isolated from their neighbours to be able to melt when the temperature reaches Tₜₐₚ.

This transition in native material which we may identify with Tₜₐₚ is reversible, whereas in solution the transition is at best only partially reversible. When a force is applied to the native sample during heating the transition still occurs but it is now irreversible. This is readily seen in a creep test, i.e., extension under a constant load. In such a test the rate of extension begins to increase at Tₜₐₚ and when the load is removed from the sample and it is cooled to below Tₜₐₚ it is found that it does not recover its original length (which it has been shown to do when no force is present). The forces required to bring about such changes correspond to extensions of the order of only 1%, i.e., within the working range of the material in its native state.

**Role of Polysaccharide in Thermal Stability**

It was stated earlier that all collagens occur naturally in association with polysaccharide material and the role of these other components in the physical properties has often been questioned. Recent work has shown that for vertebrate collagens the associated polysaccharide does not have much effect on the thermal stability. For example, cartilage containing 40% by weight of polysaccharide gives the same values for Tₜₐₚ and Tₙₐₚ as tendon containing less than 1% polysaccharide.

However, a number of shellfish living on the N.S.W. coast have been found to have Tₜₐₚ and Tₙₐₚ values much higher than was to be expected from their proline and hydroxyproline values. These invertebrates contain about 4% polysaccharide bound to their collagen and when this was removed their transition temperatures fell by as much as 18°C in some cases, to the expected value. Removal of polysaccharide from the vertebrate samples had no effect upon Tₜₐₚ and Tₙₐₚ. These experiments indicate that polysaccharides may be separated into those which are chemically bound to collagen and those which are only loosely attached.

**Biological and Physiological Significance of the Physical Properties of Collagen**

In the introduction the observation was made that there is a correlation between the amount of proline and hydroxyproline and the environmental temperature of the animal from which the collagen sample has been taken. In this context environmental temperature means the limits of temperature within which the animal body functions, not necessarily the temperature of its surroundings. Thus the environmental temperature for a human is about 37°C when healthy, and higher when ill. It has become usual to accept the relation between proline and hydroxyproline and Tₘ and Tₚ as the more fundamental. However, recent work suggests that, in fact, the correlation between Tₘ and Tₚ and environmental temperature may be the more fundamental.

Briefly, it was found that the collagen of a parasitic worm, Ascaris, which lives in mammalian intestines has a very much larger amount of proline and hydroxyproline than the collagen of its host, but has values of Tₘ and Tₚ identical with that of its host. In other words the environmental temperature appeared to be the determining factor for Tₘ and Tₙₚ. Such considerations will have to
await more knowledge of the detailed structure of
the individual chains comprising the molecule before
any conclusion can be reached.

We referred in the previous section to the marked
effect of polysaccharide on the transition tempera-
ture of the collagen of shell fish, in contrast to
the lack of such effect in warm blooded and other
vertebrates. The biological reason for this may be
that these creatures live between high and low
water marks and have to endure great extremes of
heat and moisture, and unlike cold blooded land
creatures they cannot easily move into shelter when
necessary. Since they are essentially sea creatures
they have collagen with thermal stability, appropriate
to the sea, and need bound polysaccharide to give
them the added thermal stability in order to survive
their unusual environment.

Finally we point out some possible consequences
of the fact that the melting temperature of the
human collagen molecule $T_D$ is very near to normal
body temperature. Special conditions may exist, for
example, if body temperatures are abnormally high
for any reason, e.g., fever, or if the collagen is low
in proline and hydroxyproline, and most particularly
if the tissue is under a mechanical force. Under such
conditions, structural transitions may take place
with serious physiological and pathological conse-
quences. These observations are relevant to
rheumatic fever, where prolonged fevers are
encountered. It may be significant that in this disease
damage commonly occurs to the tendons which
assist in controlling the position of heart valves,
the implication being that the combined elevated
temperature and tension cause an irreversible change
in the mechanical properties of the tendon. Similar
consideration would apply to any part of the body
where mechanical forces are prolonged or excessive,
e.g., joints. Naturally these changes may be exceed-
ingly small, but we must remember that collagen
has a low or even negligible rate of metabolic
turnover in most parts of the body so that deleterious changes in structure will tend to be
retained. Thus damage caused to connective tissue
may only become manifest after accumulating for
many years.

In conclusion, we may become even more
speculative and suggest that, by virtue of its property
of undergoing a precise structural transition at a
temperature very close to normal body temperature,
degeneration of connective tissue over long periods
of time is the basic cause of physiological and
pathological conditions which have found no
explanation in conventional pathology, e.g., ageing,
and the rheumatic diseases.

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**AMENDMENTS TO THE BY-LAWS**

Notice is hereby given to all members that
By-Laws 29 and 72 have been amended as follows:

**By-Law 29:** In sub-clause (2) after the date
“30th” insert the following—“June in any year
shall be liable for only half the annual subscription
and if elected or transferred after 30th”.

**By-Law 72:** In sub-clause (2) after “provide”,
insert—“Alternatively if a Group is composed of
regional Sections the Chairman of each Section
shall be a member of the Group Committee if he
is elected by the members of the Group who are
members of his Section; the Chairman, Vice-Chair-
man and Honorary Secretary and Honorary Treas-
urer or Honorary Secretary-Treasurer of the Group
may be elected by the Chairmen of the Sections
and shall be members of the Group Committee”.

The first of these amendments is to provide for
persons joining the Institute in the period 1st July
to 31st December to be charged only half the
annual subscription for that year.

The amendment of By-Law 72 is to provide for
circumstances such as those of the Education
Group, where it is proposed that the Group Com-
mittee should comprise the Chairman of each State
Section with one Section providing the Chairman,
Vice-Chairman and Secretariat for the Group. This
structure is favoured because it is expected that
differences between Education Sections in different
States will lead to widely different types of Sec-
tional activity.
Matriculation Results as an Indicator of Probable Success at University

W. A. Macky

Physics Department, University of Queensland.

The results of students taking first year Physics at University of Queensland from 1960-1964 are compared with the results in Physics and Mathematics I in the Queensland matriculation examination. When students are divided into nine groups, with the different possible combinations of grades in matriculation Physics and Mathematics I, it is found that the percentages of passes and of credits in first year Physics decreases in a reasonably steady manner from the group with matriculation grades of A in both subjects to the group with C in each. It is possible therefore on the basis of matriculation results to predict the probability of any student passing Physics Ia at the University.

INTRODUCTION

The large failure rate in first year University classes is a subject of much discussion and perhaps the argument advanced most frequently to excuse it is that first year results and not matriculation are the only satisfactory indicator of potential success. A comparison of Queensland matriculation results in Physics and first year Physics at University of Queensland has been made to determine what relationship exists between the two.

In the University, first year Physics is divided into two main classes called Ia and Ib. The students who wish to continue Physics beyond first year must take Ia and this study covered the first year students of the five years 1960-64 who had done matriculation examination in Queensland and were doing Physics Ia for the first time.

In the five years 1959-1963, 122,000 persons reached eighteen years of age in Queensland and 23,400 took the matriculation examination held in November. The percentage of matriculation candidates who took Physics increased from 53% in 1959 to 57% in 1961, 1962, 1963, and Physics was taken as a matriculation subject by 13,206, of whom 9,500 passed and 1,728 became the Ia students studied.

The matriculation passes are graded in classes A, B, or C which correspond to distinction, credit and pass in University examinations. Over the five years, the average percentages of Physics candidates awarded each grade in matriculation Physics were A 10%, B 23%, C 39%. A pass in matriculation Physics is a pre-requisite of Physics Ia and the students taking Physics Ia from 1960-1964 were made up of 40% with A in matriculation Physics, 43% with B and only 17% with C.

The basis of this study was a determination of the pass rate in Physics Ia by students with each of these grades in matriculation Physics and Mathematics.

In tables and diagrams, all figures and percentages refer to averages over the five years 1960-1964. In numbers and percentages of students, "Pass" implies pass or better and "Credit", credit or better.

Relation of Results in Physics Ia to Grade Obtained in Matriculation Physics

Table 1 gives the results obtained in first year University Physics by students, divided into groups according to the grade obtained in matriculation Physics. The variation in pass rate with grade in matriculation Physics is very clear. A student with A in matriculation has a high probability of passing Ia, a student with B has an even chance, and a student with C only a small chance.

<table>
<thead>
<tr>
<th>Grade in Matriculation Physics</th>
<th>Number of students</th>
<th>Pass</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>692</td>
<td>84</td>
<td>39</td>
</tr>
<tr>
<td>B</td>
<td>735</td>
<td>51</td>
<td>12</td>
</tr>
<tr>
<td>C</td>
<td>301</td>
<td>15</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1

Percentages of Pass and Credit in Physics Ia. Students grouped according to grades in matriculation Physics.

The variation between grades is even more pronounced in the percentages of credits. Credit or higher is gained by two students out of five with an A, one out of eight with a B and only one in fifty with a C.

Relation of Results in Physics Ia to Grade Obtained in Matriculation Mathematics I

Owing to the amount of Mathematics involved in Physics, it is to be expected that the probability of a pass in Physics will increase with mathematical ability. This is shown by Table 2, which gives the rates of pass and credit in University Physics obtained by students grouped according to their grades in matriculation Mathematics I. Of the students being considered 66% obtained an A in matriculation Mathematics I, 25% a B, and only 9% a C. These are appreciably higher grades than they obtained in matriculation Physics.

THE AUSTRALIAN PHYSICIST, APRIL, 1966 51
There is the same variation of University results with matriculation Mathematics as was found with matriculation Physics but the pass rates with A or B in Mathematics I are less than with A or B in Physics.

<table>
<thead>
<tr>
<th>Matriculation Grade in Mathematics I</th>
<th>Number of students</th>
<th>Pass</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1142</td>
<td>71</td>
<td>28</td>
</tr>
<tr>
<td>B</td>
<td>427</td>
<td>37</td>
<td>9</td>
</tr>
<tr>
<td>C</td>
<td>159</td>
<td>21</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2
Percentages of Pass and Credit in Physics Ia. Students grouped according to grades in matriculation Mathematics I.

Matriculation Results in Physics and Mathematics I as Indicator of Results to be Expected in Physics Ia

As seen from Tables 1 and 2, results in the first year University examinations show a marked relationship with grades in matriculation Physics and Mathematics I separately and it can be expected that there would be a closer relation with Physics and Mathematics I results combined.

This is shown in Table 3 where students are divided into the nine groups which in matriculation obtained the possible different combinations of A, B or C in Physics and Mathematics I.

<table>
<thead>
<tr>
<th>Matriculation Grade in Physics</th>
<th>Matriculation Grade in Mathematics I</th>
<th>Number in Group</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>597</td>
<td>86</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>83</td>
<td>71</td>
</tr>
<tr>
<td>A</td>
<td>C</td>
<td>12</td>
<td>75</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>461</td>
<td>59</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>225</td>
<td>59</td>
</tr>
<tr>
<td>B</td>
<td>C</td>
<td>51</td>
<td>31</td>
</tr>
<tr>
<td>C</td>
<td>A</td>
<td>84</td>
<td>26</td>
</tr>
<tr>
<td>C</td>
<td>B</td>
<td>121</td>
<td>13</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>96</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 3
Percentages of Pass and Credit in Physics Ia. Students grouped according to grades in matriculation Physics and Mathematics I. Averages 1960-1964

The groups vary considerably in size. The group with highest grades, A in each subject, is the largest (597 students) and together with the two groups which have B in Physics and A or B in Mathematics I includes almost three-quarters of the students.

By far the smallest group is that with A in Physics and C in Mathematics I, its smallness being an indication that good Physics marks are seldom combined with weak Mathematics.

The data are plotted in the Figure, omitting the A-C group, and the histograms show that the decrease in percentage of passes from 86% to 8% as matriculation grades are lowered from A-A to C-C is a reasonably steady change. The three biggest steps occur with Physics grades unaltered at A, B or C and a change from A to B in Mathematics I. The percentage of credits is more than halved from 42% to 18% as the matriculation grade changes from A-A to A-B and then decreases steadily to 1% in the C-C group.

The data indicates therefore that the matriculation results give a good forecast of probable results in first year University.

Table 4 gives the minimum grades in matriculation Physics and Mathematics I which are necessary to give the stated percentage chance of passing Physics Ia.

<table>
<thead>
<tr>
<th>Matriculation Grade in Mathematics I</th>
<th>Matriculation Grade in Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>mathematics I</td>
<td>75%</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>50%</td>
<td>B</td>
</tr>
<tr>
<td>25%</td>
<td>C</td>
</tr>
<tr>
<td>10%</td>
<td>C</td>
</tr>
</tbody>
</table>

Table 4
Minimum grades in matriculation Physics and Mathematics I necessary for a student to have the stated probability of passing University Physics Ia.

Conclusion
1. A student's matriculation grades in Physics and Mathematics I give a good indication of his probable success in University Physics Ia.
2. A survey such as the above is therefore of value to inform a student of the probable outcome if he takes Physics Ia.
3. The tables could also be the basis for setting the entrance standard at a level which admits only those with a reasonable probability of passing. The frustration experienced at present by so many who begin the course when their chance of passing is very low would seem to justify this.
Although it is unlikely that any university physics department at present fails to make available to its undergraduates a course in solid state physics, it seems probable that there is considerable variation in the content of these courses from department to department. This can be expected due to the wide range of subjects which may be discussed under the heading of solid state physics coupled with the usual limitations on the time available for instruction. Also, although solid state physics as such can scarcely be said to be new any more, it has yet to exhibit the fairly rigid structure that, for example, atomic spectroscopy and thermodynamics show these days at this level. The topics dealt with in an introductory course and their sequence of presentation therefore depend to a greater extent on the personal preferences of the lecturer in solid state physics than in these other cases. With the possibility of this variation in mind it was considered worthwhile setting down the details of the course presented by one physics department. Lecturers new to the subject as a whole and faced with the task of having to establish a complete course including laboratory work may also find the information given here of value.

The main undergraduate course in solid state physics at the A.N.U. is presented in their third year to students majoring in physics and comprises a total of approximately thirty lectures. Some isolated topics like diamagnetism and paramagnetism are presented in an introductory form at the second year level as part of other separate courses. In addition to the main lecture course there is, of course, an appropriate group of laboratory experiments.

The main lecture course is split into two roughly equal parts: broadly speaking, the first of these deals with those properties of solids controlled by the presence of defects, and the second with those properties dependent upon the presence of electrons.

The topics dealt with in the first part are:

- Historical introduction: evolution of solid state physics generally.
- General treatment of interatomic forces.
- Cohesive energy of ionic solids.
- Classification of solid types.
- Arrangement of atoms in crystals: close packing; crystal structure; nomenclature of crystallography.
- Methods of determining crystal structure.

Specific heat of solids due to lattice vibrations: Einstein and Debye models; description of approach via modes of vibration of arrays of mass points.

Point defects in crystals: Schottky and Frenkel defects; methods of determining defect concentrations.

Atomic diffusion in solids: self-diffusion and impurity diffusion in metals; Kirkendall effect; diffusion in ionic crystals.

Internal friction in solids; example of interstitial impurity atom movements in alpha-iron.

Ionic electrical conductivity; Einstein equation.

Dislocations: explanation of observed low mechanical strengths; definitions; elastic strain field of a screw dislocation; dislocation motion under shear stress; Frank-Read source; groupings in crystals; obstacles to movement of dislocations; simple ideas behind methods of increasing strength through alloying; crystal growth from the vapour.

The topics dealt with in the second part of the lecture course are listed below. Lectures from this part begin towards the end of those from the first part. This timing is felt to be necessary on the grounds that down-to-earth topics like crystal structure and classification of solids should be presented before the more abstract electronic processes in solids are discussed.

Difficulties of the classical model of the free electron gas in metals.

Quantum theory of electrons in a potential well; Fermi energy; resolution of specific heat and paramagnetism difficulties.

Motion of electrons in a periodically varying potential; Bloch functions; forbidden energy zones.

Effective mass of an electron; effective number of free electrons; holes; general picture of conductors, insulators, and semi-conductors.

Brillouin zones: detailed for two dimensional lattice but only qualitatively for three dimensional lattice.

Energy bands and atomic energy levels: transition from discrete levels to bands.

Density of states in the band model; zone structure in particular cases; correlation of zone structure with physical properties.

Hall effect: both positive and negative coefficients.

Semi-conductors: introductory ideas; intrinsic and extrinsic conductivity; donor and acceptor levels; n and p type conductivity.

Metal — semi-conductor rectifiers.
The p-n junction as a rectifier.
The transistor.

Ferromagnetism.
The practical experiments associated with the lecture course do not form a special group but are dispersed in the laboratory amongst other experiments associated with other parts of the third year course. The descriptions of these experiments which are given below are very brief, providing as they do just an outline of the method used. Further information is available in the literature in those cases where the experiments have been previously described. In other cases where this information is not so available the writer will be happy to provide details should they be required.

Ferromagnetism: This experiment consists in the determination of the Curie point of nickel and the demonstration of the crystalline anisotropy of the magnetisation of iron. For the first part the A.C. power transferred by the nickel-cored toroidal transformer illustrated in figure 1 is measured as a function of increasing temperature. When this drops to a minimum the Curie point temperature has been reached.

The second part makes use of the fact that silicon-iron transformer steel develops a preferred grain orientation when cold-rolled into sheets in which the [100] direction is parallel to the rolling direction and a (110) crystal plane lies in the plane of the sheet. Two small transformers are used, one of which has the rolling direction of its laminations parallel to the magnetic flux and the other with the rolling direction at right angles to the flux. The different characteristics of these transformers are compared using standard ballistic techniques and the results obtained related to the easy and medium directions of magnetisation in the b.c.c. iron structure cell.

Figure 1
Nickel cored transformer for Curie point determination.

Figure 2
Philips "Peltier Battery" type PT 20/20.

Thermoelectric Heat Pump: This experiment is aimed at measuring the figure of merit and coefficient of performance of an n-p semi-conductor thermoelectric heat pump. The centre piece of the apparatus is a Philips "Peltier Battery" type PT 20/20 (see figure 2) which is a 2V cooling unit incorporating a series connection of 20 n-p type bismuth telluride thermoelements mounted between, but electrically insulated from, two copper cover plates. The details of the experiment are given elsewhere.

Hall Effect: Investigation is made of the Hall effect in germanium using a commercial probe (AWV type AS13). The standard experiments which are carried out are to demonstrate the proportionality between Hall voltage and probe current and, from the constant of proportionality when extrinsic conduction may be assumed, to determine the density and effective sign of the majority charge carriers. Additionally, by measuring the Hall voltage as a function of the temperature of the probe by circulating temperature-controlled water
past it while it is located in the magnetic field, it is possible to determine the temperature dependence of the Hall coefficient over a limited range. This information may be used as a basis for a preliminary discussion of the type of conduction region which is operative at room temperature. Figure 3 shows the Hall probe and the water flow cell positioned in the field of a permanent magnet. 

Resistivity: Some of the factors which affect the resistivity and the temperature coefficient of the resistivity of metals are demonstrated in this experiment. The first part involves the measurement of the resistance of a coil of nickel wire as a function of temperature from 200°C to 500°C. The presence and absence of magnetic ordering below and above the Curie point respectively leads to the observation of a singularity in the temperature coefficient of resistance at this transition. The second part shows that the increments in resistivity of copper due to the addition separately of one atom per cent. of zinc, gallium, germanium, and arsenic are proportional to the square of the excess valence of these impurities relative to copper. In this case the measurements are made on a series of specially made alloy wires.

Internal Friction: This experiment demonstrates the interstitial diffusion of impurity nitrogen in alpha-iron. It consists in the measurement of the logarithmic decrement of the oscillatory motion of a torsional pendulum utilizing a commercially available iron suspension wire of high purity. Measurements are made over a conveniently small temperature range and from the results obtained the activation energy for the diffusion of the predominant impurity can be found. The experiment is described in detail elsewhere but, for the interest of the present reader, the general laboratory arrangement of the pendulum, draught shield, and temperature measuring and control apparatus is shown in Figure 4.

Energy Gap: The energy gaps of the semiconductors germanium and silicon are determined in this experiment by measuring the extrapolated long wavelength cut-offs in the response of photocells utilizing these materials. A Farrand grating monochromator complete with the manufacturers recommended infra-red filters is used in conjunction with a simple incandescent lamp light source to provide the required infra-red radiation of variable wavelength.

As a comparison, the energy gap for germanium is also determined by measuring the temperature dependence of the saturation reverse current of a germanium junction diode.

Germanium Filament: This entirely standard experiment is based on an AWV type AS14 semiconductor filament. Measurements are made of hole mobility and lifetime using the well-known techniques for this purpose.

This then is a description in outline of the undergraduate course in solid state physics as it is presented at the A.N.U. It will be seen to be fairly wide in its coverage without being greatly detailed in any particular area. This would seem to be the most desirable aim at this level of instruction.

Those students who go on to a fourth year are exposed to advanced lectures on isolated subjects in this field. At the end of this year these students and others, providing they satisfy departmental requirements, may undertake research.
within the department in this field leading eventually — all being well — to the M.Sc. or Ph.D. degree of this University.

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Notes and News

Report on Lecture by Professor H. B. G. Casimir

A combined meeting of the A.I.P. (S.A. Branch),
Institute of Engineers (Australia) and I.R.E. was
held on Friday, October 20, in the Parson's Lecture
Theatre, S.A. Institute of Technology.

Professor Casimir discussed "Industrial re-
search, its impact on Industry and Science". With-
out a doubt, research on a global or international
scale has been and still is a very profitable invest-
ment. Many industries would not exist without
preceding research and even those industries, which
flourished before the impact of modern science,
have been influenced by the results of develop-
mental and applied science. While research can be
shown to be of fundamental importance to modern
industry only a small percentage of the national
income is directed towards research. Without this
research, past and present, much of the gross
national product would not materialise.

However, in one specific country or industry,
the importance of research is not as obvious but
the problem is even more urgent. The success or
survival of a nation or an industry is determined
by how well the results of research and develop-
ment are applied. As one realises, there are many
problems associated with the application of re-
search in development.

Questions related to its administration, budget-
ing and financing are becoming a growing con-
cern in most countries and industries. In the
U.S.A., research on research is being carried out
especially in the Sloan Institute and Fortune
magazine contains such titles as "Harnessing the
R. and D. monster", etc. While the title of lecture
was sweeping, Professor Casimir explained that he
did not wish to make sweeping statements; in fact,
he was less certain now how industrial management
should be organised than he was ten years ago,
when he had less experience in this field.

The remainder of the lecture was confined to a
discussion on the organisation of research in
the Netherlands. Each country has its own prob-
lems but Australia and the Netherlands could be
compared in some ways as they have approximately
the same populations but, of course, vastly different
areas. Three separate organisations were discussed;
the Universities, Government establishments and
industrial research laboratories. The relations be-
tween these institutions is rather different in the
Netherlands than in other countries as will be
seen in this report.

There are six Universities of which four are
supported by the Government and two are denomi-
national (Roman Catholic and Presbyterian), each
having the usual facilities—except Engineering.
Engineering is taught in separate Institutes of
Technology or Technical Universities. There are
three of these institutions, one at Delft, another at
Eindhoven and the third almost completed at
Enschede. At present there is no equivalent of the
Bachelor's degree as full training is for the Master's
degree. The formal curriculum takes five years
for engineering and six for science. Few people
reach the degree in this time, taking one to three
years longer. The students are free to attend or
not to attend lectures, to present or not present
themselves for examinations. Professor Casimir
considered this is not a very healthy state of
affairs. There have been attempts to modify this
basic principle of freedom but they have met with
much opposition. However, the pressures of the
economy and employers have had some effect on
the students and many realise that they have to
complete their degree as quickly as possible, as it
is becoming well known that the time taken will
affect their careers.

The higher degree of doctor of philosophy
follows with no further examinations or lectures,
but the candidate must present and defend a
thesis. A member of the faculty acts as a "promotor"
(supervisor) and it is his responsibility to see
that it is acceptable. The research work can be
carried out anywhere; in the University, research
laboratory or even at home (theoretical work).
There is no time limit and sometimes people write
a thesis after they retire.

There is another class of engineers trained in
twenty four technical schools. This course covers
three years plus one year practical. Professor
Casimir felt that this course was fairly efficient and
produced good practical engineers, although at a
slightly lower level than the bachelor degree in
Australia.

Next, Professor Casimir discussed the require-
ments of industry with respect to the training of engineers, physicists and chemists. He admitted that his views were influenced by his position but he found they were confirmed by his colleagues in other sections of the Philips organisations. He would not put a high value on technical knowledge and skill alone. The danger of this aspect is that it will become obsolete. He requires a University graduate to have a sound training in fundamentals, perspective (i.e., a feeling for what are new steps in science and technology), and to meet up with new work in science and technology. In the latter the student should be confronted with new designs and new research problems. Research should be an essential part of the University curriculum, in fact an integral part.

To give one example: it is useful to learn how to solve a mathematical problem but much more important to be able to condense an engineering problem into a mathematical problem and this is not learnt from texts and classroom experiments but only by an involvement in present day research and development problems.

It is universally recognised in the Netherlands that, notwithstanding the Government research establishments and industrial laboratories, most fundamental ideas come from Universities and the inspirations from young and bright students. Young graduates tend to keep a research laboratory youthful and Professor Casimir intimated that he would like to keep it that way.

Professor Casimir then discussed the roles of University and Government establishments in the fields of research and development. While in some fields of research the Dutch Universities are in the forefront of their field, the overall picture is not as good as he would like to see. The Government establishment Z.W.O. (pure scientific research) gives additional support to the Universities. T.N.O. (applied scientific research), the other Government institution, co-operates partly with the institutes of technology but has its own laboratories as well. The T.N.O. laboratories are financed to the extent of 60% by Government and 40% by industry. They are first class in standardising, testing and approving and providing technical assistance, but they have not been so successful in fostering the creation of new products.

There are a number of industrial research laboratories such as Shell Oil, Unilever, A.K.U. (artificial fibres), State Mines (now becoming a Chemical Industry because coal as a fuel is being replaced by natural gas) and Philips Electrical Industries.

The activities of Philips Electrical Industries were discussed in some detail. These activities are in the fields of electronics and light electrical engineering, world-wide and employing 240,000 people. Each division has some independence and controls its own commercial activities, factories and developmental laboratories. Besides these divisional laboratories there is a central research laboratory. This is situated in Eindhoven and employs about 2,000 people of which approximately 350 are graduates and 500-600 are highly trained technical assistants from technical colleges, secondary schools or the internal training school of Philips.

There are also smaller research laboratories in England, France and Germany. Central research is financed by levying each division. The distinction between research and the work in the developmental laboratories is not always clear cut. In general the work in the research laboratories is more fundamental but this does by no means exclude work on new products and in some cases even pilot production may have to be set up. Broadly speaking the work of the development laboratories consists of the development of a clearly specified item by known engineering methods.

The purpose of fundamental research in an industrial laboratory is not only to contribute to existing knowledge but also the building up of competence, which is an integral part of applied research, and some 20% of the work is devoted to this. The creator of the Philips Research Laboratories, Dr. G. Holst, saw the emerging fields in academic research and decided to investigate them in view of possible further applications. For example, Bohr's theory of the atom and the Franck-Hertz experiment prompted research into gas discharges which led to the development of the sodium vapour lamp and the Penning (or Philips) ionization gauge to name just a few. Later, the work of Sommerfeld, Bloch, Peterls and others encouraged establishing solid state research. More than half of the work in the central research laboratories is directed to new products and applications. It differs from work in development laboratories in that the aims are less clearly defined, the methods to be employed less obvious and the chances of success less certain. Also, the development laboratories have a more pragmatic approach (i.e., once it works then the problem is left) whereas the research laboratory aims at better understanding. This leads to "second-round" activities, a direct service to a manufacturing division when the problem is outside the scope of the development laboratory. About 20% of the work comes in this category.

The questions after the lectures emphasised Professor Casimir's deep and wide knowledge and the interest he had aroused in the audience. Professor Casimir's thought-provoking lecture emphasised the great need for Australian administrators in the academic, Government and industrial circles to give further thought to the place of research in the national economy. The benefits will not be reaped immediately but will be vital in Australia's future.
S.A. Section, A.I.P. Education Group

At the inaugural meeting of the S.A. Section of the Education Group, Professor M. H. Brennan, Physics Department, Flinders University, gave a very interesting lecture entitled "Some modern developments in the teaching of Physics".

In the early 20th century the then obscure theoretical physicist Einstein shattered the Newtonian picture of space and time, but little has filtered into the early undergraduate courses and very little into the secondary schools. However, this state of affairs is changing and Professor Brennan outlined this revolution in physics teaching.

The work in the late 1950's in the U.S.A. and U.K. culminating in the P.S.S.C. and Nuffield projects were pointed out, especially the financial aspects. This work was motivated by the dissatisfaction with courses at all levels and curricula were developed to bring the students to an understanding, at an appropriate level, of the physical world as physicists understand it today. Professor Brennan took much care in emphasizing that it was the physical world of today, not the 19th century.

As an example, the speaker compared three new undergraduate courses developed in the U.S.A. with the traditional physics course as is outlined in say Halliday and Resnick. While the Feynman Lectures, the Berkeley textbooks (Kittel and Morrison) and the M.I.T. lectures differ in detail they all have the same approach. No longer is "modern" physics squeezed into the last few weeks of the third term but rather modern physics occupies the whole course.

Professor Brennan suggested that the laboratory most needed reform. Teaching institutions have used 19th century apparatus and methods for too long. These conditions must surely have turned scores of students away from physics. Perhaps the answer is provided by the use of modern equipment and the introduction of modern topics into the laboratory. The fundamental change seems to have been to divide contact with experimental physics into two areas which had overlapped in the past; "props" for lectures and "real" experimental physics. "Props" should not just be lecture demonstrations but enlarged to include corridor experiments and film loops. In the "real" experimental physics, the emphasis should not be on techniques but on doing physics in an atmosphere which resembles, at least in some respects, the atmosphere of the research laboratory. We should dispense with the "cook-book" approach, the stylized laboratory book, the manipulation of knobs and the reading of dials for achieving an answer which everyone already knows, with far more accuracy. As examples Professor Brennan commented on the Berkeley Physics Laboratory, which used electrical analogues to illustrate physical principles, and M.I.T., which has no compulsory first year laboratory work in physics. Undergraduates need only take one science laboratory period in their first year as each science aims to illustrate the scientific approach, which can be applied to all science subjects.

In concluding Professor Brennan expressed the hope that the Education Group of the A.I.P. would participate in and indeed stimulate work in revision of curricula and in the provision of new teaching aids and techniques in both tertiary and secondary institutions. They should strive to reach the high degree of cooperation (which is evident in the U.S.A.) between the practising physicist and the teacher of physics. The evening concluded with an enlightening discussion and Professor Brennan should feel satisfied that he had aroused great interest and enthusiasm in his audience. It is to be hoped that this enthusiasm will spread rapidly in the tertiary, secondary and primary institutions.

Sixth Annual Meeting of Physics in Medicine and Biology

The Sixth Annual Meeting of Physics in Medicine and Biology will be held in Melbourne from August 22-26, 1966, and the organizer will be Mr. K. H. Clarke, Physics Department, Cancer Institute, 278 William Street, Melbourne, C.1.

Arrangements have been made for Professor Theodor D. Sterling of the Medical Computing Center, University of Cincinnati, Ohio, U.S.A., to be guest lecturer at this meeting. Professor Sterling attended the International Atomic Energy Commission conference on dosimetry in Europe in October, 1965, and will be present at the Symposium on Computer Applications in Radiology and Hospital Radiation Physics in Cambridge in June, 1966. He has agreed to present two papers at the Annual Meeting of Physics in Medicine and Biology in August, 1966, one relating to Computer Applications and one relating to Dosimetry.

It is hoped to arrange a number of symposia covering (1) Radiation Dosimetry, (2) Electronics applied to Medical and Biological problems, (3) Radiotope Scanning and Whole Body Measurements, (4) Health Physics, (5) Applications of Computers to Biological Problems, (6) Diagnostic Techniques. Would potential contributors to this meeting please communicate with Mr. K. H. Clarke as soon as possible. It is hoped to publish the final programme by 1st June, 1966.

Contributors will be asked to supply a 100-200 word summary of their papers by 1st June for prior distribution to delegates.

Summer School in Group Theory

During the week commencing 28th February, 1966, an informal summer school in group theory and its application in physics took place at Melbourne University, sponsored jointly by the Physics Departments of Melbourne and Monash Universities. Among the audience of forty participants who completed the course there were several chemists and mathematicians.

Professor David Peaslee (A.N.U.) discussed the
theory of finite groups from a novel standpoint. He showed, by considering the regular representation and the collection of irreducible representations as alternative ways of spanning the group algebra, a great deal of insight can be gained in group representation theory that is hidden in the more usual treatments that proceed through Schur's lemmas.

Dr. Alan Roberts (Monash) discussed the continuous groups. He showed us the horrors that were hidden in the "jungle" of the arbitrary infinite groups and the pleasures that were to be found in the "garden" of semi-simple Lie groups. After discussing the standard representation of semi-simple Lie algebras, he showed us applications in elementary particle physics of SU₃.

Dr. Geoffrey Opat (Melbourne) spoke on the properties of the symmetric group, and the analysis of the representations by Young's tableaux. His remarks were illustrated by applications to atomic and nuclear structure.

In the light of the success of this informal summer school a similarly sponsored summer school in "field theory" is being considered for next year.

Addresses of Members Required
The following members have left the addresses which are in the Institute's records. Would anyone knowing the present address of any of the following please advise the Honorary Treasurer or the Honorary Secretary.

Mr. G. J. Sprott, Queensland.
Mr. A. J. Webb, Queensland.
Mr. A. B. Barry, Queensland.
Mr. A. R. Haly, New South Wales.
Mr. J. A. Deacon, Western Australia.
Dr. F. Hirst, Victoria.
Mr. I. Lowe, New South Wales.

Institute Affairs

REPORT OF COUNCIL MEETING
The Institute's Eighth Council Meeting, held in Sydney on the 14th and 15th February, 1966, was attended by representatives from each of the Branches, except Tasmania. Representatives of the Biophysics and Geophysics Groups and the Editor of "The Australian Physicist" attended as observers for discussions relevant to their particular interests.

Newcomers to Council were Dr. F. D. Stacey (Chairman, Queensland Branch) and Dr. R. S. Crisp (proxy for the W.A. Branch Chairman).

Matters likely to be of particular interest to members are summarized below:

Membership
Membership stands at a total of 1050 corporate members, Students and Subscribers.

Increasing use is being made by employers of Institute Membership as a "yard-stick" of qualification, and while Council is pleased to see this in respect of actual membership of the Institute, it decided against acting as consultant to employers on qualifications of non-members.

"The Australian Physicist"
A careful analysis by the Editor of the costs of "The Australian Physicist" indicates that to date it has averaged 9.2c per copy, but that taking account of current advertising support and a notified increase in printing costs, it will probably cost 10c per copy in 1966, i.e., about $1700.

It was unanimously agreed that it was important that "The Australian Physicist" should continue even if virtually none of the cost can be offset by advertising. The Editor was asked to arrange for direct distribution from the publisher. Further endeavours will be made to obtain concessional postage rates.

The Editor stressed that members could do much to improve the use of the journal by advertisers, by increasing the "feed-back" to the advertisers.

Members should note that "The Australian Physicist" is issued to them for their personal use, not for transfer to libraries.

Biophysics Group
This group's annual meeting of Physics in Medicine and Biology, held in conjunction with the Hospital Physicist's Association in October, 1965, was well attended and successful. It is proposed to hold a mid-year meeting in Sydney, which will be largely a social gathering.

Geophysics Group
The Bass Strait Upper Mantle Project was still in progress during the meeting and Council noted with satisfaction the large number of co-operating parties and the good prospects of the project being brought to a successful conclusion. This is reported elsewhere.

Education Group
An amendment to the By-laws, reported in this issue, has cleared the way for the election of the Group Committee and the acceptance of the West Australian Section's offer to provide the secretariat for the Group.

Sections in a number of States are already active.

Summer School and Conference
The first Institute Summer School and Conference at the University of New England in February,
1966, was an undoubted success and Council expressed its appreciation of the work of the host University and the Organizing Committee. A separate report appears in this issue.

It is hoped it will be possible to arrange for a 1967 School and Conference to be held in Canberra, to overlap with the Summer Research Institute of the Australian Mathematical Society, which will include aspects of theoretical physics.

Pawsey Memorial Lectures

Arrangements were made to present to Professor Bok the memento of his first Pawsey Memorial Lecture before he leaves Australia.

The 1966 Lecture will be given in Hobart in May by Mr. J. A. Ratcliffe, Director of the Radio and Space Research Station, Slough.

Instrument Exhibition

The New South Wales Branch is planning an Instrument Exhibition and a convention on "Recent Advances in Scientific Instrumentation" for August, 1966, and the Victorian Branch will probably hold an Instrument Exhibition in 1967. It was noted with satisfaction that the Tasmanian Branch's Exhibition, arranged at very short notice to be held in conjunction with A.N.Z.A.A.S. in 1965, had shown a profit of $350.

National Service for Postgraduate Students

Council is proposing to seek in consultation with National Service for postgraduate students, to avoid interruption in their training.

On Walkabout

Student member, Mr. K. Parcell, has graduated with honours from Queensland University and has taken up a position as a Scientific Officer in the Ionospheric Physics Group of the Weapons Research Establishment in South Australia. Mr. J. W. Crompton has resigned as Head of the School of Applied Physics of the S.A. Institute of Technology and taken up a position as Principal Research Scientist in the Weapons Project Division of W.R.E.

Mr. C. B. Rogers has resigned from W.R.E. and returned to the United Kingdom.

Dr. C. J. E. Kempster is on study leave during 1966 from Adelaide University at the Crystallographic Laboratory of the Cavendish. Dr. D. J. Sutton of Adelaide University is spending 1966 on study leave at the Seismographic Station of the University of California at Berkeley, California.

Dr. Olin J. Eggen of the staff of Mount Wilson and Palomar Observatories, formerly Assistant Chief Astronomer at the Royal Greenwich Observatory, has been appointed Professor of Astronomy and Director of Mount Stromlo Observatory. Dr. Eggen, who is well known to the Mount Stromlo Observatory staff from his earlier visits to the Observatory, is expected to take up his new appointment early in July of this year. On February 21st, the Vice-Chancellor appointed Dr. Hogg to act as Interim Director from the middle of March until the arrival of Professor Eggen.

Professor Bart Bok visited Mount Stromlo Observatory on March 28th and went, with Mrs. Bok, to Siding Spring Observatory for one more week of observing starting March 20th. He is taking up his appointment as Professor of Astronomy at the University of Arizona on April 16th, 1966.

Dr. James Campbell, F.A.I.P., was elected in December to the Council of the University of Melbourne. He is the Director of the Australian Wool Testing Authority and has been for a number of years strongly associated with the Graduate Union and the Graduate House of which he has been President. He is the youngest member of the Melbourne University Council.

Dr. Brian Spicer, F.A.I.P., the first Chairman of the Victorian Branch of the Australian Institute of Physics, has been appointed to a Personal Chair in the Physics Department of the University of Melbourne. Professor Spicer has been working with considerable success in the field of low energy nuclear physics.

It is with great regret that we announce the sudden death of Dr. A. R. Hogg, Interim Director of the Mount Stromlo Observatory, on Thursday, March 31.
Although Weiss had given a phenomenological theory of the Curie point, it was not until his brief paper in 1925 which first introduced an atomic model to explain these transitions. Ising obtained, the exact solution for the one-dimensional chain of 'scalar spins' by local methods, showing that there was no transition predicted. Heisenberg in 1928 attempted to discuss spins, representing them as true quantum mechanical operators, and in 1933 Bragg and Williams obtained an approximate solution to the Ising problem for an arbitrary lattice, and this turned out to be equivalent to the use of the Weiss internal field. There were many attempts to improve the approximate solutions but the next major step was taken by Onsager and Kaufman in 1941, who gave a solution of the one-dimensional chain in terms of matrices. This step led Onsager and Kaufman to their exact solution of the two-dimensional Ising problem. The simplicity of Onsager's results compared to the heavy matrix algebra of the proof must have suggested to several people that there may be a simpler derivation, and it seems as if the recent work of Green and Hurst will stimulate further work in this direction.

The Ising model is clearly defined, simple to state and mathematically attractive; it has for physicists something like the friendly polish of a well known and well used armchair. It may be that there are other more up-to-date chairs, which may be more functional, but why should we desert such an old friend? The essence of the model which is the pattern of two sites on a lattice, with a two-valued algebra, is certainly too simple to apply to the solid CO₂ lattice where the unit is the linear CO₂ molecule. On the other hand, the model can be applied to a fluid (without saying if it is a gas or a liquid), by making one site occupied and the other unoccupied and preserving the number of occupied sites constant.

What, therefore, have Green and Hurst contributed? No less than a new method of getting the known exact results. Their new method involves the combinatorial problem of the number of different closed polygons which can be constructed on a lattice and this is cleverly solved by using Pfaffians (square roots of antisymmetric determinants), which the authors introduced in their article of 1960. This is probably an unfamiliar technique and the authors give admirable appendices.

The unusual algebraic technique raises interesting questions. Will it give the solution to the three-dimensional problem if it exists? And will the solution be as simple as that for two dimensions? If this solution is found, an enormous amount of effort on approximate solutions will be put aside but it will of course be seen in retrospect before this happens. Green and Hurst clearly feel no attraction for these approximate solutions and give only scanty attention to them. It is worth while at this stage making a comparison with the long review articles of Domb (Advances in Physics (1960) 9, 149-245, On the theory of co-operative phenomena in crystals), which might well have been published as a book a few years ago. Domb certainly gives a wide view to the subject including a critical survey of the approximate methods. There are times, however, when the direct attack on the exact solution of a physical problem is the best procedure and Green and Hurst's book is an admirable example of this.

The first two chapters introduce the problem and discuss some of the physics of the order-disorder phenomenon; then follow three chapters on the new methods. Links with other approaches in this field of the exact solutions are given by Green and Hurst in their chapter six, and chapter seven contains a discussion of outstanding problems, especially the three-dimensional crystal and the lattice in a magnetic field. If in this time we will look back on the Ising problem as a closed chapter in physics, it may well be that this book will have substantially helped to that end.

FUNDAMENTALS OF VACUUM SCIENCE AND TECHNOLOGY.


Reviewed by M. T. Elford, Australian National University.

The author states that this book is designed "to aid the research worker who is not a vacuum expert but who needs high vacuum technique as a tool to provide the proper environment required in many scientific studies". To cover all aspects of vacuum technique and yet to be only 248 pages in length has of necessity meant that most aspects are dealt with briefly but the extensive use of references enables the reader to amplify subjects of interest.

Chapters 1 and 2 follow the usual pattern of dealing with elements of the kinetic theory of gases and the flow of gas through tubes and orifices. The computational formulae are stated without proof; both chapters are clear and concise. Chapter 3 dealing with surface effects is the longest chapter in the book and reflects the emphasis now being placed on surface effects in the understanding of the behaviour of pressure gauges and vacuum systems. The many types of reactions which can occur between photons, ions and
molecules both with the surfaces of the vacuum chamber and hot filaments are considered in some detail. Chapter 4, although only 6 pages long, deals with the evacuation of a vacuum vessel taking into account the effects of pumping tubes and degassing. An understanding of this chapter is vital in designing a practical vacuum system and a numerical example of an actual design is helpful in making the procedure clear.

The discussion of pressure gauges and the measurement of pumping speed and conductance in Chapter 6 is very well done, particular emphasis being placed on the problems and limits of each type of gauge. One criticism of this chapter is the very short section dealing with leak detection. For the research worker "who needs high vacuum as a tool" the problem of leak detection can be an important one and this section of only a page and a half could well have been expanded to deal with the more simple methods of detecting leaks. After all not every laboratory possesses a helium leak detector.

The chapter on pumps is distinguished by a discussion of the problems involved in using sputter-ion pumps. Although widely used particularly in ultra high vacuum systems their limitations are sometimes overlooked.

In summary, this book will be a significant addition to the library of any laboratory employing vacuum techniques and is an excellent introduction for a research worker into the fundamentals of vacuum science and technology.


Reviewed by Mr. W. Lamb, Weapons Research Establishment, Salisbury, South Australia.

As the title suggests, this book covers a large extent existing airborne telemetry practice with which the author has a long experience in missile and spacecraft development. Although the material is intended to provide practical design information for airborne applications, it will be generally useful over a much wider range of data acquisition situations including those which may not require a radio link. The book is not intended for the worker involved in research and development of telemetry but rather for the experimentalist who is confronted with a telemetry instrumentation problem as a means of acquiring data for analysis.

Chapter 1 will be of great assistance to those whose choice of system is not constrained by a data reduction system for example, and who have to resolve which system to use. There are valuable comparative theoretical results in this introductory guide to telemetry. When the system type has been selected, specification of that system would be aided by the practical design consideration provided in the second chapter. The section on telemetry standards in this chapter is particularly valuable, because the experimentalist will most likely become involved with a telemetry data reduction facility which will have regard to some standards. The information indicates which system parameters are likely to be standard, although the actual standards (particularly in the Australian setting) may well differ from the American standards contained in the book. In all this, the emphasis is on system design and principle rather than component equipment design which would detract from the theme anyway.

Chapters three and four give further practical assistance by way of comprehensive treatments of transducers and data reduction respectively. The remaining three chapters, however, are descriptive and encyclopedic in nature rather than of design significance. They deal with spacecraft experiments and missile range instruments such as radar, optical trackers, and radio doppler systems for trajectory measurement. While these chapters are somewhat out of place they are of complementary interest, and occupy a relatively small space.

The text is liberally supplied with design graphs, system diagrams and photographic illustrations which assist the description. Individual papers are listed in a bibliography at the end but are not referred to throughout the text.


Reviewed by Dr. J. V. Ramsay, National Standards Laboratory, Sydney.

The number of papers published on lasers continues to increase at a rapid rate. This is illustrated by the following estimate (Laser Newsletter No. 20; U.K. Scientific Mission, North America.) of papers published in the U.S.A.: 1960, 18; 1961, 105; 1962, 250; 1963, 650, with a further increase in 1964. In such a rapidly expanding field a book which coordinates and collates this information is very welcome. G. Birnbaum does this successfully in his book "Optical Masers"; the bibliography lists over 500 references and an appendix describes more than 140 laser transitions.

The book is set out very systematically dealing in turn with threshold conditions, spectral line shapes, steady state theory of operation, transient behaviour, optical resonators, particu-


Reviewed by Professor J. H. Carver, University of Adelaide, South Australia.

Ultraviolet physics has attracted increasing interest in recent years because of developments in space research and plasma physics. Koller's book gives a concise account of many of the phenomena, techniques and applications of ultraviolet radiation in a form which will provide a useful handbook for physicists, chemists, biologists and others who have occasion to use this radiation but who are not themselves specialists in this field.

After describing various laboratory ultraviolet sources, Koller discusses the solar radiation and includes an account of the far ultraviolet spectrum of the sun as determined by rocket spectroscopy. Much of the material included in these chapters was not, of course, available in 1952 when the first edition of this book was published. The remaining chapters of the book describe the transmission, reflection and detection of ultraviolet radiation and discuss certain applications, particularly in the biological field. This book collects a wealth of information, most of which is otherwise available only in the original literature. It can be recommended to all those who have occasion to use ultraviolet radiation.
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