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Ice—N. H. Fletcher ........................................ 131

The Register .................................................. 134

Vacuum—Physics Newsletter .............................. 135

Letter to the Editor .......................................... 136

Institute Affairs ............................................. 137

Book Reviews ................................................ 138

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Ice

N. H. Fletcher
Department of Physics, University of New England, Armidale, N.S.W.

Water is, by almost any criterion, one of the most important substances on the surface of the earth. Its presence as vapour in the atmosphere is the primary cause of most weather phenomena, its condensation and flow shape the surface topography of the earth and, without it, life as we know it could not have developed. One interesting feature of water is that, though it is a very reactive solvent, it occurs in immense quantities with a remarkable degree of purity. This is particularly the case with the solid phase, ice, which, because of impurity segregation in condensation and freezing processes, almost always occurs in a state of purity rivalling that of laboratory analytical reagents or the finest metallurgical products.

For these reasons, if no others, an extensive programme for the study of ice could be well justified. It turns out, however, after the most preliminary of surveys, that ice is a material which presents such a fascinating variety of physical properties that any detailed study of it is almost an exemplar of the principles of chemical physics. Most of our detailed understanding of these properties has only been arrived at during the past 20 years and the rate of progress is still great—a tribute to the almost inexhaustible richness of the subject. In the present article I can but touch upon a few of the more easily accessible phenomena.

The Water Molecule

Without exception, the unusual properties of ice can be traced back to the structure of the water molecule, \( \text{H}_2\text{O} \). Its electronic configuration is well known: the oxygen atom has two valence electrons free for bonding, \( 2p_x \) and \( 2p_y \), say, and the remaining electrons of this sub-shell, \( (2p_z)^2 \), form a lone pair. In the first-order configuration, the two hydrogen atoms lie on the \( x \) and \( y \) axes, their 1s electrons forming combined orbitals with \( 2p_x \) and \( 2p_y \) respectively, and the molecule has a triangular shape with an \( \text{H-O-H} \) bond angle of 90°. The energy can be lowered, however, if this angle opens somewhat, since the two \( \text{O-H} \) bonds are not neutral but repel one another. This change in angle forces some hybridization on the oxygen orbitals and the final

(a) Schematic electron distribution in the water molecule. (b) Idealized tetrahedral shape of the water molecule.
result is a more or less tetrahedral structure with a bond angle of 104.5°. As shown in Fig. 1a, the proton vertices tend to have net positive charges, while the lone-pair electrons contribute a ridge of negative charge density between the other two vertices. It is this tetrahedral structure, which can be idealized as in Fig. 1b, which determines the crystallography of the many ice polymorphs. The low mass of the protons, which encourages quantum phenomena, is the other feature of the molecule which contributes to the unusual behaviour of ice.

**Crystal Structure of Ice**

The simplest way of packing together water molecules with the shape shown in Fig. 1 is to arrange the tetrahedra point-to-point, with a positive vertex of one next to a negative vertex of its neighbour. In this way the co-ordination number for the molecules is 4 and a very open structure results. There are just two possible structures: a diamond cubic arrangement like that in silicon and germanium or a hexagonal wurtzite (ZnS) structure with water molecules at both Zn and S sites. Both forms of ice can, in fact, be produced but ordinary ice (Ice Iₖ) has the hexagonal form shown in Fig. 2. The bonding in this sort of structure is of the form O–H...O with the proton lying directly on the O–O line but at a position about one third of the way along. The integrity of water molecules is thus preserved and the bond is known as a hydrogen bond.

Even having decided upon the hexagonal arrangement, however, the crystal structure of ice is not uniquely determined. We have, in effect, the following two rules, due to Bernal and Fowler:

(i) there is just one proton on each bond (i.e. tetrahedra always join plus to minus)
(ii) there are just two protons near each oxygen (i.e. water molecules are preserved)

A simple calculation, due to Pauling, shows that, for a crystal of N molecules, these rules lead to \((3/2)^n\) different proton configurations, all presumably of very nearly the same energy. One particular configuration obeying these rules is shown in Fig. 2.

The existence of this large number of configurations explains why ice has such a high static dielectric constant (about 100) since, in the presence of an electric field, the statistical balance shifts in favour of those configurations giving a dipole moment parallel to the field. The actual shift takes place through the motion of defects, which we shall discuss later, and takes about \(10^4\) s at \(-10^5\)°C so that, if the frequency of the applied field is greater than about \(10^4\) Hz, the configuration change cannot follow it and the dielectric constant falls to about 3.2, which is the value contributed by molecular distortion and electronic polarization.

Another consequence of the large number of possible configurations is that, if the temperature is lowered and the defects which allow relaxation are frozen in while \(kT\) is still much greater than the energy difference between configurations, the configurational entropy \(Nk \ln (3/2)\) may be preserved at 0 K. This is the case and actual determinations of this residual entropy from heat capacity measurements by Giaque and Stout agree with Pauling's calculated value to within 1 per cent.
High-Pressure Polymorphs

Since the crystal structure of Ice I is so open, one would expect that the application of high pressures might lead to the formation of more closely packed molecular arrangements. This does, in fact, occur and seven high-pressure forms of ice have been made and studied by Bridgman and, more recently, by Kamb and by Whalley. The phase diagram, to the extent it is known today, is shown in Fig. 3. The well known fact that ordinary ice is less dense than water is exhibited by the downward-sloping I-L boundary which shows that ice can be melted at temperatures down to −22°C by the application of pressure. All the other ices are more dense than liquid water at the same temperature and pressure, and the melting line of Ice VII has been followed up to 200 kbar, where it melts at 440°C, without evidence of further high-pressure phases.

Studies of the crystallography of the high-pressure ices reveal the surprising fact that in none of them is the tetrahedral hydrogen bonding of water molecules upset—it is, as we remarked before, a dominant characteristic imposed by the structure of the water molecule itself.

The medium-pressure Ices I to V (Ice IV is omitted since it is only a metastable form) accommodate to the higher pressure through a bending and re-linking of hydrogen bonds, so that the molecular packing is more dense and the molecular tetrahedra are somewhat distorted. In Ice II this distortion is sufficiently large that the protons are ordered in only one single configuration throughout its range of existence, giving a dielectric constant ε of only 3.7. In Ice III the distortion is less and the protons are disordered (ε = 117) but, if Ice III is cooled metastably to below −100°C, the protons order to produce a new phase which is antiferroelectric (ε ~ 4) and which has been designated Ice IX. There is, as yet, no real evidence that the protons in Ice IX can be induced to order at low temperatures. We have already mentioned the metastable diamond cubic Ice Ic, which can be produced by condensation of water vapour below −100°C or by transformation of some of the high-pressure ices, but this too is disordered. A metastable amorphous phase (vitreous Ice) can also be produced by vapour condensation below −160°C but its properties have been little studied.

The high-pressure Ices VI, VII, and VIII achieve an increased packing density while maintaining tetrahedral bonding in a very interesting way. Any tetrahedrally bonded framework necessarily contains many regularly repeating cavities of considerable size and the possibility exists that one might build up two identical independent interpenetrating frameworks in such a way that the molecules of one occupy the cavities of the other. Such a structure might be called a self-clathrate, after the clathrate structures like chlorine hydrate, in which the chlorine molecule occupies the cavity in a cage formed by tetrahedrally-bonded water molecules.

Ice VI is of just this form, each framework consisting of complex interconnected chains running parallel to the c-axis. There is complete hydrogen bonding within each framework but no bonds connect the two independent structures. Ice VII, which appears to be the ultimate high-pressure ice, has a structure consisting of two interpenetrating diamond-cubic Ice Ic structures and, when released metastably to atmospheric pressure at liquid nitrogen temperature, has a density of 1.5 g cm⁻³ compared with 0.92 for ordinary ice. In both Ices VI and VII the protons are disordered (ε in the range 150 to 200) but in Ice VII they order below about 0°C to give the new phase Ice VIII.

Because the bonding in all these ices is similar, their optical and infrared properties are also generally similar. The disordered ices, however, have the important property that all their lattice vibrational modes couple to the electromagnetic field and are therefore active in absorption approximately as the square of their frequency ν. A measurement of the optical density divided by ν² in the far infrared (20 to 300 cm⁻¹) therefore gives a direct indication of the lattice vibration spectrum and has been interpreted in this way by Whalley.

Defects and Electrical Properties

An examination of the structure of an ice crystal, confining our attention from here on to ordinary Ice Ic, shows that it is impossible for the proton configuration to relax without the aid of some sort of lattice defects. The simplest defects are those which result from violations of the two Bernal-Fowler rules for the ice structure.

The first rule can be broken if a single molecule rotates through 2π/3 about one of its bonds or,
Figure 5
(a) Formation and (b) motion of positive and negative ion states in ice.

equivalently, if a proton jumps from one tetrahedral position to another, as shown in Fig. 4a. This creates a doubly occupied bond (D-defect) and an unoccupied bond (L-defect) which can then move independently as shown in Fig. 4b. The motion of these defects, sometimes referred to as Bjerrum defects, is by a classical activated-jump mechanism and their passage past a molecule changes its orientation and thus allows the proton configuration to relax.

If the second rule is broken, by the jump of a proton along a bond as in Fig. 5a, then two ion states H$_3$O$^+$ and OH$^-$ are created. Each can move independently, as in Fig. 5b, the jumps actually being by a quantum tunnelling process, and their motion again changes the proton configuration.

The concentration of Bjerrum defects in pure ice at $-10^\circ$C is about $10^{16}$ cm$^{-3}$ and their mobility about $10^{-4}$ cm$^2$ V$^{-1}$ s$^{-1}$. For ion states the concentration is about $10^{10}$ cm$^{-3}$. The mobility of negative ions is uncertain (about $10^{-2}$ cm$^2$ V$^{-1}$ s$^{-1}$) while that of positive ions has the remarkably large value of 0.1 cm$^2$ V$^{-1}$ s$^{-1}$, this being associated with the efficiency of the quantum-jump process. It is, in fact, possible to treat positive ion-state motion by a method analogous to the energy-band treatment of electrons in semiconductors.

This reference to semiconductors brings out the point that the concentration of 'carriers' (L and D defects and $+$ and $-$ ion states) in ice is quite comparable with that of electrons and holes in pure semiconductors. Pure ice is, in fact, a protonic semiconductor with a conductivity of order $10^{-20}$ ohm$^{-1}$ cm$^{-1}$ at $-10^\circ$C, though its theoretical treatment is rendered more difficult than that of electronic materials through the existence of four rather than just two carriers, the interactions between them being important.

Just as we have donor and acceptor impurities in silicon or germanium, so we can have proton-donor or proton-acceptor impurities in ice. HF, for example, is a proton acceptor and introduces a positive ion state and an L defect (leaving an immobile substitutional F$^-$ ion) while NH$_3$ gives a negative ion state and a D defect (leaving an NH$_4^+$ ion in the lattice).

These impurities have considerable effect on electrical conductivity and dielectric relaxation, as one would expect. They also affect the thermoelectric power (which is of the order of millivolts per degree) and would be expected to change the protonic Hall voltage, although this has, as yet, only been measured for pure ice. Even the mechanical properties of ice are predictably dependent upon the defect concentration.

Conclusion
The chemical physics of ice is, as we said at the beginning, an immense field whose possibilities we are only now beginning to explore. As a solid, ice is sufficiently simple that we have the ultimate possibility of reaching a nearly complete understanding of almost all phenomena, while at the same time it is sufficiently complex and subtle that their variety seems never-ending.

Reference
A detailed discussion of these and other phenomena, together with extensive bibliography, will be found in the author's book 'The Chemical Physics of Ice' to be published by Cambridge University Press early in 1970.
Vacuum and Space: Editorial

Two spectacular events in space technology two months ago aroused more than passing interest in the role that vacuum physics plays in the space programme. Landing men on the moon and sending a spacecraft to mars to test whether conditions there can support life require, besides rocketry, celestial navigation and space tracking, and the application of many ultra-high vacuum techniques and processes. These are: space simulation studies to measure radiation, temperature, lubrication, and degradation effects of space equipment, satellite-borne mass spectrometers and vacuum gauges to measure gas densities, development of ion and plasma-electric rocket engines for propulsion to other planets, and deposition of metals in vacuum for spacecraft construction. Even the most basic needs are involved, for example, food for astronauts is being vacuum-processed by freeze-drying.

Another direct result of the space programme is that certain lubricants have been found to malfunction in vacuum. For example graphite, excellent in the earth's atmosphere, fails badly in space, and it is thought the reason for this is the absence of moisture in the vacuum of space.

A more important concept is that the upper and outer atmosphere of the earth exists as a large laboratory for vacuum-physics research. Already a 'Redhead' cold-cathode gauge and a nude mass spectrometer have been flown on the Explorer 17 satellite to measure molecule and electron densities in the ionosphere above 100 km. Accurate density measurements have been obtained, after correcting for outgassing in initial orbits and in changing heights of the perigee of the satellite.

It would appear that the vacuum physicist and technologist could be more involved in astrophysical and upper-atmospheric research in future. As it so happens, 99 per cent. or more of our universe is plasma in ultra-high vacuum of about $10^{-24}$ torr, presently out of reach in terrestrial laboratories ($10^{-14}$ torr might be the best vacuum), but only 100 000 km away in interplanetary space.

Symposium—Exhibition 1970

The Committee plans to hold a Symposium—Exhibition in Sydney on 24–26 August 1970. Following the meeting and for the remainder of the week the A.I.P. plans to hold a Symposium on Transport Phenomenon in Solid-State Physics. It is thought that some Vacuum-Physics Group members may want to stay in Sydney for both events if they were held together.

Arrangements are being made with the University of Sydney to hold the lectures and exhibits there, and a well-known scientist is expected to open the Symposium—Exhibition.

The programme will of course depend on titles of papers that might be offered for presentation. Most of the firms who helped to make the last exhibition a success by providing displays of equipment will probably do so again. The possibility of providing accommodation and catering at one of the colleges of Sydney University is being examined. During a three-day meeting a technical visit could be arranged, and with suitable breaks in the programme for seeing the exhibits, we might perhaps have a well-balanced programme. As soon as our plans materialize we will issue a 'call for papers' to all members and we would hope a venue would follow in due course.

Sectional Notes

N.S.W.: The N.S.W. section met on 19 August to hear a lecture on Molecular Beams by Dr J. C. Macfarlane, C.S.I.R.O. National Standards Laboratory. Dr Macfarlane's subject concerns many of the practical aspects of vacuum technology having their origin in the means of producing and detecting molecular beams during the period 1920 to 1969, and the extensive use the study also has made of kinetic theory and the sciences of vacuum physics and surface physics.

Western Australia: The W.A. Section is arranging a lecture to be given by Dr B. G. Hyde of the Department of Physical Chemistry of the University of Western Australia. The meeting will be held at 8.00 p.m. on Tuesday, 30 September, in the Ross Theatre, Physics Department, University of Western Australia.

Dr Hyde will describe the problems imposed by thermomolecular forces in the operation of high-sensitivity microbalances, and the relative advantages of operating such instruments at near atmospheric pressure rather than under high-vacuum conditions. He will also describe how controlled reactions are carried out at near atmospheric total pressures with oxygen activities which are equivalent to the partial pressure of oxygen being less than $10^{-14}$ torr.

News Items

The Committee appeals to any member of the A.I.P., and others, interested in the work of the Vacuum Physics Group who may be wishing to join to get in touch with the Honorary Secretary, Dr J. W. Kelly, A.A.E.C. Research Establishment, Private Mail Bag, P.O. Sutherland, N.S.W. 2232, (telephone: Sydney 531 0111), or their local representative. Members of the A.I.P. can simply join the Group by signing a registration form without paying an additional fee, whereas others need first of all to become members or subscribers of the A.I.P. in addition to signing a registration form. All Vacuum Physics Group members are requested to register their name and address with their State Representative.

Mr James Browne, former chairman, presented a paper entitled 'Vacuum Physics' at the 41st ANZAAS Congress, Adelaide, on 19 August.

Mr Peter Cockburn, a member of the Committee
has resigned upon transfer from Dynavac High Vacuum Pty Ltd to the P. H. Phillips group of companies, Queensland. Mr Cockburn is prepared to receive any inquiries regarding the formation of a Vacuum-Physics Group in Queensland. His address: c/- P. H. Phillips Pty Ltd, 458 Brunswick Street, Fortitude Valley, Qld 4006.

Dr W. I. B. Smith, Wills Plasma Physics Department, University of Sydney has joined the Committee.

Mr Bill Cole has relinquished the position of Honorary Treasurer because he now lives in Coffs Harbour, where he has his own vacuum business. The newly elected Honorary Treasurer is the former Technical Manager of Dynavac High Vacuum Pty Ltd. Mr F. Ross Sellenger, Manager, Precision Air Equipment Co., 275a Wontora Road, Blakehurst, N.S.W. 2221.

Technical Information
RC Electrical-Circuit Analogues Applied to Vacuum Systems:

The theory of molecular flow of pure gases in simple vacuum tabulation, similar to that used to describe dc electrical circuits, is common knowledge.

In a recent paper the theory of pulsed molecular-flow networks is extended to include the behaviour of gases in vacuum systems which are not at constant pressure. With the method of breaking the vacuum with a gas mixture flowing through an orifice, the rise in pressure in terms of the electrical analogue of charging a condenser through a non-inductive resistance is given by

\[ P = P_i \left( 1 - \exp \left( -t/\tau \right) \right) \]

where \( P_i \) and \( P \) are the vacuum and external pressures respectively, \( \tau \) is the partial pressure of the component gas, \( t \) is the time, \( V \) is the volume of the chamber, \( M_i \) is the molecular weight of gas in a.m.u., \( K \) is a constant referred to as unit mass resistance which is expressed in seconds per litre, and the summation is taken over values of \( t \) from 1 to \( n \).

Other more complicated pulsed networks have been considered by applying five basic network equations for gas mixtures derived from electrical analogues. Two networks have been used experimentally, one for recording pressure transients by a diaphragm capacitance manometer connected externally to the vacuum chamber and another for gas analysis in which the molecular weight of gas is readily found by measuring the time interval between convenient points on the pressure waveform. The theory might possibly be extended to alternating gas flow, especially for analysis of vacuum filter networks and oscillators.


Vacuum Freeze-Drying For Astronauts' Food

A possible spin-off from the space programme, which is not so obvious, is an improvement to non-refrigerated packaged food. Vacuum freeze-drying, now the key to successful preparation and provisioning of food for astronauts, may be very useful in other areas of food preservation. The process, involving removal of water by sublimation of ice at \(-20^\circ\)C to vapour which is trapped by refrigerated coils at \(-40^\circ\)C, operates in a vacuum chamber at pressures in the range 0.1 to 1 torr. The freeze-dried foods are usually vacuum packed or nitrogen-filled packed in plastic-aluminium foil laminates to prevent oxygen, water vapour, and light causing spoilage. In such containers the light-weight dehydrated products will keep for long periods without refrigerated storage and transport. Precooked, they can be ready instantly by dunking in the requisite amount of hot water. As astronauts’ food they are particularly suitable for space feeding under conditions of weightlessness, and are therefore packaged in flexible pouches that can be kneaded with water from a dispenser before squeezing directly into the astronaut's mouth. Thus cooking, crumbs, and spilling in weightlessness are avoided. Freeze-dried foods can also be pressurized, comminuted, and then encapsulated in an edible coating; they are then most suitable for use in space.

Although the products have many outstanding handling properties, vacuum freeze-drying of some whole foods, like all food preservation processes, reduces palatability—a certain amount of the colour, flavour, and texture can be lost in the process and in storage, and these properties cannot be restored upon reconstitution. Moreover, the products can be less nutritious. Could the solution to this problem be found in medicine? In a review of vacuum freeze-drying, Gheorghiu uses the medical term excipient—a fluid which could provide protective action thereby limiting loss of consistency, colour, and flavour in processing.

Retention of flavour in vacuum freeze-dried foods is at present an important subject of research; it is affected by the vapour pressure of the flavour compound, the volatility relative to that of water, and vacuum and heating conditions during the initial stages of freeze-drying. However, it also has been found that retention can be influenced by interaction of the food components. The addition of certain edible substances (e.g., excipients) to the food can greatly affect the retention of flavour during vacuum freeze-drying.


Surfactants

The attainment of ultimate cleanliness of vacuum systems towards improving vacuum pressures is very important in high-vacuum work. The use of a chemical-concentrate surfactant (surface-active agent) could be the answer to an arduous problem.

Letter to the Editor

Part-Time Work for Married Women

Sir.—As is widely known, it is very difficult for married women, especially those with young children, to get part-time work. A few years ago I worked in an establishment—the Radio and Space Research Station, run by the Science Research Council in England—who made use of married women who had done some University Courses in Mathematics and Physics. They had a scheme whereby a woman was assigned to a professional officer who was very busy and who wanted someone to do calculations or graphs. Often it was purely routine work, but sometimes she was given an interesting problem—depending on her qualifications. The work was done at home and the woman only visited the establishment to receive the problem or when she was stuck. This enabled a qualified woman to keep some interest, even though a small one, in physics.

I wondered if it were practical to set up an agency attached to each State Branch of the Institute of Physics for the purpose of keeping a record of women and perhaps also retired people who wanted to do part-time work, and of their qualifications. Then any establishment that wanted some part-time help of a scientific nature could apply to this agency.

I'd be interested to hear comments on this scheme and to know if there were many people who would appreciate a part-time job in physics.

4 Hedderwick Street, Essendon, Victoria.

Mrs. M. V. Oliphant.

Institute Affairs

FAIP LISTING IN COMMONWEALTH UNIVERSITIES YEARBOOK

The Association of Commonwealth Universities has agreed to include the Fellowship of the Australian Institute of Physics among the non-university qualifications listed after names in the Commonwealth Universities Yearbook, commencing with the 1970 edition. The abbreviation FAIP will be used, without intervening full stops.

The listing of FAIP in the Yearbook is significant not only in itself but also because many Australian universities adopt the Yearbook's practices in compiling their own printed staff lists. Steps are therefore being taken to inform all Australian universities officially of this decision.

It should be noted that the Yearbook will not list Associateship or Graduateship of the Institute, in line with its practice for other institutes.

ANNUAL SUBSCRIPTIONS

Members' 1970 subscription notices will be mailed early in October 1969. Prompt payment by all would be appreciated, but especially by those subscribing to journals.

Members are welcome to pay by banker's order, but are asked to forward journal subscriptions by cheque to the Institute office.

New Rates for Journals

A.J.P. subscriptions have been increased to $2.50 if ordered before 1 January and to $4.00 otherwise. This has been found necessary because of the increased cost of distribution.

J. of Phys B and C, and Rep. Prog. Phys. subscriptions have been increased; the latter will comprise 12 issues, or three bound volumes, and members failing to specify which they require will receive the latter. No special rate for combined subscriptions to J. of Phys A, B, C or A, B, C, D, E is quoted, but may possibly be negotiated on written application.

Other I.P.P.S. and I.E.E. journals are available on special application.

Concessions

The following concessions may be available to certain members on written application:

1. The subscription of an Associate or Graduate member who is a full-time postgraduate student may be reduced to half.

2. The subscription of a member absent from Australia for a continuous period of 12 months or more may be reduced to half. (This concession does not apply in the case of a postgraduate student already paying reduced subscription.)

3. The subscription of a member on National Service may be waived during the period of service.

4. The subscription of a member who has attained the age of 60 years and has been a member for ten or more years (including membership of the I.P.P.S.) may be waived.

Benevolent Fund

The Institute maintains a Benevolent Fund to assist ex-members and their dependants. Although the Fund stands at $2500, income exceeded expenditure by only $50 in the current year. Therefore, it is hoped that the generous donations of the past will not only continue, but that more members will contribute in this way; even the small change in rounding up your payment to the nearest dollar is welcome.

J. K. Mackenzie
Honorary Treasurer.

THE AUSTRALIAN PHYSICIST, SEPTEMBER 1969 137
Notes and News

National Committee for Pure and Applied Physics

The present composition of this Committee is Dr J. S. Dryden (Chairman), Dr R. W. Crompton, Professor H. C. Bolton, Dr A. G. Fenton, Professor N. H. Fletcher, Dr A. F. Nicholson, Professor R. W. Parsons, and R. W. Stanford. Dr W. Boas, Chairman of the National Committee for ten years, has retired from the Committee; he is still however a Vice-President of the International Union. Dr Dryden, who is also a member of the Editorial Committee of The Australian Physicist, will attend, as will Dr Boas, the Thirteenth General Assembly of the International Union of Pure and Applied Physics at Dubrovnik, Yugoslavia, 10–13 September.

Heterojunctions and Layer Structures

A 'Conference on the Physics and Chemistry of Semiconductor Heterojunctions and Layer Structures' will be held at the Hungarian Academy of Sciences, Budapest, 10–17 October 1970. The address of the Organizing Committee is Budapest IV, Ujpest 1, P.O.B. 76, Hungary.

Electrical Contacts

The Fifth International Research Symposium on Electric Contact Phenomena will be held in Munich, 4–8 May 1970. The Symposium is organized by the scientific board of the Verbandes Deutscher Elektrotechniker (VDE), Organisationsbüro ITK, 8 München 19, Wainhausstrasse 4.

Cybernetics Congress

The Sixth International Congress on Cybernetics will be held in Namur, Belgium, 7–11 September 1970. With it will be held the Ordinary General Assembly of the International Association of Cybernetics.

The Secretariat of this Association is at: Palais des Expositions, Place André Rijkmans, Namur, Belgium.

Fourier Spectroscopy

An international conference on Fourier spectroscopy will be held at Aspen, Colorado, 16–20 March 1970. The Secretary is Dr Doran J. Baker, Utah State University, Logan, Utah 84321, U.S.A.

Fellowships

Notice has been received of the following fellowships at universities and research institutes.

Netherlands Government Scholarships 1970/71 (3), for graduates or final year students, 10 months in Holland, approximately $A1500.


Alexander von Humboldt Research Fellowships, postdoctoral, 6 months to 2 years in Federal Republic of Germany, approximately D.M. 1400 per month plus grants for travel and dependants.

Application forms: Embassy, Federal Republic of Germany, Canberra.

Book Reviews


Reviewed by J. L. Griffiths, University of New South Wales.

In the introduction the author states that his aim is primarily to give an account of as many finite difference schemes for the solution of partial differential equations as he can find. The book contains at least 50 such methods. Many of the schemes are well known in English and the author has, as expected, included a large amount of Russian work of his own and of his contemporaries.

The majority of the schemes cover Parabolic (Heat) Laplace and Hyperbolic equations, but work on elasticity, hydrodynamics with a little of the transport equation is included.

The book opens with a large number of definitions on correctness, consistency and stability. This is followed by the list of schemes. It is not until near the end of the book that the reader is able to find any idea of the significance of the definitions.

In a few cases, where the explanation has appeared doubtful to the translator, supplementary notes have been added. The translator has put some of the schemes through an IBM 7044 machine to give some idea of the time, using Fortran and Algol. There are a few misprints and a reader should check programmes before using them.

On the theoretical side, the author says that he is working in arbitrary Banach spaces of functions. It is obvious that this cannot be correct. The nature of the approximation of derivatives by differences is usually not specified. Probably strong convergence is implied. In the final pages the author introduces a notion called weak convergence which is somewhat related to convergence in the L1 norm. In terms of this idea, he is able to relate the original definitions with properties of the solutions of the equations.

The price of this paperback of about 200 pages puts it beyond the reach of students. However, the collection of all the various schemes together in one volume should make it a handy reference to a worker in the field.
Reviewed by C. N. Watson-Munro, University of Sydney.

It is pleasing to see Volume 2 of this treatise on Plasma Physics—which first appeared in French in 1966 as "Physique des Plasmas, Tome 2"—published in English. The book constitutes the second part of a programme Professor Delcroix is giving as a post-graduate course in the Faculties of Science at Paris and Orsay. Volume 1 covered Hydrodynamics and Kinetic Theory—this second volume deals with weakly ionized gases and there is a third volume yet to appear presumably initially in French on completely ionized gases. Volume 2 discusses inelastic collisions, electric field effects in slightly ionized gases, "intermediate" plasmas (defined by Delcroix as plasmas where electron-electron reactions are strong enough to insure electron thermal equilibrium, but the magnitude of T_e is still determined by electron-molecule collisions), diffusion recombination and attachment in weakly ionized gases.

The book is well written, with the theory clearly developed and up-to-date experimental results quoted.

I feel the book should find a place in every physics library and certainly should be used as a text, but not the only text, for a plasma-discharge physics course in these topics.

Reviewed by I. D. Johnston, School of Physics, University of Sydney.

There are many textbooks these days from which the beginner can pick up his elementary quantum mechanics, and therefore the publication of yet another "Basic Quantum Mechanics" will be greeted with less enthusiasm. And this response will be strengthened if anything, when one realizes that there is nothing significantly new contained in the book, nor is any one section done so particularly well as to earn it a place on everybody's reference lists.

As stated in the preface, it is based on a set of lectures given to the equivalent of our third year students, and suffers from exactly those defects which would be expected because of this. For a textbook it lacks completeness, it must be read in conjunction with other books on the subject, and for a general reading book it lacks conciseness. On the credit side the author makes a very real effort to reach the undergraduate at whom he is aiming. In particular, his willingness to write out matrices in full and to use pictorial diagrams to illustrate his points—why is this so rare in this field?—are to be applauded. But, all in all, the book contains no material which is not in hundreds of others, and its presentation is no better—so why buy it?

Reviewed by Robert M. May, University of Sydney.

The scope and style of this monograph cannot be better described than in the words of the author: "The tenuous matter between stars is of interest in several ways. The interstellar material plays a very major part in the evolution of stars and of the Galaxy; groups of new stars are believed to have their birthplace within interstellar clouds, and ejection of matter from old stars, especially from supernovae enriches the interstellar gas in its abundance of heavy elements. In addition, the diverse physical processes which occur in between the stars make interstellar matter research both challenging and fascinating."

Chapter 1 provides an historical introduction, Chapters 2 and 3 summarise the primary observational data. The theory is then developed in Chapters 4-6, where accounts are given of interactions among interstellar particles, the dynamics of the gas, and current notions about the formation of stars.

Like Spitzer's well-known plasma physics monograph, this book is lucid and succinct. It is eminently suited to an honours or post-graduate course in astrophysics.

Reviewed by J. M. Cowley, School of Physics, University of Melbourne.

The author of this book is the head of the Department of Electron Devices at the Warsaw Technical University, a man of considerable experience and many publications who for the last 10 years has had considerable administrative responsibilities. This book is based on lectures on electron optics given over the period of a decade to students of roughly degree standard to introduce them to the basic theory and practical procedures "for calculating and designing the electron-optical systems for electronic valves and other vacuum devices". It is clearly the work of a careful and thorough teacher, but one suspects strongly that the decade of the lectures was that preceding the first Polish edition of the book, published in 1960, rather than the 1968 edition which is the one translated into English.

Apart from the fact that very few of the many references are to publications after 1960 (and those mostly in Polish), the whole concept of the book is somewhat dated. It ignores, for example, the great move towards precision in electron optics. There are many useful graphs for deriving focal lengths of lenses but lens aberrations are dismissed very briefly. The use of digital computers is not mentioned but crude analogue devices are treated in detail.

THE AUSTRALIAN PHYSICIST, SEPTEMBER 1969 139
Within these limitations, it is a good, well presented, carefully developed account of the movement of electrons in electric and magnetic fields and the basis of electron-optical design for simple lenses and related devices, with none of the distractions that would result from reference to modern instruments.

Reviewed by D. B. Pike, School of Electrical Engineering, University of Sydney.

This is an extremely formal work dealing with rather elementary results of network analysis by means of abstract mathematics.

Five chapters develop the mathematics through detailed attention to graph theory and one-dimensional algebraic topology, with a brief review of linear algebra. The sixth chapter enunciates Ohm's law and Kirchhoff's current and voltage laws in consistency of abstract form. The remaining two chapters accomplish the solution for branch currents of resistor networks under excitation completely from voltage sources or completely from current sources.

The results do not extend to the area of real usefulness to the electrical engineer, viz. to networks with inductors and capacitors added to the resistors, or to such networks with the further addition of active elements. The author acknowledges that such extension would involve a prohibitive amount of space and effort.

For this reason the book is of no use to the practising engineer and will appeal to very few research engineers interested in circuit theory. The book will make its mark only upon the library shelf, being essentially a mathematical exercise carried out by the author.

Reviewed by W. H. Steel, National Standards Laboratory, Sydney.

This book is written for electrical engineers who are familiar with the mathematical tools of Fourier analysis and the theory of linear systems, but not with the principles of classical optics. It therefore uses fairly advanced mathematics to present simple optics in the way most useful to people entering it as a new field. The level aimed at is that of a graduate course, and well-chosen problems are given in each chapter.

After an introduction outlining the ties between optics and communication theory, the author covers Fourier analysis (in two dimensions, as used in optics) and linear systems, and treats scalar diffraction very thoroughly. Next are given the Fourier-transforming and imaging properties of lenses; it is most instructive for one brought up on classical optics to see how these are derived from a more sophisticated approach. A treatment of the frequency analysis of coherent and incoherent optical systems follows, and then two chapters on the important fields of modern optics: optical image processing and holography.

Even with the current spate of books on this type of optics, this book is outstanding. The treatment is not oversimplified but explanations are so clear that quite complex theory is made almost obvious. It is the first book with a really satisfactory treatment of holography, although this could perhaps have been tied more closely to the results in the preceding chapter. The account of super-resolution by analytic continuation is perhaps rather optimistic in view of present practical experience. The only mistakes noticed were trivial and the references given are comprehensive, though somewhat biased towards work in the United States.

This book is not only of interest to those for whom it has been specifically written; it is most valuable for anyone working in modern optics, whether they have been classically trained or not. The production is very good and the style of writing outstanding.

Reviewed by D. A. Smith, Physics Department, Monash University.

In recent years it has become fashionable to amalgamate textbooks on thermodynamics and statistical mechanics under the blanket title 'Statistical Physics'. The motives for doing this are not clear; one suspects that apart from the pedagogical value of a modern unified treatment the new crop of textbooks arises as a compromise between the proponents of classical thermodynamics and those who find no place for it in the current university syllabus.

In this case the title is slightly misleading, as Professor Brown's book contains much more straight statistics than one might expect. The main aim is to use the elementary theory of probability for an exposition of the Boltzmann distribution and all that that implies. In fact, a lot of water flows under the bridge before this point is reached—a sound orthodox summary of the kinetic theory of gases and transport in gases, elementary probability, and a long section on the statistics of free paths. By the time Chapter 5 is reached the derivation of the Maxwell-Boltzmann distribution appears to be carried out in a particularly heavy-handed fashion, and it is disappointing to see that so little use is made of it thereafter.

All in all, this is a rather disconnected little book and one not likely to appeal to those looking for a short textbook on the Boltzmann distribution, entropy, etc. However, it ought to prove a useful collation of ideas on various disparate subjects; the section on probability is very well written, and there is an excellent chapter at the end on rate processes. The author has obviously kept the needs of the student in mind.
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