WA8. Preparation of Junctions in Single Crystals by Surface Melting. K. LEHOVEC AND E. BELMONT, *Sprague Electric Company.*—Present methods of producing $p-n$ junctions in single crystals are based on the pulling of a single crystal from a melt. It is a drawback of these methods, as applied to the production of multiple junctions, that time enters as a parameter determining the width of the junction. In the following method the time is not a critical factor. The surface zone of a single crystal slice is melted by radiation while the bottom is cooled. The position of the interface between melted zone and solid zone is a function of (a) rate of heating from the surface, (b) rate of cooling from the bottom, and (c) geometry. The position of the interface can be shifted arbitrarily by changing (a) and/or (b). If the position of the interface is shifted slowly toward the top, the melt solidifies as a single crystal of same orientation as the bottom part. Impurities can be introduced at any given moment into the melted zone. In this manner $p-n$ junctions in germanium have been prepared with electric properties comparable to those in pulled crystals. $p-n$ junctions have been prepared also by melting a slice of p type crystal on a slice of n type crystal (or *vice versa*).

WA9. Some Electrical Properties of Elementary Boron.* L. W. FRIEDRICH AND V. P. JACOBSMEYER, *St. Louis University.*—Samples of pure elementary boron were prepared by pyrolysis of diborane at deposition temperatures ranging from 700°C to 1500°C. Those deposited at approximately 1000°C and at 1500°C showed best crystallinity. These also exhibited the most different values of resistivity; that of the 1500°C sample was about 10^6 ohm cm at room temperature, and that of the 1000°C sample was about 0.1 ohm cm. The activation energy of the 1500°C sample for apparently intrinsic conduction was 1.12 ev. Irradiation for 16 hours with Cu $K\alpha$ x-rays permanently increased the resistivity of the boron samples in a manner indicating that electrons, freed in the ionization by x-rays of donor type impurity centers, and combined with positive holes in the valence band of the boron to reduce the carrier concentration. The magnetoresistance of one sample was found to vary approximately as the fourth power of the magnetic field intensity.

* Research carried out under contract with U. S. Office of Ordnance Research.

WA10. Lattice Absorption in Diamond: A One-Dimensional Model. MELVIN LAX, *Syracuse University,* AND ELI BURSTEIN, *Naval Research Laboratory.*—The lattice absorption in diamond, silicon, or germanium can possibly be explained on the basis of a second order electric dipole moment, i.e., a moment quadratic in the displacements. To determine quickly the qualitative consequences of such an explanation, a calculation was performed on a one-dimensional lattice with some of the symmetry properties of diamond: two atoms per unit cell with a center of symmetry halfway between these atoms. Using these symmetry properties it was possible to reduce drastically the number of independent coefficients in the quadratic form. If interactions are neglected beyond second neighbors, only one coefficient remains, and the *form* of the absorption spectrum is determined. The vibrational transition involves two phonons, either of which may be created or destroyed. At temperatures well below the Debye temperature, only creation is possible. One of these phonons must be acoustical, and the other optical: speaking classically, an electric moment is produced only when an optical and acoustical vibration are simultaneously present. Furthermore, the momentum of the photon may be neglected, so that these phonons must have equal and opposite momentum. Finally, the short wavelength phonons are found to make the principal contribution. We expect that most of these qualitative conclusions will be borne out in a three-dimensional calculation.

SATURDAY AFTERNOON AT 2:00

NBS, Materials and Testing

(W. W. WATSON presiding)

General Physics; Biophysics

X1. Noise in Storage Tubes. STANLEY WINKLER AND SEYMOUR NOZICK, *U. S. Naval Material Laboratory.*—The performance of storage tubes is evaluated by their ability to accurately reproduce a given input signal, the maximum writing speed, the quantity of information which can be stored, the accessibility of stored data and factors related to efficiency of operation. All of these are affected by noise, and the importance of noise is accentuated by the low signal levels encountered at the output of storage tubes. Noise is defined as the undesired signal which constitutes the difference between the output of and the input to a storage tube. This noise is divided into random noise and transfer effect. Random noise is incoherent information and is similar to noise encountered in any electron tube device. The transfer effect is the regular functional distortion which is characteristic of individual storage tubes and is erroneous information coherent with the desired signal. A transfer function is defined as the operator which transforms the input signal into the output signal (excluding random noise). The sources of random noise and the transfer effect and their relative importance are discussed in detail. A definition of a noise figure for storage tubes is attempted. The results of preliminary measurements on experimental storage tubes are given.

X2. A High Accuracy, High Speed Shaft Position Digitalizer. DONALD H. JACOBS, MILTON E. PUGH, AND SEYMOUR SCHOLNICK, *The Jacobs Instrument Company.*—A previous paper[1] described a device for determining, in digital terms, the angular position of a shaft relative to a selected reference point. This digital value of shaft position could be recorded, or employed as the input to a digital computer. That digital converter could make readings to a high order of accuracy at low speed or to a lower order of accuracy at high speed. Recently a requirement for a device to give high accuracy at high speed has arisen, and the device described was conceived. This also uses a counting technique to determine the value of the unknown angle. However, instead of giving one determination of the angle for each rotation of the search probe, this device permits the measurement to be made during a very small angular motion of the search probe. Hence it is now possible to make a measurement of angle in less than 0.1 millisecond without the use of high speeds for the probe.

[1] D. H. Jacobs and S. Scholnick, Phys. Rev. **85**, 731 (1952).

X3. The Information Content of Living Systems. HAROLD J. MOROWITZ, *National Bureau of Standards.*—The living cell is an efficient unit for storing a large quantity of information in a small volume. The ability of many cells to survive temperatures near absolute zero indicates that the information is stored exclusively in the molecular structure, the cells information storage being analogous to a punch card rather than electronic memory. Since many cells are able to survive almost complete drying it may be assumed that the cellular water is not a part of the information unit. The residual unit for bacterial cells has a mass of the order of 10^{-13} gram ($\sim 10^{10}$ atoms) and is composed largely of protein and nucleoprotein. From these data it is possible to make preliminary calculations of the information content of a bacterial cell.

X4. Improved Equilibrium Ultracentrifuge.* A. ROBESON,† N. SNIDOW, AND J. W. BEAMS, *University of Virginia.*—A 7.5-in. diameter ultracentrifuge rotor is magnetically suspended in a vacuum chamber (pressure 10^{-6} mm Hg) and driven to operating speed by an air turbine below the chamber. The turbine is connected to the rotor with a thin flexible shaft which passes through a vacuum tight gland and which is disengaged from the rotor at operating speed. The rotor coasts freely during the observations and loses less than 1 rps per day. The concentration across the ultracentrifuge cell is determined by the refractive index measured by an interferometer arrangement which employs both white light and monochromatic fringes. A shift of 0.05 fringe is measurable. When desired, the rotor speed may be held constant without observable heating by driving it in a manner similar to that of the rotor of a synchronous motor with piezoelectrically controlled circuits. The rotor speed may be measured to one part in 10^6 and the rotor temperature maintained constant to 0.01°C. The apparatus is especially adaptable to molecular weight determinations in the range from 300 to 10 000.

* Supported by Navy Bureau of Ordnance.
† U. S. Rubber Company, Fellow.

X5. A Series Method for the Comparison of Resistances. HAROLD J. HOGE, *Leeds and Northrup Company.*—A method of comparing resistances is described in which two sources of emf, each with an associated dropping resistor, are connected in series with two resistors to be compared in such a way that the latter are not adjacent. The circuit may then be adjusted so that the potentials at the two ends of one of these resistances are equal to the potentials at the corresponding ends of the other resistance, while both carry the same current. Convenient means of detecting and adjusting to this condition are described. The circuit may be used as an alternative to either the dc or the ac bridge. The method is suitable for work of either high or low accuracy. Its chief advantage over methods now in use is that it permits the continuous observation or recording of resistance without error due to uncontrolled changes in the resistances of the connecting leads. Readings are obtained directly, without the necessity of averaging or otherwise mathematically combining the results of more than one observation. If desired, more than two resistances to be compared may be included in the circuit, provided they are alternated with an equal number of emfs and associated dropping resistors.

X6. Very High Resistance Measurement. FRANK J. LYNCH AND CLARENCE L. WESENBERG, *Argonne National Laboratory.*—An instrument for the accurate measurement of resistance in the range of 10^9 to 10^{13} ohms is described. A constant current flows through the resistor under test, and the potential drop across it is measured with an electrometer. The constant current is the displacement current flowing into the plates of a standard condenser when the potential difference between the plates changes linearly with time. The potential drop across the resistor is measured by a recording dynamic condenser electrometer. The accuracy of the resistance measurement is dependent only upon the accuracy of wire-wound potential dividers and the dimensions of the standard condenser. The present accuracy is ± 0.25 percent, but better accuracy may be achieved. The time of measurement for this accuracy is about $6\,R\cdot 10^{-11}$ second.

X7. The Subject of Social Physics. JOHN Q. STEWART, *Princeton University.*—A minimum definition restricts social physics to consideration of the social role of such physical and measurable factors as time, distance, mass of material, availability of energy, and the numbers of people—analyses of data being conducted in ways that have succeeded in physics. Empirical regularities are stressed for which mathematical expressions exist. Many important results can be cited, but their significance is for sociology more than physics. However, it is proving advantageous to center maximum rather than minimum emphasis on physics—as the best universal model of advanced pure thought from which (in Leibnizian manner) conceptual patterns are deducible for subjects of widely different content. These isomorphisms stimulate in their turn re-examination of all the most general principles of physics itself. Such studies tend to re-establish physics as the "natural philosophy" which uniformitarian natural-law thinking represented it to be, before specialization enlarged the technological applicability of physics while deforming its cultural leadership. For example, Hegel's misnamed "thesis-antithesis-synthesis" pattern for describing progression seems allied to Henry's rule for electromagnetic induction; and the sharpened attention is so directed to the localization and progressive movement of energy finds that these characteristics have not yet been completely described in physics.

X8. The Inactivation of Desoxyribonucleic Acid by Bombardment with Deuterons and Electrons.* CYRIL L. SMITH, *Yale University.*—Commercially obtainable highly polymerized desoxyribonucleic acid (D.N.A.) was evaporated from solution on to glass cover slips and then bombarded with deuterons of maximum energy 3.7 Mev produced by the Yale cyclotron. The D.N.A. is assayed after placing the cover slips in a measured quantity of distilled water, by measuring the change in absorption of the solution at 2700A when it is depolymerized by means of desoxyribonuclease (D.N.A'ase). The activity-dose curve is logarithmic. Similar cover slips were also inactivated by electrons of 2 Mev energy produced by the Van de Graaff generator at the Brookhaven National Laboratory. The activity-dose curve is again logarithmic. From the slopes of these two curves a cross-sectional area and volume may, respectively, be calculated. These dimensions can be shown to give the maximum size of the average unit into which the D.N.A. is broken down by the D.N.A'ase. The cross-sectional area and volume, so calculated, are found to be $600A^2$ and $2500A^3$, and the molecular weight of the unit is therefore approximately 2400. This corresponds to the molecular weight of 7 or 8 nucleotides. It may be significant that Astbury has shown that there are x-ray reflections from D.N.A. corresponding to a repeat distance every 8 nucleotides.

* Supported by the U. S. Atomic Energy Commission.

X9. The Inactivation of Bovine Serum Albumin with Low Voltage Electrons. FRANKLIN HUTCHINSON AND BARBARA DOYLE, *Yale University.**—Monomolecular layers of bovine serum albumin (BSA) adsorbed on an evaporated chronium film were irradiated with electrons with energies ranging between 1 ev and several hundred ev. The biological activity of the BSA after irradiation was determined by measuring its ability to combine specifically with the homologous antibody. For one-volt electrons, no inactivation was observed with 10^{16} electrons/cm², but at 3 ev, inactivation was pronounced at about 10^{15} electrons/cm². Calculations indicate that the maximum temperature rise due to the electron bombardment was less than 1°C, so that the inactivation could not be thermal

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Low Temperature Diamagnetism of Electrons in a Cylinder*

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(Received January 19, 1953)

The exact eigenfunctions are found for an electron in a cylindrical container in the presence of a uniform axial magnetic field. The eigenvalue spectrum, while superficially similar to that in free space, is so essentially different that the statistical properties of an electron assembly in the cylinder are entirely different from those derived in previous work. It is therefore of interest to use an integration approximation in computing the energy of the assembly at 0°K. It turns out to have a very strong size-dependent paramagnetic term, and the reasons for this are carefully explained. The work lends support to the view that the observed diamagnetism of electrons in the superconducting state cannot be understood in terms of any free-electron approximation, and that interactions with the lattice potential play an essential role.

INTRODUCTION

PREVIOUS work on the quantum-mechanical properties of electrons in a magnetic field has been characterized by a wide variety of conflicting results. Recently in two important papers Osborne and Steele[1] have shown how very carefully one has to handle the statistics in order to avoid some of these conflicts. However their work, and apparently much previous work, has treated the boundary value problem of fitting the eigenfunctions to the walls of the container by the WKB method, and the concept of localized reflected electron orbits is basic to the work.†

The present paper derives from the idea that this concept of reflected localized orbits may be inapplicable to the low temperatures pertaining in superconductivity work. The fuzziness of the Fermi surface in wave-number space, representing the possible uncertainty in the momentum of any particular electron, is too sharp to provide localized wave groups in ordinary space for the conducting electrons: the uncertainty in position is necessarily at least of the order 10^{-5} cm. Especially for small cylinders it would therefore be quite unsafe to picture an electron as a particle capable of being reflected in a definite orbit.

In itself, this is not a serious objection to the WKB approximation. At least for one-dimensional problems, the WKB approximation necessarily becomes equivalent to an exact solution for large quantum numbers, and does not depend on the particle being localized in (one-dimensional) space. In three dimensions the situation is somewhat different. One first separates the variables and then applies the WKB method to each variable separately if the equation does not solve exactly. For a cylindrical box one knows the angular-momentum quantum-number spectrum exactly, and the axial or longitudinal quantum numbers are usually obtained by using periodic boundary conditions at the ends. The WKB method is used only on the radial equation. The radial equation does not have the proper boundary conditions for a rigorous application of the WKB method and one always has to add a fictitious potential $1/4r^2$ to modify the singularity at the center of the cylinder, before a proper path can be set up over which the wave number can be integrated between $r=0$ and $r=a$. The order of magnitude of this fictitious term must be small compared with any significant term except over a small circle round the origin whose radius is negligible compared with that of the cylinder. The method works well for the H atom problem in spherical coordinates because the fictitious term does no more than modify the centrifugal term, effectively changing the angular-momentum quantum number from an integer to half an odd integer. Because this quantum number does not occur in any other term, this modi-

* This paper constitutes a technical report of work done under contract with the U. S. Office of Naval Research.

[1] M. F. M. Osborne, Phys. Rev. **88**, 438 (1952); M. C. Steele, Phys. Rev. **88**, 451 (1952).
† *Note added in proof:*—R. B. Dingle, Proc. Roy. Soc. (London) **A216**, 118 (1953), used the WKB method and obtained different results again from Osborne and Steele.