Technical Papers by IBM Authors Published Recently in Other Journals

Accuracy and Rounding Data, Part I, I. Belson, *Evaluation Engineering* **3,** No. 4, 29-30 (July/August 1964).

This article discusses the roundoff method in handling data and the errors that accrue if the method is used sloppily. Examples point out how errors can be quite large if attention is not directed toward the reduction of data to its final form.

Acoustoelectric Effect of Microwave Phonons in GaAs, M. Pomerantz and J. R. A. Beale,* *Physical Review Letters* **13,** No. 6, 198-200 (August 10, 1964).

An acoustoelectric current induced by a 9-Gc/sec acoustic wave has been observed in GaAs. The dependence of the current on acoustic power, illumination level and temperature has been measured and is in fair agreement with theory. These are the first reported measurements of acoustoelectric currents produced by microwave phonons.

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Activation Energies for Diffusion and for the Zener Relaxation in Dilute Solid Solutions, D. P. Seraphim, A. S. Nowick and B. S. Berry, *Acta Metallurgica* **12,** No. 8, 891 (August, 1964).

The problem of the discrepancy between the activation energies for diffusion and the activation energy for the Zener relaxation in substitutional solid solutions is examined for the case of dilute alloys. Using single crystals of αAg-Zn alloys it has been possible to obtain (by extrapolation) a value $Q_r = 39.0$ kcal/mole for the activation energy for relaxation in alloys approaching infinite dilution. This value is distinctly below the activation energies for diffusion of Zn and of Ag into pure silver. The interpretation of these three activation energies and the reasons why they differ are much more apparent for the dilute alloys than for the concentrated alloys previously studied. Specifically, Q_r is the activation energy involved in the reorientation of a Zn-Zn pair, while the tracer measurements relate to the jump of isolated Zn and Ag atoms, respectively.

The orientation dependence of the relaxation time in single crystals of the 26 at. % Zn alloy was also measured. The results show that the relaxation time is very nearly independent of orientation.

Adiabatic Theory of the Electron-Phonon Interaction, T. R. Koehler and R. K. Nesbet, *The Physical Review* **135,** A638-A639 (August 3, 1964).

Second-order corrections to the electronic energy due to the electron-phonon interaction have been obtained by several authors using the formalism of the adiabatic theory. Their result differs from the commonly accepted expression first given by Fröhlich in 1950. It will be demonstrated in the present paper that terms were omitted in the adiabatic theories which reconcile the two results. In addition, a comparison will be made between this paper and a recent paper along similar lines by Englman.

Advances in Ferrites, Part II, Bernard Schwartz, *Semiconductor Products and Solid State Technology,* No. 7, 26-29 (July, 1964).

The applications of ferrites are traced historically from their first recorded application in 600 B.C. to the present. The dramatic increase in production and application during the past ten years is discussed, including the use of "square loop" ferrites in computer systems and "high frequency" ferrites in linear applications. A description of improved fabrication technology, with a resultant higher quality and lower cost, suggests a continued growth in this field.

Amplification of Microwave Phonons in Germanium, M. Pomerantz, *Physical Review Letters* **13,** No. 9, 308-310 (August 31, 1964).

We report the results of some theoretical calculations and experiments on the interaction between an electronic current and a hypersonic wave at a frequency of 9 Gc/sec in germanium. The theory predicts that amplification of the acoustic waves should be possible and we have experimentally observed this amplification in the presence of suitable drift currents.

Analysis and Synthesis of Communication Networks, R. T. Chien, R. E. Gomory and T. C. Hu, *IEEE Transactions on Circuit Theory* **CT-11,** No. 1, 19-22 (March, 1964).

This paper surveys that part of the theory of communication nets that is related to network flow theory.

Analytical Hartree-Fock Functions, IV. Isoelectronic Series for 31 to 36 Electrons and Conclusions, E. Clementi, *Journal of Chemical Physics* **41,** No. 2, 303-315 (July 15, 1964).

The Hartree-Fock functions have been obtained in the Roothaan-Hartree-Fock approximation for the neutral, first positive and first negative ions of the elements Ga, Ge, As, Se, Br and Kr. The ground and the excited states of the ground state configuration are reported. With this paper, we have completed the analysis of the first third of the periodic system in the Roothaan-Hartree-Fock approximation. The experience gained in this work was used in analyzing the major obstacles which lie ahead in order to complete the analysis to the remaining elements of this periodic system. The major obstacles are i) in the treatment of the relativistic energy, ii) in the construction of a "control program" which will supervise the use of a relativistic Hartree-Fock program, and iii) in the programmation of a relativistic Hartree-Fock program which combines speed and accuracy.

Analytical Self-Consistent Field Functions, III. Isoelectronic Series with 19 to 30 Electrons, E. Clementi, *The Journal of Chemical Physics* **41,** No. 2, 295-302 (July 15, 1964).

The ground-state Hartree-Fock wavefunctions are reported for the K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, and Zn atoms. The basis sets have fully optimized orbital exponents, and each function satisfies accurately the virial theorem. The basis set consists of 11 exponential functions of s symmetry, 6 exponential functions of d symmetry. With basis sets of the same size, the positive ions isolectronic series have been computed up to $Z = 30$. For the positive ions only the essential features of the computation are reported.

Anelastic and Dielectric Relaxation Due to Impurity-Vacancy Complexes in NaCl Crystals, R. W. Dreyfus and R. B. Laibowitz,* *The Physical Review* **135,** A1413-A1422 (August 31, 1964).

Appreciable pairing of divalent metallic impurities with Na^+ vacancies occurs in NaCl below 300°C. The reorientation of such pairs or complexes had previously been observed under an applied electric field. In the present work stress-induced reorientation of pairs in NaCl doped with $CaCl_2$ and $MnCl_2$ has been studied by means of internal friction measurements. An internal friction peak attributed to pair reorientation under stress was observed near 100°C for a vibration frequency of ~10 kc/sec. Data obtained for longitudinal stress along both the <100> and <111> crystal directions yields information about the rates of relaxation corresponding to various mechanical relaxational modes. The data can be interpreted consistently in terms of an extension of the theory previously applied to dielectric relaxation, according to which the paired vacancy occupies only nearest neighbor (n.n.) and next-nearest neighbor (n.n.n.) sites to the impurity. Relations obtained between the relaxation rates and the various possible jump rates for a Na^+ ion into the vacancy enabled each of the specific vacancy jump rates to be determined. It is concluded that the most rapid means for the reorientation of an impurity-vacancy pair between two n.n. sites is for the vacancy to move via a n.n.n. site. The rate of jump of the impurity ion into the vacancy is found to be a relatively slow process.

* Cornell University.

Anisotropic Spin-Wave Thermal Conductivity in Ferromagnets, S. H. Charap, *Physical Review Letters* **13,** No. 7, 237-239 (August 17, 1964).

It is shown that the magnetic dipolar coupling has the effect of favoring heat transport by magnons in directions perpendicular to the magnetization. Calculations made for the europium chalcogenides indicate that they are favorable materials in which to observe this phenomenon.

Atomic Dipole Polarizabilities from the Uncoupled Hartree-Fock Approximation, M. Yoshimine and R. P. Hurst,* *The Physical Review* **135,** A612-A617 (August 3, 1964).

Electric dipole polarizabilities are computed for a large number of 2-, 3-, 4-, 10-, 11-, 12-, 18-, 19-, and 20-electron atoms and ions. These results are all obtained within the framework of the uncoupled Hartree-Fock approximation. All calculations are made using analytical Hartree-Fock wave functions. For the lighter atoms and positive ions the results of these calculations are in fairly good agreement with the experimental and other more accurate theoretical values. However, for the heavier atoms and ions the results are too large. It is also found that great care must be exerted in selecting self-consistent functions for use in making polarizability calculations.

* State University of New York at Buffalo.

Atomic Negative Ions: The Iron Series, Enrico Clementi, *The Physical Review* **135,** A980-A984 (August 17, 1964).

Results of the Hartree-Fock calculations on the ground state for the ions $K^-(^1S)$, $Sc^-(^3F)$, $Ti^-(^4F)$, $V^-(^5D)$, $Cr^-(^6S)$, $Mn^-(^5D)$, $Fe^-(^4F)$, $Co^-(^3F)$, $Ni^-(^2D)$, and $Cu^-(^1S)$ are reported. By first-order perturbation calculation on the Hartree-Fock functions, the relativistic energy has been computed. The relativistic and the Hartree-Fock energies now available, and the correlation energy of the corresponding neutral atoms, previously obtained, make it feasible to obtain accurate estimates of the electron affinities for the above series of negative ions. These are 0.92, —0.14, 0.40, 0.94, 0.98, —1.07, 0.58, 0.94, 1.28, 1.80 eV for K^-, Sc^-, Ti^-, V^-, Cr^-, Mn^-, Fe^-, Co^-, Ni^-, and Cu^-, respectively, for the states above indicated. The uncertainty on the above data is estimated to be from 0.1 to 0.35 eV.

A Characterization of Comparability Graphs and of Interval Graphs, P. C. Gilmore and A. J. Hoffman, *Canadian Journal of Mathematics* **16,** No. 3, 539-548 (1964).

Necessary and sufficient conditions are given for an undirected graph to have the property that its edges may be so directed in order that the directed graph be isomorphic to a partially ordered set. Also, necessary and sufficient conditions are given for an undirected graph to be isomorphic to intervals of an ordered set, with vertices corresponding to intervals, and adjacent vertices corresponding to overlapping intervals. For each problem, an algorithm is given for constructing the isomorphism, or discovering that the given conditions are not satisfied.

Charge Model of Fast Transistors and the Measurement of Charge Parameters by High Resolution Electronic Integrator, Cornel L. Hegedus, *Solid State Design* **5,** No. 8, 23-36 (August, 1964).

This article introduces a new measuring circuit and an electronic integration system for low-level fast signals, by which the charge model of fast transistors is developed experimentally. The high resolution of the integration system provides the means to characterize fast transistors by both extrinsic and intrinsic charge parameters.

The measurement of the intrinsic charge parameter (the base charge) cannot be measured directly by any other method known to date because of its extremely small size. The definitions of the charge parameters introduced in this article are selected in such a manner that they are equally valuable to the device and to the circuit designer.

A Cluster Expansion for the Electrical Conductance of Solutions, H. L. Friedman, *Physica* **30,** No. 3, 509-536 (1964).

The starting point for this theory is a Kubo-type expression for the conductance of a mixture of ions and non-ionic solvent molecules. Cluster methods from equilibrium theory are applied to convert this expression into a series expansion

of the conductance in powers of the solute concentrations. The coefficients in the expansion are themselves concentration-dependent cluster integrals in which the cluster functions are determined by the solvent-averaged distributions and solvent-averaged motions of the solute particles in the solution at equilibrium. The solvent-averaged motion of the solute particles is not Markoffian.

The derivation includes a chain-sum step like that in equilibrium theory to overcome the tendency of the cluster integrals to diverge because of the long range of the Coulomb and hydrodynamic forces among the solute particles in the solvent.

Computer Automated X-ray Stress Analysis, G. Koves and C. Y. Ho, *Norelco Reporter* **11,** No. 3, 99-102 (July/September 1964).

An x-ray diffraction stress analysis procedure capable of measuring and evaluating macroscopic and microscopic internal stresses is discussed. Both the measuring and the evaluating processes are automated to a high degree. The measuring method utilizes automatic step scanning and direct punched card data output. The evaluation procedure is completely computerized including data correction, curve approximation by Fourier harmonic analysis, and stress calculation. The result is a combination of high speed and accuracy.

Concentration-Dependent Electron Spin Resonance, Gerald Burns, *The Physical Review* **135,** A479-A481 (July 20, 1964).

A number of workers have studied the decrease of the intensity of a nuclear magnetic resonance (NMR) line as one adds impurities to the specimen. Usually the intensity of the lines is $\propto (1 - c)^n$, where $c =$ the concentration of the impurities and n is the so-called wipe-out number, i.e., if the impurity is within a sphere containing n neighboring positions its effect is large enough so as to cause a nuclear quadrupole splitting of the host nuclei so that they no longer contribute to the NMR line. Experimentally one can determine n. The extension of this type of experiment into the domain of electron spin resonance (ESR), in a very simple way, is described. Also, the wipe-out number for Mn^{2+} in two systems $(Zn_{1-c} + Cd_c)S$ and $Zn(S_{1-c} + Se_c)$, is measured. One finds $n = 157$ and 270, respectively.

The Concept Library: Containing the Information Explosion, Robert B. Miller, *1964 IEEE International Convention Record,* Part 10, 74-82 (August, 1964).

The increasing pressures for interdisciplinary knowledge in innovation and in technical and managerial decisions cannot be met by traditional practices in education and library service. Frequently it is sufficient to know the central working concepts and principles in a new field of science, technology or management for the development of hypotheses, the making (or withholding) of project evaluations, or for instigating literature searches in unfamiliar domains. Using insight, many technical topics can be abstracted into less than a dozen major principles, variables and working ideas. With further care and insight, a defining concept or principle can be communicated to the educated layman by test and diagram in a single page. Each page has bibliographic and index terms for more detailed reference. Many individual pages may be recombined into different sequences for different needs and contexts. A library of thousands of such pages covering many technologies can be envisioned. Aside from snap briefings in new fields, or as quick review of once-learned knowledge, such a file of concepts could be made to serve as a dynamic link between the information dissemination and retrieval functions of an organizational library and the teaching functions of the educational facilities.

The Deflection of Turbulent Jets Between Bounding Walls, J. B. Alblas* and H. G. Cohen, *Proc. of Koninkl. Nederl. Akademie Van Wetenschappen, Amsterdam, Series B* **67,** No. 3, 258-288 (1964).

The behavior of a turbulent jet between bounding but not contacting walls is investigated as a hydrodynamic model for one stage of the flow in a fluid jet amplifier. For the steady flow, by means of free jet mixing theory, the entrainment in the bounded regions exterior to the jet is determined. A formula for the Coanda effect that exhibits the mixing properties is developed. This steady flow is then perturbed by the application of pressure differentials across the jet. The deflection of the jet is determined as a function of the applied pressures, the wall angle, and other flow parameters.

* Technological University, Eindhoven.

Diffusion Mechanism of Zn in GaAs and GaP Based on Isoconcentration Diffusion Experiments,† L. L. Chang and G. L. Pearson,* *Journal of Applied Physics* **35,** No. 6, 1960-1965 (June, 1964).

Precise relationships between the diffusion coefficient D and the zinc concentration C are obtained from isoconcentration diffusion experiments performed at 900°C for zinc in GaAs and at 1000°C for zinc in GaP. It is found that D varies with C from a slightly less than cubic to a somewhat less than square dependence over the concentration range 10^{18} to 10^{20} cm^{-3}.

Possible mechanisms that result in concentration dependent diffusion are discussed. Under the conditions given above, it is concluded that diffusion occurs by an interstitial-substitutional mechanism with the interstitial mode being dominant. The charge states of the various species involved in the diffusion are believed to be: (1) interstitial zinc atoms are doubly ionized donors; (2) substitutional zinc atoms are either neutral or singly ionized acceptors; and (3) gallium vacancies are neutral. A theoretical expression for D versus C, derived under these assumptions, fits the isoconcentration diffusion data over wide ranges of D and C through the use of only one adjustable parameter.

† Work performed at Stanford University.
* Stanford Electronics Laboratory, Stanford University.

Doping of Alkaline Earth Halide Single Crystals, P. F. Weller and J. E. Scardefield, *Journal of The Electrochemical Society* **3,** No. 8, 1009 (August, 1964).

Single crystals of rare earth doped CaF_2, SrF_2, BaF_2 and $SrCl_2$ have been grown by a Bridgman-Stockbarger technique. The major growth problem of oxide contamination was eliminated by using a "scavenger" such as PbF_2. Consideration of the standard oxidation potentials involved, however, has shown that Pb^{+2} also acts as an effective oxidizing agent and oxidizes divalent rare earths, and rare earth metal to the trivalent state and uranium metal to the +4 oxidation state. Consequently, divalent rare earth and U^{+3} doping can only be obtained in the absence of Pb^{+2}.

Dynamics of Tape Whirling in a Narrow Annulus, W. E. Langlois, *Industrial Mathematics* **23,** 334A-336A, (September, 1964).

A flexible tape, one end of which is attached to a rotating drum, is considered to whirl within the confines of a small annular gap. The governing equations are derived and used to determine the steady-state profile of a tape whirling in vacuum, but subject to frictional drag on the boundaries of the annulus. Solution of the problem involves the use of singular perturbation techniques.

Effect of Electron Concentration on Magnetic Exchange Interactions in Rare Earth Chalcogenides, F. Holtzberg, T. R. McGuire, S. Methfessel and J. C. Suits, *Physical Review Letters* **13,** No. 1, 18-21 (July 6, 1964).

In the solid solution system between the insulating ferromagnets EuSe, EuS and the metallic antiferromagnets GdSe, GdS, it is possible to investigate the relationship of magnetic Curie temperature and electrical conductivity, as the conductivity varies twelve orders of magnitude without change of the NaCl-type crystal structure. The *n*-type semiconductive samples with small free carrier concentration are ferromagnetic with a magnetic Curie temperature increasing proportional to the free electron concentration. In the region of samples with metallic type electrical conductivity a change from ferromagnetic to antiferromagnetic order takes place when the free electron concentration becomes larger than about 0.6 free electrons per rare earth ion, which is in agreement with theoretical predictions for the case of indirect magnetic interactions via conduction electrons in the 5*d*-levels of the Eu ions.

Effective Information-Searching Strategies Without "Perfect" Indexing, R. J. Tritschler, *American Documentation* **15,** No. 3, 179-184 (July, 1964).

Computer searching of an information file offers significant advantages over manual searching when it can utilize strategies that are impractical for a human searcher to use. This paper examines several existing strategies, and then suggests that increased emphasis be placed on one that is relatively tolerant of "imperfect" indexing. Since "perfect" indexing does not exist, such a strategy would have considerable value. The general procedure consists of counting the number of search-matched index terms and then calculating a relevance factor for each item found, thus enabling the final search-output listing to be prepared in order of probable relevance. This technique is essentially the same as the strategy used successfully in such diverse tasks as identifying criminal suspects by their modus operandi, selecting suitable gifts for department store shoppers, and locating misspelled names in an airlines reservation file.

Efficient, Visible Electroluminescence from p-n Junctions in $Zn_xCd_{1-x}Te$,† F. F. Morehead and G. Mandel, *Applied Physics Letters* **5,** No. 3, 53 (August 1, 1964).

The simultaneous diffusion of Zn and P under a Cd atmosphere into a CdTe crystal grown from a melt containing excess Te and 1 mole % Al produces a *p-n* junction in material of composition $Zn_xCd_{1-x}Te$. An external quantum efficiency as high as 6% has been obtained from $Zn_{0.4}Cd_{0.6}Te$ at 7060 Å at 77°K. The resistance of the contact to the *p*-type side of the junction, a serious problem with CdTe diodes, was reduced so that pulsing at 4°K was possible, without, however, observing any lasing action.

† The research herein reported is part of Project DEFENDER under the joint sponsorship of the Advanced Research Projects Agency, the Office of Naval Research and the Department of Defense.

Electroluminescent Gallium Arsenide Diodes with Negative Resistance, K. Weiser and R. S. Levitt, *Journal of Applied Physics* **35,** No. 8, 2431-2438 (August, 1964).

Electrical and optical properties of gallium arsenide diodes with a p-p°-n structure were studied between 4.2° and 90°K. The diodes were prepared by first diffusing manganese, and then zinc, into *n*-type gallium arsenide, keeping the zinc junction depth much shallower than that of the manganese junction. The p° region, dominated by the manganese, becomes one of high resistivity at these temperatures because of freezeout of holes on the deep-lying manganese centers. The low-resistivity n and p regions on either side serve as electron and hole injecting contacts, respectively. The diodes are electroluminescent and exhibit a negative resistance over a portion of their current-voltage characteristics when a forward bias is applied. At 77°K, a typical voltage for the onset of the negative resistance is 5V at a current of 5 mA; at about 2.2V the dynamic resistance becomes positive again. The spectrum of the emitted light indicates recombination through both zinc and manganese centers. It appears that the mechanism responsible for the negative resistance is not the one suggested by Lampert. Possibly, the absorption by the p° region of light emitted at the p-p° boundary is responsible for the phenomena observed, as suggested by Dumke. At voltages below the onset of the negative resistance, the current-voltage relation in the p° region obeys Ohm's law at low injection levels but eventually the current depends on the square of the voltage. This behavior, as well as the spatial origin of the light, is in good agreement with the theory of Ashley and Milnes.

Electronic Structure of HCl, R. K. Nesbet, *The Journal of Chemical Physics* **41,** No. 1, 100-104 (July 1, 1964).

An approximate molecular Hartree-Fock electronic wavefunction has been obtained for the ground state of the hydrogen chloride molecule at three closely spaced internuclear distances. This work is of accuracy intermediate between the LCAO approximation and a true molecular Hartree-Fock calculation, since a double orbital basis set is used for the L and M shells of Cl together with extra H orbitals, but 3*d* basis orbitals are not included. There are 12 basis orbitals of σ symmetry and five of π symmetry. Orbital exponents are determined by variational calculations on atomic chlorine. The computed results include molecular electric dipole and quadrupole moments and their derivatives, estimates of the excitation energy of several low-lying excited states of the neutral molecule and of the positive ion, estimates of the equilibrium internuclear distance of those states that are bound, and identification of the lowest purely repulsive state.

Electrostatic Torsion Balance for Magnetic Film Measurements,† S. T. Siegle and W. R. Beam, *The Review of Scientific Instruments* **35,** No. 9, 1173-1175 (September, 1964).

An automatic torsion balance has been built for measurement of magnetic film properties. The use of electrostatically generated restoring torques results in a substantial simplification of the suspension system over previous arrangements.

Furthermore, the reduced sensitivity of this system to background vibrations has made the attainment of 3×10^{-4} dyne-cm sensitivity fairly simple.

† Work performed at Rensselaer Polytechnic Institute. Supported by N.S.F.

Epitaxial Growth of Silicon in Ultra-High Vacuum, H. Widmer, *Applied Physics Letters* **5,** No. 5, 108 (September 1, 1964).

Silicon was evaporated in ultra-high vacuum (10^{-10} Torr) on (111) surfaces of silicon that had been cleaned by heat treatment above 1000°C in ultra-high vacuum. With deposition rates of 6Å/sec, epitaxial films formed at substrate temperatures of 550°C and above. Films deposited at 800°C and above were perfect single crystals and did not contain stacking faults.

Evidence For Oxidation Growth at the Oxide-Silicon Interface from Controlled Etch Studies, W. A. Pliskin and R. P. Gnall, *Journal of the Electrochemical Society* **3,** No. 7, 872-873 (July, 1964).

A dilute etch of hydrofluoric and nitric acids can be used for delineating SiO_2 from the P_2O_5/SiO_2 "glass" layer formed on the oxide film after exposure to phosphorus diffusion. This is accomplished by plotting the film thicknesses after various etch times. The etch rate of the P_2O_5/SiO_2 layer is one to two orders of magnitude greater than that of SiO_2 and thus a sharp demarcation between the glass and the silicon dioxide is observed. Etch rate plots were made of films of P_2O_5/SiO_2 which were subjected to both steam and dry oxygen oxidation. From these plots, it is concluded that the new oxide is formed at the oxide silicon interface.

Experimental Personalized Array Translator System, H. Hellerman, *Communications of the Association for Computing Machinery* **7,** No. 7, 433-438 (July, 1964).

A system designed for intimate man-machine interaction in a general-purpose problem-solving environment is experimentally operational. The system utilizes an array-oriented symbolic source language containing powerful statement types. These include numeric, Boolean, relational and selection operators on operands which can be entire arrays. The system also permits simple specification of test and argument arrays in single statements.

The completely symbolic operating system includes display and entry of program and data. Sequence control is aided by an interrupt switch which allows the user to interact with the program during execution. In addition to normal stored program sequencing, the system provides trace options and the ability to enter any statement for immediate execution. Present implementation of the system is with an interpretive translator on an IBM 1620 computer.

An Explicit Terminal Guidance Technique for Lunar Landing Using Cross-Product Steering, W. J. Budurka and N. L. Pleszkoch, *AIAA Journal of Spacecraft and Rockets* **1,** No. 4, 431-433 (July/August 1964).

This report describes a terminal guidance technique which may be used to effect a soft-landing at a preselected site on the lunar surface. The technique requires that two feedback guidance channels be operative throughout the powered portion of the descent. One of the channels functions to nullify an error generated by means of an application of a form of so-called cross-product steering and thereby ensures passage of the vehicle trajectory through the desired landing site location. The other channel functions to nullify a second error signal which ensures a terminal value of vertical velocity which is within the bound required for a "soft" landing. Although the technique is applicable to descent from a circumlunar orbit as well as direct descent from a hyperbolic earth-moon transfer trajectory, simulation results obtained so far are restricted to the former case. The simulation results presented here for the case of an unmanned spacecraft are necessarily of a preliminary nature and serve only to provide a quantitative demonstration of feasibility.

A Formal Language for Describing Machine Logic, Timing, and Sequencing (LOTIS), H. P. Schlaeppi, *IEEE Transactions on Electronic Computers* **EC-13,** No. 4, 439 (August, 1964).

An informal description of the LOTIS language is presented. LOTIS is intended for formally describing the logical structure, the sequencing, and the timing of digital machines. An effort has been made to produce a hardware notation that is convenient and lucid, precise and flexible. In a LOTIS machine description, every linguistic constituent corresponds to a unique machine element. Timing can be specified in the synchronous or asynchronous mode or in any combination of both. Autonomous control units have a notational counterpart by which concurrency of several machine sequences, timesharing of facilities by several control units, and interlocks, can be concisely expressed. A machine description has a hierarchical structure with an arbitrary number of levels; this permits it to be readily segmented. Depending on the focus of interest, the level of descriptive detail can be varied over the different segments.

Free-Radical Reactions of Pyrroles, R. J. Gritter and R. J. Chriss,* *Journal of Organic Chemistry* **29,** No. 5, 1163-1167 (May 20, 1964).

The free radical resulting from hydrogen atom abstraction from the methyl group of *N*-methylpyrrole has been shown to dimerize, forming 1, 1′-ethylenedipyrrole, and to attack the diene system of *N*-methylpyrrole, giving 1-methyl-3-(1-pyrrolylmethyl) pyrrole after radical chain transfer. Pyrrole under similar conditions gave 2, 2′-(1′-pyrrolinyl) pyrrole. The structure of the latter product indicates that hydrogen atom abstraction occurs at the 2-position of pyrrole and that the pyrrole ring acts as an effective free-radical trap. In addition, the reactivities toward free-radical attack of a number of related compounds have been established and shown to lie in the order *N*-methylpyrrole > toluene > 4-picoline > benzene for the compounds examined.

* University of Connecticut.

Frequency Spectra of Body-Centered Cubic Lattices, B. C. Clark,* D. C. Gazis and R. F. Wallis,** *The Physical Review* **134,** A1486-A1491 (June 15, 1964).

A Born-von Karman model has been used to determine the frequency spectrum for a body-centered cubic lattice. The model used contains noncentral angular stiffness forces as well as central forces between nearest and next-nearest neighbors. Frequency distributions have been calculated for vanadium and compared with experimental frequency distributions available from slow neutron experiments. Qualitative agreement was found between the shapes of the experimental and theoretical distributions. The calculated maximum frequency for vanadium was within 2% of that derived from

the experimental frequency distribution. Dispersion curves for iron were also calculated, and were found to be in good agreement with experiment.

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Gallium Arsenide Laser Linewidth Measurements by Heterodyne Detection, J. W. Crowe and R. M. Craig, *Applied Physics Letters* **5,** No. 4, 72-74 (August 15, 1964).

The authors report on new methods of measuring the linewidths of gallium arsenide laser beams. By using a form of heterodyne detection, beat frequencies generated within an extended laser cavity were measured. The beat frequency in a normal ½ millimeter Fabry-Perot cavity length is about 85 Gc/sec, which is too high for conventional measuring techniques. But by extending the cavity length to seven centimeters by external optics, the authors were able to produce beat frequencies of 1.88 Gc/sec, which can be measured by existing photodiodes. With heterodyne detection, better frequency resolution, with a conseqüent lowering of channel noise, can be achieved. To help eliminate the noise further, narrowed bandpasses can be used to receive the narrowed linewidth.

Heisenberg Exchange Interaction of Two Mn Atoms, R. K. Nesbet, *The Physical Review* **135,** A460-A465 (July 20, 1964).

A complete ab initio approximate Hartree-Fock calculation has been carried out on the Mn_2 molecule at three internuclear distances, R=4.5, 5.0, and 5.5 a_0. The theory of the Heisenberg exchange interaction, applied in an earlier paper to the nitrogen molecule at large R, is used to identify the Hartree-Fock configuration of lowest energy and to evaluate the effective exchange intergral J. The Hartree-Fock energy has a minimum value with respect to separated atoms in a $^6\Sigma_g^+$ state. The exchange integral is small but negative, so a $^1\Sigma_g^+$ state of complex structure lies below this. The energy of this $^1\Sigma_g^+$ state has a minimum value of −0.79 eV, with respect to separated atoms, at R =2.88 Å, neglecting the part of the net molecular correlation energy that is independent of spin. These two states are members of a closely spaced set with total spin $S' = 0, 1, 2, 3, 4$ coming from the coupling of spins $S = 2$ on each atom. The last occupied σ orbital is of molecular form (bonding molecular orbital, doubly occupied) while the last π and δ orbitals are localized and singly occupied. The existence of localized spin-coupled orbitals at equilibrium R is very unusual for diatomic molecules, and this is the distinctive property of magnetic materials expected in the present theory.

High-Density Binary Recording Using Nonsaturation Techniques, E. Hopner, *IEEE Transactions on Electronic Computers* **EC-13,** No. 3, 255-261 (June, 1964).

Commercially available magnetic tape units have longitudinal recording densities of up to 2000 bits per inch, whereas analog instrumentation recorders are capable of recording up to 10,000 cycles per inch. These figures contrast with a theoretical recording density limitation for iron oxide of 250,000 bits per inch, and the reasons for this discrepancy are analyzed.

Two experimental systems having recording densities of 5000 and 10,000 bits per inch using analog recording techniques are described. Conclusions drawn from these experiments indicate that a density of 20,000 bits per inch should be possible using commercially available analog tape recording machines. Experimental machines indicate the practicability of densities on the order of 100,000 to 200,000 bits per inch, depending on the method of recording used.

High-Order Transverse Modes in GaAs Lasers, Kurt Weiser and Frank Stern, *Applied Physics Letters* **5,** No. 6, 115-116 (September 15, 1964).

High-order transverse modes have been observed in GaAs laser diodes with a wide high-resistivity p-type layer between the n-type and p-type layers. Evidence for these modes comes from the near-field radiation pattern, which has many bright stripes parallel to the junction, and from the far-field pattern, which has two main beams about 30° apart in a plane perpendicular to the junction plane and the diode face. Calculations for an optical model of these diodes show that the mode of highest gain is a high-order mode, and give a far-field pattern in good agreement with the observed one.

IBM Audio Response System, G. E. DuBois, *Modern Communications* **3,** No. 3, 10-12 (July/August/September, 1964).

A new IBM Teleprocessing System that provides information from a computer in the form of spoken words was introduced recently by International Business Machines Corporation. The IBM 7770 Audio Response Unit makes the millions of business facts within a computer available over the telephone.

The IBM DSD Technical Information Center—A Total Operating Systems Approach Combining Traditional Library Features and Mechanized Computer Processing, H. S. White, ADI 1963 Annual Meeting, *Automation and Scientific Communication,* Part 2, 287-288 (1964).

The IBM Data Systems Division Technical Information Center (TIC) provides an operating developmental system for integrated and compatible mechanized processing of technical information received within the organization. The system offers several advantages:

1. It is a sophisticated mechanized system for dissemination and retrieval.
2. It is compatible with all library mechanized records produced under a standard processing format within IBM libraries, providing such traditional tools as 3 × 5 catalog cards, circulation records and overdue notices.
3. It is reversible, so that discontinuation of machine processing would not cause gaps in the library's manual records.
4. It is controlled, producing statistical evaluations of its own program efficiency.
5. It is user-oriented, providing 24-hour copy access and immediate microfilm access to its documents.
6. It is relatively simple, relying on the IBM 1401 Data Processing System for all its processing and output.

Since the system has been operating for over a year, the conclusions drawn are based on actual experience.

Increased Areal Density in Magnetic Recording, W. T. Frost and B. H. Singer,* *Proceedings of the International Conference on Magnetic Recording,* Institution of Electrical Engineers, 44-47 (1964).

Digital storage at linear densities as high as 20,000 bits per inch has resulted from an investigation establishing recording methods which provide optimum resolution. Means have also been devised for increasing lateral densities so that

1000 tracks per inch can be recorded by special head structures and 4000 tracks per inch by selective-erasure techniques. These developments remove some of the apparent limits of areal density in magnetic recording, and have demonstrated densities as high as 32 million bits per square inch. The possibility of such economical use of recording surfaces has interesting implications for system design.

* Stanford University.

The Influence of Hydrolysis on the Deposition and Co-deposition of Iron-Group Metals (Fe, Co, Ni) at the Dropping Mercury Electrode, Harald Dahms, *Journal of Electroanalytical Chemistry* **8,** No. 1, 5-12 (July, 1964).

The deposition and co-deposition of iron (II), cobalt (II) and nickel (II) ions were studied polarographically in weakly acid (pH 3 to 5.5) solutions. Variation of pH in this region does not affect the waves. By adding oxygen to the solution, high pH values were generated at the electrode surface ($O_2 + 2\ H_2O + 4\ e \rightarrow 4\ OH^-$) leading to hydrolysis of the discharging metal ions. Hydrolysis not only reduces the concentration of the discharging species due to $Me^{2} + 2\ OH^- \rightarrow Me(OH)_2 \downarrow$ but also leads to absorption of hydroxides at the interface. Chronopotentiometric measurements showed that about 3×10^{-10} moles/cm^2 $Fe(OH)_2$ are adsorbed at the electrode. Hydrolysis changes the rate of single metal discharge only slightly, but has a strong effect on the co-deposition of metals. The discharge of one metal can be suppressed by the presence of a second iron-group metal. Ferrous ions cause the strongest suppression followed by cobaltous ions. The same sequence ($Fe^{2+} > Co^{2+} > Ni^{2+}$) is found in the suppression of T^{1+} discharge. This sequence is interpreted on the basis of adsorption measurements.

Injection Electroluminescence in p-Type ZnTe,† M. G. Miksic, G. Mandel, F. F. Morehead, A. A. Onton, and E. S. Schlig, *Physics Letters* **11,** No. 3, 202-203 (August 1, 1964).

Injection electroluminescence was attained in *p*-type ZnTe at temperatures beween room temperature and 77°K. The emission peak at 77°K was at 5340 Å, with external quantum efficiencies of 1 to 2% in the best units at current densities on the order of 10^4 A/cm^2.

† The research herein reported is part of Project DEFENDER under the joint sponsorship of the Advanced Research Projects Agency, the Office of Naval Research and the Department of Defense.

The Injection Laser, W. von Münch, *VDI-Zeitschrift* **106,** No. 24, 1196-1198 (1964).

Laser action is achieved in *p-n* junctions of certain semiconductor materials, as for instance, gallium arsenide. The pumping energy which causes the population inversion is obtained directly from the current flowing through the diode. The electric emitted radiation can therefore easily be modulated by varying the diode current.

The Interface Transport Properties of Ge-GaAs Heterojunctions, L. Esaki, W. E. Howard and J. Heer, Proceedings of the International Conference on the Physics and Chemistry of Solid Surfaces, *Surface Science* **2,** 127 (1964).

The interface conductance of Ge-GaAs heterojunctions has been measured as a function of junction field up to 1.2×10^5 V/cm. It is seen that for samples with surface mobility of about 500 cm^2/V-sec, the mobility μ_s varies with field, at most, as $E^{-0.1}$ up to about 8×10^4 V/cm, but for higher fields it varies approximately as $E^{-0.35}$. Measurements have been made also of junctions whose properties are affected by the proximity of a free surface and junctions which have been heat-treated at 600 to 650°C. A comparison of these results with those of normal heterojunctions is seen to lend further support to the Shockley-Anderson model for abrupt heterojunctions. Namely, in terms of interface states, normal heterojunctions have no detectable interface state densities within the present experimental errors ($< 5 \times 10^{10}$/cm^2), while some heat-treated junctions have acceptor type interface densities of more than a few times 10^{11}/cm^2.

Introduction to FORMAC, J. E. Sammett and E. R. Bond, *IEEE Transactions on Electronic Computers* **EC-13,** No. 4, 386-394 (August, 1964).

The purpose of this paper is to give an over-all view of the FORMAC language. FORMAC is an experimental programming system designed to permit the manipulation of mathematical expressions. The paper includes a brief description of the FORMAC language and samples of complete FORMAC programs.

It should be noted that FORMAC is an experimental program, and that at the present time IBM has no intention of releasing it to its customers.

Kohn Effect in Na and Other Metals, Seymour H. Koenig, *The Physical Review* **135,** A1693-A1695 (September 14, 1964).

It is pointed out that if the Kohn effect is looked for, not as an obvious kink in the phonon dispersion curves of metals as originally suggested, but as a damped sinusoidal variation of the interplanar force constants with separation, then (1) the effect has been observed in many metals and (2) for Na, which is very close to a free-electron metal, the measured force constants oscillate with the expected wavelength (π/kF). From the data for Al and Pb, it would appear that even though the Fermi surface is quite close to a free-electron sphere in the extended zone, electrons do not scatter isotropically around this surface, but presumably stay within their respective Brillouin zones even at temperatures of the order of the Debye θ.

Magnetic Tape Recording Materials, C. D. Mee, *IEEE Transactions on Communication and Electronics* **83,** No. 73, 399-408 (July, 1964).

The design criteria for magnetic recording tapes are considered with respect to the desirable physical and magnetic characteristics for high-resolution recording systems; in particular, the magnetic properties of the universally used iron-oxide powders are compared with possible competitive permanent magnet materials. The properties of oxide and metal powders and of metallic thin films are compared, and the possibility of their future use in high-output high-resolution tapes is also assessed in this paper.

The Matched-Filter Concept, H. M. Sierra, *Electro-Technology* **74,** No. 2, 48-51 (August, 1964).

The basic communications concept of matched filters is used extensively in the design of radar, sonar, radio-teletype and optical-data-transmission systems. When the signal spectrum is known, the matched filter provides a solution to the fundamental problem of recovering signals after transmission through a noisy environment.

Measurement of He-Ne Laser Linewidth Utilizing the Doppler Effect, P. J. Magill and T. Young, *Applied Physics Letters* **5,** No. 1, 13-15 (July 1, 1964).

This paper describes a method for measuring the linewidth of an He-Ne gas laser system. Through the use of a modified self-beat technique, a low frequency signal is obtained wherein instrument resolution is greatly increased. Through the use of this method the resultant optical linewidth of a 6328 Å gas laser was found to be 25 to 35 cps.

Modification of the Threshold Current and Near-Field Emission Pattern of a GaAs Laser by an Adsorbed Dielectric Layer, E. J. Walker and A. E. Michel, *Journal of Applied Physics* **35,** No. 8, 2285 (August, 1964).

We have observed the near-field emission patterns of a number of GaAs diode lasers. The onset of laser action is accompanied by an abrupt increase in the intensity of light emission at the one or several spots along the junction. The adsorption of a dielectric film at a constant rate on one or both surfaces of a laser causes the threshold current to vary periodically with time. The position of the threshold spot did not vary as long as the film was of uniform thickness along the junction; however, the emission pattern could be altered by a suitable nonuniform film. The variation of the threshold current with film thickness can be fitted by a simple model that assumes the gain in the active region is proportional to the current density. Calculated values for the loss and gain factors ranged from 10 to 60 cm^{-1} and 0.5 to 4×10^{-2} cm/A, respectively.

A Modified X-ray Diffraction Microscope Technique for Study of Dislocations in Crystals, J. S. Makris and C. H. Ma, *Transactions of the Metallurgical Society of AIME* **230,** No. 5, 1110-1112 (August, 1964).

This paper describes a modified x-ray diffraction microscope method based on the general principles of Berg-Barrett's Method, Lang's Method, and Wooster's Technique. This new method may be used for stationary or oscillatory photomicrographs, with both reflection and transmission techniques. In the stationary technique, a small point-source of a divergent x-ray beam of white radiation is used; in the oscillatory technique, a monochromatic divergent beam is employed. The chief advantages of the method described herein are that only approximate alignment of the Bragg angle-of-interest is needed during exposure, and that a large portion of a crystal-specimen surface can be irradiated.

Multiple Cavity Molecular Beam Maser,† Paul Erdös, *Helvetica Physica Acta* **37,** No. 3, 252 (1964).

The theory of multiple cavity molecular beam oscillators is developed. It is shown that the frequency stability of the oscillator can be increased to any required degree by coupling empty resonators to the cavity containing the beam. The coupling constants are determined. The beam intensity required to operate the device increases proportionally to the number of coupled cavities, thus the frequency stability is ultimately limited by the maximum available beam intensity.

† The major part of this work was completed while the author was on leave from IBM at the Florida State University.

A New Reversible Photochemical Reaction in Concentrated Solution of Chlorophyll, S. S. Brody and S. B. Broyde, *Photochemistry and Photobiology* **3,** 265 (1964).

A new photochemical reaction of chlorophyll, occurring only in concentrated solution, has been observed. When a 10^{-3} molar oxygen-free solution of chlorophyll in ethanol is illuminated in white light (5×10^4 ergs/cm²-sec) for about an hour, in the presence of 2×10^{-1} molar phenylhydrazine, a green species is produced, with absorption maxima at about 640 and 410 millimicrons. The reaction product reverts to the original chlorophyll on standing in the dark for several hours. The nature of the spectral shift occurring in this interaction indicates that ring V of the chlorophyll molecule is transformed in the 640 millimicron absorbing species.

Non-Linear Optimization and Control of Gas Pipelines, R. A. Mugele, *Pipeline News* **36,** No. 7, 31-35 (July, 1964).

This paper describes methods which have been developed for the solution of certain problems encountered by dispatchers in the transmission of natural gas through long pipelines. Some of these problems are difficult because of the transient, i.e., time-dependent, nature of the flow. The computer programs which have been developed to solve these problems will be useful to dispatchers in maintaining efficient as well as safe control of natural gas pipeline operations.

A Note on the Application of the Stress Dependency of Wear in the Wear Analysis of an Electrical Contact, R. G. Bayer, W. C. Clinton and J. L. Sirico, *Wear* **7,** 282-289 (May/June 1964).

This paper describes an analysis of a sliding electrical contact for wear properties; the analysis develops specifications which insure a desirable, but not excessive, amount of wear for each traverse of the contact.

A Note on the Formation of a Free List, William M. Waite* and H. Schorr, *Communications of the Association for Computing Machinery* **7,** No. 8, 478 (August, 1964).

In list processing systems all store registers not used by the program should be placed on an *available space list.* An attractive method of obtaining such a list on the IBM 7094 using information supplied by the BSS loader is presented.

*Columbia University.

Observation of an Infrared Absorption Band from s-f Exchange Interaction in Antiferromagnetic Holmium, C. Chr. Schüler, *Physics Letters* **12,** No. 2, 84 (September 15, 1964).

The antiferromagnetic spin structure in holmium represents a superlattice which acts through *s-f* exchange coupling on the conduction band electrons and gives rise to a new band-gap. We have observed optical absorption, corresponding to excitation across this gap, with a bandedge of about 0.3 eV. The exchange energy can be found directly from this to about $\mathcal{J}(q) = 0.05$ eV.

On the Effect of Component Tolerances in the Balanced-Pair Tunnel-Diode Circuit,† R. K. Brayton, *IEEE Transactions on Circuit Theory* **CT-11,** No. 3, 351-356 (September, 1964).

The purposes of this study are (1) to determine for the balanced-pair tunnel-diode circuit the minimum amount of control required when specified parameter imbalances are present, and (2) to illustrate a method of analysis using perturbation theory which can be applied to nonlinear almost symmetrical circuits.

† The results reported in this paper were obtained in the course of research jointly sponsored by the Air Force Office of Scientific Research [Contract AF 49(638)-1139] and IBM.

On Equi-Cardinal Restrictions of a Graph, J. C. Beatty and R. E. Miller, *Canadian Mathematical Bulletin* **7,** No. 3, 369 (July, 1964).

A k-equi-cardinal restriction of a graph G is defined as a restriction of G, each of whose connected components is of cardinality k. The minimum number d is determined for which every regular graph of order a multiple of k and degree $\geq d$ has a k-equi-cardinal restriction.

On the Integro-Differential Equations of the Nonlocal Theory of Superconductivity,† F. M. Odeh, *Journal of Mathematical Physics* **5,** No. 8, 1168-1182 (August, 1964).

The nonlocal model of superconductivity has, in recent years, received strong support on both microscopic theoretical and experimental grounds. In the present report two of the mathematical aspects of the theory are discussed. One concerns the question of well-posedness of the equations and boundary conditions. The other concerns some methods of obtaining approximate solutions.

Existence and uniqueness theorems are given for the solutions of the integro-differential equations governing the vector potential, under suitable restrictions on the kernels involved. Both diffuse and specular reflection types of boundary conditions are considered in both scalar (one-dimensional) and vector (three-dimensional) problems. An existence theorem is also given for the time-dependent equations.

Approximate solutions for the problem of a film in a parallel magnetic field are given in two limiting cases. In one the small coherence length limit in the Pippard model under diffuse scattering boundary conditions is considered, and a boundary layer type solution is given. In the other a thin film approximation to the diffuse problem is found. An exact series representation is also given for the solution of the problem of a circular cylinder in a parallel magnetic field with specular reflection boundary conditions.

† The results reported in this paper were obtained in the course of research jointly sponsored by the Mathematics Branch of the Office of Naval Research [Contract Nonr-3504(00)] and IBM.

On The Limiting Law For Electrical Conductance In Ionic Solutions, H. L. Friedman, *Physica* **30,** No. 3, 537-562 (1964).

The cluster theory of conductance presented in a preceding paper is applied to a model in which a single solute particle in the solvent obeys the law of Brownian motion, the force between two solute particles is derivable from macroscopic electrostatics and hydrodynamics, and the interactions among many solute particles in a solution may be expressed as a sum of pair contributions. These hypothetical solute particles are called *brownons.*

It is found that the relaxation term in the limiting law derives from the electrical part of the force between brownons, while the electrophoretic term derives from the hydrodynamic part of this force as well.

Onsager's relaxation term is recovered exactly in the case of a solution of a single cationic and a single anionic solute species observed at zero frequency. The $1 + q$ factor in the denominator, which was Onsager's improvement over the earlier theory of Debye and Huckel, is found to come from the sums over force-propagator chains in the cluster theory. In the case of more than two ionic species or non-zero measuring frequency, one of the cluster integrals that makes a minor contribution has yet to be evaluated.

The hydrodynamic part of the force between brownons corresponds to an unsolved problem in hydrodynamics, but the calculation of the electrophoretic term has been carried through using the approximation to this hydrodynamic force, based on neglect of inertial effects, that underlies the derivation of Stokes law. This approximation may not be adequate for use in the cluster theory. Nevertheless it is remarkable that it leads to an electrophoretic term in agreement with Onsager's if and only if the chain sums are neglected.

On the Line Graph of a Complete Bipartite Graph, A. J. Hoffman, *Annals of Mathematical Statistics* **35,** No. 2, 883-885 (June, 1964).

It is shown that the line graph of the complete bipartite graph on $m + n$ vertices is characterized by conditions due to J. W. Moon and S. S. Shrikhande, with the exception noted by Shrikhande of the case $m = n = 4$. The proof is an application of matrix concepts to verify some cases when m and n are small that were previously unsettled.

Optimum Block Codes for Noisless Input Restricted Channels, C. V. Freiman and A. D. Wyner, *Information and Control* **7,** No. 3, 398-415 (September, 1964).

A method for determining maximum-size block codes, with the property that no concatenation of codewords violates the input restrictions of a given channel, is presented. The class of channels considered is essentially that of Shannon (1948) in which input restrictions are represented through use of a finite-state machine. A partial ordering is first defined over the set of states. On the basis of this ordering, complete terminal sets of states are determined. Use is then made of Mason's general gain formula to obtain a generating function for the size of the code which is associated with each complete terminal set. Two important classes of binary channels are considered in detail. In the first class, an upper bound is placed on the separation of 1's during transmission while, in the second class, a lower bound is placed on this separation. Universal solutions are obtained for both classes.

Orientation of Stacking Faults and Dislocation Etch Pits in β-SiC, W. K. Liebmann, *Journal of the Electrochemical Society* **3,** No. 7, 885-886 (July, 1964).

The orientation of stacking faults and dislocation etch pits in epitaxial layers of β-SiC has been determined. From the thickness of the epitaxial layer and the size of the stacking fault triangles it was found that the pyramidal planes of the stacking fault correspond to {111}, while the side planes of the etch pits correspond to {311}. The orientation of the dislocation etch pits becomes plausible if one assumes that the etching is most rapid in crystalline directions where the removal of individual atoms leaves the surface energy of the specific crystal plane unaltered.

Oxygen Adsorption on Silicon Surfaces Observed via Electron Spin Resonance,† K. A. Müller,* P. Chan,§ R. Kleiner,‡ D. W. Ovenall** and M. J. Sparnaay,§§ *Journal of Applied Physics* **35,** No. 7, 2254 (July, 1964).

In this communication, the possibility of investigating the oxygen adsorption and layer formation on isolators and semiconductors with electron spin resonance is successfully demonstrated for silicon. The linewidth of a spin resonance line due to centers created near the surface of silicon in moderate vacuum broadens logarithmically with pressure upon admission of oxygen, air or mixtures of oxygen with other gases via dipolar interaction of O_2. No line broadening is observed with admission of pure diamagnetic gases. The experiments indicate that the number of adsorbed oxygen molecules on the silicon surface increases logarithmically with pressure. It is shown that such a dependence is obtained when repulsive van der Waals forces are present between the adsorbed molecules on a surface.

† Work performed at Battelle Institute, Geneva, Switzerland, and supported by the Philips' Gloeilampenfabrieken, Eindhoven.
* IBM and the Physics Institute, University of Zurich.
§ Battelle Institute, Geneva.
‡ Present address: Cyanamid Research Laboratory, Cologny-Geneva.
** Present address: E. I. du Pont de Nemours and Company, Wilmington.
§§ Philips' Research Laboratories, Eindhoven.

PACTOLUS—**A Simulator Language Which Makes a Digital Computer Feel like an Analog Computer,** Robert D. Brennan, *Simulation* **3,** 13-19 (August, 1964).

This paper describes an innovation in digital analog simulator programs-on-line, operational flexibility comparable to that of the analog computer. The program was developed for the IBM 1620 system as an illustration of the man-machine intimacy which will be possible with System/360 through use of remote terminals and visual display units. The configuration, initial conditions, and parameters of the simulation are conveniently specified and may be simply changed at will. The user monitors the primary output as it is plotted by the IBM 1627. Secondary output variables are recorded by the typewriter. Sense switches provide the user freedom of action to use the computer in an experimental mode. Examples illustrate actual use of the program.

Peak-Shift Study in High-Density Magnetic Tape Recording, H. S. Templeton, G. Bate, *IEEE Transactions on Communication and Electronics* **83,** No. 73, 429-432 (July, 1964).

This paper examines the influence of magnetic tape, read-write head, and other recording parameters on peak shift encountered in high-density recording. In particular, the effect of prior erase polarity on peak shift is discussed. A technique for examining the remanent moment in a sample of the recorded tape track as a function of write current, density, and angle from the plane of the oxide coating is described.

Perturbation Walls in Thin Magnetic Double Permalloy (Ni-Fe) Films, S. Middelhoek, *Applied Physics Letters* **5,** No. 4, 70 (August 15, 1964).

Perturbation walls are walls in which the magnetization rotates through 360°, such that the magnetization in the domains at both sides of the walls are parallel. Up to now, perturbation walls were only observed in very thin Ni-Fe films ($\approx$ 100 Å). This paper reports on the observation of perturbation walls in double films consisting of two 400-Å Ni-Fe layers separated by a 200-Å SiO layer. Also in Néel walls, a large reduction of the wall motion coercive force and less creep sensitivity are observed.

Photolytic Decomposition of Aryldiazonium Salts. The *p*-dimethylaminophenoxy Radical, P. J. Zandstra and E. M. Evleth, *Journal of The American Chemical Society* **86,** No. 13, 2664-2666 (July 5, 1964).

The photolytic decomposition of *p*-dimethylaminobenzenediazonium chloride in aqueous solution with pH above 5 leads to the formation of a paramagnetic species. The electron spin resonance spectrum is the same as that obtained on air oxidation of *p*-dimethylaminophenol in the same pH range. On the basis of this evidence as well as the ESR spectrum, the structure of the radical could be established as being the *p*-dimethylaminoazonium compound. Similarly, the *p*-diethylaminobenzenediazonium chloride was photolytically decomposed to yield the corresponding phenoxy radical. The nitrogen and ring proton hyperfine coupling constants are the same in both radicals. In the diethyl radical the alkyl spin density is much lower than in the dimethyl radical. Therefore, the inductive effects of the alkyl groups on the spin distribution are very small and the alkyl spin density is determined by hyperconjugation. In the diethylamino radical the rotation of the ethyl groups around the C-N bonds is restricted as compared to the case of the methyl groups of the dimethylamino radical. The ESR spectra of these radicals are strongly dependent on the solvent used. In dimethyl sulfoxide-water solutions similar solvent polarization occurs, as observed by Fraenkel, et al.

Piezo-Galvanomagnetic Effects in Bismuth, A. L. Jain and R. Jaggi, *The Physical Review* **135,** A708 (August 3, 1964).

The electrical resistivity and Hall coefficient in single crystals of bismuth have been measured as a function of uniaxial stress along the trigonal axis at 4.2, 77, and 295°K. Values of elastoresistance and elasto-Hall coefficients have been calculated by combining the results of the present experiment with our earlier measurements of the pressure dependence of the galvanomagnetic effects. The data are analyzed in terms of a model consisting of a conduction band overlapping a valence band. The deformation potential components defining the strain dependence of the overlap energy ($E_o = 0.03$ eV) are evaluated to be $E_1 = -2.7$ eV and $E_2 = +2.8$ eV.

***P-N* Junction Lasers,** G. Burns and M. I. Nathan, *Proceedings of the IEEE* **52,** No. 7, 770 (July, 1964).

A review of *p-n* junction injection lasers is presented. The literature published up to November, 1963, as well as a number of preprints, is fairly completely covered. Also included is a section covering "recent work."

Precision Over-Under Four-Point Probe with a Small Probe Spacing, P. A. Schumann, Jr., L. S. Sheiner, *The Review of Scientific Instruments* **35,** No. 8, 959 (August, 1964).

The design for an over-under four-point probe for resistivity measurement of semiconducting material is given. The minimum probe spacing obtainable with this probe is 2.0 mils (50.8 μ). A comparison between this four-point probe at a spacing of 5.3 mils (135 μ) and others for the measurement of non-epitaxial slices is given. A thickness correction factor

for these slices is calculated. The small probe spacing obtainable with this probe makes it possible to map the resistivity variations across slices accurately and to measure $N/N+$ or $P/P+$ epitaxial layer resistivity.

A Primal Method for the Assignment and Transportation Problems,† M. L. Balinski* and R. E. Gomory, *Management Science* **10,** No. 3, 178-182 (April, 1964).

This paper describes a simple calculation for the assignment and transportation problems which is a natural dual to the well-known Hungarian Method. While the Hungarian is a dual method, this method is primal and so gives a feasible assignment at each stage of the calculation. A bound on the number of steps required for the assignment problem can be given. It is the same as the best bound known for the Hungarian Method.

† Work of M.L.B. supported by the Princeton University—Office of Naval Research Logistics Project; work of R.E.G. supported in part by the Office of Naval Research under Contract No. Nonr 3775(00), NR047040.
• Princeton University.

A Procedure-Oriented Machine Language, A. P. Mullery, *IEEE Transactions on Electronic Computers* **EC-13,** No. 4, 449 (August, 1964).

A study of the general area of problem solving with a digital computer has revealed characteristics of data that are essentially ignored or suppressed in conventional systems. In an attempt to increase the capability and flexibility of a digital system, a new, high-level language, which utilizes these data characteristics, has been defined. A machine organization, which implements this language as a machine language and yet imposes no restrictions on the use of the language, has been proposed. This paper presents a general description of the philosophy and structure of the language.

Process Controls in Ferrite Core Manufacturing, Allan Getto, *Ceramic Age* **80,** No. 9, 58-60 (September, 1964).

Supplying coincident-current, ferrite memory cores for IBM computers poses a broad range of technical problems for the company's Components Division, which fabricates these key storage devices. As production schedules have steadily increased for these devices in the past few years, the demand for faster and larger memories has led to sharp reductions in the core's physical size. Also, each part has to be manufactured to close dimensional tolerances and must meet stringent electrical requirements for several parameters. Thus, when one considers the wide scope of variables involved in supplying hundreds of millions of several distinct core types, great technological strides have been required to fill these needs. This article gives a broader understanding of the fabrication of this family of high-volume, close-tolerance ceramics.

Reflectivity Spectra of GaSb-InSb and GaAs-InAs Alloys,† J. C. Woolley* and K. W. Blazey, *The Journal of Physics and Chemistry of Solids* **25,** No. 7, 713 (July, 1964).

Polycrystalline specimens of GaSb-InSb and GaAs-InAs alloys produced by a slow directional freeze method have been used to determine the visible and u. v. reflectivity spectra for various alloy compositions. It is found for both systems that unlike the fundamental band gaps, which vary non-linearly with composition, the various reflectivity peaks show a linear variation with composition consistent with a virtual crystal model.

† Work performed at the University of Nottingham.
* Present address: University of Ottawa.

RS-Machines with Almost Blank Tape, C. C. Elgot and J. D. Rutledge, *Journal of the Association for Computing Machinery* **11,** No. 3, 313-337 (July, 1964).

Finite automata which communicate with counters or with tapes on a single letter alphabet with end mark are studied. A typical machine system studied here consists of a family of machines; the finite automaton part of each of the machines is identical; each machine has one reset counter (almost blank loop tape) and one non-reset counter (almost blank straight tape); the first counter counts up to a, say, and the second counts up to b. For each pair of natural numbers a, b there is a machine of the system with counters running up to a, b respectively. The system "accepts" those pairs (a, b) such that the (a, b)-machine eventually halts, when started in standard position. Thus the system defines a binary relation on natural numbers. Some solvability and unsolvability results are obtained concerning the emptiness of the set accepted by a system or the emptiness of the intersection of the sets accepted by two or more systems. Some of the theorems strengthen results of Rabin and Scott. It is shown for a certain class of systems that the relations defined by them are exactly the same as those definable in the elementary theory of addition of natural numbers. For another class of systems it is shown that an intersection problem is equivalent to Hilbert's tenth problem.

Sensory Feedback Analysis of Stereotelevision Pursuit Tracking,† J. D. Gould* and K. U. Smith, *Journal of Applied Psychology* **48,** No. 3, 152-160 (1964).

A stereotelevision system, capable of presenting binocular cues for remote depth perception, has been developd for research on problems of optical design and for sensory feedback studies in space science. Preliminary experiments evaluated a color-separation system, which was found to be faulty for research. Detailed visual acuity and stereoscopic acuity tests with a binocular-separation system disclosed that a very adequate and reliable 3-dimensional system can be devised for laboratory studies of remote binocular vision. A specific experiment tested the utility of a nondirectional auditory cue in aiding visual pursuit tracking in depth. Results indicated that the effectiveness of the auditory cue varies as a function of the speed of the target course.

† Work supported by the National Science Foundation (Project 7589) and by the National Institute of Mental Health (Project MH-4469).
* Research Fellow, National Institute of Mental Health; now at Thomas J. Watson Research Center.

Solubility and Crystal Growth of $ZnAl_2O_4$ and Al_2O_3 in Molten PbF_2 Solutions, Edward A. Giess, *Journal of the American Ceramic Society* **47,** No. 8, 388 (August, 1964).

The solubility of $ZnAl_2O_4$ (gahnite spinel) and Al_2O_3 (corundum) in their respective molten PbF_2 solutions was determined by a sealed-tube quenching method between 900° and 1250°C. Differential thermal analysis was used below 900°C. The solubilities (crystal-constituent/PbF_2 weight ratio) at 1200°C were 0.151 for Al_2O_3 and 0.108 for $ZnAl_2O_4$, whereas at 900°C they were 0.093 and 0.048, respectively. These

results are compared with those of single-crystal growth experiments and the crystalline products are described.

Some Properties of GaSb-Ga_2Se_3 and GaSb-Ga_2Te_3 Alloys,† J. C. Woolley* and K. W. Blazey, *Journal of the Electrochemical Society* **3,** No. 8, 951 (August, 1964.)

The ranges of solid solution of Ga_2Te_3 and Ga_2Se_3 in GaSb at 500°C have been determined by annealing powdered samples to equilibrium and measuring lattice parameters by x-ray methods. For the Ga_2Te_3 alloys, periods of annealing of up to 12 months were required to give equilibrium conditions. The limits of solid solution at 500°C were found to be 36 mole % for Ga_2Te_3 and 10 mole % for Ga_2Se_3. Measurements of room temperature optical energy gap and Hall coefficient have been made for alloys containing up to 5 mole % chalcogenide. Starting with *p*-type GaSb, the alloys become *n*-type with addition of very small amounts of chalcogenide, and values of electron concentration of up to 4×10^{17}/cc and 2×10^{20}/cc were found for telluride and selenide alloys, respectively. Corresponding minima in the values of E_g due to compensation were observed. The nonstoichiometry at low concentrations of chalcogenide which results in these values is discussed and the results compared with those for GaSb heavily doped with tellurium and selenium.

† Work performed at the University of Nottingham.
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Some Properties of the Rank and the Invariant Factors of Matrices, R. E. Gomory, A. J. Hoffman and N. C. Hsu, *Canadian Mathematical Bulletin* **7,** No. 1, 89-96 (January, 1964).

The invariant factors of all (0, 1) matrices of order ≤ 8, with constant row and column sums, were computed (and are presented in the appendix). Several conjectures suggested by these data are proved, along with some theorems discussing conditions on a nonsingular matrix in order that it be imbeddable in a double stochastic matrix of the same rank.

Stimulated Brillouin Scattering in Liquids, R. G. Brewer and K. E. Rieckhoff, *Physical Review Letters* **13,** No. 11, 334-336 (September 14, 1964).

Stimulated Brillouin scattering and coherent acoustic waves of frequency $\sim 6 \times 10^9$ cps have been produced in liquids by excitation with a giant pulse ruby laser. Brillouin components of several orders were identified interferometrically. This process is accompanied by dielectric breakdown, cavitation, and additional intense acoustic waves of low frequency ($\sim$ 1 Mc/sec). Intensity measurements of these low frequency components reveal that they are at least a factor of 20 larger than the maximum value expected for the Brillouin acoustic waves and probably originate in the resulting plasma.

Stimulated Raman Scattering and Induced Optical Absorption in Liquids, R. G. Brewer, *Physics Letters* **11,** No. 4 (August 15, 1964).

Liquids which are normally transparent to low intensity red light can exhibit a large induced absorption (20%) when exposed to the focused beam of a giant pulse ruby laser ($\sim$ 2 MW). This nonlinear absorption is found experimentally to result from stimulated Raman scattering in the case of benzene, nitrobenzene, and cyclohexane and is doubtless a dominant process in other liquids as well.

Stresses on a Thin Strip or Slab with Different Elastic Properties from that of the Substrate Due to Elliptically Distributed Load, D. Barovich, S. C. Kingsley and T. C. Ku, *International Journal of Engineering Science* **2,** 253-268 (1964).

The solution for the state of stresses on a thin strip (or a thin slab in the three dimensional case) and the semi-infinite substrate, rigidly adhering to each other and with different elastic properties, under elliptically distributed normal and tangential boundary stresses is obtained in terms of Fourier integrals. Nominal results are obtained to show the effect of the difference in the elastic properties between the thin strip (or slab) and the substrate on the state of the existing stresses.

Strong Axial Electron Paramagnetic Resonance Spectrum of Fe^{3+} in $SrTiO_3$ Due to Nearest-Neighbor Charge Compensation,† E. S. Kirkpatrick,* K. A. Müller, and R. S. Rubins,** *The Physical Review* **135,** A86 (July 1, 1964).

An axial electron paramagnetic resonance (EPR) spectrum in iron-doped (cubic) strontium titanate has been observed at 3.3 and 1.85 cm wavelength with effective g values $g_\perp^e = 5.993 \pm 0.001$ and $g_\perp^e = 0.001$, respectively, and $g_\parallel^e = g_\parallel = 2.0054 \pm 0.0007$. The same spectrum was found after charge displacement due to heat treatment in the dark or by reduction in crystals which contained, in addition to iron, other transition metal ions. The spectrum is attributed to $\Delta M = 1$ transitions of the $S_z = \pm \frac{1}{2}$ level of $Fe^{3+}(3d^5)$ in a strongly tetragonal electric crystalline field produced by local charge compensation at a nearest-neighbor oxygen site. The theory is developed for ions of half-integral spin in an axial field much greater than the Zeeman splitting. By applying the theory to the special case of $S = 5/2$ and using the measured effective $g_\perp^e$ values and resonance magnetic fields $g_\perp = 2.0101 \pm 0.0008$ and a zero-field splitting parameter $|2D|$ of 2.85 ± 0.15 cm^{-1} is obtained. This is the largest splitting which has so far been observed for Fe^{3+} in any inorganic crystal and could be useful for submillimeter maser applications.

† Work performed at Battelle Memorial Institute, Geneva.
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Superresolution for Nonbirefringent Objects, A. W. Lohmann and D. P. Paris, *Applied Optics* **3,** No. 9, 1037-1043 (September, 1964).

The theory of a superresolution experiment is developed. To achieve superresolution one must know in advance some properties of the objects, e. g., nonbirefringence, and time independence or wavelength independence. Assuming that the objects are nonbirefringent, it would be wasteful to use the two possible states of independent linear polarization of the light for simultaneously carrying the same information twice through the image-forming system. One can avoid this waste by inserting polarizers and certain double-refracting components into the system, such that the two states of polarization instead carry different information through the conventional image-forming system. The transfer function of such a superresolution system is derived for coherent and incoherent object illumination. The system is then modified so that the one-dimensional restriction of the original concept is eliminated. This imposes a further constraint on the class of allowed objects: the objects must be time-independent or only slowly time-varying.

Synthesis of Control Systems With Stability Constraints via the Direct Method of Liapunov, G. W. Johnson, *IEEE Transactions on Automatic Control* **AC-9,** No. 3, 270-273 (July, 1964).

A technique of quasi-optimization is developed in this paper which utilizes the direct method of Liapunov to constrain the admissable control policies such that specifically defined stability properties, for a desired solution, are obtained. As illustrated in the paper, in the event that a quadratic form in system state is chosen as a Liapunov function, the quasi-optimal realizations involve (in the presence of saturation constraints) some form of relay control with linear switching logic for an important class of performance criteria.

Tables of Distribution-Free Tolerance Limits, L. Danziger and S. A. Davis, *The Annals of Mathematical Statistics* **35,** No. 3, 1361-1365 (September, 1964).

Consider an ordered sample $X_1 \leq X_2 \leq \ldots \leq X_n$ and a second finite random sample $Y_1, Y_2, \ldots, Y_N$ from an infinite population with a continuous density function, $f(x)$. The one-tolerance limit problem is: for any integer r, such that $1 \leq r \leq n$, and for any integer N_0 such that $0 \leq N_0 \leq N$, find the probability that at least N_0 of the Y_i's are greater than X_r. The two-tolerance limit problem can be similarly stated.

The probability that N_0 of the Y_i's lie above X_r is given by

$$P(N_0) = \binom{N_0 + n - r}{N_0}\binom{N - N_0 + r - 1}{N - N_0} \Big/ \binom{N + n}{N}. \quad (1)$$

It can be shown that the probability of a least N_0 of the Y_i's lying between X_{r1} and X_{r2} is equal to the probability of at least N_0 of the Y_i's being greater than X_r, where $r = r_1 + n + 1 - r_2$, i.e., all two-tolerance limit cases are equal and are reducible to (1), the general one-tolerance limit case.

From Eq. (1), iterative computation was performed using

$$P(N) = \frac{n!\,(N + n - r)!}{(n - r)!\,(N + n)!}$$

and

$$P(N_0 - 1) = P(N_0)\,\frac{(N - N_0 + r)N_0}{(N_0 + n - r)(N - N_0 + 1)}$$

such that

$$\sum_{N_k = N_0}^{N} P(N_k) \geq K.$$

The tables show that the probability is at least K that N_0, or more, of a second sample of N will lie between the r_1 and r_2 values of the first sample of size n. Or, equivalently, it gives the least N_0 which lies above the r^{th} lowest.

Techniques For Obtaining Uniform Thin Glass Films on Substrates, W. A. Pliskin, E. E. Conrad, *Electrochemical Technology* **2,** No. 7-8, 196-200 (July/August, 1964).

By proper centrifuging techniques, pinhole-free, uniform, thin glass films ($\geq 0.4\ \mu$) can be attained. These films are formed by centrifuging colloidal suspensions of glass onto the substrate. After decanting the suspending fluid, the packed powdered glass forms a continuous film when fired for 5 minutes at a temperature close to the glass softening point. The physical properties of the suspension which must be considered for attaining high-quality glass films are the dielectric constant, viscosity and volatility of the suspending medium and the colloidal glass particle size. These factors are discussed.

Temperature Dependence of Domain Wall Creep in Thin NiFe Magnetic Film, M. E. Sweet, *Journal of Applied Physics* **35,** No. 3 (Part 2), 814-815 (March, 1964).

This paper presents the results of an experimental program undertaken to determine the temperature dependence of the creep of magnetic domain walls in uniaxial thin NiFe magnetic film and its relationship to the temperature dependence of the anistropy field H_k, the coercive force H_c, and the critical fields required to initiate domain wall motion. Results show that domain wall creep velocity and the magnetic properties of the thin film are temperature dependent and that the temperature dependence of the former is related to the temperature dependence of the latter. Curves of creep velocity, H_c, H_k as functions of temperature are given and experimental and constructed curves of constant creep velocity were plotted. A set of the latter curves is used to show the degree to which the experimentally measured values are satisfied by calculated values.

A Theory of Nonlinear Networks, II, R. K. Brayton and J. K. Moser,* *Quarterly of Applied Mathematics* **22,** No. 2, 81-104 (July, 1964).

In this paper we rederive the existence and the form of the mixed potential function for complete electrical networks using a graph theoretic approach. Besides some detailed proofs complementing the paper, "A theory of nonlinear networks, I," several additional results are obtained. Also, some well-known results for electrical networks are discussed and rederived starting with the existence of a mixed potential function. In the last section a theorem on the existence of periodic solutions for periodically excited nonlinear circuits is proved. This result can be considered as an extension of a theorem of R. Duffin.

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The Triggering Point of a Blocking Oscillator,† Dan M. Bowers, *Electronic Industries* **23,** No. 8, 91-94 (August, 1964).

The triggering voltage and the cutoff voltage, and the margins associated with both, are determined analytically for a particular blocking oscillator configuration. Regenerative properties of the circuit are determined as a function of the peak amplitude of an input pulse which is rising at a specified rate. The approach is such that it may be easily adapted to other circuits and conditions.

† Work performed at Catholic University of America.

Two-Photon Capture Cross Sections of Pyrene and Benzpyrene from SCF-MO Calculations, E. M. Evleth and W. L. Peticolas, *Journal of Chemical Physics* **41,** No. 5, 1400-1407 (September 1, 1964).

The two-photon capture cross sections for pyrene and 3, 4-benzpyrene are calculated using SCF-CI pi-electronic wavefunctions and the theory of Goeppert-Mayer. The cross section is shown to be dependent on the product of the photon flux and a constant, δ, which may be calculated from suitable matrix elements and the line shape function. For randomly

oriented molecules and polarized light the calculated values of δ for pyrene and 3, 4-benzpyrene are, respectively, 260×10^{-51} and 1500×10^{-51} cm^4 sec atom^{-1} photon^{-1}. These are to be compared with the experimental values of, respectively, 1×10^{-51} and 50×10^{-51} cm^4 sec atom^{-1} photon^{-1}. The effect of molecular symmetry on the two-photon absorption of polarized light is illustrated for molecules of D_{2h} symmetry. For a two-photon transition to a B_{1g} state, the maximum probability is shown to lie approximately 45° between the x and y axes of the molecule which are the axes of maximum probability for one-photon absorption.

Vibrational Interactions in Pariser-Parr Theory. I. Bandwidths and Transition Intensities, W. E. Donath, *The Journal of Chemical Physics* **41,** No. 3, 626-631 (August 1, 1964).

It is shown that bandwidths of some transitions can be calculated with good accuracy in the Pariser-Parr theory. For these calculations the critical point is a knowledge of the variation of the bond resonance integral β with respect to distance, which is given by $\kappa = -d \ln(-\beta)/dR = 2.0$ Å^{-1}. Calculations are carried out for the bandwidths of the N-V transition of ethylene and the $^1A_{1g} \rightarrow {}^1E_{1u}$, $^1E_{2g}$ transitions of benzene and the intensities of the $^1A_{1g} \rightarrow {}^1B_{2u}$, $^1B_{1u}$ transitions of benzene. Satisfactory agreement with experiment is obtained; the neglect of electronic repulsion terms is demonstrated to have a relatively small effect. Selection rules are established for the strength of vibrational coupling in alternant hydrocarbons.

Wavefunctions and Binding Energies of the Titanium Monoxide Molecule, K. D. Carlson and R. K. Nesbet, *Journal of Chemical Physics* **41,** No. 4, 1051-1062 (August 15, 1964).

Approximate wavefunctions for the low-lying $^1\Sigma^+$ state of the titanium monoxide molecule have been calculated by the method of Roothaan at three internuclear distances about the minimum of the potential energy curve. Basis orbitals were chosen to represent the principal effects of distortion and polarization of the atomic constituents for a very limited set of atomic basis orbitals. The calculations yield approximate Hartree-Fock molecular constants and binding energies for the $^1\Sigma^+$ state, and for the $^3\Delta$ ground state and other excited states relative to the $^1\Sigma^+$ state. An empirical estimate of the net molecular correlation energy relative to separated atoms is made using purely atomic data for appropriate ionic constituents of the molecule. The computed dissociation energies are in qualitative agreement with experimental values but have small errors partly owing to the approximations employed in the calculations. The ground-state parameters obtained here are $D_e = 5.61$ eV, $R_e = 1.539$ Å, $w_e = 1262$ cm^{-1}, compared with experimental values $D_e = 6.86 \pm 0.30$ eV, $R_e = 1.620$ Å, $w_e = 1008.4$ cm^{-1}.

Letters to the Editor

Atomic Shielding Parameters, Gerald Burns, *Journal of Chemical Physics* **41,** No. 5, 1521 (1964).

Biliary Excretion of Ceruloplasmin Copper,† P. Aisen, A. G. Morell,* S. Alpert* and I. Sternlieb,* *Nature* **203,** No. 4947, 873 (August 22, 1964).

† Work done at the Albert Einstein College of Medicine, New York.
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Crystal Field Theory, G. Burns, *Helvetica Physica Acta* **37,** No. 3, 208 (May 15, 1964).

Effect of Surface Imperfections on Gallium Diffusion in Silicon, J. G. Kren, B. J. Masters, and E. S. Wajda, *Applied Physics Letters* **5,** No. 3, 49-50 (August 1, 1964).

Effektive Austauschkonstante (Effective Exchange Constant), Paul Erdös, *Helvetica Physica Acta* **37,** No. 3, 183 (May 15, 1964).

Ferroakustische Resonanz in Terbium Eisen Garnat (Ferroacoustic Resonance in Terbium Iron Garnet), B. Lüthi, *Helvetica Physica Acta* **37,** No. 3, 185 (May 15, 1964).

Improved Calculation of Vertical Trajectories, L. B. Schlegel and P. J. Bonomo, *AIAA Journal* **2,** No. 8, 1487-1489 (August, 1964).

Nondestructive Read-Out in Thin Magnetic Film Memories, Wilhelm Jutzi, *Proceedings of the IEEE* **52,** No. 7, 875 (July, 1964).

Radio Propagation Observations During the July 20, 1963 Solar Eclipse, P. I. Klein,* *IEEE Transactions on Antennas and Propagation* **AP-12,** No. 5, 643-644 (September, 1964).

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Refinement of Crystal Structure of Tris (Thiourea) Copper (I) Chloride, Y. Okaya and C. B. Knobler,* *Acta Crystallographica* **17,** Part 7, 928 (July 10, 1964).

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Triangular Injection Lasers, J. C. Marinace, A. E. Michel, and M. I. Nathan, *Proceedings of the IEEE* **52,** No. 6, 722-723 (June, 1964).

Ueber die Aenderung der Bandstruktur von Wismut unter Druck (On the Change of the Band Structure of Bismuth under Pressure), R. Jaggi and H. Weibel, *Helvetica Physica Acta* **37,** No. 3, 198 (May 15, 1964).

Ultrastructures in First-Order Model Theory, Erwin Engeler, *Notices of the American Mathematical Society* **11,** No. 4, 465 (June, 1964).