April through June 1960

IBM Technical Papers Published in Other Journals

Abbreviating Words Systematically, June A. Barrett and Mandalay Grems, *Communications of the ACM,* **3,** No. 5, 323-324 (May, 1960).

This paper describes a consistent method for shortening words or phrases to a 6-, 5-, 4-, 3- or 2-letter abbreviation. The rules for abbreviating a word or phrase are the same when used by hand or when coded for a computer. The resulting abbreviation is always consistent but not necessarily unique.

Accurate Determination of the μ^+ Magnetic Moment,* R. L. Garwin, D. P. Hutchinson, S. Penman† and G. Shapiro§, *The Physical Review,* **118,** No. 1, 271-283 (April 1, 1960).

Using a precision technique, the magnetic moment of the positive mu meson is determined to an accuracy of 0.007%. Muons are brought to rest in a bromoform target situated in a homogeneous magnetic field, oriented at right angles to the initial muon spin direction. The precision of the spin about the field direction, together with the asymmetric decay of the muon, produces a periodic time variation in the probability distribution of electrons emitted in a fixed laboratory direction. The period of this variation is compared with that of a reference oscillator by means of phase measurements of the "beat note" between the two. The magnetic field at which the precession and reference frequencies coincide is measured with reference to a proton nuclear magnetic resonance magnetometer. The ratio of the muon precession frequency to that of the proton in the same magnetic field is thus determined to be 3.1834 ± 0.0002. Using a re-evaluated lower limit to the muon mass, this is shown to yield a lower limit on the muon g factor of $2(1.00122 \pm 0.00008)$, in agreement with the predictions of quantum electrodynamics.

*Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
†Now at the University of Chicago.
§John Tyndall Fellow.

Analysis of Lithium Metal and Lithium (1) Mixtures, M. Berkenblit and A. Reisman, *Analytical Chemistry,* **32,** No. 6, 721-722 (May, 1960).

In studies concerned with correlation of physical properties of Li^0 dispersed in mineral oil as a function of volume concentration, it was necessary to evaluate $Li^0 - Li^+$ mixtures by an independent method. A procedure is based on the controlled hydrolysis of the metal in an oxygen atmosphere, catalytic combination of the evolved hydrogen with the carrier gas, and titration of the hydrolysis residue.

An Analytical Method of Determining Pole Locations of Certain Types of Feedback Amplifiers, R. L. Gamblin, *AIEE Transactions* (Application and Industry), **48,** 41-44 (May, 1960).

The pole locations of feedback amplifiers of an arbitrarily large number of stages, but with only one or two characteristic time constants, can be solved analytically. The resulting expression is then general for all of a class of amplifiers. A solution of the case of n stages of one time constant and m stages of another with $n/m \gg 1$ is presented. The case with $m=1$ and with ideal matched transmission lines in the loop is also solved. Other cases presented are for $m=0$ and $m=n$. The analysis is shown to be good for high or low frequency investigations where the system bandwidth is broad enough to prevent high and low frequency response interference.

Anelastic Measurements of Atomic Mobility in Body-Centered Cubic Li-Mg Solid Solution, D. P. Seraphim, *Transactions of the AIME,* **218,** No. 3, 485-487 (June, 1960).

Single crystals of bcc Li-Mg solid solution were grown and their internal friction was measured as a function of temperature. A peak of the Zener type was found in the damping spectrum. The activation energy for the relaxation process is 21.5 ± 1 kcal per mole and the frequency factor is $10^{15.7 \pm 0.7}$ sec^{-1}.

Automation of Computer Panel Wiring, G. W. Altman, L. A. DeCampo, and C. R. Warburton, *Communication and Electronics,* **48,** 118-125 (May, 1960).

This paper describes one of the machine design programs IBM uses for preparing back panel wiring lists. The function of these lists is to describe how the physical components of circuits are connected to perform the logic of the machine. In addition, the lists provide bills of material and other related information to production control.

A Comment on Matrix Inversion by Partition, G. H. Swift, *SIAM Review,* **2,** No. 2, 132-133 (April, 1960).

Under special conditions, partitioning a matrix can be a good approach to its inversion. For example, if it is easy to see that certain of the blocks of a partition can be guaranteed zero matrices and others guaranteed nonsingular matrices, many of the problems are eliminated. These guarantees may make it possible to write the block arithmetic in a 'closed enough' form that is not overly unreasonable for programming. Sufficient restrictions are given on the blocks of $n \times n$ partitions for 'closed enough' block arithmetic.

Contributions to the Knowledge of Excess Noise, H. P. Louis, *IRE Transactions on Electron Devices,* **ED-7,** No. 2, 95-99 (April, 1960).

This paper describes measurements on the noise behavior of a long, magnetically focused electron beam with a convergent Pierce-type electron gun having a shielded cathode. It is found that the excess noise phenomenon is initiated by a scalloped

beam amplification and is essentially dependent on the nonlaminarity of electron flow in the beam. The beam reaches a state of high thermal equilibrium which may be caused by strong electron-electron interaction. An estimation shows that this should be theoretically possible.

Control by Stochastic Adjustment, J. E. Bertram,* *Transactions of the AIEE,* Part II (Applications and Industry), **78,** 485-491 (January, 1960).**

This paper is concerned with the problem of designing an "adaptive controller" for the control of a certain class of dynamic processes. In general, these processes consist of a dynamic element governed by a nonstationary, linear differential equation. It is assumed that the designer knows only the form of the differential equation and bounds on the parameter variations but not the exact equations. A further complication of the problem is that all measurements of the state variables of the process are obscured by additive noise.

Control is exerted by means of a piecewise continuous signal which can change only at "sampling instants." The problem is to design a controller, on the basis of this meager information, which is capable of generating an input sequence that will take the process to equilibrium with zero steady-state error from any initial state. A controller capable of achieving this performance in a stochastic sense is shown to consist of a very simple multi-feedback arrangement in which the only unconventional element is a time-varying gain element.

*At Columbia University, New York, N. Y. when this work was done.
**For period January through March, 1960.

Control Makes Test Safe, Accurate, F. J. Clounie, P. M. DeGroat, and E. M. Szymanski, *Electronics,* **33,** 88, 90 and 91 (May 6, 1960).

This report describes an automatic control unit which can be adapted to any commercially available, manually-operated dielectric tester. The automatic tester achieves a high degree of accuracy, reliability, and repeatability while eliminating hazardous operating manipulations. Cost and portability were criteria for the design of this unit, which can be adapted not only to dielectric testers, but also to any application requiring variable voltage control over a fixed period of time.

Control System Analysis and Design via the "Second Method" of Lyapunov.* I. Continuous-Time Systems, R. E. Kalman** and J. E. Bertram, *Journal of Basic Engineering* (Transactions of the ASME), **82,** Series D, No. 2, 371-393 (June, 1960).

The "second method" of Lyapunov is the most general approach currently in the theory of stability of dynamic systems. After a rigorous exposition of the fundamental concepts of this theory, applications are made to (a) stability of linear stationary, linear nonstationary, and nonlinear systems; (b) estimation of transient behavior; (c) control-system optimization; (d) design of relay servos. The discussion is essentially self-contained, with emphasis on the thorough development of the principal ideas and mathematical tools. Only systems governed by differential equations are treated here. Systems governed by difference equations are the subject of a companion paper.

*This research was supported in part by the U. S. Air Force Office of Scientific Research under Contract AF 49(638)-382.
**Research Institute for Advanced Study, Baltimore.

Control System Analysis and Design via the "Second Method" of Lyapunov.* II. Discrete-Time Systems, R. E. Kalman** and J. E. Bertram, *Journal of Basic Engineering* (Transactions of the ASME), **82,** Series D, No. 2, 394-400 (June, 1960).

The second method of Lyapunov is applied to the study of discrete-time (sampled-data) systems. With minor variations, the discussion parallels that of the companion paper on continuous-time systems. Theorems are stated in full but motivation, proofs, examples, and so on, are given only when they differ materially from their counterparts in the continuous-time case.

*This research was supported in part by the U. S. Air Force Office of Scientific Research under Contract AF 49(638)-382.
**Research Institute for Advanced Study, Baltimore.

A Control System for Logical Block Diagnosis with Data Loading, M. E. Senko, *Communications of the ACM,* **3,** No. 4, 236-240 (April, 1960).

This paper describes a section of an integrated diagnostic monitor system which facilitates the checking of sections of instructions or subroutines anywhere in the object program. A new method of specifying all diagnostic operations in a format similar to a computer program makes the system convenient to use and relatively simple to understand. The paper also describes a number of other novel diagnostic features which can be included in the system.

A Controlled Diffusion Process for Indium in N-Type Germanium, F. Barson, M. J. Dyett, C. Karan, and W. E. Mutter, *Journal of the Electrochemical Society,* **107,** No. 5, 459-461 (May, 1960).

In the diffusion of impurities into wafers of relatively high resistivity *N*-type germanium, a frequent problem is the thermal conversion of the bulk material. A diffusion process is described wherein a liquid layer of suitable composition on one side of a wafer serves both as a source of the desired diffusant and as a sink for deleterious impurities which contribute to thermal conversion. Details of the process and the control of surface concentration of the diffusant are discussed.

Cross Relaxation Studies in Diamond,* P. P. Sorokin, G. J. Lasher, and I. L. Gelles, *The Physical Review,* **118,** No. 4, 939-945 (May 15, 1960).

A microwave double resonance experiment performed on the paramagnetic nitrogen centers in diamond shows that in this system cross relaxation occurs via a four-spin flip mechanism which exactly conserves Zeeman energy. In this process, which was first postulated by Bloembergen and co-workers in their paper on cross relaxation, two spins of the center line make a downward transition while a spin belonging to each satellite makes an upward transition. Simple rate considerations for this process indicate that if a saturating microwave field is suddenly applied to one of the three lines of the nitrogen spectrum, a weak probing microwave signal at either of the two other lines should register a definite change in absorption in a time T_{21}. Specifically, if T_{21} is much less than other relaxation times of the system, then setting the pump upon the center line should force the absorption at either satellite to drop to zero. Setting the pump at the position of one of the satellites, on the other hand, should reduce the

center line absorption to $\frac{2}{5}$ its thermal equilibrium value but should increase the absorption measured at the other satellite by the factor 6/5. This behavior was precisely observed at 1.6°K, using a bimodal cavity.

By resolving the rate at which a satellite decays to zero when the pump is set on the center line, T_{21} is measured for all five satellites in the three principal orientations: $H_0 \| [100]$, $H_0 \| [110]$, and $H_0 \| [111]$. The measured anisotropy is discussed.

It is shown that the four-spin flip transition may be used in special cases to establish continuous wave maser operation by inverting the population of one of the satellite lines. Steady state inversion of one of the nitrogen satellites is incidentally observed in a number of diamonds.

*A preliminary account of this work was given at the International Conference on Quantum Electronics, held at High View, New York, September 14-16, 1959 (Proceedings to be published).

Dielectric Behavior of Single Crystals of Tri-Glycine Sulfate (TGS) from 1 kc to 2500 Mc, A. Lurio and E. Stern, *Journal of Applied Physics,* **31,** No. 6, 1125-1126 (June, 1960).

The dielectric properties of single crystals of TGS were measured in the ferroelectric direction as a function of temperature and frequency. At each frequency, the relative dielectric constant ε', was measured as a function of temperature, giving rise to a family of curves with shapes characteristic of a second order transition. These measurements were made over a frequency of 1 kc to 2000 Mc.

Domain Wall Velocities in Thin Iron-Nickel Films, N. C. Ford, Jr., *Journal of Applied Physics,* **31,** No. 5, 300S-301S (May, 1960).

An apparatus based on the Kerr magneto-optical effect has been used to measure the velocity of domain walls in thin iron-nickel films. Polarized light, after being reflected by a film, is analyzed and detected by a photomultiplier tube. The slope of an oscilloscope trace resulting from the photomultiplier signal is directly proportional to the domain wall velocity, as the wall traverses a light spot of known size. Wall velocities are found to be well described by an equation of the form $v = m(H - H_0)$, where m is the wall mobility and $H - H_0$ the excess applied field. Measurements have been made on films varying in thickness from 4000 A to 700 A with corresponding mobilities of 0.5×10^4 cm/sec-oe for the thicker film and 4.9×10^4 cm/sec-oe for the thinner film. The wall mobility is found to be inversely proportional to $B_s \sigma d$ where σ is the electrical conductivity and d the film thickness. This is the dependence that is predicted on the basis of a simple eddy current model indicating that, even in films as thin as 700 A, the dominant loss mechanism in wall motion is caused by eddy currents rather than intrinsic damping of the Landau-Lifshitz type.

Domain Walls in Thin Magnetic Ni-Fe Films, S. Methfessel, S. Middelhoek, and H. Thomas, *Journal of Applied Physics,* **31,** No. 5, 302S-304S (May, 1960).

Néel proposed a transition from the normal type of domain wall (i.e., rotation of the magnetization vector in the plane of the domain wall) to the Néel type (i.e., rotation of the magnetization vector in the plane of the film) at a certain film thickness, which is due to the thickness dependence of the magnetostatic energy. It is suggested that the cross-tie walls observed in thin Ni-Fe films with uniaxial anisotropy correspond to such a transition, in which the cross ties serve to decrease the magnetostatic energy.

According to this explanation, such a structure should occur in a certain thickness range only. Experimental observations on Ni-Fe wedge-shaped films show the occurrence of the cross-tie structure in the thickness range 400-900 A, which is approximately that predicted by theory. The coercive force shows an anomaly in the same range.

The energy reducing function of cross ties is also shown by the Bitter patterns near scratches in the easy direction in negative magnetostrictive material. In a region along the scratch, the magnetization in the plane of the film is perpendicular to the original easy direction due to the local stresses and again a cross-tie structure is observed.

"Dry Circuit" Contacts, B. E. Blake, *Engineering Proceedings of the Pennsylvania State University 1959 Seminar on Electrical Contacts,* **P-36,** 85-95 (April, 1960).

The influence on contact resistance of the method of resistance measurement is discussed. The advantage of low energy resistance measurement is presented, and a definition of "dry circuit" contacts is proposed. An accelerated environmental method of contact testing is outlined, with emphasis on predicting static contact performance in "dry circuit" applications.

Effect of Geometry on Thick Film* Toroids, James C. Sagnis, Jr., Michael Teig, and Robert L. Ward, *Journal of Applied Physics,* **31,** No. 5, 190S-191S (May, 1960).

In the study of thick-film magnetic circuits, it has been found that thick film cores of certain sizes could not be completely switched if a concentrated drive winding was used. In addition, the induced voltages differed in waveshape as a function of the location of the sense windings with respect to the concentrated drive winding. Both phenomena were obviously detrimental to the "normal" operation of the device as a magnetic storage or logical element. Studies of these phenomena were conducted using planar thick film toroids, photoetched from $\frac{1}{4}$ mil and $\frac{1}{2}$ mil thick Square Loop Hy-Mu 80.† From the results of these studies, qualitative explanation of the aforementioned phenomena is offered in the form of a three-part flux pattern model.

*1-20 microns.
†Magnetics Inc., Butler, Pa.

Elastic Switching Properties of Some Square Loop Materials in Toroidal Structures, W. C. Seelbach and J. R. Kiseda, *Journal of Applied Physics,* **31,** No. 5, 135S-136S (May, 1960).

Elastic switching properties of some square loop materials are presented and the concept of an elastic switching constant $S_{w(r)}$ is introduced. The plot of applied "turnover" field strength vs the inverse of the drive width indicates that the inelastic switching constant for a given material is four to five times greater than the elastic switching constant $S_{w(r)}$. The "turnover" field strength is defined to be that value of field strength at which inelastic switching just starts and therefore is considered to be the upper limiting field strength for elastic switching. To a first-order approximation, the ratio of $S_{w(r)}$ to S_w is shown to be equal to the percentage of the total flux capacity of the core that can be switched in an elastic mode of operation. $S_{w(r)}$ values for Molybdenum Permalloy ranged from 0.0347 oe-μsec for $\frac{1}{8}$ mil tape to 0.0913 oe-μsec for $\frac{1}{2}$ mil tape.

Empirical Explorations of the Geometry Theorem Machine, H. Gelernter, J. R. Hansen and D. W. Loveland, *Proceedings of the 1960 Western Joint Computer Conference,* San Francisco, pp. 143-149 (May, 1960).

This report describes the results of a study in the simulation of intelligent behavior in machines, utilizing an IBM 704 program for the proof of theorems in elementary Euclidean plane geometry as a tool for the investigation.

Equilibria in the System Rb_2O-Nb_2O_5 and Sequential Trends in Oxide-Oxide Interactions. The Prediction of Compound Retention, A. Reisman and F. Holtzberg, *Journal of Physical Chemistry,* **64,** No. 6, 748-753 (June, 1960).

As part of the general investigation of oxide-oxide interactions, the present study of the congener series alkali oxide-Group VB pentoxide was continued with an investigation of the system Rb_2O-Nb_2O_5. Eight compounds have been identified in this system. Three of these, the 1:4, 4:11 and 4:1 members melt congruently at 1315, 1319 and ca. 1300°, respectively; the remainder having base-to-acid ratios of 2:15, 1:2, 2:3, 1:1 and 4:3 melt incongruently at 1351, 1185, 1148, 964 and 830°, respectively. On the basis of the observed liquidus behavior of the several compounds appearing in the sequence of interactions studied, the preliminary model hypothesis previously discussed is expanded upon, and predictions concerning compound repetition in the Cs_2O-Nb_2O_5 interaction are presented.

Experimental Flux Pattern Determination in Magnetic Cores, Robert L. Ward, *Journal of Applied Physics,* **31,** No. 5, 192S-193S (May, 1960).

The difficulties in determining the quiescent flux patterns in nonlinear magnetic structures is considered and two techniques are briefly described for measuring these patterns in magnetic cores etched from sub-mil thicknesses of 4-79 Molybdenum Permalloy. Both methods utilize a sensing loop formed by moveable surface probes and a part of the core itself, which conductively completes the sense circuit. A detailed description of the measuring apparatus and the testing technique is given, and the graphical procedure for plotting the flux configuration, of a two aperture multi-path core is outlined. Finally, additional applications are enumerated.

Extension of Longitudinal-Beam Parametric-Amplifier Theory,* H. Sobol, *Proceedings of the IRE,* **48,** No. 4, 792-793 (April, 1960).

This paper presents an analysis of the longitudinal-beam parametric amplifier in which coupling is allowed between the signal and the first upper and lower sidebands around the fundamental pump frequency. Previous analyses[1] have considered coupling only between the signal and lower sideband. The effect of including the multi-frequency coupling is to reduce the gain to one half the db value predicted by the earlier analyses and also to cause a heavy excitation of the upper sideband. The theoretical results are seen to be much closer to measurements than were the results of the earlier analyses.

*This work was performed while author was at the University of Michigan.

[1] W. H. Louisell and C. F. Quate, **Parametric Amplification of Space-charge Waves,** *Proceedings of the IRE,* **46,** No. 11, 707-716 (April, 1958).

External Fields from Domain Walls of Cobalt Film, B. Kostyshyn, J. E. Brophy, I. Oi, and D. D. Roshon, Jr., *Journal of Applied Physics,* **31,** No. 5, 772-775 (May, 1960).

By scanning the surface with a Hall probe, domain patterns on thin cobalt films have been mapped by measuring the fringing flux normal to the film surface. The samples studied were cobalt approximately 2000 A thick. At the domain boundaries, peak fields ranged in intensity from less than 0.5 to 4.5 oe. The probe to film gap was 13μ. The sensitive area of the probe was a square of bismuth 20μ on a side. It was observed that along specific boundaries, reversal of flux direction occurs. The boundaries exhibiting low peak fields were generally parallel to the easy direction of magnetization, whereas the boundaries exhibiting high fields were skewed relative to the easy direction of magnetization. Kerr effect and Hall probe patterns for the same domain configuration are shown to agree.

Ferrite Films — New Logic and Storage Devices, J. M. Brownlow, W. L. Shevel, Jr., and O. A. Gutwin, *Journal of Applied Physics,* **31,** No. 5, 121S-122S (May, 1960).

Magnetic devices for storage and switching applications in digital computers have been fabricated in the form of open flux path elements. The geometry employed is that of a planar film with thicknesses in the range of 5 to 50μ and other dimensions in the fractional inch range. These elements have the advantages of a ferrite composition and of open flux paths without many of the disadvantages present in similar metallic devices. For use in storage systems, these devices possess excellent squareness characteristics and have coincident selection times comparable with ferrite-toroidal devices. Properties of these devices are given in terms of switching curves, low-frequency hysteresis loops, and one-to-zero signal ratios. Other aspects that are discussed include disturb sensitivity of storage elements, heating effects due to high pulse repetition frequency, and mechanical properties. For each of these, comparison is made with other types of magnetic elements such as toroids and metallic films. Applications are discussed in terms of drive requirements, packing densities, and switching times.

A Fortran-Compiled List Processing Language, H. Gelernter, J. R. Hansen and C. L. Gerberich, *Journal of the Association for Computing Machinery,* **7,** 87-101 (April, 1960).

This paper describes a compiled computer language for the manipulation of symbolic expressions organized in storage as Newell-Shaw-Simon lists. Statements in the language are written in the usual FORTRAN notation, but with a large set or special list-processing functions appended to the standard FORTRAN library. The algebraic structure of certain statements in this language corresponds closely to the structure of a list in machine storage.

Further Studies of GPI Zone Formation Al-2 at. % Cu, C. Chiou, H. Herman,* and M. E. Fine,* *Transactions, Metallurgical Society of AIME,* **218,** 299-307, (April, 1960).

From variation in Young's modulus and Vicker's hardness during GPI zone formation in Al-2 at. pct Cu the following was observed: 1) the presence of grain boundaries does not have any perceptible effect on the aging reaction; 2) the modulus change is orientation dependent; 3) the activation energy for zone growth is confirmed to be 11 ± 1 kcal per mole; 4) re-aging after reversion is preceded by an incubation time that varies with temperature. An analysis is applied to the present data and to data of other workers and kinetic laws dependent on the quenching rate are determined.

*Northwestern University.

High Density Digital Magnetic Recording Techniques, A. S. Hoagland and G. C. Bacon, *IRE Transactions on Electronic Computers,* **EC-9,** No. 1, 2-11 (March, 1960).*

The merit of any high density detection method is ultimately dependent on the "resolution" characteristic of the magnetic recording components. Justification of readback waveform synthesis through "single pulse" superposition is given. A comprehensive, yet general readback simulation program is described which will automatically, for any characteristic pulse, simulate all possible readback signal patterns and test them for specified reading logic as a function of bit density. Amplitude, phase, peak, et cetera, sensing are compared and the influence of parameter variation on performance indicated. Good correlation with experiment has been realized and has greatly reduced time at the bench. The significance of pulse waveform is clearly revealed and this study has provided a guide to head design (ring and probe), permitting the optimization of a total recording system for high-density storage.

* For period January through March, 1960.

Influence of Nearby Conductors on Thin Film Switching, J. S. Eggenberger, *Journal of Applied Physics,* **31,** No. 5, 287S-288S (May, 1960).

The usual concept of a thin film or other open flux path magnetic element consists of the material itself closely encircled by drive and sense conductors. Strips of conductor of width approximately that of the element are attractive for several reasons, i.e., low resistance, low skin effect, and low line impedance. However, these strips, being closely coupled to the element, can severely influence its dynamic properties by means of induced eddy currents.

These conductors manifest themselves in three ways:

1. A slowing of the switching due to the air return flux path of the element passing through a conductor and being damped.
2. A dynamic distortion of the air return flux due to shielding effects.
3. A dynamic distortion of an applied field due to shielding effects.

All of these effects can be detrimental to the operation of the element. In this paper, approximate calculations are presented to show the extent of these effects. The geometry considered is that of a "conventional" flat thin film element, driven and sensed by strip transmission lines. Several drive and sense configurations are considered, and experimental evidence is presented in support of these calculations. Although the cases considered are somewhat arbitrary, the methods and many of the results are applicable to other cases of utilization of open flux path elements.

Intervalley Noise, P. J. Price, *Journal of Applied Physics,* **31,** No. 6, 949-953 (June, 1960).

A theory is developed for the spectrum of electrical noise due to electron transitions between several quasi-isolated groups of states, in the general case where each group may carry part of an electric current. It is applied to the noise due to transitions between valleys of the conduction band of germanium, and the possibility of observing this noise is discussed using the data of Weinreich, Sanders and White on the frequency of intervalley transitions.

Intrinsic and Anneal-Induced Anisotropy in Cobalt-Substituted W-Type Hexagonal Oxides,* L. R. Bickford, Jr., *Journal of Applied Physics,* **31,** No. 5, 259S-260S (May, 1960).

The intrinsic and anneal-induced anisotropy of cobalt-substituted hexagonal ferrous W compounds containing some vacancies in lattice sites normally occupied by metal ions were measured by the torque method. Six oriented polycrystalline samples, corresponding to $y=0.03$, 0.06, 0.12, 0.24, 0.45, and 0.9 in the formula $BaCo_yFe_{17.9-y}O_{27}$, and one single crystal of composition $Ba_{0.27}Sr_{0.73}Co_{1.845}Fe_{16.155}O_{27}$, were investigated. The results confirm the prediction that the cobalt ions and vacancies would be located in the spinel portion of the W lattice and therefore respond to magnetic annealing in much the same way as in the ferrite system $Co_xFe_{3-x}O_4$. The contribution per cobalt ion to the anneal-induced anisotropy constant K_u was found to be approximately the same in the two systems (ca 3×10^{-16} erg/cobalt ion for annealing at 100°C). Other points of comparison include the dependence on cobalt concentration of K_u and the relaxation times characterizing the annealing process, the activation energy and the variation of K_u with temperature of anneal.

The first-order intrinsic hexagonal anisotropy constant K_1 becomes more negative with increasing cobalt concentration reaching a value of -4.35×10^6 erg/cc at 27°C for the single crystal. The value of K_3, the constant which determines the anisotropy in the basal plane, is much larger for this crystal than for any other hexagonal oxide reported so far ($K_3=-1.22\times10^4$ erg/cc at 27°C and $+1.35\times10^5$ erg/cc at −196°C). Two of the compositions ($y=0.45$ and 0.9) have cones of easy magnetization at −196°C.

*Based on experimental work performed while the author was guest scientist in the Philips Research Laboratories, N. V. Philips Gloeilampenfabrieken, Eindhoven.

Magnetic Anisotropy in Evaporated Iron Films, E. W. Pugh, J. Matisoo, D. E. Speliotis, and E. L. Boyd, *Journal of Applied Physics,* **31,** No. 5, 293S-295S (May, 1960).

A torque method has been used to measure the magnetic anisotropy of iron films deposited from the vapor at various incident angles on glass substrates. The anisotropy is found to be largest in films prepared with large incident angles and low substrate temperatures. A theoretical calculation of the anisotropy expected in an iron film with a [111] fiber axis has been made for various angles of the fiber axis and as a function of stress in the film. The theoretically calculated values are not only an order of magnitude lower than most measured anisotropies, but they always have the wrong sign. Iron films deposited on rock salt exhibit anisotropies before and after removal from the substrate which indicate that the anisotropy is affected by cold-working but not by stress relief. It is concluded that the magnetic anisotropy in iron films is primarily related to the faulted regions formed in the films during deposition and not to stress or the proposed fiber axis structure.

Manufacturing Quality Evaluation, J. Schneider, *Industrial Quality Control,* **16,** 14-16 (March, 1960).**

The gist of this procedure is to reveal a means of evaluating and reporting quality of a machining and assembly function in a manufacturing activity.

The evaluation is accomplished by making a statistical comparison between an established quality standard and the quality currently produced. This evaluation is confined to the individual manager's area of quality responsibility, thus

promoting an incentive for each manager to improve his quality status. This evaluation pinpoints areas of concern and indicates when and where corrective action is necessary.

The reporting procedure is a system of timely notifications. Whenever a departmental manager's quality plots out of control, he is notified immediately and a chain of corrective action is started. There is also a description of the quality history on a monthly basis in summary form. This is done graphically, giving management a pictorial presentation of the quality accomplishment of each manager. This summary and its circulation completes the chain of reporting for adequate correction and evaluation activity.

** For period January through March, 1960.

A Martingale Inequality and the Law of Large Numbers, Y. S. Chow, *Proceedings of the American Mathematical Society,* **11,** 107-111 (February, 1960).*

An inequality was obtained, which includes both Doob's martingale inequality and Hajek and Renyi's extension of Kolmogorov's inequality. A theorem on the law of large numbers has been proved, which includes the theorems of Brunk, Chung, Kawata and Udagawa, Lévy, Loeve and Prohorov.

*For period January through March, 1960.

Mayer's Ionic Solution Theory Applied to Electrolyte Mixtures, H. L. Friedman, *Journal of Chemical Physics,* **32,** No. 4, 1134-1149 (April, 1960).

For solutions of a mixture of two electrolytes with a common ion, the characteristic free energy function is $\Delta_m G^{ex}$, the change in excess free energy on forming the solution from solutions of the single electrolytes. This is closely related to $\Delta_m \mathcal{G}$, where $\mathcal{G}$ is the cluster integral sum of the Mayer theory. For systems that conform to Harned's rule the contributions of most of the cluster integrals to $\Delta_m \mathcal{G}$ are negligible. The form of the principal contribution to $\Delta_m \mathcal{G}$ depends on whether the two electrolytes have the same charge type (symmetrical mixtures) or not.

The equations for symmetrical mixtures which nearly conform to Harned's rule are developed in detail, first for the general case in which the components of the potential of average force are arbitrary and then for the special case of hard sphere ions, designated as the primitive model for electrolyte solutions. The leading term of $\Delta_m \mathcal{G}$ is determined by the difference in short-range interaction of pairs of ions of the same charge and does not depend at all on the common ion. Another general result is that $\Delta_m G^{ex}/1^2$ does not vanish as $1 \rightarrow 0$, as has sometimes been expected on the basis of the Brønsted principle of specific ion interaction, but approaches a finite value in a way that is governed by a higher-order limiting law.

Comparison with experiment is made on the basis of the primitive model. The results are roughly consistent with the free energy effects in alkali metal chloride mixtures if it is assumed that the effective radii of the alkali metal ions are about double their crystal radii.

The Mechanism and Efficiency of Electroluminescence in ZnS Phosphors, F. F. Morehead, Jr., *Journal of the Electrochemical Society,* **107,** No. 4, 281-287 (April, 1960).

This work describes the application of a model of the electroluminescent process to the photon emission and power consumption of insulated electroluminescent phosphors as a function of voltage and frequency. The model represents an extension of one described earlier. The model leads to a convenient summary of such data and an increased understanding of their significance. An upper limit to the efficiency of impact electroluminescence in insulated particles is proposed on the basis of the implications of the model.

Microcalorimetric Technique for the Study of Damping and Hysteresis in Ferromagnetic Films, J. R. Mayfield, *Journal of Applied Physics,* **31,** No. 5, 298S-299S (May, 1960).

Experience with experimental techniques for the study of damping and hysteresis in thin films has suggested that many of the difficulties and complications encountered might be avoided by the direct approach of measuring the heat generated by the irreversible processes which are of interest. This suggestion has led to the development of a simple and reliable microcalorimetric apparatus with which accurate loss determinations may be made over a frequency range of about 100 cps to 100 Mc.

The loss detector employed is a thin-film thermocouple which develops an emf proportional to the total heat flux emerging from the ferromagnetic sample. The zero drift of the heat-detecting system is eliminated, and the overall noise level greatly reduced by imposing a low-frequency square-wave modulation on the magnetic losses, amplifying the resultant ac component of the thermal emf with a narrow-band amplifier, and rectifying the output by means of a commutator phase-synchronized with the modulator. It appears that losses as small as 10^6 erg/sec per cc of sample volume are readily detectable. The thermal method thus has a degree of sensitivity which compares favorably with that of other experimental techniques, and has the added advantage of providing a direct measure of energy loss.

Millimicrosecond Magnetization Reversal in Thin Magnetic Films, W. Dietrich and W. E. Proebster, *Journal of Applied Physics,* **31,** No. 5, 281S-282S (May, 1960).

A special pulse equipment including a pulse sampling oscilloscope with an overall response time of 0.35 mμsec for the observation of the millimicrosecond flux reversal in thin permalloy films is described. Output signals as short as 1 mμsec have been obtained and are discussed with respect to the underlying reversal processes. Inverse switching times versus driving field curves have slopes of about 10^8/oe sec. Coherent rotation and oscillation of the magnetization have been clearly detected by picking up the flux change transverse to the driving field.

Minority Carrier Recombination in a Cylindrical Transistor Base Region, D. P. Kennedy, *Journal of Applied Physics,* **31,** No. 6, 954-956 (June, 1960).

This paper establishes the validity of transport efficiency calculations using a simplified one-dimensional model in which minority carrier spreading within the base region is not considered.

Multiprogram Scheduling: Parts 1 and 2. Introduction and Theory,* E. F. Codd, *Communications of the ACM,* **3,** No. 6, 347-350 (June, 1960).

In order to exploit fully a fast computer which possesses simultaneous processing abilities, it should to a large extent schedule its own workload. The scheduling routine must be capable of extremely rapid execution if it is not to prove self-defeating.

The construction of a schedule entails determining which programs are to be run concurrently and which sequentially with respect to each other. A concise scheduling algorithm

is described which tends to minimize the time for executing the entire pending workload (or any subset of it), subject to external constraints such as precedence, urgency, etc. The algorithm is applicable to a wide class of machines.

*Parts 3 and 4, **Scheduling Algorithm and External Constraints,** will appear in a future issue.

New Approach to High-Speed Storage — Low Flux Density Materials, W. L. Shevel, Jr., and H. Chang, *Journal of Applied Physics,* **31,** No. 5, 125S-126S (May, 1960).

This paper presents a new approach toward overcoming the factors currently limiting the frequencies at which storage devices may be switched from one information state to another. Ferrite elements for random access storage have been developed which require a fraction of a microsecond for a cycle.

A series of ferrimagnetic oxides have been developed with properties such that the limits on minimum cycle time are appreciably extended. The most important of these properties is the saturation flux density. Over a range of composition, flux densities have been obtained which extend from 100-500 gauss. The lower flux density results in an appreciably lower energy dissipation in the magnetic structure and consequently in higher switching rates for a given temperature rise within the magnetic material. In addition, temperature dependence of those magnetic properties which determine storage applicability is more favorable than with the better known ferrites.

Toroids have been fabricated with these materials which are suitable for random access memories. These elements have been operated successfully in free air at repetition frequencies in excess of 2 Mc.

The improvements in array characteristics that result are discussed in terms of impedances and transmission delays.

Nomograms for Weight and Volume of Stock, M. E. Arthur, *Machine Design,* **32,** 185-187 (June 9, 1960).

This paper consists of a brief description of the use of two nomograms of a new type which relates four variables without requiring a turning scale. By use of a straightedge and a right triangle any one of the variables may be determined if the other three are known.

Note on the Hyperfine Structure of the $2S^22p^2P_{1/2}$ State of Boron 10 and 11, H. Lew and R. S. Title, *Canadian Journal of Physics,* **38,** 868-870 (June, 1960).

In an attempt to detect a "hyperfine structure anomaly" for Boron 10 and 11 the hyperfine structure of the $2S^22p^2p_{1/2}$ ground states of this pair of isotopes have been measured by the atomic beam magnetic resonance method. The results are

$\Delta_\nu(B^{11}, {}^2P_{1/2}) = 732.153 \pm .003$ Mc/sec.

$\Delta_\nu(B^{10}, {}^2P_{1/2}) = 429.048 \pm .003$ Mc/sec.

$g_J(B^{11}, {}^2P_{1/2}) = 0.6656 \pm 0.0004$

The anomaly is found to be zero to within 2 parts in 10^5.

Paramagnetic Resonance Detection of Trapping in a Photoconductor, R. S. Title, *Physical Review Letters,* **4,** 502-503 (May 15, 1960).

The photoconductor ZnS: Gd was found to show a Gd^{3+} paramagnetic resonance absorption when irradiated with 385 mμ radiation. This resonance absorption decreased slowly on removal of the exciting radiation and could be quenched rapidly by irradiating with red or infrared light. The wavelength dependence of the excitation and quenching of the optical emission was found to be in agreement with the paramagnetic data. A model explaining both the paramagnetic and optical results is given. The photoconductivity predicted by this model was observed using a microwave technique. The technique makes use of the same equipment as needed for paramagnetic resonance.

The Pareto-Lévy Law and the Distribution of Income, B. Mandelbrot, *International Economic Review,* **1,** No. 2, 79-106 (May, 1960).

This is the first installment of a less mathematical account of the author's work concerning what he has proposed to call the "Pareto-Lévy" theory. It is shown that one can express in a fairly simple and intuitive way the properties of the addition of independent random variables in the case where the limit law *is not* the gaussian. These considerations are applied to several problems in economics; more precisely, the Pareto problem of the distribution of income is used as an illustration all through, so that a model of the law of Pareto is provided.

Physik Des Eises, H. Gränicher* and F. Jona, *Helvetica Physica Acta,* Suppl. V, p. 50 (February 3, 1960).**

The problems involved with the structure, the electric and elastic properties of ice are reviewed. An account of the most recent experimental and theoretical results is given.

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**For period January through March, 1960.

Power-Supply Circuit Design by Digital-Computer Method, H. J. Joyal, *Electrical Manufacturing,* **65,** No. 5, 171-177 (May, 1960).

Relieving the design engineer of time-consuming, routine chores is one of the functions of high-speed, digital computers. Power-supply circuitry was designed with the aid of the IBM 704, and the laboratory data compared with computed data. This same problem could be solved on other digital computers.

Precipitation of Dispersed Fine-Particle Magnetite, Lynore E. Slaten, *Journal of Applied Physics,* **31,** No. 5, 74S-75S (May, 1960).

A method has been developed for preparing well-dispersed fine-particle magnetite by precipitation *in situ.* A solution of Fe^{++} and Fe^{+++} is formed into a sol by the addition of agar-agar and polyvinyl alcohol; magnetite particles are then precipitated by diffusing NaOH into the resulting semi-rigid gel. The size range of these particles is from 40 A to 800 A. Typical magnetite films exhibit a coercivity of about 50 oe, with a B_r/B_s ratio of 0.4.

A study of the precipitation reaction has shown that the properties of the resulting magnetic particles appear to be limited by factors intrinsic in the mechanism of the reaction rather than by the limitations imposed by the gel-resin system used.

Preliminary Results on the Aggregation of Ice Crystals, R. E. Hallgren and C. L. Hosler,* Monograph No. 5, "Physics of Precipitation," *American Geophysical Union,* pp. 257-263 (April, 1960).

A brief description of the experimental apparatus and procedure is given. Preliminary results of measurements of the

collection efficiency of a 170 micron sphere as a function of temperature show a decrease of collection efficiency with temperature from 0.17 at −4°C to 0.04 at −20°C. The results are discussed with reference to growth of snowy cakes, charge separation in thunderstorms and the bright band.

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A Preliminary Wear Study of Gold Plated Contacts, B. E. Blake and G. D. Fatzer, *Engineering Proceedings of the Pennsylvania State University 1959 Seminar on Electrical Contacts,* **P-36,** 39-55 (April, 1960).

A thorough study of sliding gold plated contacts must include measurements of both wear rate and contact resistance. The study described in this paper includes only the preliminary determination of wear (transfer) with resistance measurements limited to the static case. This study is significant primarily from the standpoint of metal transfer and wear characteristics. The data generally presented in the literature on sliding contacts refers to base metals where transfer and wear phenomena are influenced by surface films. With gold, surface film formation on sliding will be greatly reduced, probably to an insignificant level. This paper presents data on metal transfer obtained by sliding a gold plated wire on a solid gold alloy wire. Radioisotope techniques are described which were used to measure gold transfer.

The Preparation and Properties of Fe-Ni Films, I. Tsu, *Plating Magazine,* **47,** No. 6, 632-633 (June, 1960).

A chloride bath is described for the preparation of Fe-Ni films by electrodeposition. These films are isotropic, as indicated by measurements of 60-cycle B-H loops. This behavior is similar to that of the nickel-rich films described in the literature. However, the wall motion coercive force (H_c) is lower for the iron-rich films than it is for the nickel-rich films due to the relative magnetic properties of iron and nickel. The evidence presented shows that the anisotropic character of Fe-Ni films does not depend solely on film composition. The addition of thiourea to the chloride bath causes extreme changes in the composition and physical properties of the plated films. The effects of adding 0.2 g/l of thiourea are reported.

Programmed Temperature Gas Chromatography,* S. Dal Nogare† and W. E. Langlois, *Analytical Chemistry,* **32,** No. 7, 767,770 (June, 1960).

A derivation of solute retention behavior in programmed temperature gas chromatography is presented. The final equation, for the dependence of retention time on heating rate, mass flow rate of carrier gas, and starting temperature, was integrated by computer for a linear temperature program, and yielded results in good agreement with experiment. A correlation is noted between relative retention time and the ratio of flow rate to heating rate. Under identical linear temperature programming conditions, increasing the liquid phase polarity increases the retention time of each member of a polar homologous series by the same amount. The effect of liquid phase loading on resolution and the limitations imposed by the liquid phase are discussed.

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Pyroelectric Effect in the Cubic ZnS Structure, R. Landauer, *Journal of Chemical Physics,* **32,** No. 6, 1784-1785 (June, 1960).

The classical theory of pyroelectricity which uses only the symmetry of the crystal class, is shown to be incorrect. The surface structure is also relevant. The case of cubic ZnS is discussed in detail.

Realization of a Geometry Theorem-Proving Machine, H.Gelernter, *Proceedings of the First International Conference on Information Processing,* Paris, pp. 273-282 (June, 1959).

This paper describes an IBM 704 simulation program for the proof of theorems in elementary Euclidean plane geometry. The theorem-proving program relies upon heuristic methods rather than upon exhaustive enumeration or a decision procedure. The particular problem of theorem proving in plane geometry was chosen as representative of a large class of difficult tasks that seem to require ingenuity and intelligence for their successful completion.

Sampling Oscilloscope for Millimicrosecond Signals, H. P. Louis, *Elektronische Rundschau,* **14,** No. 4, 137-144 (June, 1960).

The specifications desirable for oscilloscopes needed in the development of fast switching devices cannot easily be met, even by distributed amplifiers. However, by the use of sampling techniques, good time resolution and high sensitivity can readily be simultaneously achieved. The principles of such methods are described and their advantages and disadvantages discussed. A relatively inexpensive oscilloscope with a resolution time of 0.35 mμsec is described with special attention to the details of circuit design which influence the effective bandwidth, noise and distortion.

Simulation of a Simplified Job Shop, C. T. Baker and B. P. Dzielinski, *Management Science,* **6,** No. 3, 311-323 (April, 1960).

This is a report of the results of some digital computer simulation studies of a simplified model of a job shop production process. Such factors as the average effectiveness of schedules under the impact of random variations in processing times and the effect of changing operating policies are considered. The average manufacturing times and predictability of completion times were used as measures of effectiveness.

Single Crystal Growth and Purification of Tantalum, D. P. Seraphim, J. I. Budnick, and W. B. Ittner III, *Transactions, Metallurgical Society of AIME,* **218,** No. 3, 527-533 (June, 1960).

A reliable technique has been developed for producing single crystals of tantalum in the form of small diameter wires. By suitably heat treating these and polycrystalline samples, first in an oxygen atmosphere and finally in vacuum, it has been found possible to reduce residual resistivities to 10^{-3} microhm-cm. The purity of these samples is thus comparable to the purities obtained in zone-refined silver, copper, and aluminum.

Single-System Film Production, J. Bohmer, *American Cinematographer,* pp. 368-369, 376 (June, 1960).

This paper describes how IBM's technical film group solved single-system's inherent editing problem in order to utilize its time-saving and other advantages over double-system production.

Solving Linear Programming Problems in Integers, R. E. Gomory, *Proceedings of Symposia in Applied Mathematics,* **10,** 211-216 (1960).

An algorithm for finding the best integer solution to a linear programming problem is outlined and a small numerical example is given.

Space Charge Fields in $BaTiO_3$, S. Triebwasser, *The Physical Review,* **118,** No. 1, 100-105 (April 1, 1960).

Experiments have been performed in which observations have been made in the presence of dc electric field bias of: (1) hysteresis loops, (2) double loops above the Curie point, (3) Kerr electro-optic effect above the Curie point and (4) capacitance above the Curie point in $BaTiO_3$. The purpose of these experiments was to determine field distributions in the crystal under an externally applied difference of potential and to examine the extent to which space-charge surface layers cancel the bulk field. The first three types of observations were qualitative in nature. The biased hysteresis loops show normal behavior with no evidence of field cancellation. Double loop measurements show some evidence of field cancellation, while Kerr electro-optic measurements show strongly nonuniform fields indicating anomalous space-charge fields. The measurements of capacitance above the Curie point indicate that surface layers build up in the presence of a dc field, and these surface layers have a capacitance that varies with applied voltage. The results can be understood qualitatively if simple Schottky exhaustion barriers are assumed at the two metal electrode-crystal contacts. Observed asymmetries with respect to the applied fields are discussed.

Special Solder for Use in Cryogenic Circuits, A. W. Grobin, Jr., *The Review of Scientific Instruments,* **30,** No. 11, 1057 (November, 1959).*

In this note a method is shown for making mechanically strong wire connections to thin films evaporated on glass substrates. The connections may be immersed in liquid helium repeatedly without damage.

The solder used for connecting wire leads to fused silver tabs has a melting point of 130°C and is composed of approximately 19% lead, 30% tin, 50% indium and 1% silver.

*For period October through December, 1959.

Specifying a Pulse Transformer for Computer Use, R. R. Blessing, *Communication and Electronics,* **47,** 44-47 (March, 1960).*

The pulse transformer described in this report is a specialized current-driven device that functions as a precision component in large ferrite core memories, and also as a switching device in computer logic. Typical transformer characteristics do not satisfy the exacting demands of computer applications. Greater precision in specifying and measuring these components is required, along with closer tolerances. This paper shows how these specifications are arrived at, how the devices are measured, and how these characteristics are related to the application.

*For period January through March, 1960.

Theoretical Hysteresis Loops of Thin Magnetic Films, H. J. Oguey, *Proceedings of the IRE,* **48,** No. 6, Part I, 1165-1166 (June, 1960).

A simple analytical method as well as a graphical method (due to J. C. Slonczewski, but unpublished) for the determination of hysteresis loops due to uniaxial anisotropy, are given.

Theoretical Power Output and Bandwidth of Traveling-Wave Amplifiers,* H. Sobol and J. E. Rowe,** *IRE Transactions on Electron Devices,* **ED-7,** 84-94 (April, 1960).

Expressions are developed to calculate the theoretical power output of traveling-wave amplifiers using any type of RF structure. Calculations are made for helix-type tubes and it is shown how to calculate the power output of tubes using more dispersive structures in terms of calculations made for helix tubes.

The principal factors accounting for higher power output of dispersive structures are presented and discussed. The gain and bandwidth of forward-wave helix amplifiers are derived from the small-signal theory as functions of frequency and it is shown that the gain in db times the frequency bandwidth is a constant as a function of helix length for high $\gamma_0 a'$ and the gain times the bandwidth squared is a constant for low $\gamma_0 a'$.

*The work was performed while H. Sobol was at the University of Michigan.

**University of Michigan.

Thermodynamic Excess Functions for Electrolyte Solutions, H. L. Friedman, *Journal of Chemical Physics,* **32,** No. 5, 1351-1362 (May, 1960).

A system of excess functions is developed for electrolyte solutions and other solutions with an essentially unsymmetrical solvent-solute relation. These new functions vanish for a solution whose practical (molal scale) osmotic coefficient is unity at all compositions, temperatures and pressures. The use of these excess functions offers some advantages over other methods of comparing Mayer's ionic solution theory with experiment, of representing the properties of solutions of single or mixed electrolytes, and of making qualitative interpretations of the molecular basis of thermodynamic properties.

Graphs showing the ionic-strength dependence of the excess free energy, excess enthalpy, excess entropy, and excess volume are given for several aqueous solutions of single electrolytes up to 6 molal. Experimental values of the cluster integral sum, the characteristic function of the Mayer theory, have also been calculated. The concentration dependence of this function is very similar to that of the excess free energy.

Thin Magnetic Films Switch in about One Millimicrosecond, W. Dietrich and W. E. Proebster, *Electronics,* **33,** No. 23, 79-81 (June 3, 1960).

Strip transmission line is used in measurement apparatus for determining polarity reversal time of thin magnetic films. Fast rise pulse is obtained from a charged coaxial cable.

Time Decrease of Initial Permeability in $Mn_xFe_{3-x}O_{4+y}$, W. A. Crapo, *Journal of Applied Physics,* **31,** No. 5, 267S-268S (May, 1960).

The time decrease of initial permeability has been measured for several stoichiometric and nonstoichiometric compositions of $Mn_xFe_{3-x}O_{4+y}$. The samples were in the form of polycrystalline toroids with compositions $x=0.5$, 0.7, 0.85, and 0.9. The stoichiometric compositions, $y=0$, were fired to maintain a metal-oxygen ratio of 3:4, while the nonstoichiometric samples were fired to produce the maximum vacancy concentration. The permeabilities were measured at a peak

driving field of 0.002 oe in the temperature range $-15°$ to $+35°$C. The time-decrease data was described by three relaxation times. Activation energies calculated on the basis of these relaxation times were within experimental error equal and independent of the Mn/Fe ratio, i.e., $Q=0.46 \pm 0.06$ ev. The activation energy for the nonstoichiometric samples was equal to that observed for the stoichiometric samples. The magnitude of the effect in the stoichiometric samples was found to decrease approximately linearly with the increasing Mn/Fe ratio.

Transfer Function and Error Probability of a Digital Magnetic Tape Recording System, John W. Hung, *Journal of Applied Physics,* **31,** No. 5, 396S-397S (May, 1960).

In spite of the complexities of the digital magnetic recording system, it has been discovered that the output of the system for the input of a unit step of current can be approximated by a Gaussian probability function $A \exp[-a(x-d)^2]$. The value "a" in $A \exp[-a(x-d)^2]$ is a figure of merit of the system.

This yields an analytic expression for the transfer function of the system. Experimental results correlate quite well with those based on this approximate transfer function.

Using this transfer function, the output of the system for any Nonreturn to Zero recording method can be predicted. For example, the reduction in system output with increasing bit densities is established. In addition, when Gaussian noise is introduced into the system, the error probability is obtained. The effect of the input rise time to the output amplitude is discussed.

Two-Phonon Indirect Transitions and Lattice Scattering in Si, W. P. Dumke, *The Physical Review,* **118,** No. 4, 938-939 (May 15, 1960).

The probability of indirect transitions with the emission of two phonons has been calculated. Several of the intensity maxima in the intrinsic low-temperature emission spectrum of Si are explainable in terms of these transitions. Scattering matrix elements obtained from an analysis of the observed emission spectrum indicate that intervalley scattering is the dominant scattering mechanism for electrons in Si, with 0.023-ev and 0.046-ev longitudinal acoustic mode phonons which umklapp scatter electrons between valleys on the same and on different crystal axes, respectively. The valleys are approximately 82% of the way from the center to the edge of the Brillouin zone. Optical mode scattering in the valence band is largely responsible for the anomalous temperature dependence of the intrinsic hole mobility.

Vapor-Deposited Single-Crystal Germanium,* R. P. Ruth,† J. C. Marinace, and W. C. Dunlap, Jr.§, *Journal of Applied Physics,* **31,** No. 6, 995-1006 (June, 1960).

Germanium layers have been formed on single-crystal Ge substrates by the thermal decomposition of GeI_2. The single-crystal nature of the layers has been established by x-ray and electron diffraction examination and by electrical measurements. The deposition process is described briefly. The crystal growth rate varies with crystal direction, and under certain conditions Ge whiskers appear. The layers as deposited are generally n type; p ranges from 1 to 5 ohm-cm and μ_H from 1200 to 2700 cm^2/v-sec at room temperature. A donor level is found approximately 0.2 ev below the conduction band, with a concentration of active centers of about $10^{16}/cm^3$. Heat treatment at 550°C gradually converts the layers to p type, for which p is 10 to 40 ohm-cm and μ_H 1500 to 2400 cm^2/v-sec at room temperature; an acceptor level is found at about 0.05 ev above the valence band, with a density of active centers of 10^{14} to $10^{15}/cm^3$. The layers can be doped intentionally to produce either conductivity type, permitting fabrication of junction devices. Although iodine and other impurity atoms are considered, it is concluded that interstitial Ge atoms and lattice vacancies, occurring in unequal numbers at the time of deposition, are the most likely source of the donor and acceptor levels, respectively, and of the observed heat treatment properties.

*This work was first described by the authors at the June 1956 meeting of the American Physical Society at New Haven, Connecticut [Bulletin of the American Physical Society Ser. II, 1, 294 (1956)], and later at the Electrochemical Society Semiconductor Symposium at Cleveland, Ohio, October 3, 1956.

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Variable Rejection Band Filter, W. C. Dersch, *Electronic Equipment Engineering,* **8,** No. 5, 54-56 (May, 1960).

Voltage-sensitive band-pass filter circuits are described which were used in equipment for re-creating speech or vocal sounds by selecting audio frequencies from a noise signal source containing a wide range of frequencies in response to a control voltage developed from a sampling of frequencies in the original spoken words.