PROCEEDINGS OF THE AMERICAN PHYSICAL SOCIETY

MINUTES OF THE NEW ORLEANS MEETING, DECEMBER 29–30, 1931

The 33rd Annual Meeting (the 175th regular meeting) of the American Physical Society was held in New Orleans at Tulane University on Tuesday and Wednesday, December 29–30, 1931, in affiliation with Section B-Physics of the A. A. A. S. The presiding officers were Dr. W. F. G. Swann, President of the Society, Professor H. A. Erikson, Dr. K. K. Darrow and Dr. E. A. Eckhardt. There were about 200 physicists in attendance at the meetings.

The annual joint session with Section B and the American Meteorological Society was held on Wednesday morning. The presiding officer was Professor Bergen Davis, Vice-president of Section B. The Retiring Vice-president, Professor F. K. Richtmyer, delivered an address on "The Romance of the Next Decimal Place" and he was followed by Dr. H. H. Kimball of the U. S. Weather Bureau, who spoke on "Solar Radiation as a Meteorological Factor". The attendance at this session was about 150.

On Tuesday morning and afternoon there were Mathematical Symposia held as joint sessions of the American Physical Society with the American Mathematical Society and Section A of the A. A. A. S. In the morning there were two invited papers, (1) "Stability and Instability of Physical Systems" by G. D. Birkhoff of Harvard University; (2) "The Significance of the Fundamental Concepts of Modern Atomic Theories" by W. F. G. Swann, of the Bartol Research Foundation. In the afternoon the papers were (1) "The Calculus of Variation of the Quantum Theory" by G. A. Bliss of the University of Chicago, and (2) the annual Josiah Willard Gibbs Lecture on "Statistical Mechanics and the Second Law of Thermodynamics" by P. W. Bridgman of Harvard University. These sessions were held in Dixon Hall on the Newcomb Campus and the attendance at the morning session was about 250 and in the afternoon about 275.

On Wednesday afternoon there was a joint session of the American Physical Society with Section E of the A.A.A.S. and the American Society of Petroleum Geophysicists. This was a Geophysics Program arranged and presided over by E. A. Eckhardt of the Gulf Research Laboratory. About 60 were in attendance.

The annual dinner of the Society was held on Wednesday evening at 6:30 o'clock as a joint dinner with the Geophysicists, the Meteorologists, and the American Association of Physics Teachers. There were 100 present and W. F. G. Swann presided. The guests left the dining room at the Roosevelt Hotel and went to the Municipal Auditorium to attend the meeting held in honor of the late Thomas A. Edison. President Swann presided at this meeting and the

speakers were Frank B. Jewett, Charles Edgar of the Boston Edison Electric Illuminating Company, R. A. Millikan and K. T. Compton.

Annual Business Meeting. The regular annual business meeting of the American Physical Society was held on Wednesday morning, December 30, 1931 at 9:30 o'clock in the Chemistry Building at Tulane University. The meeting was presided over by W. F. G. Swann who delivered the Presidential Address on "Reality in Physics". The President had appointed Professors Anthony Zeleny and C. W. Chamberlain to canvass the annual ballots. They reported the following electons for the year 1932:

President—W. F. G. Swann
Vice-president—Paul D. Foote
Secretary—W. L. Severinghaus
Treasurer—George B. Pegram
Managing Editor—John T. Tate
Members of the Council four year term—F. L. Mohler
Members of the Council four year term—J. H. Van Vleck
Members of the Board of the Physical Review three year term—R. C. Gibbs
Members of the Board of the Physical Review three year term—E. O. Lawrence
Members of the Board of the Physical Review three year term—J. H. Van Vleck

The ballots also showed an almost unanimous approval of the following Modifications of the Constitution which had been recommended by the Council:

A. Change Article VI, paragraph 2 to read as follows: "The Managing Editor and such other elected and appointed members as the Council may from time to time designate shall constitute the Board of Editors, and shall have charge, as designated by the Council, of the several publications of the Society. Not fewer than ten members of the Board of Editors, including the Managing Editor, shall be elected in the manner specified in Article VII."

B. Insert after Article VII two new Articles as follows: "Article VIII—Sections
   1. Members and fellows residing in any locality may, with the approval of the Council, organize a local Section for the more active furtherance of the object of the Society as stated in Article II.
   2. Any Local Section of the Society may be dissolved at the discretion of the Council."

C. Article IX—Divisions
   1. "The Council may, upon petition by members of the Society, form a Division within the Society charged with the advancement and diffusion of the knowledge of a specified subject or subjects in physics.
   2. Each Division shall elect an Executive Committee, the Chairman of which shall report its activities and needs to the Council.
   3. Any Division may be dissolved at the discretion of the Council."

The insertion of Articles VIII and IX will automatically change the number of the Article on Amendments from VIII to X.

The Secretary reviewed the four important resolutions passed at the last Annual Meeting (Proceedings, Physical Review, **37**, 454, (1931)) and reported that during the year they had all been carried out. The Secretary further reported that during the year there had been 168 elections to membership, deaths of 11 members, 26 resignations and 31 who had been dropped. The membership of the Society as of December 29, 1931, is as follows: Members: 1882; Fellows: 679; Honorary Members: 6; Total Membership; 2567.

The Treasurer presented a summary of the financial condition of the treasury of the Society. The complete audited report has been printed and distributed to all members.

The Managing Editor presented a statement of the condition of the Physical Review and the Reviews of Modern Physics and the new journal, Physics, established within the year. The journals are all being well received with a very considerable increase in the amount of material published. The complete audited statement which has been printed and distributed to all members shows that the three journals, as a combined venture, present a deficit for the year of more than $6000. This deficit is being covered very largely through the generosity of the Chemical Foundation.

Meeting of the Council. At the meeting of the Council held on Monday, December 28, 1931, twenty-four persons were elected to membership. *Elected to Membership:* Robert I. Allen, Luang Brata, Fukita Buntaro, Elizabeth Cohen, H. Richard Crane, John M. Davies, John H. Dodge, Jr., Willis Fleisher, Jr., Frederic E. Fuller, John A. Gillin, Monica Healea, Herrick L. Johnston, Norris Johnston, Frank E. Knowles, David B. Langmuir, O. C. Lester, Jr., Paul E. Lloyd, C. R. Moe, William R. Perret, Rudolph E. Peterson, Robert D. Richtmyer, Philip Rudnick, George B. Sabine and John H. Williams.

The regular scientific program of the Society consisted of 64 papers. Numbers 1, 10, 13, 17, 31, 32, 36, 43, 58, 59, 60, 61, 63, and 64 were read by title. The abstracts of these papers are given in the following pages. An **Author Index** will be found at the end.

W. L. SEVERINGHAUS, *Secretary*

ABSTRACTS

1. Thermal expansion of heat-resisting alloys. PETER HIDNERT, *Bureau of Standards, Washington, D. C.*—A comprehensive investigation on the linear thermal expansion of various heat-resisting alloys (nickel-chromium, iron-chromium and nickel-chromium-iron alloys) has recently been completed. These alloys contain 0 to 77 percent nickel, 5 to 27 percent chromium, and 0 to 82 percent iron. The coefficients of expansion of the alloys were determined for various temperature ranges between 20 and 1000°C, and the effects due to temperature, chemical composition, heat treatment, etc., were determined. Some of the expansion curves show critical regions. The data are useful in several ways. It is possible to select heat-resisting alloys which have the same coefficients of expansion for a given temperature range as other materials, for example, brass, copper, porcelain, steel, etc. It is possible to predict the coefficients of expansion of similar new alloys. It is also possible to determine the heat treatment suitable for each type of alloy for a specific purpose as governed by the desired structure. The data (including names and chemical compositions of the alloys) will be published soon in Research Paper of the Bureau of Standards No. 388. This publication will be available through the U. S. Government Printing Office, Washington, D. C., or at Government depository libraries in many cities.

2. Heat treatment of fine metallic suspensions. N. N. ZIRBEL AND A. B. BRYAN, *The Rice Institute.*—When a suspended system is supported by a fine wire the equilibrium position usually changes slowly for a long time after the load is applied. The equilibrium position also changes with temperature. It is found that both of these disturbing factors can be eliminated by a suitable heat treatment of the wire. Observations have been made on tungsten and platinum-iridium wires of sizes suitable for use in the Eotvos torsion balance.

3. The effect of Brownian motion on the useful sensitivity of the resonance radiometer. G. A. VAN LEAR, JR., *University of Oklahoma and* J. D. HARDY, *National Research Fellow, University of Michigan.*—A general treatment of the effect of Brownian motion on the useful sensitivity of the resonance radiometer is given which takes into account the effect of electromagnetic damping. The treatment follows the lines of that given by Hardy in his first paper on the instrument, but is carried through in general terms (the assumption of constants for a specific instrument is not necessary, as heretofore), and leads to a result which depends upon, aside from the temperature, only the resistance of the instrument and the time required to take an observation. When expressed in these terms, the limitation is practically identical with that for the critically-damped galvanometer. Results are also given for certain variations of the instrument as originally described, the limitation found being virtually the same in all cases. However, the advantages remaining to the resonance radiometer for high sensitivity work are pointed out.

4. A kinetic theory of the elasticity of highly elastic gels. E. KARRER, *Medical School, Western Reserve University.*—Studies of several physical properties of colloid systems point to general theory to account for the great elasticity of rubbery gels. Fluidity, $\phi = A - q/T$. T is temperature; q, energy factor; A, number of moving elements, etc. Changes of constants, A and q with concentration and mastication suggest long filamentous molecules of rubber hydrocarbon, that may entrain much solvent. To account for change of viscosity with mechanical agitation (thixotropy) interplay between chaotic forces of thermal agitation, and of local asymmetrical orientating forces of attraction of molecules or particles is envisaged. Orientating forces are adsorptive, but may be those of primary valence, as in litharge-glycerine, electric charges; or may be mechanical, as in stretching and flowing of rubber, or magnetic. Rubber and muscle contain long thin molecules, which in thermal equilibrium are anything but straight. (This may be called a principle of maximum mechanical or geometrical chaos.) Stretching forces produce straightness and tautness. Lateral cohesive forces must be less than end-on forces. Stiffness and ridigity depend also on shape of molecules. Side chains and polar groups affect this markedly, as evidenced by studies of nature and measurement of frictional forces. Stretching eliminates longitudinal degrees of thermal freedom, therefore, heating.

5. An extension of the application and interpretation of the Faraday fluxes. ANTHONY ZELENY, *University of Minnesota.*—The elemental electric fields about electrons and protons are treated as physical entities and inseparable parts of the individual charges. These elemental fields extend indefinitely, interpenetrate freely, and possess inertia and power to transmit energy. An observed electric field is the resultant of such superposed elemental fields which retain their individual identities. A magnetic field is a property of a moving electric field which it possesses by virtue of motion. The term magnetic flux applies to this property and not to an independent physical entity. The magnetic field about a conductor exists without an apparent electric field because the resultants of the two kinds of elemental fields neutralize each other's action on electric charges at rest. Accelerating electrons in a conductor produce a distortion in their resultant negative field. This distortion has an electric component whose action on charges is not neutralized by the opposing positive field. It carries energy outward which it continues to transmit to the as yet stationary part of the field giving it velocity and thereby the property of a magnetic field. The observed intensities of the magnetic fields about loops and charged rotating spheres show that the elemental fields move with their lines of force always parallel to themselves. These facts and points of view enable the well established facts of electricity and magnetism to be clearly explained in terms of definite physical concepts.

6. On the origin of the solar system. Ross Gunn, *Naval Research Laboratory.*—A new account of the formation of the solar system, based on the rotational evolution of a single star, is given which describes the system in some detail and avoids the major difficulties encountered by earlier investigators. Electromagnetic effects have been shown by the author to permit the angular velocity of a star to increase until the star breaks into two components of comparable mass. The component stars are thermally asymmetrical and momentum is radiated more rapidly from the hot face than from the cool. This important new effect, which is quantitatively satisfactory, adds kinetic energy and angular momentum to the companion stars (in a manner analogous to the mechanism of a skyrocket) and may operate to separate the stars to infinity. Applying this to the solar system, the parent semiliquid sun is supposed to have divided and lost its companion. While each companion was inside the Roche limit of the other centrifugal and tidal forces broke off the planets. These in turn immediately broke up and formed the planetary satellites. Tides and tidal couples transferred the momentum of axial spin of the two component stars to that of orbital momentum, while the planets because of their small size largely escaped the effects of this process. Planetary rotations play an important role in the theory. The account replaces the earlier improbable and "accidental" theory by a systematic evolutionary process which is probably quite common in the Universe.

7. Resistance bridge thermometer. Loraine Decherd and Arnold Romberg, *University of Texas.*—A resistance thermometer intended as a secondary standard is described, in which all four branches of the bridge, two of copper and two of manganin, are at the temperature of the bath. All resistances are permanently joined by hard solder or welds, with multiple leads, and mounted on a rigid support. Moving contacts and flexible resistances are absent. The thermometer is simpler to use than other resistance thermometers, and requires no auxiliary apparatus other than battery and galvanometer. The last two figures of a temperature are read by deflection. Simplicity of calibration is secured by equality, at all temperatures, of the two parallel branches of the bridge between galvanometer terminals.

8. Production and recording of continuous seismic waves in the ground. W. R. Ransone, *University of Texas. (Introduced by Arnold Romberg.)*—The first recorded data on the transmission of continuous seismic waves of variable frequency are presented. A discussion of the apparatus used and method of setting up the waves in the ground and recording them is given. The records indicate that the velocities of the continuous waves are not the same as that of the first impulses from impact (dynamite) excitation; that interference patterns exist, and that the ground may be resonant to some frequencies. Feasibility of using the method of continuous waves in geophysical exploration is suggested.

9. A simple ultracentrifuge. J. W. Beams, *University of Virginia.*—The method of rotating the centrifuge is a modification of that used by Henriot and Huguenard, (C.R. **180,** 1389 (1925) and J. de Phys. et Rad. **8,** 443 (1927)), and similar to one previously described for obtaining high rotational speeds, (Rev. Sci. Inst. **1,** 667 (1930) and Science **74,** 44 (1931)). A simple arrangement has been devised by which the light absorption and approximate index of refraction of the materials being centrifuged can be measured as a function of the distance from the axis of rotation of the rotor at full speed. Mounted in a channel cut along a diameter of the top of the rotor is a Pyrex or quartz rod polished flat on its ends. The rod is ground along a narrow strip parallel to its axis which appears illuminated when light enters from either end. Above and next to this strip is mounted a Pyrex tube containing the substances under investigation, through which the strip is observed. With this arrangement centrifugal forces of the order of $10^5 \times$gravity have been obtained. However, this should not be the upper limit for with small all-metal rotors forces of the order of a million gravity have been obtained under favorable conditions. Simple methods of measuring the approximate temperature and rotational speed are discussed.

10. A laboratory apparatus for the determination of the acceleration of a freely falling body. P. H. Carr and R. M. Bowie, *Iowa State College, Ames, Iowa.*—There has been a need for an inexpensive, laboratory method for determining the acceleration of a freely falling body. Such a device has been developed for use in our elementary course. This apparatus is composed of only

such things as Ford coils, electric lamps and potassium iodide soaked paper and operates on 110 v, 60 cycle, alternating current. A ball, suspended from an electromagnet, is released by a key. During the time of fall, spots are made at the rate of 120 per second on the potassium iodide paper. At the end of the fall the ball opens a switch, thus concluding the record. In the hands of elementary students results obtained by this method agree with the accepted value to within two percent.

11. Spatial energy decay due to absorbing boundaries. H. H. GERMOND, *University of Florida.*—A fundamental error in Franklin's derivation of the spatial energy decay due to absorbing boundaries is demonstrated and corrected. The average energy density over the surface is derived in terms of the average throughout the space.

12. Note on the transmission and reflection of wave packets by potential barriers. L. A. MACCOLL, *Bell Telephone Laboratories.*—In previous studies, by the methods of wave mechanics, of one dimensional motion of particles in cases in which there are intervals in which the value of the potential energy function $V(x)$ exceeds the value of the total energy E, attention has been confined to wave functions of the form $f(x, E) \exp(-2\pi iEt/h)$. In the present note wave packets are considered, instead of these trains of waves. The function $V(x)$ is taken as follows: $V(x)=0$ for $x<0$ and for $x>a$, and $V(x)=V_0>0$ for $0<x<a$. A wave function is set up which initially represents a wave packet moving toward the point $x=0$ from the left. The separation of the incident packet into a reflected packet and a transmitted packet is studied. It is found that the transmitted packet appears at the point $x=a$ at about the time at which the incident packet reaches the point $x=0$, so that there is no appreciable delay in the transmission of the packet through the barrier.

13. Quantum mechanics of lithium hydride. MORRIS MUSKAT, *Gulf Research Laboratory,* AND ELMER HUTCHISSON, *University of Pittsburgh.*—Quantum mechanical calculations have been carried through for the normal state of the lithium hydride molecule. Two cases were considered. First, the radial eigenfunction of the valence electron of lithium was taken as nodeless as given by Slater. Second, the function derived by Guillemin and Zener with a node at $0.18a_0$ was used. In both cases the K electrons of lithium were neglected. The results are as follows:

Type of eigenfunction	Equilibrium distance in Angstroms	Heat of dissociation electron volts/molecule	Fundamental frequency in cm^{-1}
Slater	1.427	2.30	1.4×10^3
Guillemin and Zener	1.454	2.21	1.4×10^3
Experimental values	1.6	2.56	1.380×10^3

These results are seen to be in reasonable agreement considering the approximations made, and justify at the same time the use of the simpler and nodeless Slater functions in other calculations.

14. The absorption and emission of sodium light by sodium flames. T. W. BONNER, *The Rice Institute. (Introduced by H. A. Wilson.)*—The variation of the luminosity of a sodium flame with the concentration of the sodium and the thicknes of the flame has been measured with a spectrophotometer. The flame more than filled the angular aperture of the photometer so that the distance of the flame or parts of it made no difference. In agreement with previous work by Gouy, H. A. Wilson and G. L. Locher it was found that the luminosity is a function of the product of the concentration and the thickness or of the mass (M) of sodium per cm^2. This function is proportional to M when M is very small but increases less rapidly than M when M is large. It is only very roughly proportional to $M^{1/2}$. These results do not agree with the recent ones of C. D. Child, (Phys. Rev. **38,** 670 (1931)). Reasons for this discrepancy are suggested.

15. Excitation of atomic mercury by electron impact. W. G. PENNEY, *University of Wisconsin. (Introduced by J. H. Van Vleck.)*—The probability of excitation by electron impact of the four P levels (2^1P_1, 2^3P_2, 2^3P_1, 2^3P_0) of Hg has been calculated. It is found that, although

with increasing velocities the excitation of two of the triplet levels vanishes compared with that of the singlet, that of the middle triplet level approaches a small constant value, which can be computed from the singlet-triplet separation. An estimate is made of the relative excitation of all four P levels for fairly slow electrons, and these are all of the same order of magnitude. A brief comparison with experiment is given.

16. The Zeeman effect of the K II spectrum. ALBERT E. WHITFORD, *University of Wisconsin.*—The Zeeman effect of the $p^5 \cdot 4p \rightarrow p^5 \cdot 4s$ transitions of K II has been studied in an effort to throw light on the failure of the $p^5 \cdot 4s$ configuration to obey Houston's multiplet relations and of the ${}^3P_2 - {}^3P_0$ interval to follow the regular doublet law. The magnetically resolved lines from a Back vacuum arc were photographed in the 3rd order of a 21 ft. 15,000 line concave grating in a Rowland mounting. Not all of the Zeeman patterns were completely resolved, but g values were obtained from triplet and quartet blends by the method of Shenstone and Blair. Analysis of the results showed that the classification of deBruin and Bowen is correct. The g values of the p terms follow closely those found by Back for Ne I and obey the g sum rule within the limits of experimental error. The g sums for the s terms based on completely resolved patterns are definitely greater than those predicted by the sum rule. The g sum rule would not be expected to hold if the anomalous intervals among the terms labeled $p^5 \cdot 4s$ are caused by interaction between the configurations $p^5 \cdot 4s$ and $p^5 \cdot 3d$. The levels of these configurations overlap in K II and also in Rb II, where a similar anomaly has been noted.

17. Pressure shift of spectral lines. HENRY MARGENAU, *Yale University.*—The pressure shift of spectral lines, unexplained by the usual theories of pressure broadening, together with other interesting effects of pressure upon the appearance of absorption lines, can be adequately treated on the basis of the following theory, the details of which are worked out for the absorption of λ2537(Hg) in foreign gases. (Experiments by Füchtbauer, Joos, and Dinckelacker, Ann. d. Physik **71**, 204(1923).) The wave mechanical interaction energy between an Hg atom and an unexcited foreign atom is computed as a function of the distance of separation (1) for the case in which the Hg atom is unexcited, (2) when the Hg atom is in the $2p_2$ level. The perturbation energy is in both cases proportional to $1/R^6$, but the coefficient in case (2) is larger. This implies that, on the average, the energy difference between the two states of the Hg atom is slightly smaller than that corresponding to λ2537A (red shift). Statistical considerations permit an estimate of the shift and broadening, the results being in satisfactory agreement with experiment. The shift is proportional to the density of the perturbing gas. The theory allows blue shifts in cases which, apparently, have not been tried experimentally.

18. Active nitrogen. JOSEPH KAPLAN, *University of California at Los Angeles.*—Striking similarities are pointed out between two independent experiments on active nitrogen. The first experiment is the production of metastable nitrogen molecules in nitrogen-mercury mixtures, by the quenching of the second positive bands of nitrogen by mercury atoms (Phys. Rev. **37**, 226, (1931)), and the second one is the production of the nitrogen afterglow in uncondensed discharges (Phys. Rev. **37**, 1004, 1931). Although no visible glow was observed in the Hg-N_2 experiments, the presence of active nitrogen was shown by the excitation of the violet cyanogen bands, the cyanogen having been produced in the discharge-tube reaction $CO + N(^2D) = CN + O$. The strong second-positive bands of N_2, which are always very intense in the usual active-nitrogen producing discharges, were nearly completely missing in these experiments. There was a strong enhancement of certain band heads of the first-positive group of N_2, which has been correlated with predissociation. The appearance of the afterglow in the uncondensed discharge is probably due to the change in surface brought about by constant running of the tube. The main significance of these experiments lies in the fact that the afterglow has been produced under conditions which disagree violently with the ones usually necessary for the production of active nitrogen.

19. The wave-length of the molybdenum and copper K series. J. A. BEARDEN, *Johns Hopkins University.*—The quantum theory of dispersion as developed by Kronig, Kramers, Kallman and Mark may be written for incident frequencies ν greater than the natural frequencies ν_s of the refracting electrons in the form

$$\lambda = \delta^{1/2}\left[\frac{\rho}{w}\cdot\frac{e}{m}\cdot\frac{F}{2\pi}\sum_1^s N_s\left\{1+\frac{\log(x^2-1)}{x^2}-\frac{2\pi q}{x^3}\right\}\right]^{-1/2}$$

where $\delta = 1-\mu$, ρ the density, w the molecular weight, e/m the ratio of charge to mass of the electron, F the Faraday constant, N_s the number of electrons per molecule of natural frequency ν_s, $x=\nu/\nu_s$, $q=k/\nu_s$ where k is the damping factor which can be obtained from the atomic absorption coefficient. The value of the bracket term is independent of small changes in ν and ν_s. Since the x-ray wave-lengths, as determined by crystals and ruled gratings, differ by 0.25 percent, we may use this relation to indicate which is correct. The writer has recently made some precise measurements of the refraction of the molybdenum and copper K series in a prism of quartz. The results are given in the following table.

Method	$\delta\times10^6$	λ(Dispersion)	λ(Crystal)	λ(Grating)
1	8.553	1.536A	1.538A	1.542A
1	6.971	1.388	1.389	1.392
2	8.560	1.537	1.538	1.542
2	6.976	1.388	1.389	1.392
1 & 2	1.805	0.7089	0.7093	0.7109
1 & 2	1.432	0.6315	0.6314	0.6328

It is difficult to believe that such an agreement between the wave-lengths as determined by dispersion and by crystals is entirely fortuitous. Thus it appears that the optical diffraction theory is not valid when applied to x-ray wave-lengths.

20. A ruler and chart method of interpreting x-ray oscillation photographs and an application to cerussite. LUCIEN LACOSTE, *University of Texas.* (*Introduced by M. Y. Colby.*)—A ruler and chart method of obtaining the reciprocal lattice projections of planes appearing on an oscillation photograph has been devised. The method is similar to Gruner's (Amer. Min. **13,** 123, (1928)) except that it eliminates all calculations and reduces the probability of working errors without any loss of accuracy. Planes whose indices are uncertain are identified, by determining the Bragg angle. This is done by taking oscillation photographs by a method in which the photographic plate is oscillated in synchronism with the crystal about an axis prependicular to the photographic plate. A comparison of this type of photograph with the usual type gives the Bragg angle. This method of identifying planes of uncertain indices can also be used in conjunction with Bernal nets (Proc. Roy. Soc. L. **113A,** 116). The ruler and chart provide a simple means of making these nets. The ruler and chart method has been used in a study of cerrussite, with the following results:

$$a=5.17\text{A},\ b=8.47\text{A},\ c=6.13\text{A}.$$

The unit cell contains four molecules. The space group is $2\text{Di}-16$.

21. X-ray diffraction patterns of mixtures. M. Y. COLBY, *University of Texas.*—Experiments have been carried out to duplicate those of Roy W. Drier (Phys. Rev. **37,** 712, 1931), in which powder photographs of mixtures of Zn and Cu at room temperature invariably exhibited eight lines that did not appear on the composite diffraction pattern of the components. These extra lines were attributed to α-brass. By using freshly prepared zinc and copper filings (200 mesh) sealed in Pyrex capillary tubes, powder photographs have been obtained with the General Electric x-ray diffraction apparatus. They show no extra lines. In agreement with Kenney and Aughey, (Phy. Rev. **38,** 1388, (1931)) the photographs of the mixture are identical with the composite photographs of the components in every case. Using a mixture of freshly prepared copper dust and old zinc dust, eight lines appear, belonging to neither Cu nor Zn. These "extra" lines, however, correspond exactly to the eight strong lines or zinc oxide.

22. Crystal structure of ammonium bicarbonate. R. C. L. MOONEY, *University of Chicago.*—X-ray data obtained from laboratory-grown crystals, of NH_4HCO_3 show that the symmetry is orthorhombic, the unit cell dimensions are $a=7.29$ A.U, $b=10.79$ A.U, $c=8.76$ A.U; there are eight molecules in the unit cell, and the space group is Pccn (V_h^{10}). Groth gives the axial ratios as 0.6726:1:0.3998. Those obtained experimentally are 0.676:1:2 (0.406). Relative intensity considerations indicate that the CO_3 groups in the structure lie approximately in planes parallel

to the a-face, in agreement with reported optical properties. (Birefringence and orientation of optical axes.) The hydrogen atoms cannot be fixed by means of intensity data, but there is strong evidence that those not belonging to the NH_4 groups lie between oxygens of different CO_3 groups. The dimensions of the CO_3 groups are, within the limit of the observations, essentially the same as in the normal carbonates.

23. The change in thermal e.m.f. produced by a magnetic field. H. E. BANTA, *Rice Institute.* (*Introduced by C. W. Heaps.*)—The change ΔE, due to a magnetic field H, of E the *e.m.f.* of a thermocouple is measured in these experiments. A commutator rotating at constant speed allows a current to flow through the couple, thus producing a temperature gradient between the junctions by the Peltier effect. This exciting current is then cut off by the commutator, and the couple connected to a very sensitive potentiometer for a short time. This process is automatically repeated every 2.5 seconds. The potentiometer is adjusted so that when the couple is connected to it the galvanometer does not jump. The two junctions are copper on a metallic crystal. The quantity $\Delta E/E$ is determined as a function of magnetic field, of temperature, of direction of field, direction of crystal axis, and of direction of heat flow. The present experiments are on a pure bismuth crystal; it is proposed to extend the investigation to other crystalline metals.

24. Low frequency vibrations in Rochelle salt and quartz plates. W. G. CADY, *Wesleyan University.*—In continuation of previous work (Phys. Rev. **33,** 278 (1929)) observations of frequency have been made on Rochelle salt resonators with flexural vibrations in planes perpendicular to all three axes and with torsional vibrations about the X axis. Best values to date for Young's modulus parallel to the X, Y and Z axes are 1.99 ± 0.06, 2.88 ± 0.06, and 2.91 ± 0.01, respectively, all multiplied by 10^{11} dynes/cm^2. For bars at 45 degrees to the YZ, ZX and XY, axes, the values are 3.02, 0.98 and 2.52×10^{11}. The observed rigidity appears to be only 0.49 $+10^{11}$. The temperature coefficient of frequency is very large, from 400 to 1400 parts in a million per degree C. However, for bars at 45 degrees to the Y and Z axes, the frequency-temperature curve has an inflection between 21 and 23 degrees C, so that for a narrow range of temperature the coefficient is practically zero. Similar frequency tests have been made with quartz resonators, using flexural vibrations in planes perpendicular to all three axes, also torsional vibrations about the Y and Z axes. A quartz flexural vibrator 9.3 cm long has been made to serve as a master oscillator at only 3000 cycles/sec.

25. Further study of effects of intense audio-frequency sound. NEWTON GAINES AND LESLIE A. CHAMBERS, *Texas Christian University.*—The magnetostrictive nickel tube vibrator mentioned in Abstract 42 (Phys. Rev. **37,** 109 (1931)) has been improved. Explosive rupture of water fleas due to one second's exposure to the sound has been observed. The bactericidal effect has been extended to organisms present in raw milk, and there has been developed a device for the continuous sterilization of milk by sound.

26. The production of high speed protons without the use of high voltages. ERNEST O. LAWRENCE AND M. STANLEY LIVINGSTON, *University of California.*—A method for the multiple acceleration of charged particles to high velocities described recently before this society (E. O. Lawrence and M. S. Livingston, Phys. Rev. **38,** 834 (1931)) has now been brought to a stage of development where it can serve in experimental studies of atomic nuclei. The present experimental arrangement automatically focusses the beam of ions all along their spiral paths as they are successively accelerated; practically no ions are lost in the course of acceleration. With the present apparatus, currents of about 10^{-9} amp. of 1,100,000 volt protons have been generated. A larger apparatus is under construction for the production of protons having greater kinetic energies.

27. Current-voltage and thermal characteristics of the copper oxide rectifier. W. B. PIETENPOL AND G. W. PRESNELL, *University of Colorado.*—It has been suggested (Gentry, Science, Sept. 23 (1927)) that the relation between current and voltage for the copper oxide rectifier may be represented by the space charge equation, $I=kV^{3/2}$. Measurements have been

made over a wide range of voltages and the slope of the logarithmic curve indicates that the space charge equation applies to a reasonable degree of accuracy for high voltages. At very low voltages Ohm's Law is obeyed while at intermediate voltages, slopes of 0.8 and 4, in the high and low resistance directions respectively, indicate the influence of an additional factor. The application of a temperature gradient to the copper, copper-oxide surface produces a current in the direction of heat flow. The temperature gradient resulting from the passage of a current therefore tends to aid the rectification, and this factor is suggested as an explanation for the variation in the slopes of the curves at intermediate voltages. A careful determination of the variation in resistance with temperature at extremely low voltages has been made. The results obtained by previous experimenters have been verified for ordinary voltages.

28. Generation of combination and harmonic frequencies by linear and non-linear vacuum tube circuits. C. P. BONER AND MARIAN O. BONER, *University of Texas.*—An audible beat method is used to measure amplitudes of the components of alternating current in a triode when the grid circuit contains electromotive forces at two frequencies. With resistance load in the plate circuit, current at the summation and difference frequencies are equal in amplitude, regardless of the equation of the characteristic. By using a parabolic section of the characteristic, measured amplitudes of these combination currents check theoretical values. As the dynamic characteristic is straightened by addition of impedance in the plate circuit both combination currents disappear, and no tone at a "beat frequency" remains. Results indicate that there is no "beat tone" generated in a receiving system, linear or non-linear. Further, the output of a vacuum tube amplifier stage contains a far smaller percent of harmonic and combination frequencies when high quality transformer coupling is used than when resistance coupling is used, provided transformer secondaries carry no load.

29. Harmonic analysis of the plate current in a vacuum tube circuit. S. LEROY BROWN, *University of Texas.*—The harmonic components of the plate current which flows when the control or grid-voltage is varied sinusoidally may be determined from the operating characteristic of the tube. The operating characteristic is analyzed as a cathode ray oscillogram with the aid of the Wiebusch Analyzer (J.O.S. and R.S.I. **15,** 355 (1927)). The analysis of a section of the static characteristic gives the amplitudes and phase relations of the harmonic components in the plate current that are produced by a sinusoidal grid voltage, the amplitude of the alternating grid voltage and the grid bias being determined by the section of the characteristic curve that is selected. When there is a load in the plate circuit, the operating characteristic may be obtained with a cathode ray oscillograph and the analysis of the oscillogram gives the harmonic components of the plate current for the particular operating conditions and load impedance.

30. The calculation of detection performance in a vacuum tube circuit for large signals. J. P. WOODS, *University of Texas. (Introduced by S. Leroy Brown.)*—It is mathematically proven that a detector tube which has a broken straight line for its plate-current, grid-voltage static characteristic will detect the standard radio signal without distortion, regardless of signal strength. The plate detection performance of a tube having a given curve for its static characteristic can be calculated from the extended power series which represents the characteristic. The power series analysis of the curve is obtained from a Fourier series analysis by a method which saves labor and is more accurate than the method of simultaneous equations. Thus, by using twelve or fifteen terms of the power series instead of only the first two or three, and by setting up special formulae, detection performance can be calculated for any signal strength and any modulation. The method is applicable to the tube alone, to a circuit containing the tube and external resistances, and may be applied to any similar non-linear receiving system.

31. Methods of detecting molecular rays. J. TYKOCINSKI-TYKOCINER, *University of Illinois.*—The usual methods of detecting molecular beams by the use of manometers and thermocouples is fraught with difficulties due to galvanometer drifting which is produced by radiation and spurious changes in pressure. The new methods are designated to eliminate these difficulties by periodically interrupting the molecular beam. A vibrating or rotating shutter may be used for this purpose. In its simplest form the vibrator consists of a fine steel wire inserted

perpendicularly to the direction of the beam and actuated by an a.c. electromagnet placed outside the vacuum envelope. Beside the usual types of manometric receivers, a condenser-microphone may be used, whose vibrating part consists of a wire tuned to the frequency of interruption. By known methods of amplification any degree of sensitivity in the conversion of pressure variations into a.c. can thus be obtained. Also a thermocouple or a fine wire may be directly subjected to the bombardment of such molecular rays. Periodic variations of temperature are in this case converted into a.c. These methods are especially adaptable in connection with a selector which by its action subdivides a continuous beam into sequent groups of molecules of definite velocity. No additional shutter is therefore necessary when a selector is used. Two selectors, one for a frequency of 500, the other for 8000 per sec. are being tested in connection with the above methods of detection.

32. Effect of magnetic field on reflected electron beams. E. RUPP AND L. SZILARD, *German General Electric Co. (Introduced by E. P. Wigner.)*—Electron beams with velocities between 70,000 and 220,000 volts were reflected from crystals of heavy metals and subsequently subjected to longitudinal and transverse magnetic fields. The direction of polarization of the beam in a longitudinal field is shown to rotate according to the Larmor precession. The effect in the transverse field is more complicated but can be fully accounted for by the theory of the spinning electron. Further experiments are in progress with special reference to relativistic effects.

33. The nuclear spin of caesium by the method of molecular beams. I. I. RABI, *Columbia University.*—A beam of caesium atoms was sent through a weak and inhomogeneous magnetic field. The deflection pattern was observed and compared with the pattern obtained from a beam of potassium atoms in the same field. To obtain sufficiently large deflections a very long path was used (36 cm). At fields where the potassium beam is strongly split the caesium shows only a broadening. It is only at much larger fields that the caesium beam is split. At the temperature used the patterns should be entirely similar. The results show the presence in caesium of a nuclear spin which can be rather easily evaluated from a knowledge of the magnetic field and its gradient.

34. An isotope of hydrogen of mass 2 and its concentration. HAROLD C. UREY, F. G. BRICKWEDDE, AND G. M. MURPHY, *Columbia University and The Bureau of Standards.*—The proton electron plot of atomic nuclei (Urey, J. Am. Chem. Soc. **53,** 2872; Johnston, ibidem, **53,** 2866) indicates that hydrogen isotopes of mass 2 and 3 may be expected to exist. The discrepancy between the atomic masses of hydrogen as determined by Aston and by chemical methods indicates that higher isotopes of hydrogen may be present (Birge and Menzel, Phys. Rev. **37,** 1669 (1931)). A calculation of the relative vapor pressures at low temperatures of the molecules H_2^1, H^1H^2, and H^1H^3 from theory shows that the heavier molecules should be rapidly concentrated in a residue from the evaporation of hydrogen near the triple point. One of us (F.G.B.) prepared such a sample. The other two authors investigated it for atomic lines of hydrogen atoms of masses 2 and 3. It is found that $H\beta$, $H\gamma$, and $H\delta$ are accompanied by weaker lines agreeing within experimental error (about 0.02 A) with the calculated positions for an isotope of mass 2. The isotope lines have about the same breadth as the main lines. These are found in ordinary hydrogen with intensity about 1/4000 of the main lines and in the residue from the evaporated hydrogen with distinctly greater intensity indicating an abundance of about 1/800. No evidence for the existence of H^3 has been found. Work on the $H\alpha$ line is in progress. Work on the further concentration and on the molecular spectrum is planned.

35. On the range of fast electrons and neutrons. J. F. CARLSON AND J. R. OPPENHEIMER, *Berkeley, California.*—We have made calculations of the ionizing power of electrons and protons with velocity very close to that of light, taking adequate account of the retardation of the forces between the particle and the electrons in the matter through which the particle is passing, and of the binding of these electrons in atoms. If M be the rest mass of the particle and ϵMc^2 its energy, then for very large ϵ, (1) the number of ions produced per centimeter path increases with $\ln \epsilon_i$, (2) the range of the particle is just one fourth of the mean distance, which, according

to the Klein-Nishina formula, a gamma ray of the same energy should travel before its first Compton scattering. We have also computed the ionizing power of the neutrons, which were suggested by Pauli as elements in the structure of the nucleus. The number of ions produced by fast neutrons is sensibly independent of the velocity, and depends only on their magnetic moment. In conjunction with the experiments of Bothe, Kolhoerster, Rossi and Mott-Smith, the results (1) and (2) show that the ionizing radiation associated with the cosmic rays cannot be either primary of secondary electrons or protons. It is suggested that if these rays are neutrons, thin cloud-chamber tracks should be found accompanying the beta-ray tracks in a beta-ray radioactive disintegration.

36. On the use of the Wilson cloud chamber for measuring the range of alpha particles from weak sources. F. N. D. KURIE, *Yale University.*—A large Wilson cloud chamber is operated by a synchronizing mechanism similar to that described by Blackett. A single lens camera is used which takes two sharp photographs of the whole volume of the chamber by mirrors which are so arranged that they are equivalent to photographs taken by two cameras at right angles, and so enable one to study tracks inclined to the plane of the chamber. The conditions to be satisfied by the camera are discussed. The photographs are examined by replacing the developed film in the camera, using this as a projection apparatus. The two images can be caught on a suitably oriented photographic plate as one image of the same size as the original track. This may be measured in a comparator. The α-particle source may be quite large and is mounted in the center of the chamber. Tests of the method have been made, by photographing glass fibers of known length and also by determining the range of polonium α-particles. It will be applied to the range of uranium α-particles. The temperature in the chamber has been carefully studied over the cycle and over long runs to ensure accuracy in reducing the ranges to standard conditions.

37. Inelastic and elastic electron scattering in argon. A. L. HUGHES AND J. H. MCMILLEN, *Washington University, St. Louis, Mo.*—The energy distributions of electrons, scattered in argon at 10°, and having lost various amounts of energy, have been measured for 50 to 200 volt primary electrons. (The energy losses included the excitation loss, 11.6 volts, the ionization loss, 15.5 volts, and still greater losses.) It was found that the greater the energy of the primary electron, the greater was the relative probability of the larger energy losses. The angular scattering curve (5° to 35°) for all the inelastic collisions is *steeper*, the *greater* the energy of the primary electron. These angular scattering curves are *steeper* the *less* the energy *lost* in the collision. Angular *elastic* scattering curves were obtained for primary electrons having energies between 50 and 550 volts and plotted against $(\sin\theta/2)/\lambda$ (where λ is the De Broglie wave-length and θ the angle of scattering). The curves for the higher velocities are practically superposable, as they should be on Mott's theory. There is satisfactory agreement between the scattering curve obtained experimentally with 550 volt electrons, and that calculated on Mott's theory. Maxima in the angular distribution curves for 50 and 100 volt electrons were found at 100° and 90° respectively.

38. Distribution of electrons ejected in ionization of argon atoms. J. H. MCMILLEN AND A. L. HUGHES. *Washington University, St. Louis, Mo.*—Theoretically the energy of impact of an electron ionizing an atom, in excess of that necessary for ionization, may be divided in any way between the faster ionizing, and the slower ejected, electrons. Energy distribution curves for the electrons ejected by 50, 100 and 200 volt primary electrons show that the smaller the energy of ejected electron the more probable is its occurrence. This is in qualitative accord with the result that the less the energy lost by the ionizing electron the more probable is this kind of collision. The total number of 3 volt ejected electrons is of the same order as the total number of ionizing electrons which have lost 3 volts more than the ionization energy. The angular scattering curves for the low velocity ejected electrons (except for a small maximum near 120°) show a tendency towards a uniform distribution in angle, in striking contrast with the concentration of the ionizing electrons in the onward direction. The position of the small maximum in the ejected electron scattering curves depends on the energy of the colliding electrons and on the energy of the ejected electrons.

39. Photoelectric emission from cadmium and mercury. DUANE ROLLER AND HUGHES ZENOR, *University of Oklahoma.*—This paper describes the photoelectric properties and the methods of preparing thin films of pure cadmium and of pure mercury deposited on oxidized iron and on glass. New experiments on the effects of contamination on the photoelectric behavior of mercury in bulk are also described.

40. The compound photoelectric action of x-rays in oxygen and argon. GORDON L. LOCHER, *The Rice Institute.*—When an atom has a K-electron ejected by x-rays, an outer electron falls into the vacant orbit, accompanied by the emission of a quantum of K-radiation characteristic of the atom. The quantum may escape (simple photoelectric action) or eject an outer electron from the same atom (compound action). In the experiment described here, the "K-fluorescence yield", that is, the ratio of the number of cases of simple-action to the total number of both kinds for K-ionized atoms, has been determined by the direct method of counting the relative numbers of single and double tracks obtained by passing a beam of 0.709 A.U. x-rays through a Wilson cloud-apparatus containing the gas under investigation. For oxygen, 900 pairs of stereo-photographs of tracks, in an atmosphere composed of hydrogen gas and water vapor, were collected and examined; of these 14.4 percent were single and 85.6 percent double. Since 85 percent of all photoelectrons should come from the K-shell, the indicated fluorescence yield is zero, which means that no fluorescent K-radiation is emitted by oxygen. By similar procedure, the fluorescence yield of argon has been determined from 500 stereo-photographs of tracks produced in an atmosphere composed of argon, hydrogen and water vapor.

41. The photoelectric and thermionic properties of palladium. W. W. ROEHR AND L. A. DUBRIDGE, *Washington University, St. Louis.*—The photoelectric threshold of a filament of pure palladium foil was studied during 1000 hours of heat treatment in the highest attainable vacuum. It shifted from an initial value of less than 2300A to a maximum value of more than 3022A and finally approached a steady value of 2486A (4.97 volts), which could not be changed by further treatment. This value is apparently characteristic of clean palladium. The thermionic work function in the final state was found to be 4.99 ± 0.04 volts, in good agreement with the photoelectric value. The coefficient A was close to the theoretical value of 60 amp./cm^{2}deg^2. The photoelectric currents excited by monochromatic light increase with temperature over the range 300° to 1070°K, the rate of increase being greater for frequencies near the threshold. The photocurrent-frequency curves taken at the higher temperatures approach the axis asymptotically. All the results are shown to be in excellent agreement with Fowler's theory, and an analysis of the data for 8 temperatures by his method yields a *true* photoelectric work function of 4.97 ± 0.01 volts, independent of temperature.

42. A further experimental test of Fowler's theory of photoelectric emission. L. A. DUBRIDGE, *Washington University, St. Louis.*—The new theory of photoelectric emission proposed by Fowler (Phys. Rev. **38,** 45, 1931) has been shown to be in excellent agreement with observations on a number of clean metals. The theory predicts that the photocurrent-frequency curves should approach the axis asymptotically, so that there is no sharply defined threshold at any temperature above 0°K. The absolute zero threshold can however be determined from measurements at ordinary temperatures. The "temperature variation of the threshold" therefore loses quantitative significance, as do recent attempts to relate this quantity to the thermionic coefficient A. Another method of testing Fowler's equation is proposed which allows the absolute zero threshold to be determined from temperature measurements at a *single frequency*, making it unnecessary to measure the relative intensities of spectral lines. The method is to plot the observations in the form $\log(I/T^2)$ vs $\log(1/T)$. The horizontal shift required to make the observed curve fit Fowler's theoretical curve ($\phi(\mu)$ vs $\log \mu$) is equal to $\log[h(\nu-\nu_0)/k]$, from which ν_0 is determined. Analysis of data for clean palladium (DuBridge and Roehr) and gold (Morris) shows a complete agreement with the theory.

43. New method for the study of the photoelectric effect of alkali vapours. JAKOB KUNZ, *University of Illinois.*—Several methods have been applied so far in the study of the photoelectric effect of alkali vapors, and yet the problem is not completely solved. The oldest method,

which I have used together with Dr. Williams is a direct one and consists in sending a beam of light through a tube with quartz windows at a given temperature. Scattering of light, photoelectric effect of a thin film of alkali deposited on the electrodes and especially the thermionic effect of such films have to be eliminated. The new method consists in using an interrupted beam of light. The photoelectric current produced plus the thermionic current pass through a condenser to an amplifying tube, in which only the photoelectric current will be amplified, while the non-interrupted thermionic current is eliminated. The system can be calibrated by means of an ordinary photoelectric cell. The second method is used for the absorption of light in alkali vapors. A monochromatic beam of ultraviolet light passes through a tube containing alkali vapor at a given temperature and falls on a photoelectric cell. The photoelectric current is measured either directly or after amplification. Another beam of light of the same source falls on a second photoelectric cell placed in series with the first cell; this method is exceedingly sensitive to small variations of light. The arrangement can also be used as null method by proper adjustment of the potentials.

44. Eotvos torsion balance. DONALD C. BARTON, *Consulting Geologist and Geophysicist, President of the Society of Petroleum, Geophysicists, Houston Texas.*—The presence of an extra heavy (or light) body in the subsurface warps the level surfaces up (down) over the body and the lines of the vertical toward or into (away from) itself. The Eotvos torsion balance consists of a calibrated platinum-iridium torsion wire which supports a beam of negligible weight; a weight is attached to one end of the beam and a second weight is suspended from the other end. Curvature of the level surfaces and curvature of the vertical each produce at the two weights horizontal components of gravity which are respectively equal and opposite in actual but the same in rotational direction. The torque produced by the curvature of the vertical is a function of the difference of the radii of curvature of the level surface in the directions of major and minor curvature. There has been only one slight important improvement of the torsion balance in the past 25 years. There is room for improvement in the avoidance of temperature effects and in speeding up in the time necessary for observation. The mathematics of the torsion balance and of the gravitational effects of simple geometrical bodies is simple and developed. The main field of research with the torsion balance lies mainly in the geological-geophysical field of interpretation, although there are still unsolved problems in the mathematics of interpretation.

45. A new instrument for measuring very small differences in gravity. KENNETH HARTLEY, *Houston, Texas.*—Description of a new portable instrument for measuring relative values of gravity to within two or three parts in ten million, specially designed for geophysical exploration. The principles of the design are analysed and the methods for eliminating effects of elastic hysteresis, temperature changes, variations in barometric pressure, etc., are discussed. Also effects of initial stresses in materials, defects in alignment of locking mechanism, inaccurate leveling, etc. These difficulties are serious but seem to have been overcome. Results of field measurements near Houston, Texas, are given and some comparison with torsion balance surveys and with known facts of structure.

46. Charts for torsion balance readings. M. M. SLOTNICK, *Humble Oil and Refining Co., Houston, Texas.*—The fact that the equations for the gradient and curvature values are linear in the differences of the readings obtained from the torsion balance makes it possible to produce easily a series of charts from which these values may be read directly, without the necessity of resorting to the slide rule or to logarithmic calculations. Two charts for each instrument, since each instrument involves different constants. One chart yields U_{xz} and U_{Δ}, and the other U_{yz} and U_{xy}. A few of these charts made for 120°-azimuth settings for Suess and Bamberg instruments will be exhibited.

47. The calculation of the motion of the ground from seismograph records. H. A. WILSON, *The Rice Institute.*—If x denotes the ground displacement and y the deflection of a mechanical seismograph then $-\ddot{x}=\ddot{y}+k\dot{y}+p^2y$. This gives $x=-y-k\int_0^t y\,dt-p^2\int_0^t\int_0^t y\,dt\cdot dt$. The ground displacement can therefore be found if the two integrals are evaluated graphically

or otherwise. The ground motion for a given seismogram depends very greatly upon the period and damping of the seismograph. Large errors in the calculated values of x are difficult to avoid and ground oscillations of much longer period than that of the seismograph may be entirely missed. Results obtained in this way are described. The ground motion due to a distant explosion appears to consist of several similar rapidly damped oscillations which come in at different times. An integraph is described by means of which curves, giving the above integrals as functions of t, can be quickly drawn.

48. Earth-amplitudes in seismic prospecting. MAURICE EWING, *Lehigh University.*—I. A relation between the time-distance curve and the earth amplitude-distance curve is derived upon the basis of the ray equations of geometrical optics. The possibility of using this relation in seismic prospecting is pointed out. II. The earth amplitude-distance curve is computed for several hypothetical subsurface structures consisting of two layers in each of which the velocity of propagation of seismic waves is a linear function of the depth.

49. Asymmetry of sound velocity in stratified geologic formations. BURTON MCCOLLUM AND F. A. SNELL, *McCollum Exploration Co., Houston, Texas.*—In the course of explorations of subsurface geology by the seismograph the authors have frequently observed the pronounced effect of stratification on the velocity of seismic waves in shales, and this effect has often been utilized in practical seismography. Recently an opportunity was afforded for securing additional quantitative data on the velocity normal to and parallel to the bedding planes. The paper points out that the velocity parallel to the planes of stratification is, in some instances, as much as fifty percent higher than the velocity in a direction normal to the bedding planes. It is also shown that inclined stratified beds exhibit a higher apparent point-to-point velocity when sound travels in an up dip direction than when traveling down dip. The paper describes a procedure whereby this effect may be utilized for determining the direction and approximate magnitude of the dip in such stratified deposits. The method has proved to be of considerable practical importance where the stratified formations are obscured by overlying deposits.

50. Velocity of elastic waves in granite. L. DON LEET AND W. MAURICE EWING, *Harvard University and Lehigh University.*—The velocity of elastic waves in granite was determined at Quincy and Rockport, Massachusetts, and Westerly, Rhode Island. The waves measured were generated by dynamite explosions. They were recorded by portable seismographs at distances ranging from fifty feet to four thousand six hundred feet. The observed velocities for longitudinal waves were:

Quincy	$16{,}260 \pm 70$ ft/sec. or 4.96 ± 0.02 km/sec. (*)
Westerly	$16{,}400 \pm 120$ ft/sec. or 5.00 ± 0.04 km/sec.
Rockport	$16{,}670 \pm 40$ ft/sec. or 5.08 ± 0.01 km/sec.
Average	*$16{,}530 \pm 90$ ft/sec. or 5.04 ± 0.03 km/sec.*

A three-component seismograph used only at Quincy recorded transverse waves, the velocity of which was 8150 ± 90 ft/sec. or 2.48 ± 0.03 km/sec. From the two velocities determined at Quincy, and the density of specimens taken from the shooting location, 2.65 grams/cm^3, values for the bulk modulus, k, compressibility, β, rigidity, μ, Young's Modulus, E, and Poisson's Ratio, σ, were obtained as follows:

$k = 44 \pm 1 \times 10^{10}$ dynes/cm^2
$\beta = 2.28 \pm 0.05 \times 10^{-12}$ cm^2/dynes
$\mu = 16.3 \pm 0.4 \times 10^{10}$ dynes/cm^2
$E = 43 \pm 1 \times 10^{10}$ dynes/cm^2
$\sigma = 0.333 \pm 0.005$

The form of the time-distance curves, straight lines through the origin, indicated that the waves did not penetrate deeply. Accordingly, the values obtained are for pressures of at most only a few atmospheres. The bearing of these results upon earlier investigations of the elastic constants of granite is discussed. The validity of the Adams and Williamson curve for granite at pressures below 2,000 megabars is questioned, and it is concluded that there is no marked difference between dynamically and statically determined compressibilities of granite.

* The $\pm$ values given in this paper are probable errors.

51. The reflection seismograph—An application. EUGENE MCDERMOTT, *Geophysical Service, Dallas, Texas.*—The general method of operation is outlined with some reference to the earlier refraction methods. The method of determining velocity and measuring time, and the importance of correcting for the surface weathered zone are discussed. An application of the method to a faulted area in East Texas is presented with reflection records, cross sections and contour maps on two well known geological horizons.

52. Refraction profiles as aids to the reflection method. H. RUTHERFORD, *Geophysical Exploration Co., Washington, D. C.*—The relationship between the time-distance curve for refracted waves and that for reflected waves is discussed. It is shown that a refraction profile is of great assistance in identifying reflections on the records and also in determining which horizon is producing the reflections. Reflection records and time-distance graphs are shown to illustrate these points.

53. Seismological discovery and partial detail of the Vermillion Bay Salt Dome. E. E. ROSAIRE AND O. C. LESTER, JR. *Geophysical Research Corporation, Houston, Texas*—This dome is of interest because it was one of the first discovered by a seismological exploration conducted entirely by boats and over water. The organization, equipment and operation of such a crew are described. The field data resulting from this exploration are presented in full, with illustrations of the records obtained. The original interpretation of the data and the agreement with results of well drilling are presented, with criticisms in the light of later experience.

54. Some special cases of the reflection and refraction of seismic waves between similar rocks, with application to the study of crustal layers by distant quakes. LOUIS B. SLICHTER, *Massachusetts Institute of Technology*, and V. GABRILOVITCH GABRIEL, *Pasadena, Calif.*—In the first part of this paper, some particular cases of the reflection and refraction of plane elastic waves at the interface between similar rocks are computed, after the method of C. G. Knott. In the second part, the results of these computations are utilized in examining the possibility of study of a layered upper crust by means of distant, rather than local, earthquakes. For a layered crust of a type often assumed, it results that the transformed SV wave, $SP^*\overline{P}$ should produce surface amplitudes about 35 percent as large as those due to the direct wave, $SS^*\overline{S}$, when the epicentral distance is about 30°. The time lead of the derived wave $SP^*\overline{P}$ over $SS^*\overline{S}$ is here about seven seconds. The identification of this wave appears to offer difficulties, but should its recognition prove to be practicable, the study of crustal structure in regions which do not enjoy an abundance of local shocks will obviously be facilitated.

55. On the correlation of isogeothermal surfaces with the rock strata. C. E. VAN ORSTRAND, *U. S. Geological Survey.* (Published by permission of the Acting Director of the U. S Geological Survey.)—An instance of regional variation in Oklahoma, and two cases of local variation, one at Long Beach, California, and the other at Salt Creek, Wyoming, were selected for consideration from a rather large number of geothermal surveys conducted during the past few years by the U. S. Geological Survey and the American Petroleum Institute. As no theory has been developed to explain either the local or regional variations, it is not claimed that the results of the surveys, or the conclusions reached in regard to them, are necessarily applicable to other fields. Radioactivity, proximity to crystalline rocks, and transfer of heat along the strata are given careful consideration in attempting to explain the observed relations between the strata and the isogeothermal surfaces.

56. Geothermal gradient determinations in the Lake Superior copper mines. L. R. INGERSOLL, *University of Wisconsin.*—The Michigan College of Mining and Technology, in cooperation with the Calumet and Hecla Copper Company and the author, is carrying out a program of temperature measurements in the deep copper mines of Northern Michigan, extending the previous work of Agassiz and others. Temperatures are measured with mercury thermometers mounted in Bakelite tubes, placed in drill holes in mine workings where the rock has been freshly exposed, special attention being given the effects of drilling, blasting, and other heat conduction considerations. Present results give as the average gradient from the surface

to 5679 feet below (temp. 95.3°F), 1°F in 108.5 feet (0.0168°C/meter). The gradient is more nearly uniform than has sometimes been supposed. A preliminary attempt has been made at calculating the previous "thermal history" of this region. Diffusivity of specimens of the rock measures 0.0075 c.g.s. (for method see Ingersoll and Koepp, Phys. Rev. **24,** 92, 1924) and on this basis calculations of theoretical temperature-depth curves have been made for 25 different assumptions of previous temperature conditions, and compared with the actual curve. Results as yet are inconclusive but indicate that at least 30,000 years have elapsed since the last glacial epoch, a longer period than usually assumed.

57. Electrical prospecting as applied in locating oil structures. LEO J. PETERS AND JOHN BARDEEN, *Gulf Research Laboratory, Pittsburgh.*—This paper discussed in a general way the basic ideas upon which electrical prospecting is based. It gives a few of the more successful ways of carrying out these basic ideas and presents some surveys which show the extent to which success in mapping oil structures has been obtained.

58. The luminescence of solid nitrogen. JOSEPH KAPLAN, *University of California at Los Angeles.*—An explanation is proposed for all of the radiations that have been observed by Mc Lennan and his collaborators in the luminescence of solid nitrogen. The bands are associated with known bands of the second, fourth and first positive groups of nitrogen; with hitherto unobserved second-positive bands; with a new intercombination system and with new modifications of the first-positive bands. These new modifications of the first-positive bands are related to the spectra of the aurora, night-sky and planetary absorption spectra. As a result of this correlation, it is now possible to see why Vegard identified the aurora spectrum as the spectrum of solid nitrogen and then proposed his theory of the upper atmosphere.

59. Dirac's equation and the spin-spin interaction of two electrons. G. BREIT, *New York University.*—In a previous paper (Phys. Rev. **34,** p. 553) an equation has been set up for the treatment of two electrons. This equation is

$$\left\{p_0 + \mathbf{a}^{\mathrm{I}}\mathbf{p}^{\mathrm{I}} + \mathbf{a}^{\mathrm{II}}\mathbf{p}^{\mathrm{II}} + (\alpha_4^{\mathrm{II}} + \alpha_4^{\mathrm{I}})mc + \frac{e^2}{2c}\left(\frac{\mathbf{a}^{\mathrm{I}}\mathbf{a}^{\mathrm{II}}}{r_{\mathrm{I\,II}}} + \frac{(\mathbf{a}^{\mathrm{I}}\mathbf{r})(\mathbf{a}^{\mathrm{II}}\mathbf{r})}{r_{\mathrm{I\,II}}^3}\right)\right\}\psi = 0.$$

The notation is that of Dirac, and Roman numerals refer to the two electrons. The wave function ψ has 16 components. At the time the difficulty of negative energies made it plausible to regard the above equation as being correct only inasmuch as it determines relations between the four largest components, ψ_{33}, ψ_{44}, ψ_{34}, ψ_{43}. In the applications (Phys. Rev. **36,** p. 385) the integrability of $\sum_{\alpha,\beta=3,4}\psi_{\alpha\beta}^*\psi_{\alpha\beta}$ and the equations for $\psi_{\alpha\beta}$ were therefore used. These equations had to be modified in order to bring about agreement with the fine structure of He. It is now shown that if the integrability of $\sum_{\mu,\nu=1,2,3,4}\psi_{\mu\nu}^*\psi_{\mu\nu}$ is required and all of the 16 components of ψ are used the previously troublesome terms in e^4 disappear automatically. With this restricting condition the above equation is thus in agreement with the observed spin-spin interactions in $\mathrm{He^I}$ and $\mathrm{Li^{II}}$.

60. The far infrared transmissions of various solids. R. BOWLING BARNES, *Physikalisches Institut, Berlin.*—Using a wire grating spectrometer transmission curves have been measured for 12 substances from 20μ to 135μ. In fused quartz absorption bands have been found at 39μ, 86μ, 118μ and $\lambda > 132\mu$. In crystalline quartz, at 26μ, 38μ, 77μ, 105μ and 122μ. In sulphur bands occur at 21, 5μ, 25, 0μ, 37, 5μ, 40μ to 50μ, 67μ, 96 μ, 114, 5μ and $\lambda > 130\mu$. In paraffin, 82, 5μ, 106μ, and 127, 5μ. In mica 5μ thick, bands are found at 27μ, 33μ, 60μ, 95μ and at 123μ. A discussion of these absorptions including the curves for these 5 substances and the other 7 will appear at an early date.

61. The thin plate. D. G. BOURGIN, *University of Illinois.*—The problem of the very thin plate, for large displacements when bending stresses may be neglected, has been treated by Hencky by a numerical approximation method. His results for the rectangular plate are incorrect because of invalid boundary conditions. This paper derives a solution by the hitherto

unused method in elasticity problems of working directly with the stresses rather than the displacements. Experimental results of A. Falk on the bending of a steel sheet 10 in.×10 in.×0.05 in. are in accord with the assumption of negligible bending stress for this case.

62. Experimental establishment of the relativity of time. ROY J. KENNEDY AND EDWARD M. THORNDIKE, *California Institute of Technology.*—None of the fundamental experiments on which the restricted principle of relativity is based requires for its explanation that the classical concept of absolute time be modified; the present experiment was devised to test directly whether time satisfies the requirements of relativity. It depends on the fact that if a pencil of homogeneous light is split into two components which are made to interfere after traversing paths of different length, their relative phases will depend on the translational velocity of the optical system unless the Lorentz-Einstein transformation equations are valid. Hence such a system at a point on the earth should give rise to an interference pattern which varies periodically as the velocity of the point changes in consequence of the rotation and revolution of the earth. The effect to be expected for a small velocity is so very small that it has been necessary to devise a special source of light, an interferometer of great stability and a refinement of the technic of measuring displacements in the interference pattern. With the apparatus finally employed, we have shown that there is no effect corresponding to absolute time unless the velocity of the solar system in space is no more than about half that of the earth in its orbit. Using this null result and that of the Michelson-Morley experiment we derive the Lorentz-Einstein transformations, which are tantamount to the relativity principle.

63. On the law of force between the molecules in a liquid or gaseous mixture. R. D. KLEEMAN, *Schenectady, New York.* (*Introduced by W. L. Severinghaus.*)—The author has previously deduced from various data the nature of the law of force between two molecules in a pure liquid or gas. It was found that this force is given by $\phi[(T/T_c), (Z/x_c)] \cdot (\Sigma c_a)^2/Z^5$, where Z denotes the distance of separation of the molecules at the absolute temperature T, x_c the average minimum distance of separation of the molecules at the critical temperature T_c, Σc_a the sum of a number of constants each of which refers to an atom of a molecule, and ϕ a function of the quantities x_c, Z, T, T_c, which may be determined from the equation of state of the substance. The constant c_a is approximately proportional to the two thirds power of the atomic number of the atom.* It is now shown that in the case of a mixture of two substances the law of force is $K(\Sigma c_a)(\Sigma c_e)/Z^5$ where Σc_a refers to one of the substances and Σc_e to the other, and K is a quantity varying little with T.

64. The "flash" in the afterglow of argon with a fixed vacuum. CHAS. T. KNIPP, *University of Illinois.*—In a recent number of the Philosophical Magazine the writer and L. E. Scheuerman described a "flash" that appeared in the afterglow of certain gases, notably nitrogen, when the residual gas *was suddenly compressed.* Just recently (December 4th, to be exact) the writer while exhibiting the electrodeless discharge in a liter pyrex flash at the Butler meeting of the Indiana Academy of Science observed a flash in the afterglow with a *fixed* vacuum. This particular tube contains argon at a pressure of between 0.1 and 0.2 mm of mercury, and was prepared last May. No record was kept of the moisture present, or of the purity of the gas. Mr. H. C. Roberts, Assistant to the writer, said that this peculiar action of the gas was observed and briefly commented upon at the time that the tube was sealed off, but for some reason the phenomenon was passed by until the striking observation was again made as referred to above. No definite experimental theory has as yet been attempted nor has there been time to make even the most elementary observations, spectroscopically or otherwise, of this apparent recalescent phenomenon in a gas. The flash in this bulb occurs within two or three seconds after the energizing source has been removed and is of sufficient brightness to be observed by reflection on a nearby screen. Following this the intensity of the afterglow changes color slightly and dies off rapidly. It would be interesting to note whether additional flashes occur on the decay curve, possibly flashes that the eye could not detect.

* A book on the subject is "The Atomic and Molecular Forces of Chemical and Physical Interaction in Liquids and Gases, and their Effects" by R. D. Kleeman B.A., D.Sc. (Taylor and Francis, Red Lion Court, Fleet Street, London, England).