requirements of the loud speaking telephones had made the problem inherently insoluble until means had been developed for producing telephone lines with very uniform transmitting characteristics and until amplifying devices of great power, uniformity and freedom from inherent distortion production had been developed.

The physical examination of hearing and binaural aids for the deaf: R. L. WEGEL, Western Electric Company, New York City. The function of the auditory sense is to detect sounds of different wave shapes, the ratio of the pressure on the ear drum varying over a range of 1 : 1,000,000. It must also differentiate between sounds so nearly alike that no existing physical apparatus is capable of separating them. Binaural audition adds a sense of orientation and discrimination together with a more uniform sensitivity for sounds approaching from different directions. A binaural set for aiding the hard-of-hearing was exhibited. An abnormal auditory sense may be regarded as one lacking to a greater or less degree in (1) range of sensation (frequency or intensity), (2) quality of sensation in various regions of the range, (3) binaural sense. Methods have been studied for exploring the outstanding elements of these functions. A new audiometer for measurement of hearing was shown.

The relative sensitivity of the ear at different levels of loudness: DR. DONALD MACKENZIE, Western Electric Company. Up to the present time there has been no satisfactory technique for loudness comparisons of different tones. In this paper a description is given of an alternation phonometer which makes it an easy matter to adjust to equal loudness two tones of different pitches. With this instrument a determination has been made of the relative sensitivity of normal ears of both men and women, over the pitch range from bass G to C5, at sound intensities midway between the faintest audible and the painfully loud. It is found that the sound energy necessary to produce a given loudness is smaller the higher the pitch, at least within the range examined. Different ears agree more closely at these intensities than at the least audible, and no difference is detectible between men and women. Interpretation of the results shows them to be in harmony with Fechner's law, according to which the difference between the sensations due to two lights of the same color or two tones of the same pitch is proportional to the ratio of intensities of the lights or sounds causing the sensations. This simple law holds only at moderate intensities. Phonometric comparisons by a small number of observers were made at intensities from very faint to very loud. It appears that any one ear varies from day to day, but these variations are most noticeable at the extremes of loudness. The results taken all together strongly suggest that, on the average, the relative sensitivity of the ear to different musical notes is practically the same whether the sounds are loud or faint.

Recent progress in aeronautics: PROFESSOR J. S. AMES, The Johns Hopkins University.

Coefficients of slip and the reflection of molecules: DR. R. A. MILLIKAN, Norman Bridge Laboratory of Physics, Pasadena. This paper contains a presentation of the theoretical relations between the coefficient of slip and the law of reflection of gas molecules from the surfaces of solids and liquids. It presents, also new experimental data taken by the author and his pupils which completely check the correctness of this theory. It gives for the first time the exact ratio between the number of impinging molecules which are specularly reflected in the case of a given gas from given liquid and solid surfaces, and the number which are diffusely reflected. The most interesting facts brought to light by the investigation are, first, that this ratio is different for different kinds of molecules when the nature of the surface remains constant, and, second, that there is a larger coefficient of slip between oiled surfaces and gases than between the same gases and ordinary unoiled surfaces of metal or glass.

Origin of penetrating radiations of the upper air: DR. R. A. MILLIKAN, Norman Bridge Laboratory of Physics, Pasadena. It is of intense interest to know whether the penetrating radiations which have been heretofore studied up to altitudes of 9,000 meters are of cosmic or of terrestrial origin. Pre-war observations made in manned balloons in Germany gave indications that they were of cosmic origin. Observations published last year from the University of California were in opposition to this view. Indeed, the California observers attributed the increase in the rate of discharge of the electroscopes with increasing height, as found in Germany, to the effects of temperature upon the electrical conductivity of the supports of the gold leaves in the electroscopes. The observers at the California Institute of Technology have definitely proved that the temperature effects upon the supports when the experiments are properly performed are practically negligible. They are now making balloon flights in which self-recording instruments are sent up to the very top of the atmosphere, that is, to a point at which only one sixteenth of the atmosphere is

still above, and should be able to determine with certainty by these experiments whether the penetrating rays are of cosmic or of terrestrial origin. While the instruments sent up weigh but 175 grams (6 ounces) they are capable of bringing back a complete record of the temperatures, the pressure, and the penetrating radiations existing at all of the altitudes which they reach. These altitudes should be about three times as great as those ever obtained before in experiments of this kind. These balloon flights will be reported later.

On the measurement of a physical quantity whose magnitude is influenced at random by primary causes beyond the control of the observer, and on the method of determining the relation between two such quantities: DR. WALTER A. SHEWHART, New York City. The objects of scientific investigation are twofold, *i. e.*, the determination of some form of average value and its probable variation, and the determination of the relation existing between two or more such quantities. In many problems of physical and engineering science it is possible to assume that causes of variation of the variable under consideration may be controlled by the observer. Certain problems in these sciences as in the fields of economics and biology arise, however, wherein it is impossible to control the causes of variation, and they must be submitted to a statistical method of solution. An outline of the necessary analysis is given and illustrated. Application of the theory of correlation and its physical interpretation was discussed.

Ether-drift experiments at Mount Wilson in 1921 and at Cleveland in 1922: PROFESSOR DAYTON C. MILLER, Case School of Applied Sciences, Cleveland, Ohio. The Michelson-Morley experiment to detect the relative motion of the earth and ether was performed at Cleveland in 1887. In explanation of the null result then obtained, the Lorentz-FitzGerald effect was proposed. The experiment was repeated by Morley and Miller in 1904, with a much larger and more sensitive apparatus, which was also especially arranged to make a direct test of the Lorentz-FitzGerald effect. Again a null result was obtained. The suggestion was then made that the earth drags the ether, and while there is no "drift" at the surface of the earth, it might be perceptible at an elevation above the general surface. The experiment was again performed by the present author, at the Mount Wilson Solar Observatory in March and April, 1921, where the elevation is nearly 6,000 feet. The results indicated an effect such as would be produced by a true ether-drift, of about one tenth of the expected amount, but there was also present a periodic effect of half the frequency which could not be explained. The interferometer had been mounted on a steel base and in order to eliminate the possibility of magnetic disturbance, a new apparatus with a concrete base and with aluminum supports for the mirrors was constructed. Observations were made in November and December, 1921, the results being substantially the same as in April. Before any conclusions can be drawn, it is necessary to determine the cause of the unexplained disturbance. The interferometer has again been mounted at Case School of Applied Science, in Cleveland, and observations are now in progress, the results of which were reported in this paper, which was illustrated by lantern slides and motion-pictures. About 700 feet of motion-picture film was taken at Mount Wilson by a member of the observatory staff, showing the location and construction of the apparatus and also the method of making the observations.

Some extensions in the mathematics of hydromechanics: DR. R. S. WOODWARD, Washington, D. C. The most general specification of fluid motion requires a minimum of twenty symbols, or factors. Of these the most important are the three velocity components, the three spin components, and the four potentials from which the velocity components are derived by differentiation. *The first part* of the paper shows how it is more advantageous, in general, to make use of the relations between the Laplacians, or the Laplacians of the Laplacians, of these factors, than it is to make use of the relations of a lower order. It is shown that this extension greatly systematizes and simplifies the statement and the solution of problems on the motion of viscous fluids. *The second part* of the paper refers to what the author has ventured to call preharmonics, which are the triple integrals of harmonic functions which figure extensively in hydromechanics. It is shown how to find all of the preharmonics corresponding to all of the harmonic functions of positive and negative integral degrees.

Normal coordinates and Einstein space: G. D. BIRKHOFF.

Algebraic solutions of Einstein's cosmological equations: EDWARD KASNER.

The geometry of paths: OSWALD VEBLEN.

Biographical memoir of Dr. J. A. Allen: F. M. CHAPMAN.

Biographical memoir of Benjamin Apthorp Gould: G. C. COMSTOCK.

Biographical memoir of Henry Pickering Bowditch: W. B. CANNON.