"If the cosmic rays are electrified particles shot toward the earth from remote distances, as they seem to be," he said, "the effect of the earth's magnetic field will be to bend the rays away from the equator and concentrate them at the poles. This, for example, is what happens in the aurora borealis, which is due to electrons shot toward the earth from the sun. The electrons are concentrated near the earth's magnetic poles, and produce the 'northern lights' as they strike the upper atmosphere.

"If the cosmic rays are uncharged, like light rays or neutrons, they should not be affected by the earth's magnetic field."

The cosmic rays is a kind of radiation similar in effect to x-rays or rays from radium, Dr. Compton said. They come into the atmosphere from high altitudes, moving at a speed nearly equal to the velocity of light, which is 186,284 miles a second. They are observed by the fact that they make air and other gases electrically conducting.

"The rays do come from high altitudes, probably from outside the earth and possibly from interstellar space," Dr. Compton said, "though it is still as good a guess as any that they may emanate from the earth's upper atmosphere." Professor Compton found that the rays are slightly more intense in the day time than they are at night, which may lend some support to the theory that they are associated in some way with the sun, though other expeditions failed to find such an effect.

The minimum intensity of rays, according to latitude, was found at Lima, Peru, which is on the magnetic equator, 12 degrees, or about 800 miles, south of the geographical equator.

The second important result of the expedition was the observation that the rays increase in intensity continuously with altitude. "This would be expected if the rays were coming into the earth's atmosphere from outside and being absorbed by the atmosphere," Dr. Compton said. "If the rays had tended to diminish in intensity as the top of the atmosphere was approached, this would have been taken to support the wave theory."

The highest altitude where tests were made by Dr. Compton was at 19,000 feet on the volcano Mount El Misti, near Arequipa, Peru, though Professor Benade has since made tests 100 feet higher in the Himalayas. This is three miles higher than any cosmic ray mountain expedition has gone with equipment for precision work. The finding agrees with that made by Professor Piccard in his stratosphere ascension and also with the finding of Professor E. Regener, of Germany, who sent up a sounding balloon to 25 miles this spring.

One of the most significant new observations made during the summer was discovery of the sudden burst of ionization by individual cosmic rays in the apparatus. Using the burning of a single hydrogen atom in oxygen as a unit of energy, Dr. Compton said that the ionization of a radium atom would involve a million such units and the ionization of a cosmic ray several hundred millions of such units. Several hundred million volts potential would be required to produce such a ray artificially, he said.

During the tests on Mount El Misti, Dr. Compton and his wife and 15-year-old son, Arthur Alan, who served as his assistant, camped for a week at a temperature of zero and made tests 24 hours a day. On Mount Cook, in New Zealand, the heavy equipment had to be packed by the party over a mile of snow. In the Fox Basin, off Hudson Bay, probably the largest unexplored region on the continent, a new island 30 miles long was discovered by the Compton party, and named "Poole Island" for the captain of the tug *Ocean Eagle,* which carried the group.

The Carnegie Foundation shared the expenses of the expedition with the University of Chicago. The measuring device used was a steel chamber heavily sheathed with lead and copper, containing argon at 30 atmospheres pressure. An electrometer measured the varying conductivity of the argon. Dr. Compton was awarded the Nobel Prize for physics in 1927.

SCIENTIFIC BOOKS

The Theory of Electric and Magnetic Susceptibilities. By J. H. VAN VLECK. Oxford University Press, 384 pages, 1932.

THIS volume impressed the reviewer as being one of the most convincing gospels for the new quantum mechanics that he has read.

This does not imply that more apologia for quantum mechanics are needed at present, or that the works of Weyl and Dirac are not convincing in their way. But every so often, for the good of one's soul, one should go back to the experimental data which could not be made to fit the older theories and reconvince oneself that the newer theories are needed. When one is struggling with electron exchange in collisions and with spinor analysis, it is perhaps heartening to know that the beautifully straightforward methods of classical physics can not be used here, and to be certain that one has not somehow overlooked a much easier way of handling the difficulties.

Usually, one looks back to the history of the theory of radiation, to Planck's work, to the photoelectric effect and to the development of spectroscopy, to be reconvinced. This book shows that the development of the theory of the reaction of matter to static electric and magnetic fields forms just as convincing, and perhaps more understandable, a set of reasons for the necessity of revising the older theories.

This side of the argument for quantum mechanics is very little known, to some extent due to the fact that much of the original work was in the nearly unobtainable form of doctor's dissertations in Danish and Dutch. Some of it should be better known, especially the disconcerting proof by Miss van Leeuwen that every substance obeying purely classical laws of motion must have a zero value of magnetic susceptibility, which is as far-reaching in its implication of the breakdown of classical theory in atomic processes as the work of Jeans, Planck and Einstein in the field of radiation. Professor van Vleck has rendered us a service by presenting this work.

His book also sets forth the difficulties of the older quantum theory and traces the curious mutations of the numerical factor in the term for the susceptibility due to molecules with permanent dipoles. The value 1/3 had been obtained by Langevin and Debye by sort of half-hearted use of classical theory. In the early quantum theory it became a larger quantity which apparently varied in an irritating manner with the presence of other fields. The new quantum mechanics restores the value of 1/3 and shows it to be independent of other fields, as experiment shows it should be. And so a formula which had been derived by a partial use of classical theory, which fits experimental data remarkably well, but which can not be obtained by a thoroughgoing use of classical methods, is now shown to be a correct consequence of the newer theories!

But of course the historical development of the subject is not the whole of the book. Most of the space is given over to elucidating the present theory and in showing its correspondence with the large amount of data available on dielectric constants and on magnetic susceptibilities.

Although the formula for the dependence of electric or magnetic susceptibility on temperature has remained intact, while the theory has been shifted under it, the resulting change has made us attach different meaning to some of the terms in the formula. For instance, the term "permanent electric or magnetic moment" really meant *permanent* in the older theory. The value of the constant μ in the Langevin-Debye formula meant the magnitude of the moment which the molecule possessed when it was at rest and undisturbed.

Now, however, Professor van Vleck has shown that many molecules which have a value of μ different than zero would have no moment if they were isolated and at rest. Ammonia is a case of this kind; the wave function of its lowest state is symmetrical, and so it can have no electric moment. The answer to the paradox is that the phrase "moment of an isolated molecule" has no meaning, since the molecule is no longer isolated if we try to measure its moment. The Langevin-Debye formula refers to the behavior of large number of molecules under the influence of a field. When the molecule is among others of its kind, it no longer stays always in its lowest state. If there are several possible states whose energy is not much different than the lowest energy, then as the molecule is buffeted by its neighbors it will be continuously changing from one state to another. If the molecule evidences a moment during these transitions, then this must be included in the moment μ which we label "permanent." If, on the other hand, the energy difference between the lowest state and the next lowest is large, then the buffeting will seldom change the molecule's state and it may not have a "permanent" moment.

This seems to be a far cry from the original concept of permanent moment, but the new concept seems to be the right one, for it explains the exceptions to the formula as well as the formula. If the difference between having a permanent moment and having none depends simply on whether the difference in energy between two states is large or small (compared to kT, the average energy of temperature motion) then, when the energy difference is neither large or small, queer things can happen. When Professor van Vleck first published his theory several years ago he showed that the nitrous oxide molecule was such a case, and by use of band spectral data predicted how its magnetic susceptibility would deviate from the normal law. Since that time several investigators have obtained data which fit his predicted curve of deviation remarkably well.

The paramagnetism of the rare earth ions in solution is also discussed, and the correspondence between theory and experimental data is given. The last chapters are concerned with ferromagnetism and allied subjects. Here is a field where electron spin and the Pauli principle play a predominating rôle, two phenomena which are completely outside the scope of classical theory. With their help much has been cleared up, although the subject of ferromagnetism is not in a satisfactory state yet.

The book is well written, and the derivations are clearly set forth. It would be quibbling to complain that the matrix methods the author seems so fond of are perhaps less familiar to many students than the purely wave-functional methods, or than the operator methods of Dirac, since the methods are so closely alike anyway. It is too bad, however, that he did not adopt Dirac's notation for his matrices, especially since this volume is in the same series with Dirac's "Quantum Mechanics."

As a whole, the book has an amount of connected unity and completeness which is gratifying in a book on modern physics. This is due to some extent to the field it covers, which is fairly well delimited. But it is mostly due to the thoroughness of the author and his clarity. No matter what difficulties the reader may find himself entangled in, he will be sure to find, somewhere in the book, a footnote which will untangle him.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A UNIVERSAL PRECISION STIMULATOR[1]

MODERN advances in the field of nerve physiology, involving high amplification of the action potential and its visual recording by means of the cathode ray oscillograph, have revealed that the customary methods of stimulation, especially at high rates, are unsatisfactory. Induction coils, condenser discharge systems, or in fact any system in which the essential circuit is interrupted by a mechanical key must of necessity prove unsatisfactory because keys do not close or open exactly the same each time, especially if they carry an appreciable voltage or current. Furthermore, the ordinary key will not operate accurately at frequencies greater than fifty per second. This contact difficulty is particularly serious when just-threshold responses are being observed at high amplification.

At the end of his very valuable review of all known methods of stimulation, Lullies[2] offers the opinion that the only satisfactory general methods of producing shocks of any desired characteristics are those involving photoelectric cells, such as that recently described by Nicolai.[3] In this method a rotating cylinder, patterned after the shape of the shock desired, interrupts a beam of light falling on a photocell, modulating an amplifying system, thus producing a shock. We evolved a similar apparatus independently, but abandoned this general method because of the extreme difficulty of obtaining quick shocks at low rates of stimulation, and because the large capacity between the stimulating circuit and ground makes the system unsatisfactory, especially for use with the cathode ray oscillograph. The gas discharge tube method is undesirable because of this capacity effect and because of the great difficulty of synchronizing the shock with externally applied excitation. We believe that the non-mechanical method described below[4] successfully overcomes all these difficulties.

Depending upon the position of switch S, the stimulator may be made to operate in either of two manners: (1) as a self-excited oscillator capable of stimulating at any desired rate, from once every few minutes up to 400 per second, or (2) by means of external excitation from any contact, such as that on the synchronizing rotator usually employed in connection with the oscillograph. We find this switch extremely handy. For example, in work on the effect of rapid stimulation on the after-potential of nerve, throwing it toward the short-circuiting position causes the nerve to be stimulated at any rapid rate desired; then, in order to examine the after-potential at any instant during the period of rapid stimulation, one has only to throw the switch in the other direction, in which case, with properly arranged amplification and synchronization, the after-potential may be examined or photographed. Switching back again to the short-circuiting position causes rapid unsynchronized stimulation to be resumed, the entire interruption lasting only a few seconds.

Considering the apparatus first as a self-excited oscillator, the essential mechanism is as follows: A condenser C charges through a resistance R until the critical ignition voltage of the Thyratron is reached, a value controlled by the grid bias, P. Having attained this potential, the mercury vapor becomes ionized, permitting condenser C to empty itself into the primary of T. This heavy current surge, having emptied the condenser, the Thyratron de-ionizes and the cycle is completed.

The current induced in the secondary of T then serves to stimulate the nerve or muscle, the intensity of the shock being determined by the relation of the variable resistance Ω to the fixed resistance, ω. If a L and N, four dial, 10,000 ohm resistance box is used for Ω, the strength of the shock may be graded in extremely small steps over a very wide range. This arrangement is particularly useful for work where the intensity of stimulation must be very accurately adjusted, as in studies on the single axon response. Actually, assuming a fairly high tissue resistance, the shock strength may be made almost directly proportional to Ω, by substituting a similar four dial resistance box for the fixed resistance, ω, and by adjusting the setting each time on Ω and ω so that the sum of the two resistances remains constant.

If the stimulator is to be actuated by an external contact, such as that on the rotator of the usual oscillograph synchronizer, the switch, S, must be thrown so as to include the secondary of the small step-up

[1] From the Department of Zoology, Washington University, St. Louis, Missouri.

[2] H. Lullies, *Handb. d. biol. Arbeitsmethoden*, Abt. V, Teil 5 A, Heft 6, 937, 1931.

[3] L. Nicolai, *Pflügers Archiv*, 225: 131, 572, 1930.

[4] The construction of this apparatus was made possible by a research grant to Washington University by the Rockefeller Foundation.