PHYSICAL INTERPRETATION OF QUANTUM MECHANICS*

BY PROF. P. A. M. DIRAC, F.R.S.

MODERN developments of atomic theory have required alterations in some of the most fundamental physical ideas. This has resulted in its being usually easier to discover the equations that describe some particular phenomenon than just how the equations are to be interpreted. The quantum mechanics of Heisenberg and Schrödinger was first worked out for a number of simple examples, from which a general mathematical scheme was constructed and afterwards people were led to the general physical principles governing the interpretation, such as the superposition of states and the indeterminacy principle. In this way a satisfactory non-relativistic quantum mechanics was established.

In extending the theory to make it relativistic, the developments needed in the mathematical scheme are easily worked out, but difficulties arise in the interpretation. If one keeps to the same basis of interpretation as in the non-relativistic theory, one finds that particles have states of negative kinetic energy as well as their usual states of positive energy, and, further, for particles the spin of which is an integral number of quanta, there is the added difficulty that states of negative energy occur with a negative probability.

* Substance of the Bakerian Lecture of the Royal Society, delivered on June 19.

With electrons the negative-probability difficulty does not arise, and one can get a sensible interpretation of the negative-energy states by assuming them to be nearly all occupied, and an unoccupied one to be a positron. This model, however, is excessively complicated to work with and one cannot get any results from it without making very crude approximations. The simple accurate calculations that one *can* make would apply to a world which is almost saturated with positrons, and it appears to be a better method of interpretation to make the general assumption that transition probabilities obtained from these calculations for this hypothetical world are the same as those for the actual world.

With photons one can get over the negative-energy difficulty by considering the states of positive and negative energy to be associated with the emission and absorption of a photon respectively, instead of, as previously, with the existence of a photon. The simplest way of developing the theory would make it apply to a hypothetical world in which the initial probability of certain states is negative, but transition probabilities calculated for this hypothetical world are found to be always positive, and it is again reasonable to assume that these transition probabilities are the same as those for the actual world.

OBSERVATIONS MADE AT THE ROYAL OBSERVATORY, GREENWICH

THE observations made during 1936 at the Royal Observatory, Greenwich, have just recently been made available*.

The work is divided into five sections, the first of which, Section A, Meridian Astronomy, contains three subdivisions. Under (1), Transit Circle, 1936, the observed right ascensions, declinations and diameters of the sun, moon and planets are given and compared with the corresponding results as given in the "Nautical Almanac." These tabular places are derived from the well-known tables of Newcomb, Brown and Hill. The mean monthly corrections to Newcomb's place of the sun as given in the "Nautical Almanac" are shown, and also the corrections in longitude and latitude to Brown's "Tables of the Moon". These are deduced from the observed corrections to the right ascension and declination, the mean correction to the former being $0{\cdot}15^s$, corresponding to $2{\cdot}2''$ in mean longitude. Under (2), Time Service, is included a brief description of the reversible Transit "B" which was remounted on January 24, 1935, its place having previously been taken by Transit "D" on April 7, 1933. Collimation is eliminated by reversing the instrument on all stars, and observations are carried up to approximately 20^s of the meridian. Eighteen contacts are observed in each position of the instrument, when possible, and each signal is read to $0{\cdot}01^s$. Table II gives details of observation of clock corrections, and comparisons of Clocks Shortt Nos. 3 and 11 appear in Table V. The Greenwich time determinations are regularly compared with those of other observatories by the reception of wireless signals and the results are given in Table VIII. Under (3), Variation of Latitude, it is pointed out that as the Cookson floating zenith telescope was moved in 1936 to the Christie enclosure and remounted, a new observing programme being introduced at the same time, the results for the latitude variation given by the instrument will not be published for some time. The values of the latitude variation taken from the results of the International Latitude Service are given, and these have been used in the Transit Circle reductions.

Section B, Equatorial Observations, contains the results of the observations of double stars made with the 28-inch refractor. The list deals with the first observations carried out on the programme drawn up in 1936; the pairs were selected from Aitken's "New General Catalogue of Double Stars." These pairs were chosen on the following grounds:

* Observations made at the Royal Observatory, Greenwich, in the Year 1936, in Astronomy, Magnetism and Meteorology, under the direction of Dr. H. Spencer Jones. Pp. viii+A78+B16+Cix+161+D66+E46+38. (London: H.M. Stationery Office, 1939.) 35*s*. net.

(1) rapidly moving pairs for which orbits have been computed or will be computed within a few decades; (2) pairs which, though not moving rapidly, nevertheless deserve an observation in the present decade, either because they are known to have a slow motion or because they may be neglected pairs.

Section C, Photoheliographic Observations, gives the positions and areas of sunspots and faculæ for each day in the year 1936. Photographs from three observatories were used. Those obtained at the Royal Observatory, Greenwich, were taken with the Dallemeyer photoheliograph of 4 in. aperture, usually stopped down to 2·9 in., and, in a few cases, with the Thompson photoheliograph of 9 in. aperture. The diameter of the sun's image at the secondary focus in both instruments is 7½ in. at the earth's mean distance. The photographs from the Cape Observatory were taken with a Dallmeyer photoheliograph giving an image of the sun about 7½ in. in diameter. Those obtained at Kodaikánal were taken with a Cooke photovisual object-glass of 6 in. aperture, the image of the sun being on nearly the same scale. This section also gives a general catalogue of groups of sunspots for 1936 and 'ledgers' of the areas and heliographic positions of groups of sunspots for 1936.

Sections D and E, Magnetic and Meteorological Observations, give a full description of the buildings and equipment of the magnetic station at Abinger and also of the results of the magnetic observations, followed by a corresponding description of the meteorological apparatus and the results of the observations.

CONCRETE IN SEA WATER

THE current issue of the *Dock and Harbour Authority* contains the reproduction from the *Proceedings of the American Society of Civil Engineers* of a paper by Homer M. Radley in which the author gave a statement of the conclusions he has reached as a result of extended observation of concrete marine structures along the Pacific coast of the United States and Canada. Contrary to the widely held view that decomposition of concrete in sea water must necessarily occur as a result of the chemical action of sulphate of magnesium, he states that, over a long period no evidence of any attack of this nature was found, and he holds that such deterioration as occurs is due to other causes.

Arguing from the characteristic form and manifestation of attack by magnesium sulphate as advanced by Vicat, he concludes that, if this occurred in the manner described, exposure to full sea-water action for a period of twelve or fifteen years should produce distinct evidence of porosity or disintegration. His investigation showed, on the contrary, that concretes made with many brands of Portland cement continue after fifteen or more years of service to exhibit the original wood-grain and other marks of the shuttering used in construction. He points to several other causes of disintegration and disruption —the rise and fall of the tides and the alternate wetting and drying of the concrete surface, mechanical blows and abrasion from flotsam and drift, and the action of storm waves and the grinding of the boulders which they toss about. Deficiencies in the quality and structure of the concrete are responsible for the most characteristic forms of deterioration, weak concrete being readily abraded, honeycombed areas becoming cavitated, laitance seams giving rise to extended voids and so on. In these respects he finds little to choose between fresh water and salt water, and contends that the same qualities which give resistance in the one are good in the other. Associated with salt water there is, however, the scaling and disruption which arise from the crystallization of salt in the exposed upper parts. These several aspects of deterioration are discussed in considerable detail, and many photographs illustrate the different types noted.

THE IMPERIAL CANCER RESEARCH FUND

By Dr. E. Boyland

THE thirty-eighth annual report of the Imperial Cancer Research Fund was presented to the general meeting of governors in April. New work on the nature and cause of cancer has been carried out in the Fund's laboratories at Mill Hill. In addition to this normal work, Miss Ida Mann and Dr. B. D. Pullinger have carried out experiments on the effect of ascorbic acid in mustard gas burns of the eye, and on other problems for the Ministry of Supply. Several members of the staff have been absent on war service and, although the volume of research is perhaps not so large as in normal years, work of interest and real value has been accomplished.

Histology is still an important and essential branch of cancer research. Without the microscope it would often be difficult or impossible to determine whether tumours were malignant or not. Dr. L. Foulds has written a critical review on the histology of tumours[1], a field in which workers in the Imperial Cancer Research Fund laboratories have made important contributions in the past.

Dr. B. D. Pullinger has extended her investigation on the specific response which is given by mouse skin to carcinogenic substances. With the carcinogenic 5:9:10-trimethyl-1:2-benzanthracene small amounts produce the response while larger amounts destroy the epithelium without producing the characteristic reactions. This result fits in with the finding of Prof. E. L. Kennaway and Prof. J. W. Cook that this substance is a more effective carcinogenic agent in dilute than in strong solutions.

Mr. H. G. Crabtree has continued his investigations