Letters to the Editor

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, nor to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

The Factor $\frac{137}{136}$ in Quantum Theory

IT has been suggested by W. N. Bond[1] that, in some or all of the attempts to determine e/m experimentally, the quantity actually found is $\frac{136}{137}\ e/m$; for if the experimental results are corrected in accordance with this hypothesis, they are found to be in satisfactory accordance with my theoretical values of the fine-structure constant (137) and mass-ratio (1847·6). R. T. Birge[2] has confirmed this; and, quoting three important recent determinations of e/m, he has shown that the agreement is extremely close.

On theoretical grounds it seems likely that Bond's hypothesis is right. In my earliest paper on the subject[3], I gave the value of the fine-structure constant as 136, since I found the Coulomb energy of two elementary particles to be $1/136r$ in natural quantum units. This energy was $\frac{137}{136}$ times too large, because I had not allowed for the 137th degree of freedom arising from the indistinguishability of the particles. Bond's hypothesis implies that I am not the only victim of this mistake; current quantum theory in deriving from observational data the proper-energy or mass m of an electron has also obtained an energy $\frac{137}{136}$ times too large. If so, the cause is presumably the same, namely, neglect to take into account the degree of freedom due to indistinguishability.

There is nothing mystical in the effect of indistinguishability. It occasions, not an objective difference of behaviour, but a difference in what we can ascertain about the behaviour, and hence a difference of treatment. In the dynamics of two particles, we have to describe the change with time of the positions, momenta and spin-components (or of a probability distribution of them) of the particles which we call No. 1 and No. 2; and also we have to describe a growing uncertainty whether the particle, called No. 1 at the time t, is the original No. 1. If the probability that it is the original No. 1 is $\cos^2\theta$ (so that the probability that it is the original No. 2 is $\sin^2\theta$) the permutation variable θ will be a function of the time and have all the properties of a dynamical variable, giving therefore an extra degree of freedom of the system and having a momentum (energy of interchange) associated with it. When, however, the particles are distinguished without uncertainty, θ is constrained to be zero, and this degree of freedom is lost.

Thus for the treatment of two indistinguishable particles, we have to start with an a priori probability distributed over a closed domain of 137 dimensions, whereas for two distinguishable particles it is distributed over a closed domain of 136 dimensions. Naturally, the average values of characteristics of the distribution are slightly different in the two treatments. In particular, the energy tensor of the a priori probability distribution, which is identical with the metrical tensor $g_{\mu\nu}$ of macroscopic theory, is different. Hence *the two kinds of treatment are associated with different metrics of space-time.* It seems clear that a factor $\frac{137}{136}$ (neglected in current quantum theory) will be introduced by the change of metric when we equate the space occupied by the indistinguishable particles of quantum theory to the space occupied by the distinguishable parts of our measuring apparatus.

It may be asked: Why does this factor affect the mass of the electron but not that of the proton? The discrimination is, I think, not strictly between the proton and electron, but between the resultant mass $(M + m)$ which is nearly the mass of a proton, and the reduced mass of the relative motion $Mm/(M + m)$ which is nearly the mass of an electron; for it is in the relative motion that the question of distinguishing the two ends of the relation arises. It may also be asked why the factor $\frac{137}{136}$, which refers especially to a system of two particles, applies irrespective of the number of particles. The answer is that the metrical ideas of quantum theory are borrowed from those of relativity theory; and since the latter are based on the interval between two points, the former refer correspondingly to the wave function of two particles.

A. S. EDDINGTON.

Observatory, Cambridge.
June 5.

[1] W. N. Bond, NATURE, **133**, 327, March 3, 1934.
[2] R. T. Birge, NATURE, **133**, 648, April 28, 1934.
[3] A. S. Eddington, *Proc. Roy. Soc.*, A, **122**, 358; 1929.

Production of Very Low Temperatures by the Magnetic Method: Supraconductivity of Cadmium

A YEAR ago the first experiments for producing very low temperatures by adiabatic demagnetisation of certain paramagnetic substances, as suggested by Debye[1] and Giauque[2], were carried out, by Giauque and MacDougall[3], and also by de Haas, Wiersma and Kramers[4]. Continuing our former experiments[5] on the magnetic method, we have constructed an apparatus for investigations in the region of lowest temperatures. As we shall soon give a detailed report of some calculations and experimental work, we will mention here only some of our results.

We succeeded in so choosing the conditions that, on one hand, the removal of the heat of magnetisation was completed in a few minutes; on the other hand, the condensation of the residual gas on the cooled substance took place very rapidly, the latter being necessary for keeping the low temperatures attained. Hence one had to keep the magnet switched on only for a few minutes.

Using 0·5 gm. of manganese ammonium sulphate, a substance we found to be most suitable, we reached 0·1°, starting at 1° and 6,000 gauss (a stronger magnet was not at our disposal). The temperature was determined by measuring the susceptibilities and extrapolating as in the experiments mentioned above, this procedure being subject to the same objections as discussed there. The thermal insulation in our arrangement was such that it took, for example, one hour and a half to warm up from 0·18° to 0·26°.

We then made experiments in cooling down other substances with the paramagnetic salt, looking first for supraconductivity in the case of cadmium. For this purpose a tablet was pressed out of equal volumes of cadmium and manganese ammonium sulphate.