

DUBLIN INSTITUTE FOR ADVANCED STUDIES
SCHOOL OF THEORETICAL PHYSICS
64-65 MERRION SQUARE, DUBLIN

22. 2. 49.

To

Prof. Sir K. S. Krishnan Kt., F.R.S
Director, All India Physical Laboratories,
New Delhi

Dear Sir,

The Education Department of India House, when you paid a visit recently, has kindly asked me to write to you in connection with my further research work in India.

It is a great privilege for me to renew my acquaintance with you which dates back to 1936 while I was a student.

Since the middle of 1946, I have been working in the Institute here under Prof. W. Heitler on problems connected with meson field theories. The 'Introduction' (in proof) of a paper of mine to appear within a fortnight will give you an idea of the nature of my work, the second paper referred to thereunder will also appear shortly. Before I return back to India, I intend to come in touch with the different Universities in England and of the Continent.

Most humbly I solicit the favour of

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your kind advice regarding the opportunities
of future work in India.

I may be permitted to add briefly
my qualifications:

- (i) B.Sc With Honours in Physics
- (ii) M.Sc. (Cal. Univ.) 1st class
- (iii) Ph.D. (Dublin)
- (iv) Research experience under
 - (a) Prof. M.N. Saha F.R.S.
 - (b) Prof. H.J. Bhalha F.R.S.
 - (c) Prof. W. Heitler F.R.S.
- (v) Ghose Travelling Fellow, Cal. Univ.
- (vi) Author of several papers including
 - (a) Neutron-Proton Scattering, Phil. Mag. 27, 76 (1939)
 - (b) Proton-Proton Scattering, Phil. Mag. 29, 200 (1940)
 - (c) Theory of Particles of spin Half and Compton Effect
Proc. Ind. Acad. Sc. 15, 105 (1942)
 - (d) Capture of Electrons by Positive Ions
Ind. Jour. Phys. 29, 121, 1945
 - (e) Relativistic scattering of Neutrons by Protons ⁱⁿ Press
 - (f) *ibid* with damping

With my best regards,

Yours most obediently
S.B. Ghose

Enclosure: A proof sheet of a paper to appear.

(From the Dublin Institute for Advanced Studies.)

By D. BASU.¹

(Communicated by W. HEITLER.)

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1. Introduction.

IN any theoretical investigation of the scattering of neutrons by protons one meets with the difficulty that the exact nature of the interaction and the type of meson field to be used is not definitely known yet. A comparison between the experimental and the theoretical angular distribution of the neutron-proton scattering will furnish us with a means of deciding the type of exchange forces that exist in this case. The experimental position remained for a time a controversial issue, but recent experiments by Powell and Occhialini (ref. 7) and by others indicate that the ratio of the differential cross-section in the backward and perpendicular direction referred to the centre of mass system is greater than 1 for neutrons of energy 13 M.e.v. This fact shows that the interaction is at least largely of an exchange type and due to charged mesons. On the other hand, charged mesons alone fail to account for the equality of the neutron-proton and proton-proton forces in corresponding states. This leaves us with the choice of a symmetrical theory first proposed by Kemmer (1938), in which both charged and neutral mesons play rôles in a way that maintains the equality of forces between like and unlike particles.

¹ Ghose Travelling Fellow, Calcutta University.

Of the four possible representatives of meson field (scalar, vector, pseudoscalar, pseudovector) the vector theory accounts for the binding of the triplet and singlet S -states of deuteron. It is well-known, however, that the nuclear interaction based on the vector theory gives rise to a tensor force which contains an inadmissible singularity at $r \rightarrow 0$ of the type $1/r^3$. Owing to the presence of such a high order singularity the Schrödinger equation for the deuteron would have no proper solution. The tensor force also appears in the pseudoscalar theory, and has, in the non-relativistic limit, the same form but with opposite sign, as that of the vector field. To eliminate this singular part of the nuclear potential Møller and Rosenfeld (ref. 6) proposed a mixed field of vector and pseudoscalar mesons with the same coupling constants for both vector and pseudoscalar mesons. This combination eliminates completely the tensor force in the static interaction, and consequently the quadripole moment of the deuteron would vanish. However, a tensor force appears again in the non-static, velocity dependent parts of the interaction, and it can be shown that this has the order of magnitude required by the experimental value of the quadripole moment. Furthermore, Schwinger (ref. 8) suggested that in the Møller-Rosenfeld combination the mass of the vector meson may be assumed to be larger than that of the pseudoscalar meson. This also introduces a tensor force even in the static potential, but without a singularity of the type $1/r^3$. Jauch and Hu (ref. 3) found that this modification gives the right order of the quadripole moment of the deuteron but a value too small by about a factor 2. Presumably the correct value can be obtained by adding the contribution from the velocity dependent interaction.

Whilst we can thus eliminate the $1/r^3$ -singularity from the static potential the difficulty re-appears again in the velocity dependent parts of the interaction and in particular in the relativistic region. It has been shown by Hu (ref. 2) that it is not possible to eliminate this singularity by any combination of meson fields of different types.²

² That this must be so is clear from the fact that the different meson fields have different relativistic transformation properties and cannot therefore cancel.

However, in the region of high energies, where now this singular term appears, one can see the Born approximation, and the singularity will then cause no mathematical difficulty. We shall see that it exhibits itself by an increase of the scattering cross-section with energy, (at any rate as long as the Born approximation is used), and this is certainly contrary to the facts.

A further point concerns the occurrence of a contact interaction in the nuclear potential. It is well known that the evaluation of the nuclear forces between two nucleons gives rise to an interaction involving δ -functions. It has been shown by Kemmer (ref. 4) that such a contact interaction does not lead to any finite binding energy in the deuteron. It becomes, therefore, necessary to eliminate the contact potential from the interaction of two nucleons so that it is free from δ -functions. This is possible because the δ -function is relativistically invariant. By adding suitable terms to the Lagrangian from the start this can be chosen, so that the final interaction potential in non-relativistic approximation does not contain any δ -functions. In the following we shall choose the Lagrangian in this way. In the relativistic region the concept of potential loses its meaning. We cannot, therefore, say whether a contact potential will re-appear there. Besides, in the Born approximation a contact potential and an $1/r^3$ potential behave alike, and both will exhibit themselves in the manner stated above.

It is our object here to investigate the proton-neutron scattering of the high energy region, where the Born approximation can be applied, and in particular in the relativistic region. Here the effect of retardation is accounted for by the mechanism of exchange of mesons. The relativistic scattering of neutrons and protons was first calculated in this way by Bhabha (ref. 1) on the basis of a charged vector meson field. He considered the case of a scattering due to the mesonic charge of the nucleon only (g_1 -interaction). We have seen that charged vector mesons alone fail to explain the facts, and, furthermore, the scattering due to the mesonic dipole (g_2 -interaction) is much more pronounced at high energies than that due to g_1 . We shall, therefore, use the charge symmetrical combination of vector and pseudoscalar fields. In order to study the influence of the tensor-force with the $1/r^3$ singularity and of the contact potentials, results will be given separately for the various types of fields where desirable.

Born's method consists essentially of an expansion in powers of g^2/hv (v = velocity of primary particle) and the approximation employed here corresponds to taking the first term of the series. From exact calculations it appears that the Born approximation is in fact valid for energies above 50-100 M.e.v.

The results of the calculations show that the g_1 scattering of neutrons by protons with the δ -function eliminated in the way described above decreases with increasing energy and tends to a constant in the relativistic region. The g_2 scattering, with the new modifications, also decreases with energy in the non-relativistic region if Møller and Rosenfeld combination is used, but increases again in the relativistic region. This indefinite increase with increase with energy is due to the re-appearance of high order singularities in the relativistic region as mentioned above and partly, perhaps, due to contact potentials not cancelling in the relativistic region.

This increase certainly constitutes a difficulty. It is to be hoped that this difficulty can be remedied by using, in place of the Born approximation, the theory of damping. It is intended to investigate this possibility in a subsequent paper.