Letters to the Editor

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Notes on the Wheeler-Feynman Theory

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THE present writer has suggested[1] that there is a qualitative relation between Mach's principle of the relativity of inertia as employed in Einstein's general theory, and the Wheeler-Feynman principle that the radiative damping reaction is dependent upon absorbers *via* advanced potentials.[2] Professor Wheeler[3] believes this suggestion may be significant. In relativity, there would be no inertial reaction of mass particles if there were no gravitational bodies in the universe; and the retarded gravitational fields of the material universe provide these inertial reactions.[4] In the Wheeler-Feynman theory, there would be no radiative reaction of electrical particles if there were no absorbing bodies in the universe; and the half-advanced electromagnetic fields of the absorbers provide the radiative reaction of the charged particle. It may be advisable to "symmetrize" the gravitational potentials by introducing both the half-advanced and half-retarded fields. Taking the interior gravitational law for macroscopic matter under certain specified coordinate conditions and for weak fields:[5]

$$2R_\mu{}^\nu - g_\mu{}^\nu R = -\frac{16\pi G}{c^4}\cdot T_\mu{}^\nu,$$

we obtain

$$\nabla^2 f_\mu{}^\nu - \partial^2 f_\mu{}^\nu / c^2\partial t^2 = -4\pi\left(-\frac{4\pi G}{c^4}\cdot T_\mu{}^\nu\right),$$

which could be solved symmetrically over the volume v:

$$f_\mu{}^\nu = \frac{1}{2}\cdot\frac{1}{4\pi}\int\frac{\left[-\frac{16\pi G}{c^4}\cdot T_\mu{}^\nu\right]}{r}dv + \frac{1}{2}\cdot\frac{1}{4\pi}\int\frac{\left\{-\frac{16\pi G}{c^4}T_\mu{}^\nu\right\}}{r}dv,$$

where the square brackets refer to retarded time $t-r/c$, and the curly brackets refer to advanced time $t+r/c$; and where

$$f_\mu{}^\nu = h_\mu{}^\nu - \tfrac{1}{2}\delta_\mu{}^\nu h, \text{ and } h_\mu{}^\lambda = \delta^{\lambda\alpha}h_{\mu\alpha},\ h = h_\alpha{}^\alpha \text{ and } g_{\mu\nu} = \delta_{\mu\nu} + h_{\mu\nu},$$

where $\delta_{\mu\nu}$ are the Galilean values and $h_{\mu\nu}$ are the higher order deviations of the gravitational field from these values.

It also seems of considerable importance to direct attention to the fact that Wheeler and Feynman employ Frenkel's solution for a *point* charge which gives a *finite* self-energy or self-mass. In this way we can define a *point* mass for the subatomic "particles." Some years ago, L. Silberstein[6] obtained an axially symmetric line element for a gravitational field:

$$ds^2 = e^\nu dt^2 - e^{\lambda-\nu}\cdot(dx^2+dy^2) - x^2e^{-\nu}dz^2.$$

He pointed out that λ and ν cannot be functions of the time t if this line element is to remain in agreement with the gravitational law:

$$R_{\mu\nu} = 0.$$

His solution would therefore represent two resting gravitational bodies that would have to remain at fixed distances with respect to each other. For macroscopic gravitational bodies, this would be absurd. This absurdity arises from the fact that Silberstein treated these finite bodies as *point* singularities of the field, the problem thereby having axial symmetry. But if we are willing to take over the theory of Frenkel into the domain of *all* subatomic "particles," then Silberstein's solution may be most significant. Thus the proton-neutron combination could be represented by Silberstein's solution, and could give rise to fixed energy levels between these particles, i.e., with point masses in the subatomic equations, general relativity, for the first time, opens up the possibility of deriving quantization.

There are two further facts that are relevant: the laws of motion are obtainable[7] for two bodies from $R_{\mu\nu}=0$, hence quantized motion may also emerge in this case. Finally, it may be possible to obtain the nuclear forces from gravitation.[8]

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[1] C. W. Berenda, Phil. Sci. 14, No. 1, p. 19.
[2] J. Wheeler and R. Feynman, Rev. Mod. Phys. 17, 157 (1945).
[3] Private communication.
[4] H. Thirring, Physik. Zeits. 19, 33, 156 (1918); 22, 29 (1921).
[5] R. Tolman, *Relativity, Thermodynamics, and Cosmology* (Oxford Press, New York, 1934), pp. 236–238.
[6] L. Silberstein, Phil. Mag. 24, 814 (1937).
[7] Einstein, Hoffmann, Infeld, and Robertson, Annals Math. 39, 65, 101 (1938); 41, 455 (1940).
[8] M. Wang, K. Wang, and H. Tsao, Phys. Rev. 66, 103, 155 (1944); 68, 163 (1945).

Probability of Nuclear Meson-Absorption

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THE experimental studies of the decay of negative mesons stopped in various materials[1] leads to the conclusion[2] that the probability for a K-orbit meson to be absorbed by the nucleus is of the order of magnitude of 10^6 sec.$^{-1}$, i.e., about 10^{12} times smaller than would be expected on the basis of conventional meson field theory.[3] It is significant that a discrepancy of the same factor of 10^{12} was encountered in the early attempts to explain nuclear forces (and magnetic momenta) on the basis of electron-neutrino exchange theory.[4] In connection with this earlier discrepancy it was suggested by Gamow and Teller[5] that the probabilities of the three possible processes, (1) electron-pair emission, (2) electron-neutrino emission, and (3) neutrino-pair emission, may represent a geometrical progression with a ratio equal to 10^{12}, the first being the most probable and the last the least probable. Under such an assumption, nuclear forces must be due exclusively to electron-pair exchange, the processes involving β-transformations to the electron-neutrino creation or annihilation, whereas the emission of neutrino-pairs could be associated with the gravitational radiation. Since in the meson-language the process (1) should be described as the emission of a neutral meson, whereas the process (2) corresponds to charged (positive or negative) mesons, the former "*three-processes-hypothesis*" can be now reformulated in the following way. *The exchange forces between nucleons (and also their magnetic momenta) are due exclusively to the exchange of neutral mesons, whereas all the processes connected with charged mesons* (such as ordinary β-decay, K-capture, urca-processes, emission or absorption of charged mesons by various nuclei, etc.) *possess probabilities which are smaller by a factor of the order of magnitude* 10^{12}. The above-mentioned discrepancy between the observed and calculated probabilities of nuclear meson-absorption seems to represent a strong argument in favor of this point of view.

[1] M. Conversi, E. Pancini, and O. Piccioni, Phys. Rev. **71**, 209 (1947); T. Sigurgeirsson and A. Yamakawa, Phys. Rev. **71**, 319 (1947).

[2] E. Fermi, E. Teller, and V. Weisskopf, Phys. Rev. **71**, 314 (1947); J. A. Wheeler, Phys. Rev. **71**, 320 (1947).

[3] Kobayasi and Okayama, Proc. Phys. Math. Soc. Japan **21**, 1 (1939); Sakata and Tanikawa, Proc. Phys. Math. Soc. Japan **21**, 58 (1939).

[4] H. Bethe, Rev. Mod. Phys. **8**, 203 (1936).

[5] G. Gamow and E. Teller, Phys. Rev. **51**, 289 (1937).

Relative Moments of H_1 and H_3

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We have recently[1] established the fact that the triton has the spin $\frac{1}{2}$ and a positive magnetic moment about 1.067 times larger than that of the proton. In view of the interest in the result it seemed desirable to improve the accuracy of the ratio of the two moments.[2]

In order to facilitate comparison a new sample was prepared, which, according to a density determination, contained approximately equal amounts of H_1 and H_3 in the form of a 0.1 molar solution of $MnSO_4$ in water. Confirming our previous results for the spin of the triton and the sign of its moment, signals of equal sign and about equal size and shape were obtained from the two isotopes under identical radiofrequency conditions and with those values of the d.c. field at which their respective resonances were expected to occur.

A highly accurate value for the relative moments of H_1 and H_3 was obtained by superimposing in the transmitter coil two r.f. fields of different frequencies ν_1 and ν_3, delivered from independent oscillators. The receiver coil could be tuned to simultaneous response for both frequencies by two coupled resonant circuits, so that a single diode was able to detect the peak voltage of both frequencies and hence the instantaneous sum of the two signals, received from both isotopes. The original method of field modulation and representation[3] gave thus two separate signals on the screen as long as the resonance fields for the two isotopes had still different values but were already within the sweep of the modulating field. A slight variation of ν_1 resulted in the merging of the two separate signals into one of about twice the size and was continued until maximum height of this signal was observed. This indicated, within a fraction of the line width, that a common value of the resonance field for the two isotopes had been reached, so that independent of this value, their gyromagnetic ratios γ_P and γ_T had to stand in the proportion of the two frequencies ν_1 and ν_3.

A considerable improvement of the accuracy was obtained by using larger pole pieces than before so as to obtain a more homogeneous field over the region in which the sample was located. We were thus able to obtain lines with a half-width of somewhat less than 0.5 gauss.[4]

By proper setting of ν_1 we were able to ascertain equality of the resonance fields for the two isotopes within 0.1 gauss; since the d.c. field had a value of about 10,000 gauss, an accuracy of about 1 in 10^5 was thus obtained.

In the actual measurements, ν_3 and the beat frequency $\Delta\nu = \nu_3 - \nu_1$ were obtained from a Navy type LM-18 crystal calibrated frequency-indicating meter so that for the gyromagnetic ratios γ_T and γ_P of the triton and the proton we had the relation:

$$\gamma_T/\gamma_P = [1 - \Delta\nu/\nu_3]^{-1}.$$

Calibration of the frequency-indicating meter showed that frequency readings were accurate to about one part in ten thousand. An uncertainty of 1 in 10,000 in $\Delta\nu$ and ν_3 introduces an uncertainty of 1 in 10^5 in γ_T/γ_P as calculated from the above formula.

TABLE I. Results for the gyromagnetic ratio γ_T of the triton in terms of γ_P of the proton obtained from two sets of runs with different values of the d.c. field B_0.

B_0 (Gauss)	No. of Runs	γ_T/γ_P
9300	17	1.066638 ± 0.000007
9900	21	1.066635 ± 0.000011

Table I gives the results of 17 runs in which the d.c. field had a value of about $B_0 = 9300\ G$ and 21 more runs where $B_0 = 9900\ G$. The indicated probable errors for each set of runs are obtained in the usual way from mean square deviation of individual runs from the average, and it is seen that the two sets agree well within their individual errors. Taking both together, and in view of our earlier result for the spin of the triton and the sign of its moment, we obtain

$$\mu_T = (1.066636 \pm 0.00001)\mu_P$$

for the moment μ_T of the triton in terms of μ_P, that of the proton.

* Work done at Stanford University and at the Los Alamos Scientific Laboratory operated by the University of California under U. S. Government contract.

[1] F. Bloch, A. C. Graves, M. Packard, and R. W. Spence, Phys. Rev. **71**, 373 (1947).

[2] While this work was in progress we were informed that H. Anderson and A. Novick had found the gyromagnetic ratio of tritium to be 1.06666 ± 0.0001 times that of the proton; the more accurate result, reported here, lies within their error.

[3] F. Bloch, W. W. Hansen, and M. Packard, Phys. Rev. **69**, 127 (1946); **70**, 460 (1946).

[4] This confirms the recent interesting result of N. Bloembergen, R. V. Pound, and E. M. Purcell, Phys. Rev. **70**, 986 (1946), that the line width in liquids is far less than originally expected. We were not able, however, to reach their limit of 0.15 gauss, probably because of insufficient homogeneity of our field.