one 12-inch square hole for large size experimental equipment and by a number of 4-inch square holes, extending through the reactor and both shields, which permit the insertion of small experimental equipment into the body of the reactor, or are capable of releasing collimated neutron beams. The top shield of the reactor consists of removable 4-foot square blocks to accommodate thermal columns and large equipment designed to utilize the leakage thermal neutron flux (in excess of 10^{11} neutrons per square centimeter per second). The over-all dimension of the reactor including the shield in the direction of the experimental holes is approximately 38 feet. It will be possible to conduct research on three vertical faces, and on the top and bottom of the reactor.

A laboratory building specially designed for handling radioactive materials is directly connected to the reactor building proper, for research in physics, chemistry, engineering, biology, and medicine.

Construction has been started on a "hot" laboratory for work on sources of intense radiation in a building adjacent to the reactor building and connected to it by a mono-rail and by pneumatic tubes for transporting irradiated material. Within the "hot" laboratory will be three distinct types of facilities: (1) "hot-cells" for processing samples up to 50 curies of 2-Mev γ-activity by remotely controlled apparatus; (2) "semi-hot cells" for work with samples of 1 millicurie to 1 curie of 2-Mev γ-rays using semi-remote control techniques including tongs and special manipulators; and (3) "semi-works" area in which large apparatus can be erected with appropriate portable shielding. The "hot" laboratory building also includes analytical laboratories, shops, store rooms for hot and cold material, personnel locker space, offices, etc. Completion of this laboratory will be delayed until after the completion of the reactor.

Every assistance will be given to scientists desiring to use the facilities of the reactor "hot" laboratory.

Erratum: Interferometric Studies of Faster-than-Sound Phenomena. Part I. The Gas Flow around Various Objects in a Free, Homogeneous, Supersonic Air Stream

[Phys. Rev. 73, 1359 (1948)]

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MR. A. W. HAWKINS (E. I. duPont de Nemours and Company) has drawn our attention to the fact that Eq. (1) of our article (p. 1360),

$$\frac{A}{A_1}=\frac{1}{M}\left(1+\frac{\gamma-1}{2}M^2\right)^{\frac{1}{2}(\gamma+1)/(\gamma-1)},$$

has to be replaced by the following equation:

$$\frac{A_1}{A}=\frac{1}{M}\left[\frac{2}{\gamma+1}\left(1+\frac{\gamma-1}{2}M^2\right)\right]^{\frac{1}{2}(\gamma+1)/(\gamma-1)}.$$

The Magnetic Moments of the Neutron and Proton

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IN the light of the recent advances made in quantum electrodynamics it seems worth while to consider whether similar techniques applied to meson theories will yield sensible results. The basic idea is that mass and charge renormalization terms arising from the meson interactions are explicitly recognized and lumped with the originally assumed mass and charge. In the present theory these terms are infinite. However, it is hoped that in a future correct theory these terms will be but small additions to the original ones. The assumption is made that the remaining, finite, predictions of the present theory will be essentially unaltered in the correct treatment, as yet unknown. The justification of this philosophy is perhaps more tenuous for the meson case with its strong interaction than for the much more weakly coupled electromagnetic field.

Using this recognition procedure the magnetic moments of the neutron and proton were calculated in both the charged and symmetrical pseudoscalar theories using the pseudovector coupling. The proton-neutron field was treated completely relativistically. The results expressed in nuclear magnetons were: *charged theory,*

$$\mu_p=1+\frac{1}{4\pi}(g^2/4\pi\hbar C)\frac{C_1(\mu/M)}{(\mu/M)^2},$$
$$\mu_n=-\frac{1}{4\pi}(g^2/4\pi\hbar C)\frac{[C_1(\mu/M)+C_2(\mu/M)]}{(\mu/M)^2},$$

symmetrical theory,

$$\mu_p=1+\frac{1}{4\pi}(g^2/4\pi\hbar C)\frac{[C_1(\mu/M)+\frac{1}{2}C_2(\mu/M)]}{(\mu/M)^2}$$
$$_n=-\frac{1}{4\pi}(g^2/4\pi\hbar C)\frac{[C_1(\mu/M)+C_2(\mu/M)]}{(\mu/M)^2},$$

where g is the coupling constant with the dimensions of charge, μ = meson mass, and M = nucleon mass. C_1 and C_2 are slowly varying functions of the mass ratio. For U/M between zero and 0.3 these functions may change by something like 10 percent. For $\mu/M=0.1$ the numerical values are $C_1=0.55$ and $C_2=1.00$.

The first interesting point to be noted is that these quantities are finite. That is, after appropriate mass and charge renormalization no further cut-off is needed to insure convergence of the integrals for the magnetic moments. Expressed as integrals over momentum the integrals behave asymptotically as $1/P^3$. Practically all of the contribution comes from below $P=MC$ which is, therefore, the effective cut-off. While a non-relativistic theory would lead one to believe that such a cut-off would yield much too large values for the magnetic moments, this turns out to be false. The non-relativistic effects which one calculates are largely cancelled by the vacuum polarization phenomena which are contained only in the relativistic treatment.

Fitting the neutron moment to the experimental value yields values of $(g^2/4\pi\hbar C)$ between 0.2 and 0.3—in reasonable agreement with other determinations.

The interesting quantity

$$R=\frac{\mu_p-1+\mu_n}{\mu_p-1-\mu_n}$$

is independent of the coupling constant. For $\mu/M=0.1$ we find *charged theory*, $R=-0.50$; *symmetrical theory*, $R=-0.20$; *experimentally*, $R=-0.03$.

Thus R turns out to be considerably too large with the given mass ratio. However, while C_1 and C_2 are but slightly dependent on μ/M the ratio R is probablysome what more sensitive to the mass ratio. By changing this ratio somewhat and considering mesons of other spins and other coupling it is at least possible that agreement with experiment may be achieved.

The most important result would seem to be that the techniques which have succeeded so well in electrodynamics will be equally successful in obtaining sensible answers from meson theories.

In conclusion I would like to express my gratitude to Professor J. Schwinger for suggesting the problem and for many helpful discussions.

I am also indebted to the National Research Council for a Predoctoral Fellowship.

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The Magnetic Moment of Boron[11]

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SINCE our original report on the use of super-regenerative oscillators for the determination of nuclear gyromagnetic ratios,[1] several improvements have been made in the oscillator circuits and in detection methods. Since these improvements have been made, the sensitivity of our method has become comparable with the bridge methods of Purcell and Pound[2] and the nuclear induction method of Bloch.[3] We have now observed nuclear magnetic resonances for H^1, H^2, Li^7, B^{11}, F^{19}, Na^{23}, P^{31}, Cu^{63}, Cu^{65}, Br^{79}, Br^{81}, and I^{127}. Inasmuch as the gyromagnetic ratio of B^{11} has not yet been measured by the recently developed methods applicable to solids and liquids, it seems desirable to make a preliminary report on the subject at this time, especially since the results obtained to date are at slight variance with the earlier results obtained by molecular beam methods.[4]

The results reported in this note are based on a comparison of the gyromagnetic ratio of B^{11} with that of Na^{23}. Taking the magnetic moment of Na^{23} as 2.217 ± 0.002 nuclear magnetons and its spin[5] as $\frac{3}{2}$, we obtain a value of 1.800 ± 0.005 for the gyromagnetic ratio g of B^{11}. In arriving at this value for g we have made a slight correction for diamagnetism of the electrons[6] in boron and have assumed a positive moment for B^{11}. Assuming a spin[7] $I=\frac{3}{2}$ for B^{11}, we obtain a value of 2.700 ± 0.008 nuclear magnetons for the nuclear moment of B^{11}.

The gyromagnetic ratio obtained in the present work is slightly higher than the value $g=1.788\pm0.005$ obtained in molecular beam experiments.[4] Before much significance can be attached to the slight difference in the results obtained by the two methods, we feel that further work should be done. The results reported here were obtained with an aqueous solution of $Na_2B_2O_4$, for which material the Na^{23} and B^{11} resonances were both observed. We plan to make additional measurements of the B^{11} resonance in other compounds. The accuracy of measurements of gyromagnetic ratios by super-regenerative methods can be increased by a factor of 10 by making certain obvious variations in our present arrangement. We are making these changes and plan to make a more detailed report on the work in the near future.

We should like to express our appreciation to Professor E. M. Purcell for helpful discussions during the early stages of our work and to the Graduate School and University Development Fund of the Ohio State University for grants of funds used in the purchase of equipment.

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1 J. R. Zimmerman and D. Williams, Phys. Rev. **73**, 94 (1948).
2 E. M. Purcell, H. C. Torrey, and R. V. Pound, Phys. Rev. **69**, 37 (1946).
3 F. Bloch, W. W. Hansen, and M. Packard, Phys. Rev. **69**, 127 (1946).
4 S. Millman, P. Kusch, and I. I. Rabi, Phys. Rev. **56**, 165 (1939).
5 J. M. B. Kellogg and S. Millman, Rev. Mod. Phys. **18**, 323 (1946).
6 W. E. Lamb, Phys. Rev. **60**, 817 (1941).
7 S. Millman, P. Kusch, and I. I. Rabi, Phys. Rev. **56**, 303 (1939).

On the Ground State of the Deuteron

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A CONVENIENT formula for the estimation of the depth-range relation of various potentials in the theory of the deuteron is

$$-\int_0^b V(r)rdr\cong\hbar^2/M, \tag{1}$$

where b is the range of the neutron-proton force, $V(r)$ is the potential energy, and M the proton or neutron mass. Furthermore, $\hbar^2/M$ is a lower bound to the integral.

It may be of interest to note that (1) can be replaced by the exact equation

$$-\int_0^\infty V(r)u(r)\sinh\alpha r=\alpha\hbar^2/M, \tag{2}$$

where α is the reciprocal deuteron radius, $\alpha=(-ME/\hbar^2)^{\frac{1}{2}}$, and $u=\psi/r$, ψ being the wave function for the ground state of the deuteron, so normalized that

$$\lim_{r\to\infty}\frac{u(r)}{e^{-\alpha r}}=1.$$

Since (2) may be rewritten

$$-\int_0^\infty V(r)\frac{u(r)}{e^{-\alpha r}}\frac{(1-e^{-2\alpha r})}{2\alpha}=\frac{\hbar^2}{M},$$

and since $u(r)/e^{-\alpha r}\leq1$ and $(1-e^{-2\alpha r})/2\alpha\leq r$, it is obvious that $\hbar^2/M\leq-\int_0^\infty V(r)rdr\cong-\int_0^b V(r)rdr$ and hence that (2) implies (1), provided $2\alpha b\ll1$ and $u(r)/e^{-\alpha r}\cong1$ over most of the range $0\leq r\leq b$.