Gyromagnetic Ratio of Nickel at Low Magnetic Intensities

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It has recently been shown that the measured value for the gyromagnetic ratio of iron, as measured by an Einstein-DeHaas experiment, is field-dependent in the low-intensity region, and that the extrapolated zero-intensity value of this ratio checks the value which is theoretically expected from a consideration of recent ferromagnetic resonance experiments.

This experiment has been repeated for a sample of pure nickel and a similar result has been obtained. The extrapolated zero intensity value for g' for nickel is 1.801. At a higher induced magnetic intensity, the effective value of g' changes to 1.830.

INTRODUCTION

THE techniques used in these experiments have been previously described.[1,2] The rod used was of high-purity nickel, very kindly furnished by the International Nickel Company. It is the same rod that was previously used to measure the gyromagnetic ratio of nickel at the General Motors Research Laboratories. In its original state, this rod was hot-rolled, annealed, and then cold drawn 40%.

After making the improvements in the equipment described in reference 2, a series of check readings were taken on the Ni rod. These readings were taken with the rod in its original state on 10 different days during December, 1953. The value obtained from this set of runs was $\rho e/m=1.092$ or $g'=1.831$. These runs were taken using a magnetizing current of 16.00 milliamperes. The resulting magnetic moment of the rod alone was 20 871 amp cm².

After the above runs were completed, the winding was removed and the rod was annealed for 2 hours in dry hydrogen at 2000°F and furnace cooled. This resulted in a fourfold increase in magnetic permeability. The rod was rewound and the present series of experiments on the field dependence of g' were performed with the rod in this annealed condition.

TABLE I. Condensed data for determining gyromagnetic ratios of nickel.[a]

$$\rho e/m=\left(\frac{\pi I d}{4PXkm/e}-2i_e\,\Sigma A_e\right)\Big/(M_e-i_e\,\Sigma A_e).$$

i_e(ma)	M_e	P	d	$\rho e/m$
4.0008	21814	28.117	0.036084	1.097
4.0001	21811	28.105	0.036044	1.097
2.0000	10730	28.105	0.017940	1.110
2.0000	10730	28.107	0.017941	1.110
2.0000	10730	28.107	0.017951	1.110
8.0034	43902	28.122	0.072348	1.093
8.0011	43890	28.122	0.072480	1.095
16.0030	86570	28.154	0.14251	1.090
2.0001	10730	28.100	0.017963	1.111
1.0000	5203	28.109	0.008708	1.110
1.0000	5203	28.107	0.008671	1.105
1.0000	5203	28.106	0.008711	1.111
1.0000	5203	28.106	0.008691	1.108
1.0000	5203	28.105	0.008713	1.111
1.0000	5203	28.105	0.008731	1.113
3.0008	16247	28.103	0.027031	1.104
3.0004	16244	28.107	0.026958	1.101
5.0004	27326	28.109	0.045194	1.097
5.0004	27326	28.109	0.045266	1.099
4.0002	21811	28.108	0.036168	1.100
4.0004	21812	28.108	0.036126	1.099
3.0001	16243	28.106	0.027004	1.103
3.0000	16242	28.101	0.027086	1.107

[a] Moment of inertia, $I=215.26$ g cm².
Optical length, $X=1576.9$ cm.
Phase angle constant, $k=0.99941$.
Winding constant, $\Sigma A_e=78490$ cm².
Mass charge ratio of electron, $m/e=5.6844\times10^{-9}$ g coul⁻¹.
i_e = magnetizing current, amperes.
M_e = magnetic moment (rod and winding), amp cm².
P = period, seconds.
d = amplitude change per reversal of i_e, cm.

RESULTS

The condensed data shown in Table I were taken during March, and April, 1955. The average value of $\rho e/m$ for each value of the magnetizing current used is given in Table II along with the corresponding values of g'. Figure 1 is a plot of the data given in Table II. The average induced magnetic intensity of the rod which is plotted along the X axis is obtained by dividing the magnetic moment of the rod alone in amp cm² by the volume of the rod.

It can be seen from an examination of this curve that the change from the low intensity value for g' to the high intensity value apparently takes place more abruptly than is the case for Fe.

It seems possible that this change in g' might occur at a unique value of the induced magnetic intensity and that the gradual change obtained is the result of

TABLE II. Values of $\rho e/m$ and g' for various induced magnetic intensities in nickel.[a]

i_e	$\mathcal{I}$	$\rho e/m$	g'
1.0	131.8	1.110	1.802
2.0	271.9	1.110	1.801
3.0	411.8	1.104	1.812
4.0	552.9	1.098	1.821
5.0	692.7	1.098	1.821
8.0	1112.8	1.094	1.828
16.0	2194.3	1.090	1.834

[a] i_e = winding current, milliamperes.
$\mathcal{I}$ = average induced magnetic intensity of rod, amp cm⁻¹.
$\mathcal{I}=(M_e-i_e\,\Sigma A_e)/v$. $v=38.88$ cm³.

[1] G. G. Scott, Phys. Rev. **82**, 542 (1951).
[2] G. G. Scott, Phys. Rev. **99**, 1241 (1955).

nonuniformity of magnetization of the rod. If it is assumed that the rod is elliptically magnetized and that g' changes from 1.801 to 1.830 at an induced intensity of 470 amp cm^{-1}, then a curve of g' *vs* average induced intensity would be obtained, which would be nearly the same as the experimental curve. In this case, however, there would be a discontinuity in the curve at 370 amp cm^{-1} which is the average intensity at which the central region of the rod reaches the assumed critical intensity of 470 amp cm^{-1}. This hypothetical discontinuity is shown as a broken line in Fig. 1. More points and a winding which more uniformly magnetizes the

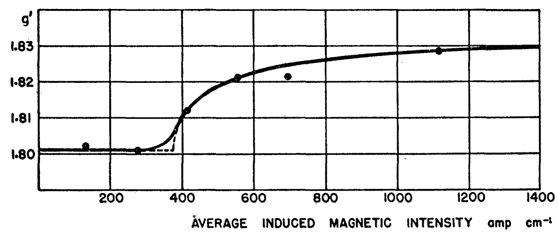

FIG. 1. Plot of g' *vs* average induced magnetic intensity for Ni rod 1.5-cm diam, 22 cm long.

specimen would undoubtedly be needed in order to decide whether or not this change occurs at a unique value of the magnetic intensity.

The extrapolated zero intensity value of 1.801 for g' is seen to check very well the value expected from microwave experiments.[3]

[3] C. Kittel, *Introduction to Solid State Physics* (John Wiley and Sons, Inc., New York, 1953), p. 171.

TABLE III. Chemical analysis of impurities in nickel rod.[a]

Iron	0.032%
Cobalt	Negligible
Manganese	0.030%
Copper	0.003%
Silicon	0.10%
Carbon	0.01%
Sulfur	0.005%

[a] Analysis made by International Nickel Company.

The higher intensity value of 1.830 checks work which has previously been done on Ni at the General Motors Research Laboratories.[4] A chemical analysis of the Ni rod is given in Table III.

CONCLUSION

It has been shown from an Einstein-DeHaas experiment that the effective value of g' for Ni depends on the induced magnetic intensity of the specimen.

When the curve of g' *vs* induced intensity is extrapolated to zero intensity, the value obtained for g' is 1.801 ± 0.002. A similar effect has recently been reported for Fe.

ACKNOWLEDGMENTS

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[4] Brown, Meyer, and Scott, Compt. Rend. **238**, 2504 (1954).