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References

EFFECT OF A CONSTANT MAGNETIC FIELD ON THE BETA DECAY RATE OF A NEUTRON IMMERSED IN A COMPLETELY DEGENERATE ELECTRON GAS

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Our previous work on the effect of a constant magnetic field on neutron decay in a vacuum is extended to the case where the process takes place in dense bodies (white dwarfs, neutron stars), at zero temperature.

As part of a general program to examine the various effects of a large magnetic field [1], we have recently calculated [2] the effect of a constant magnetic field on the rate of neutron beta decay in a vacuum and the astrophysical implications [3] arising from same. For consideration of objects such as white dwarfs and neutron stars, where magnetic fields $H$ as large as $10^{14} - 10^{16}$ G have been speculated to exist [4], it is necessary to take into account the effect on the decay rate of the existing electron sea, the latter being characterized by a number density $N$, temperature $T$ and chemical potential $\mu$. For $T = 0$, an extension of previous analysis [2, 3] leads to a total $\beta$ decay rate ($K = c = m_e = 1$)

$$\omega(H, \mu) = \frac{\gamma g^2}{\pi \lambda^2} \times \frac{n(\max)}{n'(\max)} \times \left\{ \sum_{n=0}^{n(\max)} F_n(H, W_0) - \sum_{n=0}^{n'(\max)} F_n(H, \mu) \right\},$$

where

$$F_n(H, Z) = (1 - \frac{1}{2}e^{\lambda^2}) \{K_n(W_0^2 + Z^2 - K_n^2)^{1/2} K_n - W_0 K_n Z - W_0^2 (Z^2 - K_n^2) \ar sinh[K_n (Z^2 - K_n^2)^{1/2}] \}$$

and $K_n \equiv (Z^2 - 1 - 4\gamma^2)^{1/2}$, $\lambda = g_A/g_V \approx 1.18$, $W_0 = 2.53$ is the total decay energy, $\gamma = H/2H_c$ (where $H_c = 4.4 \times 10^{13}$ G) and $n(\max)$ and $n'(\max)$

Fig. 1. The dependence of $\omega$, the $\beta$ decay rate in a magnetic field of a neutron immersed in a completely degenerate electron gas, normalized to the free-field decay rate in vacuum $\omega_0$, as a function of the nuclear matter density $\rho_0$, for values of $H/H_c$ equal to 0, 2 and 3.
are the largest integers occurring in \((W_0^2 - 1)/4\gamma\)
and \((\mu^2 - 1)/4\gamma\), respectively.

Now the energy eigenvalues \(E\) of a relativistic
electron in a magnetic field \(H = H_2\) are \([5]\)
\[
E = \left\{ 1 + \frac{k^2}{(H/H_c)(2n + s - 1)} \right\}^{1/2},
\]
where \(n = 0, 1, 2 \ldots, \ s = \pm 1\) and \(k\) is the \(z\)
component of the electron momentum. Thus,
the number density is
\[
N = \frac{1}{4\pi^2} \frac{H}{H_c} \sum_{n=0}^{\infty} \sum_{s=\pm 1} \int_{-\infty}^{\infty} \left\{ 1 + \exp[(E - \mu)/kT]\right\}^{-1} dk,
\]
and so, analogous to the non-relativistic case
\([6]\), \(\mu\) may be determined implicitly as a func-
tion of \(N\) and \(H\). Now \(N\) may be related to the nu-
clear matter density \(\rho\) by the relation
\[
\rho N = \frac{1}{2\pi^2} \frac{H}{H_c},
\]
where \(\mu_e = \text{(number of nucleons/number of protons)},\)
and \(m_n\) is the nucleon mass.

In the case of completely degenerate electron
gas, the Fermi distribution function reduces to
a step function and eq. (4) reduces to
\[
\rho_6 = 4.16 \frac{(H/H_c)^{1/2}}{\pi} \sum_{n=0}^{\infty} \left(1 + \frac{\delta_{n0}}{Q(2n + 1)^{1/2}}\right) \frac{g}{\text{cm}^3},
\]
where \(\rho_6 = 10^{-6}(\rho/\mu_e)\) and \(Q = (\mu^2 - 1)/4\gamma\). This
equation was used for the numerical evaluation
of explicit values of \(\mu\) for various values of \(\rho_6\)
and \(H\). In fig. 1 we plotted \(\omega(H, \mu)\) as a function
of \(\rho_6\) for various values of \(H\) and we have also
included the \(H = 0\) rate for comparison. The num-
ber of nodes increases with decreasing \(H\), reflect-
ing the fact that \(n'(\text{max})\) increases with decreasing
\(H\). For a given \(\rho_6\), the change in the decay rate as
a function of \(H\) is essentially caused by the effect of
the magnetic field on the density of final states
of the electron \([7]\). Similar phase space effects
are relevant to the calculation of the changes pro-
duced in the cooling rate of neutron stars \([8]\) by
a magnetic field.

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DIAMAGNETIC SUSCEPTIBILITY OF SUPERCONDUCTING TIN ABOVE \(T_C\)

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In a bulk sample of pure tin a small, but strongly temperature and field dependent diamagnetic suscep-
tibility has been found, extending over a temperature range of about 30 millidegrees above the transition
temperature to superconductivity.

Recently the onset of superconductivity has
attracted much interest \([1-5]\). The increase of
the electrical conductivity above \(T_C\), due to fluc-
tuations of the order parameter has been ob-
served by Glover \([1]\) with thin films.

According to Schmidt \([5]\) these fluctuations
should cause a singularity of the diamagnetic
susceptibility proportional to the Ginzburg-Landau
correlation length in a bulk sample, whereas
Aslamazov and Larkin \([3]\) arrive at the statement,
that anomalous diamagnetism should be absent.

We have investigated the magnetic behavior
of a single crystal of tin with a residual resistiv-
ity ratio \((\rho_{24}/\rho_{295}) = 5 \times 10^{-3}\) near the transi-
tion to superconductivity.