Comments and Addenda

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Ultrasonic Attenuation in Heisenberg Magnets

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(Received 23 October 1968)

The microscopic theory developed by Bennett and Pytte to treat ultrasonic attenuation in Heisenberg magnets overestimates the critical fluctuations. It is shown that better agreement with experiment obtains when this fact is heuristically taken into account.

In this note, we call attention to the following heuristic improvement in the ultrasonic attenuation coefficient for isotropic Heisenberg magnets. From Eq. (63) of Ref. 1 and Eq. (13) of Ref. 2, we see that our theory gives the following expressions for the ultrasonic attenuation coefficients:

$$\alpha_A \sim q^2(\chi' I)^{1/2}/\Lambda \quad \text{and} \quad \alpha_F \sim q^2(\chi J)^{3/2}/D,$$

where A means antiferromagnet, F means ferromagnet, χ' and χ are static susceptibilities, $I>0$ and $J>0$ are the magnitudes of the respective exchange integrals, Λ and D are spin-diffusion coefficients, and $q=|\mathbf{q}|$ is the wave number of the sound wave. Recent dynamic scaling theory[3] predicts that

$$\Lambda \sim \epsilon^{3\nu/2} \quad \text{and} \quad D \sim \epsilon^{\nu-\beta},$$

where $\epsilon = T_c^{-1}|T-T_c|$. Our theory[4] gives $D\sim\epsilon^{\gamma/4}$. The latter agrees with the former when $\eta=0$ and $\delta=5$. We use the conventional notation for the critical indices.[5] We note that when $\gamma=1.33$, $\nu=0.67$, and $\beta=0.33$,

$$\alpha_A \sim q^2\epsilon^{-1.67} \quad \text{and} \quad \alpha_F \sim q^2\epsilon^{-2.33}.$$

These theoretical values, 1.67 and 2.33 are substantially larger than the experimental values.[6–9] We expect this, however. We know from Eq. (B4) of Ref. 1 that our theory overestimates the critical fluctuations because it predicts specific heats of the forms

$$C_v(A) \sim (\chi' I)^{1/2} \quad \text{and} \quad C_v(F) \sim (\chi J)^{1/2}.$$

The heuristic improvement (in the sense that one agrees more closely with the experimental values for the critical indices) is to replace $(\chi' I)^{1/2}$ and $(\chi J)^{3/2}$ with $C_v(A)$ and $C_v(F)$ (χJ), respectively, in the above expressions for the ultrasonic attenuation coefficients. We then obtain

$$\alpha_A \sim q^2\Lambda^{-1}C_v(A) \quad \text{and} \quad \alpha_F \sim q^2 D^{-1}\chi J C_v(F).$$

We define ζ_A and ζ_F to be the attenuation indices for the antiferromagnet and the ferromagnet, respectively; that is, $\zeta_A \approx -\alpha - \frac{3}{2}\nu$ and $\zeta_F \approx -\alpha - 5\gamma/4$. When $\alpha \neq 0$, $\alpha \ll \frac{1}{4}\gamma$, $\gamma=1.33$, $\eta=0$, and $\delta=5$, we have ζ_A (theory) ≈ 1.0 and ζ_F (theory) ≈ 1.67. The recent experiments on MnF_2 by Neighbours and Moss[6] yield ζ_A $(MnF_2)=0.41$ and by Evans[7] yield ζ_A $(MnF_2)=0.53\pm0.05$. Golding[8] finds for $RbMnF_3$ that ζ_A $(RbMnF_3)=0.32\pm0.02$. Luthi and Pollina[9] report that ζ_F (Gd) $=1.2\pm0.01$. The above theory which treats only the ideal istropic Heisenberg magnet is least appropriate for Gd, a metal with long-range anisotropic interactions.

The author is grateful to D. L. Huber for interesting discussions.

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