receiver, and the received signal starts after a finite time determined by the velocity of first sound u_1. In this respect the situation cannot be adequately described by the classical equations of thermal conduction, which always give a received signal starting at time zero. Most phonons travel to the wall of the propagation tube where they are diffusely scattered once or many times before reaching the receiver. The signal therefore builds up gradually and the apparent arrival time may depend on the noise level or amplification of the receiver giving an apparent velocity somewhat less than u_1.

The thermal conductivity of the material of the propagation tube is usually so low that heat generated inside the tube leaks out with a long relaxation time of the order of several milliseconds. The excess phonons therefore distribute themselves uniformly throughout the enclosure, producing inside it a uniform excess temperature which then dies away with this long relaxation time, thus producing the long tail observed on the received pulse. It is worth noticing that the maximum amplitude depends only on the heat supplied per pulse and the thermal capacity of the enclosed liquid, suggesting a possible method for measuring the specific heat of the liquid at very low temperatures.

These considerations apply only to the lowest temperatures where the mean free path is large. Khalatnikov's theory would restrict their validity to the temperature range below about 0.6°K. The rise in the velocity of second sound just below 1°K is not so readily explained in terms of dispersion effects. Applying, for example, Dingle's[5] theory of viscous attenuation, the 20 percent rise[6] in velocity at 0.85°K would require a viscosity of the order of 0.1 poise, which appears rather large. A complete set of velocity and attenuation measurements in this region must be available before it can be concluded that the rise in velocity can be explained in any other way than that suggested by Landau.

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Pseudo-Quadrupole Effect for Nuclei in Molecules*

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SEVERAL years ago, Foley,[1] following a suggestion of Van Vleck,[2] calculated the pseudo-quadrupole effect for nuclei in diatomic molecules. This effect was a perturbation of the energy levels similar to that by a nuclear electrical quadrupole moment but due instead to the second-order paramagnetic interaction between the nuclear magnetic moment and the electron orbital moments.

It is the purpose of this note to point out that in addition to the effect considered by Foley there are two other magnetic terms which give rise to apparent nuclear quadrupole moments which are of similar magnitude to the term considered by Foley. One of these corresponds to the direct or low frequency term in the diamagnetic susceptibility of molecules.[3] The terms considered by Foley correspond to high frequency[3] (or second-order paramagnetism) terms of the diamagnetic susceptibility. The other new contribution is that due to the electron spins of the molecule. As recently pointed out by Ramsey and Purcell,[4] the effects of the electron spins cannot be neglected even in $^1\Sigma$ molecules when the perturbations entering in a second-order perturbation calculation correspond to magnetic fields that are not uniform throughout the molecule. In such cases the second-order contributions from the triplet state must be included. Since the magnetic field of the nuclear magnetic moment is far from uniform in the molecule, the contribution from the interaction between the nuclear magnetic moment and electron spin magnetic moment must therefore be included.

These terms can best be discussed quantitatively with the aid of the Hamiltonian used by Ramsey and Purcell:[4]

$$\mathcal{H}=\mathcal{H}_1+\mathcal{H}_2+\mathcal{H}_3,$$

where

$$\mathcal{H}_1=\Sigma_k[1/2m_k][(\hbar/i)\nabla_k+(e\hbar/c)\Sigma_l\,\gamma_l\mathbf{I}_l\times\mathbf{r}_{kl}/r_{kl}^3]^2 +V+\mathcal{H}_{LS}+\mathcal{H}_{SS}+\mathcal{H}_{II},$$

$$\mathcal{H}_2=2\beta\hbar\,\Sigma_{kl}\,\gamma_l\{3(\mathbf{S}_k\cdot\mathbf{r}_{kl})(\mathbf{I}_l\cdot\mathbf{r}_{kl})r_{kl}^{-5}-\mathbf{I}_l\cdot\mathbf{S}_k r_{kl}^{-3}\},$$

$$\mathcal{H}_3=(16\pi\beta\hbar/3)\Sigma_{kl}\,\gamma_l\delta(\mathbf{r}_k-\mathbf{r}_l)\mathbf{S}_k\cdot\mathbf{I}_l.$$

The only terms that were considered by Foley were the cross products of the two terms inside the bracket of $\mathcal{H}_1$. The additional term corresponding to simple diamagnetism is the square of the second term in the bracket of $\mathcal{H}_1$. Since Foley's term enters only in second order, these two contributions are of comparable magnitude. The other, and, in general, larger effect from the electron spin is that which results from $\mathcal{H}_2$, $\mathcal{H}_3$, and their cross terms. Although the term $\mathcal{H}_3$ gives rise to the largest matrix elements for a molecule such as D_2, it alone, even in a second-order perturbation calculation, gives rise to no pseudo-quadrupole effect since it is independent of the molecular orientation. However, the cross terms between $\mathcal{H}_2$ and $\mathcal{H}_3$ in the second-order perturbation and the terms dependent on $\mathcal{H}_2$ alone both give rise to pseudo-quadrupole effects with the contribution of the former considerably exceeding the latter in the case of D_2. If Q' is the apparent electric quadrupole moment of the nucleus produced by these magnetic interactions, the apparent quadrupole interaction $eQ'(\partial^2V^{\text{ext}}/\partial z^2)$ produced by Foley's term for D_2 is approximately -1 cycle per second when estimated by the procedure in his paper. The contribution of the simple diamagnetic term is approximately $+0.4$ cycle per second when estimated with Heitler-London wave functions. The contribution of the electron spins when estimated with Heitler-London wave functions is -2.4 cycles per second. Although all of these pseudo-quadrupole interactions are smaller than those of any nuclear quadrupole moment so far measured, they are comparable to the effects which can be measured in present precision experiments.

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A New Approach to the Problem of Higher Order Corrections in the Meson Theory of Nuclear Forces

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THE method of successive approximations,[1] outlined for classical meson field equations in a previous note,[2] is here applied to consistent quantum-mechanical calculations. For the sake of generality we present here a formalism, which contains both classical and quantum mesodynamics. Adopting the usual notations, all the equations for the meson fields can be written in the general form

$$(\Box-\mu^2)\varphi=-4\pi\Omega\delta(\mathbf{x}-\mathbf{x}_{(1)}), \tag{1}$$

where $\delta(\mathbf{x})$ is the three-dimensional Dirac function, $\mathbf{x}$ is the vector of position in ordinary space, and Ω is a linear operator characterizing the sources of the meson field component φ. In all cases considered we assume that Ω commutes with the Laplacian operator Δ.