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Klemens P G. Thermal conductivity and lattice vibrational modes.
Solid State Phys.—Adv. Res. Appl. 7:1-98, 1958.
[Division of Physics, National Standards Laboratory, CSIRO, Sydney, Australia]

The theory of lattice thermal conductivity in solids is reviewed. Interaction rates are calculated for anharmonic phonon processes, for phonon scattering by various imperfections, and for phonon-electron interactions. Poiseuille flow of phonons is predicted. These results are applied to the thermal conductivity of dielectric crystals, disordered solids, and semiconductors, and to the lattice thermal conductivity of metals and alloys. [The *SCI*® indicates that this paper has been cited in over 430 publications since 1958.]

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The theory of heat conduction in solids by lattice waves was put into its modern form by R.E. Peierls in 1929,[1] but he confined himself to general principles. Relatively little work was done in the next two decades, until F.E. Simon at Oxford University realized that the low-temperature thermal conductivity of dielectric crystals could be used to study lattice defects, just as the electrical conductivity of metals is a sensitive indicator of imperfections. He encouraged R. Berman to start thermal conductivity measurements at Oxford, which he has continued to do for 35 years.[2]

I went to Oxford from Sydney in 1948 as a graduate student in theoretical physics. My boat was delayed, and my research project was given to someone else; thus, lattice thermal conductivity became my doctoral topic. I also became interested in electronic transport properties and continued work on both topics from 1950 onward at the National Standards Laboratory, Sydney, benefiting from the enlightened leadership of G.H. Briggs and from a fruitful collaboration with G.K. White. I was fortunate to be invited to write on low-temperature thermal conductivity for the *Handbuch der Physik*.[3] **While this review is not widely known today, it no doubt helped my reputation and led to an invitation by Frederick Seitz to write on lattice thermal conductivity for the newly formed** *Solid State Physics* **series.**

My main interest in those days was the connection between the different conduction properties of metals and alloys, and how they are influenced by imperfections and by the shape of the Fermi surface. My earlier review emphasized low temperatures; this one covered both low and high temperatures.

At that time, there was much interest in thermoelectric energy conversion. Lattice thermal conductivity is important because it limits the efficiency of such devices. It was hoped to produce better materials by introducing point defects. My review, treating many of the important phonon scattering processes, was thus of interest. I joined Westinghouse Research Laboratories in 1959 to work on this problem. Less spectacular, but more significant in the long run, has been a continuing need to measure, understand, and modify the thermal conductivity of insulating solids. Important applications include nuclear reactors, space vehicles, thermal insulations, thermal shock resistance of ceramics, and thermal properties of optical components. This steady interest in the thermal conductivity of solids results in international conferences held at regular intervals.

My 1958 review is not the latest word. For example, it does not treat the role of point defects at high temperatures. A more recent review was written with the experimentalist in mind and is more up to date.[4] There have also been two small but excellent books.[2,5]

Apart from timeliness, my review article owes its success to that of the Seitz and David Turnbull *Solid State Physics* **series. Solid-state physics was small, but growing rapidly. The original volumes aimed to cover all the subfields. The great expansion of solid-state research has made such comprehensive coverage difficult, but many of the early reviews have helped this development. The credit for this belongs to Seitz and Turnbull.**

1. **Peierls R.** Zur kinetischen Theorie der Wärmeleitung in Kristallen. *Ann. Phys. Leipzig* 3:1055-101, 1929. (Cited 200 times since 1955.)
2. **Berman R.** *Thermal conduction in solids.* Oxford: Clarendon Press, 1976. 193 p. (Cited 75 times.)
3. **Klemens P G.** Thermal conductivity of solids at low temperatures. *Handb. Phys.* 14:198-281, 1956. (Cited 185 times.)
4. --------------. Theory of thermal conductivity of solids. (Tye R P, ed.) *Thermal conductivity.* London: Academic Press, 1969. Vol. 1. p. 1-68. (Cited 65 times.)
5. **Parrott J E & Stuckes A D.** *Thermal conductivity of solids.* London: Pion, 1975. 157 p. (Cited 40 times.)

