Ballistic/Diffusive (nonlocal) behavior: Boltzmann treatment of the temperature distribution near a heat source

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At distances less than carrier mean free paths ($|r-r'| < l$) , the local heat current $J(r)$ is determined not just by the local temperature gradient $dT(r)/dr$, but by the temperature distribution $T(r')$ or $dT(r')/dr'$. The Peierls-Boltzmann equation gives a rigorous way to calculate this, provided the carriers (labeled k) are well-defined quasiparticles with statistics describable by distribution functions $N_k(r)$. The necessary version of the Boltzmann equation requires a term $(dN_k(r)/dt)_{ext}$ giving the influence of heat sources at r, and constraint equations relating the source field to the temperature or current field. A rigorous version of this equation will be given, and applied to two model problems. Problem 1 is heat currents driven by parallel planar hot and cold regions. The numerical results of Zhou *et al*. [1] for GaN are analyzed in detail [2]. Problem 2 is the distribution of temperature if a solid is heated by a thin cylindrical wire. Somewhat different versions of the theory apply to metallic conductors (where electrons carry most of the heat but phonons hold most of the temperature), and to insulators (where phonons carry all the heat and hold all the temperature.)

[1] X. W. Zhou, S. Aubry, R. E. Jones, A. Greenstein, and P. K. Schelling, Phys. Rev. B **79**, 115201 (2009).
[2] P. B. Allen, arXiv:1612.01173.