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Conductivity of a perfect crystal

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Dissipation of electrical current in typical metals is due to scattering off material defects and phonons. But what if the material were a perfect crystal, and sufficiently stiff or cold to eliminate phonons – would conductivity become infinite? We realize an analogous scenario with atomic fermions in a cubic optical lattice, and measure conductivity. The equivalent of Ohm's law for neutral particles gives conductivity as the ratio of particle current to the strength of an applied force. Our measurements are at non-zero frequency (since a trapping potential prevents dc current flow), giving the low-frequency spectrum of real and imaginary conductivity. Since our atoms carry no charge, we measure particle currents with in-situ microscopy, with which both on- and off-diagonal response is visible. Sum rules are used to relate the observed conductivity to thermodynamic properties such as kinetic energy. We explore the effect of lattice depth, temperature, interaction strength, and atom number on conductivity. Using a relaxation-time approximation, we extract the transport time, i.e., the relaxation rate of current through collisions. Returning to the initial question, we demonstrate that fermion-fermion collisions damp current since the lattice breaks Galilean invariance.

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