Canadian Association of Physicists
Association canadienne des physiciens et physiciennes

Contribution ID: **3057** Type: **Oral (Non-Student) / Orale (non-étudiant(e))**

Thermal Conductivity of Square Ice

Wednesday 8 June 2022 13:45 (15 minutes)

We investigate thermal transport in square ice, a two-dimensional analogue of spin ice, exploring the role played by emergent magnetic monopoles in transporting energy. Using kinetic Monte Carlo simulations based on energy preserving extensions of single-spin-flip dynamics, we explicitly compute the (longitudinal) thermal conductivity, κ, over a broad range of temperatures. We use two methods to determine κ: a measurement of the energy current between thermal baths at the boundaries, and the Green-Kubo formula, yielding quantitatively consistent values for the thermal conductivity. We interpret these results in terms of transport of energy by diffusion of magnetic monopoles. We relate the thermal diffusivity, κ/C where C is the heat capacity, to the diffusion constant of an isolated monopole, showing that the subdiffusive monopole implies κ/C vanishes at zero temperature. Finally, we discuss the implications of these results for thermal transport in three-dimensional spin ice, in spin ice materials such as $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$, and outline some open questions for thermal transport in highly frustrated magnets.

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Session Classification: W2-8 Condensed matter theory II (DCMMP/DTP) | Théorie de la matière condensée II (DPMCM/DPT)

Track Classification: Technical Sessions / Sessions techniques: Condensed Matter and Materials Physics / Physique de la matière condensée et matériaux (DCMMP-DPMCM)