Hall effect of neutral spin excitations

IRG1: Princeton Center for Complex Materials (DMR-1420541)

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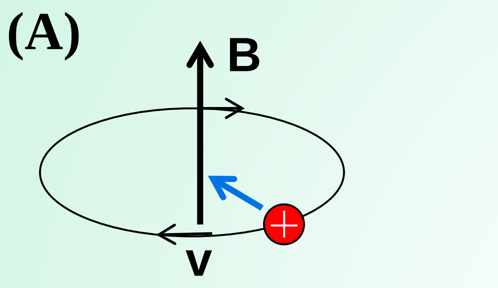
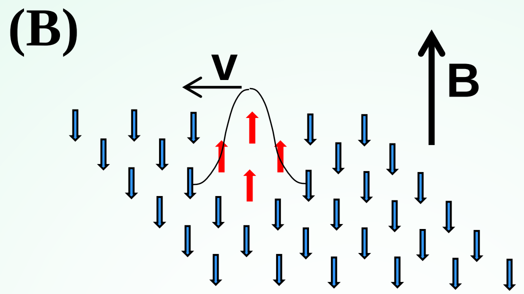
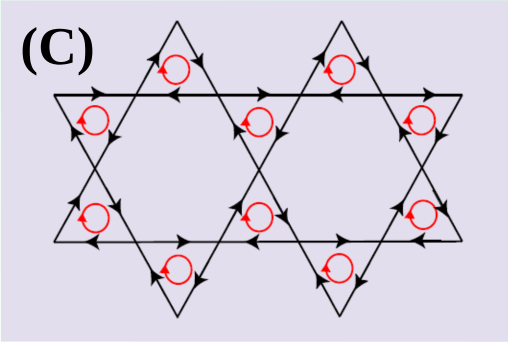


A) In a magnetic field **B**, the Lorentz force (blue arrow) causes a charged particle of velocity **v** to describe a cyclotron orbit.



B) A magnon (up red arrows) moving in a sea of “down” spins. Can the neutral magnon display a Hall effect?



(C) The kagome lattice with a spin at each vertex. The arrows indicate the systematic pattern of spin orientation.

The Lorentz force causes a charged particle moving in a magnetic field **B** to describe a cyclotron orbit (Fig. A). The curved trajectory also leads to the Hall effect. Can **neutral** particles or “spin excitations” called magnons exhibit the Hall effect in a magnetic field? In Fig. B, a magnon is depicted as a packet of reversed spins moving in a sea of “down” spins. Theory has predicted that that mobile magnons in certain quantum magnets can be deflected left (or right) by **B**. Hirschberger *et al*. recently observed this “thermal” Hall effect in two materials at cryogenic temperatures. In a kagome lattice (Fig. C), the magnons display a sizeable thermal Hall signal with a rich pattern of behavior [1]. In the pyrochlore $Tb_2Ti_2O_7$, the spins do not order even at 50 mK (a state called the spin liquid). Nonetheless, the spin excitations also display a thermal Hall effect [2]. The two results confirm that neutral “particles” do experience a novel type of Lorentz force despite lacking a charge.

1. M. Hirschberger *et al*. “Thermal Hall Effect of Spin Excitations in a Kagome Magnet,” Phys. Rev. Lett. **115**, 106603 (2015).
2. M. Hirschberger *et al*., “Large thermal Hall conductivity of neutral spin excitations in a frustrated quantum magnet,” *Science* **348**, 106-109 (2015).

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