Heterostructures and Spins Clusters

The Kondo-Heisenberg model in heterostructures and in frustrated spin clusters

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The study of the interplay between the Kondo effect and magnetic correlations in new platforms, such as heterostructures [1] and systems with spin clusters [2], may be a new path to developing materials with tailored properties. Here, we propose a heterostructure that consists of three coupled lattice layers. The Kondo-Heisenberg lattice model describes the first layer, called here the Kondo layer, with strengths of the Kondo and Heisenberg terms given by JK and JH, respectively. The other two layers are composed of non-interacting itinerant conduction electrons, with their coupling to the first layer determined by a perpendicular hopping parameter. Using the mean-field approximation within the Green's function formalism, we demonstrated that variations in interlayer coupling significantly influence the behavior of mean-field order parameters of the Kondo layer that characterize the Kondo singlet formation and short-range magnetic correlations. The resulting temperature versus interlayer hopping parameter phase diagram reveals a rich interplay of discontinuous and continuous transitions. In particular, for the regimes $|JK| < |JH|$ and $|JK| > |JH|$, we identify diverse phase diagrams that encompass Kondo, ferromagnetic, and antiferromagnetic correlations. Furthermore, we provide a detailed investigation of electronic properties, including the band structure, offering new insights into the interplay of coupling mechanisms in this class of heterostructures. Next, we discuss the interplay between Kondo interaction and magnetic frustration in a system with a cluster of spins [2]. We consider J1-J2 the model for magnetic couplings. The system is divided into identical finite clusters, with the magnetic intercluster interaction treated using a cluster mean-field approach [2]. The resulting effective intracluster problem is solved exactly, considering the Kondo coupling for different electron densities within each cluster. The results indicate that frustration weakens magnetic ordering by lowering the temperature of the order–disorder phase transitions. The Kondo interaction strongly affects these transitions, altering their critical behavior by inducing only continuous phase transitions and driving the system toward quantum critical points. This process takes place in the highly frustrated regime and becomes more pronounced as the electron density increases. Our findings suggest that even a weak Kondo coupling can affect magnetic ordering in a competitive magnetic scenario.

Bibliography

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