Collective coordinates, asymptotics and domain wall dynamics in ferromagnets

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The method of collective coordinates is a simple and widely used variational procedure for finding approximate solutions to many- or infinite-dimensional, possibly damped and driven, Hamiltonian systems. The approximate solutions are typically characterised by a small number of time-dependent parameters, which are understood to describe a small number of activated modes. The simplicity of the method comes at a price, however, as it does not allow a determination of how good (or bad) the approximation is. In certain regimes, asymptotic expansions can provide the requisite estimates, though they require more work.

This is illustrated for the problem of the motion of domain walls in ferromagnets. Domain walls are interfaces between differently oriented magnetic domains, and the dynamics of these interfaces under applied magnetic fields and currents is a problem of current physical and technological interest.

We also describe a new high-field regime, beyond the well-known Walker breakdown, where a new type of dynamics emerges, in which a nonplanar domain wall propagates with a velocity proportional to the square root of the applied field, and precesses at a frequency proportional to the applied field. This dynamics appears to be beyond the reach of the collective coordinate description. In a certain asymptotic limit, it is found to be exactly characterised through arguments of KPP (Kolmogorov-Petrovskii-Piskounov) type. The problem raises some challenges for KPP theory.

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