Iranian Journal of Physics Research, Vol. 24, No. 4, 2025
DOI: 10.47176/ijpr.24.4.71941

Emergent order in the orientation of localized dipoles in a two-dimensional elastic array

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(Received 25 July 2024 ; in final form 9 November 2024)

Abstract

Dipolar interaction plays a significant role in describing various phenomena. Analyzing a many-body system with dipolar interaction is challenging due to the vector, anisotropic, and long-range characteristics of this interaction. In this paper, a tensor approach is used to study dipolar interaction, allowing the contribution of orientation and the location of dipoles to be separated. With this approach, it can be shown that in mean-field theory, a continuous magnetic phase transition occurs in an ordered two-dimensional array of magnetic nanoparticles under the influence of dipolar interaction. However, this phase transition becomes more complex when nanoparticles are embedded in elastic tissue. Such a system is crucial from a biological view. The tensor approach is also applicable for analyzing the elastic array of dipoles. The results show that the strain in the elastic tissue aligns with magnetic order in a way that further stabilizes the emergent magnetic order against thermal fluctuations. Although this stability does not reduce the system's sensitivity to even the smallest external magnetic field at the critical point, and the system remains infinitely susceptible to an external magnetic field. This feature could be biologically important.

Keywords: dipolar interaction, continuous phase transition, coupling tensor, elastic media

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