DEPARTMENT OF PHYSICS

Fall 2016 seminar series

EFFECTIVE MEDIUM THEORIES BACKWARD IN TIME: FROM THE 21ST TO THE 19TH CENTURY

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2:15 pm
Ayer Hall 112

Electromagnetic metamaterials are artificial periodic structures engineered to control wave propagation of and to achieve physical effects not attainable in natural materials – high-frequency magnetism, negative refraction, strong absorption, lensing, cloaking, and more. Research in metamaterials started three decades ago, if not earlier, and exploded in the 2000s as a quest for "perfect lenses," "perfect absorbers," etc.

Central in metamaterials science is homogenization (effective medium theory), whose objective is to describe a composite structure in terms of effective parameters accurately representing reflection, transmission and propagation of waves on the scale coarser than the lattice cell size. Most mathematical theories of homogenization are asymptotic – i.e. valid in the limit of the lattice cell size vanishingly small relative to some characteristic scale. (For wave problems, this scale is the free-space wavelength; in statics, it is the scale of variation of the applied field and/or the size of the material sample.) It is now understood, however, that in this asymptotic limit all nontrivial properties of metamaterials – including, notably, magnetic response and negative refraction – vanish. We are developing non-asymptotic and nonlocal theories applicable to an arbitrary size and composition of the lattice cell.

Effective medium theories of classical physics (Clausius-Mossotti, Lorenz-Lorentz, Maxwell Garnett) rely on simplification assumptions that work very well for relatively simple mixtures but require extensions and enhancements in more complicated cases. While our perspective is very different from that of the 19th century physics, we shall see that classical theories fit nicely into the new framework.

The talk takes us backward in time from the novel non-asymptotic and nonlocal theories to classical ones (Maxwell Garnett, Clausius-Mossotti, and others); we show how these theories are related. We also emphasize aspects of the homogenization problem that are often overlooked and yet are essential: the finite size of the sample and the role of interface boundaries.