Bibliography on the Abraham-Minkowski Debate

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In my present view, the Abraham-Minkowski debate is about how an electromechanical system can be partitioned into "electromagnetic" and "mechanical" subsystems. A view not taken by either Abraham or Minkowski is that the "electromagnetic" subsystem consists only of the (macroscopic or microscopic) fields **E** and **B**, while the polarization densities **P** and **M** are "mechanical" entities. Then, the density of momentum in the "electromagnetic field" is

$$\mathbf{P}_{\mathrm{EM}} = \epsilon_0 \mathbf{E} \times \mathbf{B} = \frac{\mathbf{E} \times \mathbf{B}}{4\pi c}, \tag{1}$$

in SI and Gaussian units, respectively, while Abraham [28] argued that

$$\mathbf{P}_{\mathrm{EM}}^{(\mathrm{A})} = \frac{\mathbf{E} \times \mathbf{H}}{c^2} = \frac{\mathbf{E} \times \mathbf{H}}{4\pi c}, \tag{2}$$

but Minkowski's view [27] was that

$$\mathbf{P}_{\mathrm{EM}}^{(\mathrm{M})} = \mathbf{D} \times \mathbf{B} = \frac{\mathbf{D} \times \mathbf{B}}{4\pi c}. \tag{3}$$

Note that in dielectric media with unit relative permeability the Abraham momentum (2) is the same as the "field-only" momentum (1); the majority of papers in the bibliography below restrict their attention to this case. Here, it is natural to suppose that the Minkowski momentum (3) includes momentum associated with the polarization density **P** and so is a kind of "pseudomomentum", as perhaps first remarked in this context in [97]. Of course, in a magnetic medium with unit permittivity, the situation would be reversed and the Minkowski momentum agrees with eq. (1) while the Abraham momentum could be called a "pseudomomentum".

However, once one considers the possibility of quantum "pseudoparticles" such as polaritons, which are quanta of a charged-particle interaction with an electromagnetic field, it seems better to abandon the "classical" notion of a crisp partition of a system into "electromagnetic" and "mechanical" subsystem. That is, the Abraham-Minkowski debate is ultimately ill-founded: the form of the "electromagnetic" momentum relevant to an experiment can depend on the details of the apparatus (as noted in a general way by Bohr for quantum systems).

One can try to evade this quantum ambiguity by restricting attention to "purely classical" experiments, but this eliminates all examples involving waves, which latter have been the major interest in the Abraham-Minkowski debate over the past 60 years. If we confine our attention to purely "static" examples, in which the total momentum is zero and one naïvely expects there to be no mechanical momentum, when the "electromagnetic" momentum is nonzero we must entertain the arcane concept of "hidden" mechanical momentum, which is not represented in the bibliography below.[1]

[1]For some comments by the author on this last theme, see K.T. McDonald, *Abraham, Minkowski and "Hidden" Mechanical Momentum*, (June 6, 2012), http://physics.princeton.edu/~mcdonald/examples/abraham.pdf.

The Abraham-Minkowski debate has been characterized by Ginzburg as a "perpetual problem."[2]

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