Orbital magnetoelectric effects and topological insulators

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The concepts of the Berry potential and Berry curvature play an important role in the theories of electric polarization, orbital magnetization, and the anomalous Hall effect. I shall briefly review these topics, and then discuss how these concepts can be applied to develop a theory of the linear orbital magnetoelectric effect in multiferroic insulators. Remarkably, there is a geometric contribution to the magnetoelectric tensor that depends on the Berry potential and curvature in a way that is more complicated than, but highly analogous to, the Berry-phase polarization expression. For example, this geometric magnetoelectric coupling θ is only well-defined modulo 2π; shifting it by a quantum corresponds to the addition of a a surface layer exhibiting an integer quantum Hall effect, just as shifting P by 2π corresponds to the occupation of an extra surface-state band. In a development that may seem unrelated, considerable excitement has surrounding the recent theoretical prediction and experimental discovery of "strong topological insulators" (STI). These are insulators that obey time-reversal (T) symmetry but which cannot be adiabatically connected to ordinary nonmagnetic insulators without a gap closure. One can show, however, that a T-symmetric insulator must either have $\theta = 0$ or π; these cases correspond to ordinary insulators and to STI, respectively. Calculated values of θ for some magnetoelectric materials will be presented.

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