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Optical curl forces and beyond

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A physical example of a force that depends on position but is not derivable from a potential, that is, a nonconservative force with non-zero curl, is the force on a dielectric particle in an optical field. The resulting dynamics need not be Hamiltonian or Lagrangian, yet is non-dissipative, with unfamiliar chaotic dynamics Noether's theorem does not apply, so the link between symmetries and conservation laws is broken. Although unambiguous in optics, the physical existence of curl forces has been controversial among engineers. Motion under curl forces near optical vortices can be understood in detail, and the full series of 'superadiabatic' correction forces derived, leading to an exact slow manifold in which fast (internal) and slow (external) motion of the particle is separated. These classical optical forces have quantum effects.