

## **Curl forces and beyond**

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Forces depending on position but which are not derivable from a potential, that is, forces with non-zero curl, give rise to dynamics that is not Hamiltonian or Lagrangian, while also being non-dissipative. Noethers theorem does not apply, so the link between symmetries and conservation laws is broken. The physical existence of curl forces has been controversial and the subject of intense debate among engineers. But an example is familiar in optics: force on a dielectric particle in an optical field. 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.