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The Kepler Problem on Pseudo-Riemannian Surfaces

The generalized Kepler problem seeks to describe a Hamiltonian dynamical system determined by an arbitrary central potential. We introduce the classical Kepler problem as an instructive example and present original results on the generalized Kepler problem. We first demonstrate that the orbits of any Bertrand mechanical system on a pseudo-Riemannian surface of revolution are epitrochoids and provide explicit expressions for the orbital parameters. These results are complemented by numerical experiments using the recent symplectic integration methods of Tao and Pihajoki. We then construct analytic expressions for the super-integrals of the system, making explicit a result of Zagryadskii. Relevant concepts in differential geometry, geometric mechanics, and dynamical systems will be introduced.