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Symmetry Transformation Group Arising from the Laplace–Runge–Lenz Vector

The Kepler problem in classical mechanics exhibits a rich structure of conserved quantities, highlighted by the Laplace–Runge–Lenz (LRL) vector. Through Noether's theorem in reverse, The LRL vector gives rise to a corresponding infinitesimal dynamical symmetry on the kinematical variables, which are well known in the literature. However, the physically relevant part of the LRL vector is its direction angle in the plane of motion (its magnitude is just a function of energy and angular momentum).

In this talk, I will derive the infinitesimal dynamical symmetry corresponding to the direction part of the LRL vector, and obtain the explicit form of the symmetry transformations that it generates. When combined with the rotation symmetries, the resulting symmetry group is shown to be the semi-direct product of $SO(3)$ and R^3. This stands in contrast to the SO(4) symmetry group generated by the LRL symmetries and the rotations. As a by-product, the action of the new infinitesimal symmetries on all of the conserved quantities is obtained.

The results are given in terms of the physical kinematical variables in the Kepler problem, rather than in an enlarged auxiliary space in which the LRL symmetries are usually stated.