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On equations of motion, invariance of the action integral and symmetry transformations

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As it is well known, group theory has a wide application in Classical Physics and Quantum Theory, both in relativistic and non-relativistic formulation. On this subject, one of the themes of interest is the formulation of methods capable of determining the symmetry group of a given physical system. In this work, we aim to show the application of two methods: one explores the system's equation of motion and the other uses the invariance of the system's action. In the first, starting from the equation of motion and general expressions of the generators, the Lie algebra of the symmetry group is determined; in the second starting from the action integral, conditions are obtained that characterize the symmetry group that leaves the Lagrangian invariant, the invariant action and the invariant motion equation. We apply these methods to the simple harmonic oscillator and to the damped harmonic oscillator. In both cases we obtain as a result a group with eight parameters that preserves the equation of motion and a subgroup with five parameters that preserves the action named in the literature by the group of Noether symmetries. Constants of the motion for each system are also determined and explored.

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