

Dynamics on differential one-forms

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Mathematical models of dynamics employing exterior calculus are shown to be mathematical representations of the same unifying principle; namely, the description of a dynamic system with a characteristic differential one-form on an odd-dimensional differentiable manifold leads, by analysis with exterior calculus, to a set of characteristic differential equations and a characteristic tangent vector which define transformations of the system. This principle, whose origin is Arnold's use of exterior calculus to describe Hamiltonian mechanics and geometric optics, is applied to irreversible thermodynamics and the dynamics of black holes, electromagnetism and strings. It is shown that "exterior calculus" models apply to systems for which the direction of change is given by a characteristic tangent vector and "conventional calculus" models apply to systems whose direction of change is arbitrary. The relationship between the two types of models is shown to imply a technical definition of equilibrium for a dynamic system.

KEY WORDS: applied differential geometry, exterior calculus

1. Introduction

In dynamics, mathematical models that employ calculus use both the exterior calculus of Cartan and the conventional calculus for quantitative description of natural phenomena. So adequate is the agreement between the conclusions of these models and the observables in the experimental domain that Hamiltonian mechanics, irreversible thermodynamics, geometric optics and classical field theories are technically understood only with the geometric objects (e.g., differential forms) of exterior calculus. In contrast (in reference to calculus), quantum mechanics, reversible thermodynamics, physical optics and quantum field theories are not understood in this way, but rather with the geometric objects (e.g., exact differentials) of conventional calculus. A survey of the literature reveals a current period for applications of exterior calculus to dynamics that is comparable to the beginning of the eighteenth century for applications of conventional calculus.

It is shown that the above mathematical models of dynamics employing exterior calculus are mathematical representations of the same unifying principle; namely, the description of a dynamic system with a characteristic differential one-form on an odd-dimensional differentiable manifold leads, by analysis with exterior calculus, to a set

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