

## 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

# Dynamics On Differential One Forms

**Troy L. Story**



## **Dynamics On Differential One Forms:**

*Dynamics on Differential One-Forms* Troy L. Story, 2002 *Dynamics on Differential One Forms* proposes a unifying principle for mathematical models of dynamic systems In *Thermodynamics on One Forms* chapter I the long standing problem of deriving irreversibility in thermodynamics from reversibility in Hamiltonian mechanics is solved Differential geometric analysis shows thermodynamics and Hamiltonian mechanics are both irreversible on representative extended phase spaces *Dynamics on Differential One Forms II* generalizes I to Hamiltonian mechanics geometric optics thermodynamics black holes electromagnetic fields and string fields Mathematical models for these systems are revealed as representations of a unifying principle namely 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 differential equations and a tangent vector defining system transformations Relationships between models using exterior calculus and conventional calculus imply a technical definition of dynamic equilibrium *Global Analysis of Composite Particles III* uses differential topology to develop the theory of large vibration rotation interactions for composite particles A global classical Hamiltonian and corresponding quantum Hamiltonian operator are derived then applied to the molecular vibration rotation problem *Characteristic Electromagnetic and Yang Mills Gauge IV* uses differential geometry to remove some of the arbitrariness in the gauge and shows how gauge functions for electromagnetic and Yang Mills fields follow the same differential equation

*Introduction to Differential Geometry with Applications to Navier-Stokes Dynamics* Troy L Story, 2005 *Introduction to Differential Geometry with applications to Navier Stokes Dynamics* is an invaluable manuscript for anyone who wants to understand and use exterior calculus and differential geometry the modern approach to calculus and geometry Author Troy Story makes use of over thirty years of research experience to provide a smooth transition from conventional calculus to exterior calculus and differential geometry assuming only a knowledge of conventional calculus *Introduction to Differential Geometry with applications to Navier Stokes Dynamics* includes the topics Geometry Exterior calculus Homology and co homology Applications of differential geometry and exterior calculus to Hamiltonian mechanics geometric optics irreversible thermodynamics black hole dynamics electromagnetism classical string fields and Navier Stokes dynamics **Differential Dynamical Systems, Revised Edition** James D. Meiss, 2017-01-24 *Differential equations* are the basis for models of any physical systems that exhibit smooth change This book combines much of the material found in a traditional course on ordinary differential equations with an introduction to the more modern theory of dynamical systems Applications of this theory to physics biology chemistry and engineering are shown through examples in such areas as population modeling fluid dynamics electronics and mechanics *Differential Dynamical Systems* begins with coverage of linear systems including matrix algebra the focus then shifts to foundational material on nonlinear differential equations making heavy use of the contraction mapping theorem Subsequent chapters deal specifically with dynamical systems concepts flow stability invariant manifolds

the phase plane bifurcation chaos and Hamiltonian dynamics This new edition contains several important updates and revisions throughout the book Throughout the book the author includes exercises to help students develop an analytical and geometrical understanding of dynamics Many of the exercises and examples are based on applications and some involve computation an appendix offers simple codes written in Maple Mathematica and MATLAB software to give students practice with computation applied to dynamical systems problems

**Dynamical Systems and Geometric Mechanics** Jared Maruskin, 2018-08-21 Introduction to Dynamical Systems and Geometric Mechanics provides a comprehensive tour of two fields that are intimately entwined dynamical systems is the study of the behavior of physical systems that may be described by a set of nonlinear first order ordinary differential equations in Euclidean space whereas geometric mechanics explore similar systems that instead evolve on differentiable manifolds The first part discusses the linearization and stability of trajectories and fixed points invariant manifold theory periodic orbits Poincar maps Floquet theory the Poincar Bendixson theorem bifurcations and chaos The second part of the book begins with a self contained chapter on differential geometry that introduces notions of manifolds mappings vector fields the Jacobi Lie bracket and differential forms

*Mathematical Modeling I* Troy L. Story, 2010-06 Mathematical Modeling I kinetics thermodynamics and statistical mechanics MMI features traditional topics in physical chemistry chemical physics but is distinguished by problem solving techniques which emphasize the assignment of mathematical models to describe physical phenomena MMI is a starting point to unify theoretical and empirical perceptions of the following topics Kinetics distributions and collisions The first law of thermodynamics The second law of thermodynamics The third law of thermodynamics Statistical mechanics MMI can be used as a text on the above topics in the first semester part of a two semester undergraduate course in physical chemistry Since many quantum ideas are introduced in the study of kinetics distributions collisions and statistical mechanics MMI serves as a logical foundation for the study of quantum mechanics and spectroscopy in the second volume Mathematical Modeling II quantum mechanics and spectroscopy to appear in the fall of 2010

**Dynamics** Carlos M. Roithmayr, Dewey H. Hodges, 2016-03-09 This book is ideal for teaching students in engineering or physics the skills necessary to analyze motions of complex mechanical systems such as spacecraft robotic manipulators and articulated scientific instruments Kane s method which emerged recently reduces the labor needed to derive equations of motion and leads to equations that are simpler and more readily solved by computer in comparison to earlier classical approaches Moreover the method is highly systematic and thus easy to teach This book is a revision of Dynamics Theory and Applications 1985 by T R Kane and D A Levinson and presents the method for forming equations of motion by constructing generalized active forces and generalized inertia forces Important additional topics include approaches for dealing with finite rotation an updated treatment of constraint forces and constraint torques an extension of Kane s method to deal with a broader class of nonholonomic constraint equations and other recent advances

**System Dynamics** Dean C. Karnopp, Donald L. Margolis, Ronald C. Rosenberg, 2012-03-07 An expanded new edition of

the bestselling system dynamics book using the bond graph approach A major revision of the go to resource for engineers facing the increasingly complex job of dynamic systems design System Dynamics Fifth Edition adds a completely new section on the control of mechatronic systems while revising and clarifying material on modeling and computer simulation for a wide variety of physical systems This new edition continues to offer comprehensive up to date coverage of bond graphs using these important design tools to help readers better understand the various components of dynamic systems Covering all topics from the ground up the book provides step by step guidance on how to leverage the power of bond graphs to model the flow of information and energy in all types of engineering systems It begins with simple bond graph models of mechanical electrical and hydraulic systems then goes on to explain in detail how to model more complex systems using computer simulations Readers will find New material and practical advice on the design of control systems using mathematical models New chapters on methods that go beyond predicting system behavior including automatic control observers parameter studies for system design and concept testing Coverage of electromechanical transducers and mechanical systems in plane motion Formulas for computing hydraulic compliances and modeling acoustic systems A discussion of state of the art simulation tools such as MATLAB and bond graph software Complete with numerous figures and examples System Dynamics Fifth Edition is a must have resource for anyone designing systems and components in the automotive aerospace and defense industries It is also an excellent hands on guide on the latest bond graph methods for readers unfamiliar with physical system modeling

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