

## 17.1: Introduction to Relativistic Mechanics

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Newtonian mechanics incorporates the Newtonian concept of the complete separation of space and time. This theory reigned supreme from inception, in 1687, until November 1905 when Einstein pioneered the Special Theory of Relativity. Relativistic mechanics undermines the Newtonian concepts of absoluteness of time that is inherent to Newton's formulation, as well as when recast in the Lagrangian and Hamiltonian formulations of classical mechanics. Relativistic mechanics has had a profound impact on twentieth-century physics and the philosophy of science. Classical mechanics is an approximation of relativistic mechanics that is valid for velocities much less than the velocity of light in vacuum. The term "relativity" refers to the fact that physical measurements are always made relative to some chosen reference frame. Naively one may think that the transformation between different reference frames is trivial and contains little underlying physics. However, Einstein showed that the results of measurements depend on the choice of coordinate system, which revolutionized our concept of space and time.

Einstein's work on relativistic mechanics comprised two major advances. The first advance is the 1905 **Special Theory of Relativity** which refers to nonaccelerating frames of reference. The second major advance was the 1916 **General Theory of Relativity** which considers accelerating frames of reference and their relation to gravity. The Special Theory is a limiting case of the General Theory of Relativity. The mathematically complex General Theory of Relativity is required for describing accelerating frames, gravity, plus related topics like Black Holes, or extremely accurate time measurements inherent to the Global Positioning System. The present discussion will focus primarily on the mathematically simple Special Theory of Relativity since it encompasses most of the physics encountered in atomic, nuclear and high energy physics. This chapter uses the basic concepts of the Special Theory of Relativity to investigate the implications of extending Newtonian, Lagrangian and Hamiltonian formulations of classical mechanics into the relativistic domain. The Lorentz-invariant extended Hamiltonian and Lagrangian formalisms are introduced since they are applicable to the Special Theory of Relativity. The General Theory of Relativity incorporates the gravitational force as a geodesic phenomena in a four-dimensional Riemannian structure based on space, time, and matter. A superficial outline is given to the fundamental concepts and evidence that underlie the General Theory of Relativity.

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