

# INTRODUCTION

Although Descartes' natural philosophy marked an important advance in the development of modern science, many of his specific concepts of science—most notably, his concepts of space, time, and motion—have been largely discarded, and consequently neglected, since their introduction in the seventeenth century. Many critics over the years, such as Newton (in his early paper *De gravitatione*), have presented a series of apparently devastating arguments against Descartes' theory of space and motion; a generally negative historical verdict which, moreover, most contemporary scholars seem happy to accept. Nevertheless, it is also true that most historians and philosophers of science have not sufficiently investigated the viability and effectiveness of the case against Cartesian space and motion. This book, consequently, explores the success of the arguments against Descartes' theory of space and motion by determining if it is possible to formulate a Cartesian theory of science that can avoid the problems raised by Newton, as well as by a host of other past and contemporary philosophers either sympathetic or hostile to the overall design of Cartesian science. In particular, if Descartes' theory of motion can be reconciled with his hypotheses on dynamics (i.e., the branch of physics that deals with the motions of bodies under forces), then a Cartesian can successfully resolve the difficulties imposed by his critics. This book will comprise, therefore, a sustained attempt to construct a consistent "Cartesian" spacetime theory: i.e., a theory of space and time that incorporates Descartes' various theories of physics and nature without falling into the kinds of problems and contradictions as charged by, for example, Newton. Amazingly, the present investigation comprises the only known (book-length) treatise that exclusively focuses upon Descartes' theory of space and motion, as well as the possibility of its rehabilitation in the wake of much later criticism. Given the extremely important contribution of Descartes' theory of space, time, and motion to later such theories (such as Newton's, ironically), and given Descartes' preeminent importance in the overall history of Western philosophy, it is incredible that no previous commentators have devoted an exhaustive study of the potential for resurrecting Descartes' concept of space, time, and motion.

More specifically, the central difficulties for the devoted Cartesian are nicely encapsulated in Newton's argument (in his early paper, *De gravitatione*) that a theory of space and time can only meaningfully explicate the motions of bodies if it is equipped with fixed spatial locations. When endowed with such structures, a body's motion can be ascertained by simply determining the number of spatial positions traversed by the body during the temporal period spanned by its motion. Only when spatial positions are construed in this "absolute" sense—that is, as independently existing entities over and above the existence of objects—can motion be coherently described. However, Descartes held that space and time were

purely "relational," an hypothesis that consigns the existence of space and time to mere relations among bodies (thus, they are nothing over and above these material relations). Overall, absolute spatial positions violate the tenets of a relational theory, since they regard such locations as fixed independently of the relative positions and motions of bodies. Hence, Newton concludes that Descartes cannot consistently employ the concept of motion in his relationalist scientific treatises, of which the most important of these scientific works is the *Principles of Philosophy*.

In Part I, after providing the details of Newton and Descartes' views on space, time, and motion, we shall investigate the essential elements of the absolute and relational conceptions of space and time. Rather than posit absolute spatial positions or absolute velocities, it will be shown that an absolute, or substantivalist, theory of space need only accept an absolute notion of acceleration. Modern formulations of Newton's theory will reveal that his conception of space is essentially "too strong" or overly rigid, and that a workable substantivalist hypothesis (such as Neo-Newtonianism) can effectively describe the motions of bodies with a much leaner ontology. In this context, moreover, I will advance one of the principal conclusions of this book; namely, that Newton's argument presupposes that a coherent theory of space and time must possess the capacity to compare information on bodily states across time. More precisely, if a spacetime theory desires to explicate the phenomena of bodily motion (velocity, acceleration, etc.), it must be equipped with the necessary "structure" to make meaningful comparisons of the dispositions and displacements of bodies at different temporal instants. This deeper, implicit element of Newton's argument I will deem a "background geometrical structure." This investigation of Newton's argument is necessary for our critique of Descartes, moreover, since it will be argued that there exist potential formulations of a Cartesian spacetime that actually meet Newton's minimal requirement for a "geometrical background structure". That is, *when properly construed*, Newton's claims (as well as the criticisms of many other philosophers) do not necessarily pose a threat to Descartes' overall conception of space and motion. In short, it may be possible for a Cartesian to accept Newton's limited demand for a geometrical structure *without* undermining Descartes' theory of space and motion.

As for the possibility of a Cartesian dynamics that can avoid the inconsistencies that appear intrinsic to Descartes' approach (as revealed by Newton, for example), this book will investigate a plethora of diverse formulations, mainly in Part III. The primary goal of these reconstructions is to harmonize Descartes' relational theory of space and time with (1) his views on the interactions of bodies, especially (although not necessarily) as exemplified in his seven collision rules, and (2) his conservation law, which holds that the quantity of motion (size times speed) of all bodies in the universe is conserved.

While Part II will largely concern important historical issues in the interpretation of Descartes' scientific concepts (as will be discussed at greater length below), chapter 6 will continue the exploration of the possibility of constructing a Cartesian spacetime (that we began in chapter

2). In particular, chapter 6 will strive to answer the question: If Descartes' theory does constitute some form of relationalism with regards to space and motion, then which type of relationalism is it? As recent work in the philosophy of space and time has revealed (e.g., John Earman), there are several discernible variations on a relationalist theme, thus it seems legitimate to inquire into the precise details of the *type* of relational theory of motion that Descartes' allegedly employed. As in chapter 2, our investigation will explore the problem of Cartesian motion in the light of contemporary work on the structure of theories of space, time, and motion—an analysis which, to the best of my knowledge, has largely neglected Descartes in favor of his later rival, Newton. Consequently, despite any historian's misgivings, it will be assumed that modern conceptual tools, if exercised judiciously, can be quite effective in revealing hidden facets of such historical theories. In fact, chapter 6 will demonstrate that Descartes' theory of motion does not exactly fit the strict relationalism that many commentators have traditionally believed; a conclusion that some contemporary scholars, such as D. Garber and D. Des Chene, have recently pointed out, as well. Nevertheless, our modern approach to the problem of Cartesian motion will also reveal the shortcomings of many previously attempted solutions, including both Garber's and Des Chene's. In the final sections of chapter 6, a deeper, underlying reason for the limited success of most earlier readings of Descartes' theory of space and motion will be disclosed: namely, commentators have neglected the dynamics of Descartes' system (which pertains to bodily motions under the actions of forces) in favor of the kinematics (which concerns bodily motion *per se*). More specifically, whereas most commentators have attempted to treat the kinematical problems of Cartesian physics before dealing with its numerous dynamical inconsistencies, a more serviceable solution to the problem of Descartes' kinematics might take the dynamics as primary, and thus reverse the course of the standard interpretation. As will be demonstrated, the (dynamic) natural laws, and the Cartesian collision rules in particular, can play an essential role in picking out the privileged reference frames needed to secure a consistent relational account of (kinematic) Cartesian motion.

Chapter 7 will examine a relatively overlooked, but significant, set of hypotheses that Descartes' utilized in developing his relational theory of motion. Although they will ultimately be demonstrated to be deficient in various ways, a thorough examination of Cartesian motion warrants a close study of their important content. In the final two chapters of the book, the insights gained from chapter 6 will be put to use, and/or tested, by examining two apparently contrasting approaches to the problem of constructing a Cartesian spacetime. In chapter 8, for instance, we shall explore the possibility of utilizing the specific predictions offered by one of Descartes' seven collision rules as the foundation for a consistent relationalist Cartesian dynamics. This adaptation of Descartes' theory owes its origin to the work of Huygens, and invokes the concept of a center-of-mass frame. From the perspective of this reference frame, all bodies collide and rebound without losing speed, an interaction that conserves quantity of

motion. (Reference frames will form an important role in our discussions, as will be evident from Part I onward, since they provide the means by which a relationalist can attempt to coherently describe the motion of bodies without positing absolute concepts, such as absolute spatial position.) In short, if all the collisions depicted in Descartes' impact rules can be subsumed under his first rule, which is the only accurate one in the entire set of seven, then a Cartesian has a means of conserving the quantity of motion in all bodily collisions. This formulation of Cartesian science essentially accepts one of the key assumptions in Newton's argument, namely that a relationalist cannot unambiguously describe the spatial positions traversed by a moving body over an extended temporal period of time and an extended region of space. On a relationalist theory, "place" is relative to the configurations of material bodies; so, if the bodies constantly change their relative positions, as is the case in Descartes' matter-filled, plenum universe, then the places occupied by bodies cannot be ascertained over time (such as the motion of the planets around the sun). Yet, if one determines motion from the center-of-mass frame, which provides a temporary measure of the speed of two bodies during the brief instants and small spatial regions spanned by their collision, then a relationalist can (hopefully) successfully treat all bodily interactions without the need of a reference frame that describes bodily positions and speeds over a much larger period of time and region of space. The dynamics-based "rest" force procedure for upholding Descartes' natural laws and relational motion, as developed in chapter 6, will also endorse this project for locating temporarily fixed reference frames.

In chapter 9, however, we will take the opposite approach: that is, we will investigate the prospects of constructing fixed reference frames that can describe the motions and collisions of bodies over non-local regions of space and time. If Newton's assumption is incorrect, and some form of permanent reference frame can be located in Descartes' constantly changing plenum, then the relationalist can meaningfully discuss the speeds and quantities of motion of all material bodies without the need to adopt absolute notions of position or velocity. On this interpretation, furthermore, it will no longer be necessary (or beneficial) to use the specific predictions of Descartes' collision rules as the basis of Cartesian dynamics. In fact, this approach to Descartes' dynamics will basically forsake our earlier preoccupation with collisions in order to concentrate on the essential "interconnectedness" of all bodily motions in the Cartesian plenum. Specifically, since the plenum is entirely filled with material bodies, the movement of any one body entails the simultaneous displacement of a vast host of others, a phenomenon that does not easily lend itself to an analysis solely in terms of bodily collisions. In order to gain insights into the motions of bodies in a plenum, and possibly discover a means of constructing fixed reference frames in such an environment, we will examine the basic details of the modern theory of machine parts, also known as the "kinematics of mechanisms" theory. With the mechanics of gears as a blueprint, the viability of resolving the difficulties raised against Descartes will be explored. Yet, as will be evident throughout the book, we will demonstrate that, regardless of the apparent success (or failure) in devising a coherent

relationalist dynamics, the various Cartesian theories examined in our study inevitably accept some form of Newton's supposition for a "geometrical background structure."

Finally, as mentioned above, a considerable portion of this book will center upon the historical context, and contemporary debates, surrounding the particular hypotheses and concepts that form Descartes' natural philosophy, especially his dynamic theories. In chapter 3, an overview of Descartes' scientific approach and his natural laws will lead us into a discussion of the ontological assumptions and commitments underlying the Cartesian concept of "force." Chapter 3 will mainly examine the concepts of space, time, and motion as specifically presented in Descartes' primary scientific treatises, with the contextual development of the theory of relational motion, however, receiving much of the attention (as well as the related concept of "inertial" motion, whether in a straight-line or circular form). In chapter 4, on the other hand, the idealized conditions that proceed the Cartesian collisions laws will constitute the basis of a intricate study of Descartes' views of solidity, rigidity, and the individuation of material bodies in a plenum (to name just a few). Chapter 4 will also devote a great deal of attention to the vexed problem of Cartesian material substance. The intricate role of the Cartesian conservation law for the "quantity of motion" (or size times speed), examined in chapter 5, will likewise form an important part of this investigation, since it will be shown that the traditional approaches to Cartesian physics have not adequately treated, or previously understood, the many facets of Descartes' complex notion of a conservation law. All in all, investigating the specific details of Descartes' scientific theses will prove an invaluable asset to this study; for, as will become clear, many insights into the possibility of creating a consistent relationalist dynamics can be acquired from this most important of sources.

As the reader will be reminded throughout the investigation, while there have been no shortage of attempts to encapsulate Newton's natural philosophy in the modern mathematical formalism, Descartes' theories have not been as fortunate—thus the present study marks a much needed corrective to the prevailing historical bias. That is, one of the goals of the book is to demonstrate the added philosophical insights that can be gained by employing the modern "spacetime" formalism. In particular, we can briefly summarize a few of the overall conclusions of our investigation: (1) while most commentators have often vaguely perceived that a strict form of relationalism is incompatible with the Cartesian natural laws, most commentators have nevertheless been unsuccessful in perceiving that there are "weaker" formulations of relationalism that may adequately ground Descartes' physics (thus prompting our investigation for the elusive privileged reference frames, in chapters 6 through 9, that can provide a sound basis for a relational spacetime); (2) most commentators have also overlooked the fundamental importance of Cartesian dynamics in resolving the kinematic obstacles of Descartes' handling of relational motion (which, as will be first discussed in chapter 5, is directly supported in a largely unknown, but crucially important, letter to H. More). Moreover, as will

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