CHAPTER 3

THE CARTESIAN NATURAL LAWS

In chapter 1, it was necessary to briefly present Descartes' theory of space and relational motion in order to better grasp the motivation underlying Newton's argument against relationalism. If we intend to construct a Cartesian science immune to Newton's problem, however, an in-depth examination of the details of Descartes' natural philosophy is required. Only when all the components of the Cartesian theory have been revealed and their functions explained can the relationalist proceed to assemble a coherent version of Descartes' theory. Before we can effectively study, or even construct, a Cartesian spacetime, moreover, it is necessary to investigate the origin and specific content of his views on force and material interaction. These ideas represent a sort of framework or foundation on which a Cartesian spacetime must be built. Among these ideas, the Cartesian laws of nature figure prominently; for they form the basis of all applications of Descartes' relational theory of motion to the physical world. In this chapter, consequently, the content of the Cartesian natural laws will be analyzed in an attempt to uncover an effective means of resolving the dilemma imposed by Newton's argument (although the working-out of any promising candidates will have to await Part III).

3.1. The Laws of Motion

Foremost among the foundational principles of the Cartesian universe are the three laws of motion. As previously mentioned, Descartes' great contribution to the development of modern dynamics is his contention that moving bodies follow straight paths, an hypothesis that appears as the second law of nature in the *Principles.* Yet, one can also credit Descartes with the first classification of motion and rest as intrinsic or primitive *states* of material bodies without need of further explanation (although one must guard against the anachronistic interpretation that would credit Descartes with holding the modern concept of a "state" of motion). Thus, his first law of motion states "that each thing, as far as is in its power, always remains in the same state; and that consequently, when it is once moved, it always continues to move (Pr II 37)."

This realization, that a body remains in the same state unless acted upon by an external cause, is as important a conceptual breakthrough as Copernicus' situating the sun at the center of the Ptolemaic universe. For much of the Middle Ages, the Aristotle-influenced Scholastics endeavored to ascertain the causal principles responsible for the "violent" motion (or forced, unnatural motion) of corruptible, earthly bodies; that is, they focused their attention primarily on a category of momentary bodily movements on the surface of the earth that originate and conclude in a state of rest (in contrast to the perceived eternal and uniform rotation of the celestial spheres).[1] Given their lack of sophisticated mathematical and scientific devices for analyzing nature, it was probably inevitable that the Medieval philosophers would formulate the problem of violent motion as a quest for an agent or property temporarily possessed by moving bodies—thus, by their reckoning, the violent motion of all earthly bodies is occasioned by the intervention and retention of a sort of "pusher" property. The "impetus" theory suggested by John Philoponus in the sixth century A.D., and developed by Jean Buridan in the fourteenth century, is an example of this type of "qualitative" (as opposed to quantitative) theoretical reasoning. On the general outline of the impetus theories, these violent motions occur when a quality is directly transferred to a body from a moving or constrained source, say, from a stretched bow to the waiting arrow. This property generates the observed bodily motion until such time that it is completely exhausted or depleted, thus bringing about a cessation of the violent movement (and the arrow falls back to earth).[2] Implicit in the Scholastic view is the basic belief that a terrestrial body continuously resists change from a state of rest while situated upon the earth, since the depletion of the "pusher" property eventually effects a corresponding return of the body's original motionless, earthbound condition. This form of reasoning can be summarized in the following succinct question: "What causes and *keeps* a body in motion?"

Descartes, on the other hand, effectively bypassed this problem, for he instinctively accepted the existence of inertial motion (uniform or non-accelerating) as a natural bodily state alongside, and on equal footing with, the notion of bodily rest. He argues, "because experience seems to have proved it to us on many occasions, we are still inclined to believe that all movements cease by virtue of their own nature, or that bodies have a tendency towards rest. Yet this is assuredly in complete contradiction to the laws of nature; for rest is the opposite of movement, and nothing moves by virtue of its own nature towards its opposite or own destruction (Pr II 37)." Therefore, in contrast to the Scholastics, Descartes' conception that both uniform motion and rest are "primitive" facts (or basic, unreducible, etc., facts) of extended matter likely prompted him to develop his series of collision laws aimed at resolving the query: "What causes a change of motion (or rest)?" By posing the question in this manner, Descartes laid the foundation for the genuine breakthroughs in the study of motion that were to occur in the succeeding centuries (which is not to deny Galileo's immensely important role in this development). Where before the analysis had focused on explaining bodily movement, or velocity (as represented by the time derivative of the position function), the emphasis had now shifted to the description of change in motion, or acceleration (as captured by the time derivative of velocity). Yet, the importance of investigating acceleration, as opposed to velocity, was not immediately perceived in the seventeenth century. (As was noted in the previous chapter, even Newton overemphasized the significance of velocity by constructing an unnecessarily rigid spacetime in an attempt to determine the different states of inertial motion.)

While Descartes' first and second laws deal with the natural states of bodies mainly from the perspective of their individual non-interactive characteristics, the third law of motion is expressly designed to reveal the properties exhibited by collisions and interactions among several inertially moving bodies. In short, the third law addresses the behavior of bodies under the *normal* conditions in his matter-filled world: when they collide (which will be discussed at length below). "The third law: that a body, upon coming in contact with a stronger one, loses none of its motion; but that, upon coming in contact with a weaker one, it loses as much as it transfers to that weaker body (Pr II 40)." It is undoubtedly the case that Descartes has incorporated a form of conservation law within this postulate, but it is not yet clear which quantities, or possibly qualities, are being conserved. In the following sections of the *Principles,* Descartes makes explicit both the type and origin of his conservation law:

> We must however notice carefully at this time in what the force of each body to act against another or resist the action of that other consists: namely, in the single fact that each thing strives, as far as in its power, to remain in the same state, in accordance with the first law stated above. . . .This force must be measured not only by the size of the body in which it is, and by the [area of the] surface which separates this body from those around it; but also by the speed and nature of its movement, and by the different ways in which bodies come in contact with one another (Pr II 43).

As a consequence of his first law of motion, Descartes insists that the quantity conserved in collisions equals the sum of the individual products of size and speed of the impacting bodies. In some fashion, the size of a body corresponds to its volume and surface area, although we shall examine more closely the interrelationship of the concepts of volume and surface area in a later chapter. If we define B and C as the respective sizes of two bodies, and label their pre-collision inertial speeds v and w, and their post-collision uniform speeds v' and w', the equation reads:

$$Bv + Cw = Bv' + Cw' \qquad \text{(QM)}$$

This conserved property, which Descartes refers to indiscriminately as "motion" or "quantity of motion," is historically significant in that it marks one of the first quantitative attempts to come to grips with the problem of material interaction. In fact, Descartes envisions the conservation of quantity of motion as one of the fundamental governing principles of the entire cosmos. When God created the universe, he reasons, a certain finite amount of motion (quantity of motion) was transmitted to its material occupants; a quantity, moreover, that God continuously preserves at each succeeding moment.

> It is obvious that when God first created the world, He not only moved its parts in various ways, but also simultaneously caused some of the parts to push others and to transfer their motion to these others. So in now maintaining the world by the same action and with the same laws with which He created it, He conserves motion; not always contained in the same parts of matter, but transferred from some parts to others depending on the ways in which they come in contact (Pr II 62).

God's role in the Cartesian universe will be dealt with in the next section; hence, at this point, it will prove more profitable to closely examine the details of Descartes' conservation law. As developed in the *Principles,* it is important to note that Descartes defines quantity of motion as the product of size and uniform speed, and not size and velocity. Consequently, his conservation law only recognizes a body's degree of motion, which correlates to the scalar quantity "speed," rather than the vectorial notion "velocity" that pertains to a body's speed in a given direction (a distinction noted in chapter 1). This crucial distinction, between speed and velocity, surfaces in Descartes' seven rules of impact. Basically, Descartes found it necessary to augment his third law of motion with a series of postulates that spell out in precise detail the outcomes of bodily collisions (see Figure 8). A strict boundary is imposed upon their range, however, since the rules only describe the direct collisions between two bodies traveling along the same straight line (this problem will also be discussed at length in the next chapter). Nevertheless, Descartes' utilization of the concept of speed is clearly manifest throughout the rules. For example:

> Fourth, if the body C were entirely at rest, . . . and if C were slightly larger than B; the latter could never {have the force to} move C, no matter how great the speed at which B might approach C. Rather, B would be driven back by C in the opposite direction: because. . . a body which is at rest puts up more resistance to high speed than to low speed; and this increases in proportion to the differences in the speeds. Consequently, there would always be more force in C to resist than in B to drive, . . . (Fr Pr II 49).

Astonishingly, Descartes claims that a smaller body, regardless of its speed, can never move a larger stationary body. Leaving aside the obvious point that this rule is overwhelmingly disconfirmed by experience, the fourth collision rule demonstrates nicely the scalar nature of speed, as well as the primary importance of the quantity of motion, in Cartesian dynamics. In this rule, Descartes faces the problem of preserving the total quantity of motion in situations distinguished by the larger body's complete rest, and thus *zero value.* Without furnishing a rationale for his conclusion (at least in this section of the *Principles*—see below), Descartes conserves the joint quantity of motion by equipping the stationary object C with a resisting force sufficient to deflect the moving body B, a solution that does satisfy (QM) in cases where C is at rest.[3] That is, since B merely changes its direction of inertial motion, and not its size and speed, the total quantity of motion of the system is preserved: C equals zero throughout the interaction, so their combined quantity of motion is represented by the value of B. For Descartes, reversing the direction of B's motion does not alter the total quantity of motion, a conclusion that would seem to bear a certain amount of plausibility. This is in sharp contrast to the later hypothesis, usually associated with Newton and Leibniz, that regards a change in direction as a negation of the initial speed (from B to –B, a solution that, by contrast, is not nearly as intuitive). Thus, by failing to foresee the importance of conjoining direction and speed, which informs the concept of velocity, Descartes' law just falls short of that important breakthrough that would eventually lead to our modern understanding of the conservation of momentum.

In this context, the complex notion of "determination" should be briefly mentioned. Many passages in the Cartesian literature apparently refer to the direction of a body's motion as its determination: "there is a difference between motion considered in itself, and its determination in some direction; this difference makes it possible for the determination to be changed while the quantity of motion remains intact (Pr II 41)." As presented in this passage, the word "determination" seems to signify the direction of a given body's quantity of motion. Yet, Descartes takes Hobbes to task (through Mersenne) for making this very identification. In a letter dating from April 21, 1641, he states: "What he [Hobbes] goes on to say, namely that a 'motion has only one determination,' is just like my saying that an extended thing has only a single shape. Yet this does not prevent the shape being divided into several components, just as can be done with the determination of motion (AT III 356)."[4] Accordingly, just as a particular shape can be partitioned into diverse component figures, so a particular determination can be decomposed into various constituent directions. This notion is quite similar to the addition law of vector analysis, since a single determination can be conceptually broken down into a collection of several dissimilar determinations that originate from a common point. Given this distinction, one might plausibly define "determination" as the hypothetical composite direction of a body's quantity of motion.[5] In his *Optics,* published in 1637, Descartes seemingly endorses this interpretation during the course of deriving his law of refraction. He asks us to imagine the motion of a ball that is propelled downwards at a 45 degree angle, from left to right, through a thin linen sheet (see Figure 9). After the ball pierces the cloth, it continues to move to the right but now at an angle nearly horizontal with the sheet. Descartes reasons that this modification of direction (from the 45 degree angle to a smaller angle) is the net result of a reduction in the ball's downward determination through collision with the sheet, "while the one [determination] which was making the ball tend to the right must always remain the same as it was, because the sheet offers no opposition at all to the determination in this direction."[6]

http://www.springer.com/978-1-4020-0265-6

Cartesian Spacetime
Descartes' Physics and the Relational Theory of Space and Motion
Slowik, E.
2002, XII, 252 p., Hardcover
ISBN: 978-1-4020-0265-6