the highlights on this subject from Leibniz's work and its modern background must be brought into focus. (See **Box 11.**)

All competent forms of modern European science are outgrowths of the revolutionary revival of ancient Platonic science, from Pythagoras through Eratosthenes and Archimedes, by Cardinal Nicholas of Cusa.

Cusa's crucial discoveries on this account are embedded, in some significant part, among his sermons, but are otherwise

Box 11

Leibniz vs. Descartes

Following in the footsteps of the heroic accomplishments of Kepler, who poetically described the motion of the planets as "at once so well hidden and so admirable," the ongoing scientific debate of the 17th Century became centered around the elusive concept of motion, and the true science necessary to comprehend such physical change.

As Leibniz was elaborating the discoveries of Kepler with his discovery of the Infinitesimal Calculus, his disgust with the state of scientific method in his day prompted him to a polemical response:

"When I consider that practice does not profit from the light of theory, that we do not strive to lessen the number of disputes but to augment them, that we are content with specious argumentation instead of a serious and conclusive method, I fear we shall remain for a long time in our present confusion and indigence through our own fault. I even fear that after uselessly exhausting curiosity without obtaining from our investigations any considerable gain for our happiness, people may be disgusted with the sciences, and that a fatal despair may cause them to fall back into barbarism."—From the *Precepts for Advancing the Sciences and Arts,* 1680

Coming out of his experience at Colbert's Academy of Sciences in Paris from 1672-76, Leibniz was confronted with the fact that even the best of minds were not immune to the popular materialist dogma infecting the population.

In the *Discourse on Metaphysics,* written in 1686, Leibniz, echoing the Socrates of Plato's *Phaedo,* distinguishes between the popular method of the day and his own:

"As if in order to account for the capture of an important place by a prince, the historian should say it was because the particles of powder in the cannon, having been touched by a spark of fire, expanded with a rapidity capable of pushing a hard solid body against the walls of the place, while the little particles which composed the brass of the cannon were so well interlaced that they did not separate under this impact—as if he should account for it in this way instead of making us see how the foresight of the conqueror brought him to choose the time and the proper means and how his ability surmounted all obstacles."

Leibniz had no trouble, however, locating the principal figure responsible for spreading this type of thinking throughout the population: He was the popularly celebrated Descartes.

Incapable of Discovery

In a letter to Molanus from 1679, Leibniz frankly states his posture on the Cartesians:

"I have recognized from experience that those who are completely Cartesian are not capable of discovery; there have been many beautiful discoveries since Descartes, but, as far as I know, not one of them has come from a true Cartesian. Descartes himself had a rather limited mind. He excelled all people in speculation, but he discovered nothing useful in the practice of the arts."

The fraud of Descartes, coupled with a susceptibility to such contagions among the people on the Continent, provided Leibniz sufficient reason to center his early work on annihilating such disease. Hence, Leibniz would embark on a strategic refutation of Descartes and his philosophy, preventing Europe from returning to the previous age of religious war.

Descartes' popularity, largely dependent on a cult following, developed mostly from his method of analytical investigations rather than from scientific advancement. According to Descartes, "The nature of matter or of body in its universal aspect, does not consist in its being hard, or heavy, or colored, or one that affects our senses in some other way, but solely in the fact that it is a substance extended in length, breadth, and depth." A method falsely known as *mechanics,* his philosophy relegates the physical universe to empirical observations, geometric descriptions, and mathematical rules. But is this not a sufficient course of inquiry to understand the nature of objects and events?

Think back to the problems which confronted our youthful star-gazing ancestors. Follow the motions of the planets (from the Greek, for "wanderers") they observed at night. Take the famous case of Mars, or Ares to the Greeks. That a capricious and violent-natured Greek god of war would share that name has never been coincidence. Could one successfully express the future motions and oppositions of the planet merely from the previously observed whimsical behavior of the planet? Could one extrapolate the destiny of the planet based on a geometrical description of its changing angular velocities and directions upon our Celestial Sphere?

The materialist fool would assent! Thus, Kepler attacked Ptolemy for similar blunders.

Thus, Leibniz exposes the fraud of Descartes:

Box 11 continues on next page

associated in a series of his relevant writings which began with his ground-breaking statement of the principles of modern experimental physical science in his *De Docta Ignorantia.* From a Cusa working in the same environment as the celebrated, and literally towering employer of the catenary principle for construction, Filippo Brunelleschi, the development of the principal valid currents of modern physical science, runs through, most notably, Luca Pacioli, Leonardo da Vinci,

"... [O]ver and above that which is deduced from extension and its variation or modification alone, we must add and recognize in bodies certain notions or forms that are immaterial, so to speak, or independent of extension, which you can call powers [*potentia*], by means of which speed is adjusted to magnitude. These powers consist not in motion, indeed, not ... the beginning of motion, but in that intrinsic reason for motion. ... From this we shall also show that it is not the same quantity of motion (which misleads many), but the same powers that are conserved in the world."—*The Nature of Bodies and the Laws of Motion*

Laws of Motion

To begin an investigation of such ontological problems, ask yourself this question: Does an object of one pound, travelling with a velocity of four feet/second, have the same applied effect as a four-pound object travelling with a velocity of one foot/second? Consider various examples.

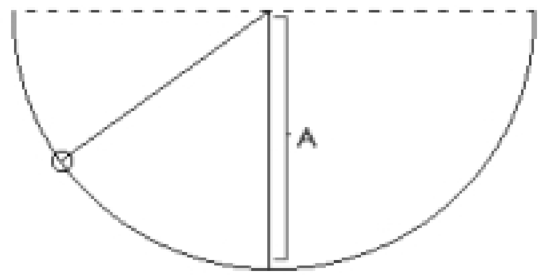
Descartes measures such potential for affecting change for any moving object as mass × velocity, or *mv,* calling this *mv* the object's "quantity of motion." That is, the power of a moving object to affect a change is a composite of the object's empirical quantities of mass and velocity. Applying this to the two objects above, both objects would be equivalent in applied effect. But is this the case? Just like the planets, are its future effects caused by the effects that had been exhibited before?

Now, go back to our two objects, the first of one pound, and the other of four pounds. How many times must you lift the one-pound object to have lifted the same amount, if you only lifted the four-pound object once? Easy, right?

If you had to carry five gallons of water, you could carry that weight all at once, or take five separate trips. Either way, the amount of effort you exert in carrying the water will be the same. Therefore, lifting a one-pound object four feet, and a four-pound object one foot, is also the same. We can say the effect is equal.

Now travel back to the 17th Century, when physicists began concentrating on the pendulum as a unique form of action. What happens when you raise the pendulum and let it drop? How far up does the pendulum ball swing? Create your own pendulum and experiment before going on. (**Figure 1**)

FIGURE 1



Circular pendulum.

If we neglect air resistance and other perturbing factors, the pendulum ball will swing back to its original height. This would mean that the velocity of a pendulum at the bottom of its swing is capable of bringing the pendulum back to its original height.

Applying this to our one-pound and four-pound objects, if we hung the first on a pendulum with an amplitude of four feet and the second on a pendulum with an amplitude of one foot, at the bottom of their swings, the first would have acquired the ability to lift a one-pound body four feet, and the second, an ability to lift a four-pound body one foot. We just found from before, however, that those two abilities were equal, right?

Well, if Descartes' "quantity of motion" argument holds true, a one-pound object dropped from a height of four feet would be travelling four times faster when it hits the ground than a four-pound object dropped from a height of one foot. Would this be the case? Think about how things fall. Work it out for yourself. How would you test this hypothesis? Do some physical experiments. What about the time it takes for each to descend?

'Living Force'

Leibniz contrasts Descartes' quantity of motion with his *vis viva,* or living force. As he says in his *Specimen Dynamicum:*

"I concluded that besides purely mathematical principles subject to the imagination, there must be admitted certain metaphysical principles perceptible only by the mind, and that a certain higher, and so to speak, formal principle must be added to that of material mass, since all the truths about corporeal things cannot be derived from logical and geometrical axioms alone, namely, those of great and small, whole and part, figure and situation—but that there must be added those of cause and effect, action and passion, in order to give a reasonable account of the order of things."

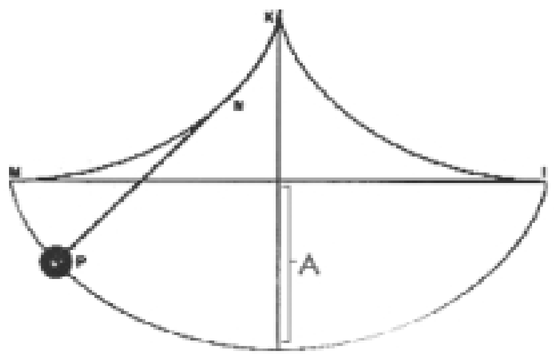
If you've done some successful physical experiments, you can grasp what Leibniz determined: that a moving object's ability to effect change is determined not by *mv,* but by a "higher notion" outside the realm of our sense perceptions, proportional to the mass × the square of the velocity, or mv^2.

Consider another example. Does a car of 2,000 pounds moving at 1 mph have the same impact as an object of one pound moving at 2,000 mph? What about when they hit you? Using Descartes' "quantity of motion," they would be the same.

Johannes Kepler, Fermat, Pascal, Huyghens, and Leibniz, through the revival of Leibniz by such outstanding figures of France's École Polytechnique as Gaspard Monge and Lazare Carnot and their anti-Lagrangian co-thinkers, and the protégés of the École Polytechnique's leading German member, and Lazare Carnot associate, Alexander von Humboldt.

With the seed of ruin of France's leading position in world science under Napoleon Bonaparte's choice of Euler's protégé

FIGURE 2



Cycloidal pendulum.

Using Leibniz's metaphysical metric the object then has a force 2,000 times the force of the car!

Just in case one might mistake Leibniz's attack as a mere academic dispute, he intervenes: "These considerations are not worthless, nor are they merely verbal, for they have important applications in the comparison of machines and motions. For if enough force is received, from water power, animals, or some other cause [steam!], to keep a heavy body of 100 pounds in constant motion, so that it can complete a horizontal circle 30 feet in diameter in a fourth of a minute, and someone claims that a weight twice as large put in its place would complete half the circle in the same time, and with less expenditure of power, and claims this means a profit to you, you may know that you are being deceived and are losing half of the force."

Science of Dynamics

So, what is Leibniz's method?

Surpassing the contemplation of momentary motion, or perceived change of place of any object, which is less easily apprehended then one may commonly think—like the Sun moving across the sky—Leibniz directs his attention toward the "cause of these changes" as "something more real," searching for the unseen powers which generate such change.

As he says in the *Discourse on Metaphysics:*

"We can see therefore how the force ought to be estimated by the quantity of the effect which it is able to produce, for example by the height to which a body of certain weight can be raised." So it is, that Leibniz has determined the *potential* to accomplish work, or in this case the ability to raise an object a certain height, as the necessary measurement of physical action.

Leibniz continues in his *Preliminary Specimen* (1691):

"When I discovered these things, I judged that it was worth the trouble to muster the force of my reasonings through demonstrations of the greatest evidence, so that, little by little, I might lay the foundations for the *true elements of the new science of power and action,* which one might call *dynamics.*"

To further grasp Leibniz's conception of *dynamics,* the reader should consider the following problem.

Given a simple circular pendulum and a cycloidal pendulum—Huyghens' tautochrone—both of the same amplitude *A,* what is the difference in *power* between the two? (**Figure 2**)

Although the reductionist physicist might argue that each has the same "kinetic energy" (i.e., mv^2) at the bottom of their oscillation, there hides within the dynamic a *power* whose effects are not expressed in the abiotic domain.

Reconsider the problem from the standpoint of a physical economist. What is the effect of the two, situated within a human economy (e.g., the 17th-Century economy)?

—*MyHoa Steger, Michael Steger, and Merv Fansler*