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ACT, POTENCY, AND ENERGY

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ENERGY IS ARGUABLY the most encompassing and fundamental physical notion in modern science. Physicists speak of energy with respect to all four fundamental forces of nature: gravity, electromagnetism, and the strong and weak nuclear forces. Motion and heat have energy. Mass is a form of energy. More recently, astronomers have discovered dark energy, whose nature is largely unknown but which makes up seventy-four percent of the universe. The Law of the Conservation of Energy is one of the most important physical laws. The notion of energy is found not only in physics and astronomy but also in chemistry and in the earth and life sciences. Analogically, it is used in economics and other such disciplines, and it is, of course, enormously important in public policy.

Etymologically, the word "energy" comes from Aristotle. *Energeia,* from *en,* meaning "in," and *ergon,* meaning "work," is a transliteration of a word invented by Aristotle and signifies a basic principle in his philosophy.[1] In Thomas Aquinas's Latin, this term is rendered as *actus, operatio,* or *agere*. The Greek and the Latin terms are commonly translated into English as "act," "actuality," or "activity."[2] The notions of work, kinetic energy,

[1] "Energy, from the Greek *energeia* (*en,* in; *ergon,* work), originally a technical term in Aristotelian philosophy denoting 'actuality' or 'existence in actuality,' means, in general, activity or power of action" (*The Encyclopedia of Philosophy,* ed. Paul Edwards [New York: Macmillan Publ. Co., 1967], s.v. "energy").

[2] For the meaning and translation of the term *energeia* and its relation to the term *entelecheia,* see the following: Rémi Brague, "Aristotle's Definition of Motion and Its Ontological Implications," trans. Pierre Adler and Laurent d'Ursel, *Graduate Faculty*

form, and potential energy also have roots in Aristotle's philosophy. Aristotle uses the term κίνησις for any of the three different kinds of motion and sometimes even more generally to include substantial change. "Form" is another basic principle in Aristotelian philosophy, and energy comes in different forms. "Potential," "potentiality," or "potency" is the correlative of *energeia* and *entelecheia* and from it William Rankine drew the term "potential energy," which he first introduced into physics in 1853.[3] According to Rankine,

> The step which I took in 1853, of applying the distinction between "Actual Energy" and "Potential Energy," not to motion and mechanical power alone, but to all kinds of physical phenomena, was suggested to me, I think, by Aristotle's use of the words δύναμις and ενέργεια.[4]

The great nineteenth-century physicist James Clerk Maxwell noted Rankine's introduction of the term and understood it in a remarkably Aristotelian way:

> Rankine introduced the term Potential Energy—a very felicitous expression, since it not only signifies the energy which the system has not in actual possession, but only has the power to acquire, but it also indicates its connexion with what has been called (on other grounds) the Potential Function.[5]

Philosophy Journal 13 (1990): 1-22; Joseph Owens, C.Ss.R., "Aristotle—Motion as Actuality of the Imperfect," *Paideia* (1978): 120-32; George A. Blair, "The Meaning of 'Energeia' and 'Entelecheia' in Aristotle," *International Philosophical Quarterly* 7 (1967): 101-17.

[3] "As the phrase 'Potential Energy,' now so generally used by writers on physical subjects, was first proposed by myself in a paper 'On the General Law of the Transformation of Energy,' read before the Philosophical Society of Glasgow, on the 5th of January, 1853 . . ." (William Rankine, "On the Phrase 'Potential Energy,' and on the Definitions of Physical Quantities" [1867] in *Miscellaneous Scientific Papers,* ed. W. J. Millar [London: Charles Griffin and Co., 1881], 229). Rankine also asserts that the scientific meaning of "energy," which was first introduced by Thomas Young in 1807, harmonizes "perfectly with the etymology of ενέργεια" (ibid., 230).

[4] William Rankine, "On the History of Energetics," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 28, fourth Series, no. 190 (London: Taylor and Francis, 1864), 404.

[5] James Clerk Maxwell, *Matter and Motion* (1877), with notes and appendices by Sir Joseph Larmor (Mineola, N.Y.: Dover, 1991), 77.

The overt terminology, its etymology, and its historical origin suggest that energy may be an instance of Aristotelian (or Thomistic) actuality and that potential energy is an instance of Aristotelian (or Thomistic) potentiality.

Perhaps more significantly, the ordinary meaning of the term "energy" also suggests that it is an instance of actuality. According to the physicist A. P. French,

> Everyone, whether a scientist or not, has an awareness of energy and what it means. Energy is what we have to pay for in order to get things done. The word itself may remain in the background, but we recognize that each gallon of gasoline, each Btu of heating gas, each kilowatt-hour of electricity, each car battery, each calorie of food value, represents, in one way or another, the wherewithal for doing what we call *work*. We do not think in terms of paying for force, or acceleration, or momentum. *Energy* is the universal currency that exists in apparently countless denominations; and physical processes represent a conversion from one denomination to another.[6]

Energy as the wherewithal for doing work is here commonly identified with activity. Things are active and make physical processes happen insofar as they have energy, which brings to mind the basic Thomistic notion that a thing acts only insofar as it is in act. Things undergo various energy transformations, which indicate principles of potency, though here French does not explicitly use the term "potential energy."

Following these indications, I shall argue that through the notion of energy the Aristotelian (or Thomistic) principles of act and potency are present in the modern scientific understanding of nature. Given the scope and depth of the subject, my treatment will be somewhat limited. I begin by briefly addressing two general concerns: the antiquated status of Aristotle's natural science and the late emergence of the notion of energy in modern science. The largest portion of the paper is devoted to the notions of work, kinetic energy, and gravitational potential energy in prerelativistic physics. I will argue that kinetic energy is an instance of the Thomistic notion of the act or activity of motion, that gravitational potential energy is an instance of Thomistic

[6] A. P. French, *Newtonian Mechanics* (New York: W.W. Norton & Co., 1971), 367.

potentiality, specifically passive potentiality, and that the energy content of a body at rest is an instance of the Thomistic notion of a motionless action, an unchanging activity of rest.

I. The Historical Status of Aristotle's Natural Science

The claim that the scientific notion of energy is an instance of the principles of act and potency may seem to many thinkers to be drawing upon something archaic and obsolete because much of the physical science accepted by Aquinas was long ago shown to be erroneous. Even more significantly, physical science has advanced in many ways and to an extent far beyond the science of Aquinas's time. Indeed, we speak of the Scientific Revolution as something that happened between his time and ours. However, an important distinction needs to be made. The very general explanatory principles of a work such as Aristotle's *Physics* or *Metaphysics* should be distinguished from the more specific principles that one finds in works such as Aristotle's *De caelo* and *Meteorology* or Ptolemy's *Almagest*. The principles of act and potency, and other principles such as form and matter, are of such generality that they are largely independent of the more specific ancient and medieval sciences in which they were originally instantiated.[7] The truth of the principles of act and potency does not depend upon Aquinas's views about gravity, levity, projectile motion, the elements, the celestial spheres, or the location of the earth. Thus, the limitations and errors of the specific ancient and medieval disciplines do not show that Aquinas's more general principles are false.

In addition, a general work such as Aristotle's *Physics* depends upon common observation and not upon the specific kinds of observations, equipment, and methodologies used by more specific sciences. Consequently, Aquinas's general principles need not be rejected on account of the theories of Newtonian and Relativistic physics, for, again, our knowledge of principles such as act and

[7] The distinction is extensively developed in Vincent E. Smith, *General Science of Nature* (Milwaukee: Bruce Publ. Co., 1958). See also Michael Augros, "A 'Bigger' Physics," Institute for the Study of Nature website (http://www.isnature.org/Files/Augros_2009-Bigger_Physics.htm).

potency does not depend upon the investigations of the specific scientific disciplines. The principles of act and potency are drawn from much more general investigations of nature and being. Indeed, since act and potency are fundamental principles of nature and being, scientists may discover, without recognizing it, specific instances of these general principles in the course of pursuing their own goals and doing their own work. Similarly, philosophers may not recognize dramatic specifications of their own general principles in the discoveries of the modern sciences. On the thesis argued for here, the notion of energy offers a highly specified Aristotelian or Thomistic way of thinking about and understanding the natural world. Correlatively, principles such as those found in Aristotle's *Physics* or *Metaphysics* provide the specific sciences with a theory of energy, a general framework in light of which energy and its corresponding notions can be further understood. Indeed, since some kind of general framework is unavoidable, we should speak of "theories of energy," using the plural in the way that John Paul II famously spoke of theories of evolution, the different theories being differentiated by the different natural philosophies upon which they draw.[8]

II. THE LATE EMERGENCE OF THE NOTION OF ENERGY IN MODERN SCIENCE

The Aristotelian character of the notion of energy has been obscured in part by the rather late emergence of the notion of energy in modern science. It is not present in Newton's *Principia* or elsewhere in his work, although it is now part of what is called

[8] John Paul II also distinguished different theories of evolution by the different mechanisms of evolution that they posit. John Paul II, "Message to the Pontifical Academy of Sciences: On Evolution," available in the EWTN Document Library (http://www.ewtn.com/library/PAPALDOC/JP961022.HTM).

Newtonian physics.[9] According to the historian of science Max Jammer,

> [E]nergy considerations were rarely found in theoretical or even practical mechanics prior to the middle of the nineteenth century. Before the development of the steam engine and the rise of thermodynamics, industry had little interest in energy calculations: force, not its integrated form, counted in the use of simple machines. The primary object of theoretical mechanics, moreover, was still celestial dynamics, where, again, energetics was of little avail. This certainly is also one of the reasons why Newton's *Principia* contains practically no reference to the concept of energy or to any of its applications. According to Ernst Mach . . . the delay of the development of energetics as compared with that of general mechanics stemmed from what he called "trifling historical circumstances," namely, the fact that in Galileo's investigations of free fall, the relationship of velocity and time was established before the relationship between velocity and distance, so that, as multiplication with mass shows, the notions of quantity of motion or momentum and force gained priority and were regarded as more fundamental than the concept of energy, which thus appeared as a derived conception. Whatever the reason for energetics' lagging behind Newtonian mechanics, it is an indisputable fact that the concept of energy became a subject of discussion among philosophers rather than among physicists or mechanicians.[10]

The notion of energy was not fully accepted into the sciences until the mid-1800s, long after the rejection of Aristotle during the Scientific Revolution and 160 years after the first publication of the *Principia*.[11] Since the notion of energy emerged in the context

[9] "In the whole of the *Principia*, with its awe-inspiring elucidation of the dynamics of the universe, the concept of energy is never once used or even referred to! For Newton $F = ma$ was enough. But we shall see how the energy concept, although rooted in $F = ma$, has its own special contributions to make" (French, *Newtonian Mechanics,* 368). See also Isaac Newton, *The Principia. Mathematical Principles of Natural Philosophy. A New Translation,* trans. I. Bernard Cohen and Anne Whitman assisted by Julia Budenz; preceded by I. Bernard Cohen, "A Guide to Newton's Principia" (Berkeley: University of California Press, 1999), 119-22.

[10] *Encyclopedia of Philosophy,* s.v. "energy"

[11] Ibid., 513. What we now call kinetic energy was discovered by Christiaan Huygens and by Gottfried Leibniz, who called it *vis viva*. Huygens derived the quantity mv^2 from Galileo's kinematics of freefall. Leibniz generalized the notion of *vis viva* in a way that proved extremely important for the eventual discovery and formulation of the principle of the conservation of energy. See G. W. Leibniz, *Discourse on Metaphysics* (1686), trans. George Montgomery (1902) (La Salle, Ill.: Open Court Publishing, 1988), 29-32; Richard S. Westfall, *Force in Newton's Physics* (New York: American Elsevier Publishing Company, 1971), 284, 292; H. G. Alexander, "Introduction," in *The Leibniz-Clarke Correspondence,* ed. H. G. Alexander (New York: Barnes and Noble, 1956), xxvi, xxix-xxxii; *Encyclopedia of*

of a well-established and mechanistically understood Newtonian physics, its Aristotelian character was obscured.[12]

III. WORK, KINETIC ENERGY, AND GRAVITATIONAL POTENTIAL ENERGY

In the modern sciences, energy is often defined as the ability to do work.[13] In classical physics, the work done on a body equals the force applied to it multiplied by the distance over which the force acts on the body. Mathematically, this may be expressed as $W = Fx$ where W equals the work, x equals the distance over which the force acts on the body, and F equals the force acting on the body along x. If the force acts in the same direction as the body's displacement, then the work is said to be positive. When the force acts in a direction that is the opposite to that of the body's displacement, then the work is said to be negative. Gravity, for example, does negative work on a projectile thrown upwards and positive work on a falling body. The work done does not depend upon the time it takes to do the work. If the force and the distance are the same, an equal amount of work is done on a body whether it takes an hour or only a minute. The amount of work done by a force also depends upon the reference frame from which it is determined.[14]

Work is related to kinetic energy, the energy of motion.[15] It is a body's capacity to do work in virtue of its velocity, though it does not depend upon the direction of motion. Mathematically,

Philosophy, s.v. "energy"

[12] "The major theme of the development of physics in the nineteenth century is the way in which theoretical innovations—the concept of the physical field, the theory of the luminiferous and electromagnetic ether, and the concepts of the conservation and dissipation of energy—were formulated according to the mechanical view of nature, which supposed that matter in motion was the basis of all physical phenomena" (P. M. Harman, *Energy, Force, and Matter: The Conceptual Development of Nineteenth-Century Physics* [Cambridge: Cambridge University Press, 1982], 2).

[13] The definition is controversial. See, for example, Robert L. Lehrman, "Energy Is Not the Ability to Do Work," *The Physics Teacher* 11 (Jan. 1973): 15-18; and Mario Iona, "Energy Is the Ability to Do Work," *The Physics Teacher* 11 (May 1973): 259, 313.

[14] Hans C. Ohanian, *Physics,* vol.1 (New York: W.W. Norton & Co., 1985), 154-61.

[15] Kenneth R. Atkins, *Physics,* 2d ed. (New York: John Wiley & Sons, 1970), 129.

a body's kinetic energy equals one half the mass of the body multiplied by its velocity squared ($\frac{1}{2}mv^2$). Thus, for example, a cannonball fired by a cannon has more kinetic energy than a ball of similar mass thrown by a shot putter with a lower velocity, and a bullet fired by a pistol has less kinetic energy than a cannonball traveling at the same velocity. In striking a target, the cannonball does more work than the bullet and more work than the shot put. However, in order to do work in virtue of its kinetic energy, a body must act upon something. A moving bullet that does not strike anything has kinetic energy but is not doing any work. Kinetic energy, like work, also depends upon the reference frame from which it is determined.[16]

Work and kinetic energy are also related according to the work-energy theorem which states that "*the work done on the particle by the net force equals the change in the kinetic energy*."[17] For example, in throwing a baseball, a pitcher does work on the ball. The change in the ball's kinetic energy from the beginning to the end of the pitch equals the amount of the work done on the ball by the net forces acting upon it over the interval of the pitch. In cases in which the speed of a body remains constant, the work done on the body equals zero. More generally, according to Hans Ohanian, "the kinetic energy represents accumulated work; it represents latent work which under suitable conditions can become active work."[18] Something with energy has work in it.[19] This relationship between kinetic energy and work—that kinetic energy does work insofar as it has work in it—exemplifies the Thomistic principle that a thing acts insofar as it is in act.

Kinetic energy and work are also related to potential energy. The focus here will be on gravitational potential energy, which is usefully illustrated by a suspended weight, such as an apple hanging from a tree. The potential energy of the apple depends upon its height above the ground and the force of gravity acting

[16] Ohanian, *Physics,* 1:162-64.

[17] Ibid., 1:162.

[18] Ibid., 1:163.

[19] "[S]omething with energy can be thought of as having 'work in' it" (Isaac Asimov, *Life and Energy* [New York: Avon Books, 1962], 4).

upon it. Expressed mathematically, the gravitational potential energy of the apple with respect to the ground equals mgh (for small displacements near the Earth's surface) where m is the mass of the apple, g is the acceleration produced by gravity near the surface of the Earth, and h is the height of the apple above the ground. Since mg equals the force of gravity on the apple, the apple's potential energy with respect to the ground equals the force of gravity on the apple multiplied by its height.[20] All other things being equal, the greater the apple's distance above the ground, the greater its potential energy. Also, the greater the force of gravity acting upon the apple through the distance with respect to which the potential energy is determined, the greater the potential energy. The same apple suspended the same distance above the surface of the Moon would have less potential energy because the Moon's gravity is weaker than the Earth's. Finally, the potential energy has a continuum of energy levels and corresponding energy states from the ground to the apple's position on the tree. As the apple falls, it moves through a continuum of decreasing levels of potential energy until it has zero potential energy upon striking the ground.[21]

In the apple example, the apple's potential energy is conveniently set to zero when the apple is on the ground. Though the zero point for potential energy can be set to other positions, the change in potential energy between any two positions will be the same. For this reason, physicists are usually concerned with the change in the potential energy rather than with the amount of potential energy itself.[22] In addition, potential energy is mutual. It belongs not just to one body but jointly to a system of bodies. In the example above, the mass of the Earth is so much greater than that of the apple that the Earth may be regarded as at rest and the potential energy as belonging to the apple, but properly speaking

[20] Ohanian, *Physics,* 1:164, 317, 321-22. The general Newtonian expression for gravitational potential energy is $-GMm/r$ where G is the universal constant of gravitation, M and m are the masses of the two respective bodies, and r equals the distance separating them.

[21] Harvey E. White, *Modern College Physics,* 6th ed. (New York: D. Van Nostrand Company, 1972), 159-61.

[22] The zero point for potential energy is often set at ∞ because as r goes to ∞, the force of gravity (GMm/r^2) and the gravitational potential energy ($-GMm/r$) go to zero.

the potential energy belongs not to the apple but to the Earth-apple system. Also, for there to be potential energy, the force with respect to which it is defined must be a conservative force. A force is conservative if the work done by it is path independent, that is, it does not depend on the path between two positions but only on the positions defining the endpoints of the path. A force is equivalently described as conservative if the work done on a body for any round trip between two positions is zero. Conservative forces are a function of position only. Gravity is a conservative force. Friction is an example of a force that is not conservative.[23] The distinction is important because all fundamental forces are conservative, and so a potential energy may be defined with respect to them.[24]

Work is related to potential energy. If the apple falls, the force of gravity does work on the apple from its position on the tree to the ground. In general, the longer the distance through which gravity acts on the apple and the stronger the force of gravity, the more work that is done. As the apple falls, the amount of work done by gravity increases, and the amount of potential energy decreases. Since the quantity of potential energy is decreased when gravity does positive work on the apple, the change in potential energy is negative. More generally, the change in the potential energy between two points equals the negative of the work done by gravity in acting upon something falling from one point to the other.[25]

IV. THE ARISTOTELIAN PRINCIPLE OF POTENCY AND THE PRINCIPLE OF POTENTIAL ENERGY

[23] Ohanian, *Physics,* 1:164-65, 174-76, 190, 317.

[24] "Actually, all fundamental forces in nature are conservative. The notion of conservative forces has been introduced to exclude frictional forces. The frictional force, which is not a fundamental force, converts mechanical kinetic energy into heat. As is well known, heat is basically motion of the atoms constituting the warm body in question. If we could keep track of each and every atom, the law of conservation of energy would be generally true, and there would be no need for the introduction of friction forces, or nonconservative forces" (J. M. Knudsen and P. G. Hjorth, *Elements of Newtonian Mechanics,* 2d ed. [Berlin, Heidelberg, New York: Springer-Verlag, 1996], 173).

[25] Ohanian, *Physics,* 1:164, 176, 317.

Of course, Isaac Newton, Pierre-Simon Laplace, and many other classical physicists did not recognize a principle of potency in nature. Likewise, when Werner Heisenberg famously said that quantum mechanics gives Aristotelian potency a fundamental status in nature he was implicitly assuming that an Aristotelian principle of potency was not already present in classical physics. Nevertheless, through the notion of potential energy, an Aristotelian principle of potency is indeed present in classical physics.

According to Aquinas, "potentiality" means what can exist but does not, and "actuality" means what already does indeed exist.[26] Minimally, the distinction between what is and what can be is part of what is meant by the principles of actuality and potentiality. In addition, potentiality or potency can be either active or passive. An active potency is a capacity to act upon or bring about a change in another based upon what a thing actually possesses but may not be using. It is act of a thing by which it can operate on another.[27] It conforms in ordinary English usage to a power or to something potent. Since kinetic energy is energy that a body actually has and by which it can do work but may not be doing work, it is an active potency. Potential energy is a passive potency. A passive potency is the potency to be acted upon. It is a receptivity in a thing to have something done to it or brought about in it. It is a principle by which something can be made other than it is. Passive potency as such has no activity and does not act. A person who does not know any mathematics but can be taught it has a passive potency for mathematics. By contrast, the person who knows mathematics but is not using it has an active potency for mathematics. Henceforth, "potency," "potential," or "potentiality" will mean "passive potency."

[26] Thomas Aquinas, *De Principiis Naturae* ch. 1, in Joseph Bobik, *Aquinas on Matter and Form and the Elements: A Translation and Interpretation of the "De Principiis Naturae" and the "De Mixtione Elementorum" of St. Thomas Aquinas* (Notre Dame: University of Notre Dame Press, 1998), 1. See also Aquinas, III *Phys.,* lect. 2 (285); XI *Metaphys.,*lect. 9 (2289)

[27] See Aristotle, *Metaphys.* 5.3.1020a1-3; 5.8.1019a15-18, 33-35; 12.1.1046a19-25. Aquinas, IX *Metaphys.,* lect. 1 (1777); and V *Metaphys.,* lect. 14 (955-56).

The notion of passive potency requires further discussion since it is often confused either with active potency or with nonbeing, mistakes that will be important for the discussion of potential energy. Yves Simon uses the following example.[28] Consider a human infant and a monkey that are born on the same day. At birth, the human and the monkey know the same amount of geometry: none. The human baby is no better a geometer than the monkey. But they do differ with respect to geometry, for the human baby can become a geometer but the monkey cannot. Teaching Euclid and Pythagoras to the monkey is futile. But teaching geometry to the human may produce genuine geometrical knowledge, and twenty years later the human may be a geometer. The human infant has a potential for geometry; the monkey has no such potential. This potential is a reality that is present in the human but not in the monkey, for otherwise the human baby and the monkey would not differ with respect to geometrical knowledge. The human may become a geometer and will then be a geometer in act. The potency for geometry will have been actualized. Other human babies may be born on the same day but may never become geometers. Their potency to be geometers will then be unactualized. The potency to geometry differs from nonbeing simply and from actual geometrical knowledge. If a potency were simply nonbeing, then the human baby and the monkey would not differ with respect to geometry. But the human baby differs from the monkey, even though it knows no geometry nor does it possess hidden or inoperative geometrical knowledge.

In order to show that potential energy is a specific instance of the Aristotelian principle of potency, the ambiguous way in which physicists often speak of potential energy needs to be addressed. This ambiguity appears in descriptions of potential energy as the energy of the configuration of a system, or the energy a body has by virtue of its position,[29] or the energy of the arrangement of a

[28] Yves Simon, *The Great Dialogue of Nature and Space,* ed. Gerard J. Dalcourt (Albany, N.Y.: Magi Books, 1970), 60-63.

[29] "*A body is said to have potential energy if by virtue of its position or state it is able to do work*" (White, *Modern College Physics,* 149).

system's parts,[30] or a body's capacity to do work by virtue of its position in space. These descriptions fail to distinguish the sense in which a body or a system is in one position or configuration from the sense in which it can be in another, a distinction which is built into the physics of potential energy.[31] The failure to distinguish between what is and what can be often leads to a view of potential energy as some kind of inoperative, latent, or suppressed actuality, as is evident in descriptions of potential energy as stored energy,[32] dormant energy, latent energy, or stored, latent, or accumulated work.[33] Similarly, physicists typically speak of potential energy as exchanged, transformed, transmuted, released,[34] liberated, redistributed, converted, or delivered.

These ambiguities and confusions are evident in the following quotation, which I will consider at some length:

> When positive work is done on a particle initially at rest, its kinetic energy increases. The acquired kinetic energy gives the particle a capacity to do work: if the moving particle is allowed to push against some obstacle, then this obstacle does negative work on the particle and simultaneously the particle does positive work on the obstacle (the mutual forces are opposite and they are an action-reaction pair). When the particle does work, its kinetic energy decreases—the total amount of work the particle can deliver on the obstacle is equal to its kinetic energy. Thus the kinetic energy represents accumulated work; it represents latent work which under suitable conditions can become active work. . . .

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[30] "ENERGY . . . The energy may be 'stored' in a system (by virtue of the arrangement of its parts in spacetime or by virtue of the energy content of the matter present)" (Delo E. Mook and Thomas Vargish, *Inside Relativity* [Princeton, N.J.: Princeton Univ. Press, 1987], 290).

[31] There are exceptions to this practice: "When an object is located at a certain height, it has the potentiality of producing work if and when it falls to the ground, and this amount of work is known as the *potential energy* of the object" (George Gamow, *Matter, Earth, and Sky* [Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1958], 31).

[32] "The potential energy of a system represents a form of stored energy which can be fully recovered and converted into kinetic energy" (David Halliday and Robert Resnick, *Fundamentals of Physics* [New York: John Wiley & Sons, 1970], 113).

[33] "We shall call this stored work the *potential energy V*" (Uno Ingard and William L. Kraushaar, *Introduction to Mechanics, Matter, and Waves* [Reading, Mass: Addison-Wesley Publishing Company Inc., 1960], 164).

[34] "In returning from B to A, the mass releases energy" (White, *Modern College Physics,* 159).

> As we have seen, the kinetic energy represents the capacity of a particle to do work by virtue of its velocity. We will now become acquainted with another form of energy that represents the capacity of the particle to do work by virtue of its position in space. This is the potential energy. . . .
>
> The gravitational potential energy represents the capacity of the particle to do work by virtue of its height above the surface of the Earth. A particle high above the surface of the Earth is endowed with a large amount of latent work which can be exploited and converted into actual work by allowing the particle to push against some obstacle as it descends; the total amount of work that can be extracted during the descent is equal to the change in potential energy. Of course, the work extracted in this way really arises from the Earth's gravity—the particle can do work on the obstacle because gravity is doing work on the particle. Hence the gravitational potential energy is really a joint property of both the particle and the Earth; it is a property of the configuration of the particle-Earth system.[35]

In this passage, both kinetic and potential energy are regarded as active capacities to do work, one in virtue of its velocity and the other in virtue of its position. A particle with potential energy is endowed with latent work that can be converted into actual work, much like kinetic energy represents accumulated or latent work that can do actual work. A particle with kinetic energy does work by pushing on an obstacle, and a particle with potential energy also does work, as it falls, by pushing on an obstacle. The kinetic energy equals the total amount of work the particle can deliver on the obstacle, and, similarly, the change in potential energy equals the total amount of work that can be extracted from the particle during its descent. Since kinetic energy is something actual, the actual energy of motion, Ohanian's comparison implies that potential energy is also something actual, although the terms "exploited," "converted," and "extracted" imply that it is an actuality that is not immediately accessible. Work must be done by gravity to extract, exploit, or convert the latent work of potential energy into actual work done by the falling particle.

However, the comparison of kinetic energy to potential energy fails in important ways, and these failures show that potential energy is not some kind of actuality but is Aristotelian potentiality. Though it is true that a body at some distance above the Earth's

[35] Ohanian, *Physics,* 1:163-65.

surface is endowed with latent work or stored energy, this is not the sense in which the body has potential energy. The chief indication that potential energy is not an actuality but is an Aristotelian potentiality is that potential energy requires that we consider a body's position both with respect to where the body is at some time and with respect to where it can be but is not. An apple hanging from a tree has potential energy only considered with respect to positions at some distance from the position in which it is located. Just as for Aristotle a body is not in potency to the position in which it is actually located, so too a body has no potential energy relative to the position it occupies. That is, it has no potential energy if the distance is zero.[36] Since a body with potential energy must include a reference to being located in a position that is attainable but unattained, potential energy must include such a position potentially. And once such a position has been attained—once the apple has fallen to the ground—it no longer has potential energy with respect to that position. The relevant privation is gone. Likewise, in Aristotelian philosophy, once a body's potentiality for something has been attained, the body is no longer in potency in that respect. Its potency has been made actual. By contrast, a body with kinetic energy requires no comparison or ordering to what it lacks to have its kinetic energy. Although various positions are used in determining its velocity, a body with kinetic energy has kinetic energy in virtue of the velocity it actually has, with no necessary ordering to a velocity it can have but lacks. Thus, potential energy is an instance of Aristotelian potentiality because it refers to something that a body lacks but can acquire, whereas kinetic energy is something actually possessed in a body's motion.

[36] The point made at the end of the quotation from Ohanian that gravitational potential energy is a joint property, a property of the configuration of the particle-Earth system, does not solve this difficulty, for the configuration of a system can be considered either as it actually exists or as it can be but is not. The particle-Earth system has potential energy with respect to a configuration that it can have but does not actually possess.

Furthermore, Aristotelian potentiality is open to contraries, and it may or may not become actualized.[37] Since potential energy can be determined with respect to many different positions, and since a body may or may not fall to any of these positions, potential energy manifests an openness to contraries that is characteristic of Aristotelian potentiality. By contrast, a body is actually only in one position at a given time. Furthermore, a body with kinetic energy has the one value of kinetic energy that it has. That value may change, but a body cannot possess many different values of kinetic energy at the same time as determined from the same reference frame. Potential energy cannot, then, be an active potency because active potencies are not open to contraries but are determined to one thing.[38]

Another indication that potential energy is an instance of Aristotelian potentiality is that potential energy as such does no work. As Ohanian explains in the passage quoted above, "the work done by the falling particle really arises from the Earth's gravity." The work done by gravity causes the falling particle to have kinetic energy, and it is in virtue of its kinetic energy, not its potential energy, that the particle does work by pushing on an obstacle it encounters during its fall. The potential energy of the particle, like an Aristotelian potentiality, does not itself do anything, for potentiality as such has no activity. Indeed, as Ohanian notes, for work to be done, potential energy must be "converted." It must become or receive something else, such as kinetic energy, in which case it is no longer potential energy. Thus, potential energy is not a latent actuality analogous to kinetic energy.

[37] "It is clear that the same subject is in potency to contraries, as humor or blood is the same subject which is potentially related to health and sickness. . . . It is clear, therefore, that the nature of the subject insofar as it is a certain being and insofar as it is a potency to another is not the same. Otherwise potency to contraries would be one according to nature" (Aquinas, III *Phys.,* lect. 2 [290]). All quotations from Aquinas's *In octo libros Physicorum Aristotelis expositio* are from Thomas Aquinas, *Commentary on Aristotle's Physics,* trans. Richard J. Blackwell, Richard J. Spath, and W. Edmund Thirlkel (New Haven: Yale University Press, 1963).

[38] Aquinas, IX *Metaphys.,* lect. 2 (1789-93), lect. 9 (1868).

A similar argument can be made with respect to force. Aristotelian passive potency depends upon active potency.[39] Similarly, the potential energy of a body depends upon a force that can do work upon the body. Without a conservative force that can do work on a body through some distance, the body has no potential energy. In addition, for an Aristotelian potentiality to be made actual, an agent must operate on the body that is in potency. If the agent does not operate, then the potentiality of the patient remains unactualized. Likewise, if a force does work on a body with potential energy, then in that respect the body's potential energy becomes something else. If a force is present, but does no work on a body, then the body's potential energy remains potential energy. As long as an apple hangs on a tree and gravity is present, the apple continues to have potential energy. Kinetic energy, however, does not require the continued presence of a force to be kinetic energy. A moving cannonball, for example, retains its kinetic energy without a force continually acting upon it. In addition, the cannonball, once its motion brings it into contact with something, does work of itself by virtue of its kinetic energy. In virtue of its kinetic energy and through its motion, the cannonball is, as it were, an agency for doing work. Consequently, kinetic energy is reasonably thought to be an active potency, but potential energy is passive, not active.

If potential energy were some kind of active principle, an actual stored energy, then it is hard to see why it would depend upon a force or why it would become something else in order for work to be done. Terms such as "extraction" and "exploited" undoubtedly have metaphorical and other reasonable uses. However, their literal use in describing the role of gravity and its relation to potential energy in doing work implies a very odd conception of gravity and of energy. Energy is not a nugget or thing that can be

[39] "Hence, since the state of being acted upon depends upon action, the definition 'of the primary kind of potency,' namely, active potency, must be given in the definition of both senses of potency" (Aquinas, IX *Metaphys.,* lect. 1 [1779]). All quotations from Aquinas's *In duodecim libros Metaphysicorum Aristotelis expositio* are from Thomas Aquinas, *Commentary on the Metaphysics of Aristotle,* trans. John P. Rowan (Chicago: Henry Regnery, 1961).

extracted or delivered.[40] The use of terms such as "extraction" suggest that gravity withdraws energy from something else that gets left behind, or that gravity removes some kind of hindrance that prevents potential energy from doing active work or that gravity redirects an actual potential energy to a different use. Not only do these terms suggest that gravity is only indirectly related to the work done but also they fail to capture the sense in which a new form of energy is produced when gravity does work on a body with potential energy and produces kinetic energy. A force does not "extract" potential energy, but instead makes a body's potential energy become some actual form of energy that the body did not possess. Thus, the operation of the force of gravity is better understood as generating something in a falling body from its potential energy and thereby making the body be other than it is. Thus understood, potential energy would be a potency to be other and so an instance of Aristotelian potentiality.

Furthermore, unlike actuality, potency is not intelligible just by itself. A potency, Aquinas maintains, is intelligible with respect to some correlative actuality or actualities, and, therefore, is always referred to some sort of act.[41] Not surprisingly, potential energy is classified not in itself but with respect to some form of energy or with respect to some kind of conservative force. Thus, one speaks of gravitational potential energy, electromagnetic potential energy, or nuclear potential energy.[42] By contrast, kinetic energy is just kinetic energy no matter what force produces it or what

[40] Feynman makes this point in discussing the conservation of energy by means of an analogy with blocks: "What is the analogy of this to the conservation of energy? The most remarkable aspect that must be abstracted from this picture is that *there are no blocks*. . . . It is important to realize that in physics today, we have no knowledge of what energy *is*. We do not have a picture that energy comes in little blobs of a definite amount. It is not that way" (Richard P. Feynman, Robert B. Leighton, and Matthew Sands, *The Feynman Lectures on Physics* (Reading, Mass.: Addison-Wesley Publishing Company, 1963),vol. 1, ch. 4, p. 2.

[41] "But potency or capability can only be defined by means of actuality, because the first characteristic of the capable consists in the possibility of its acting or being actual. . . . The concept of actuality must therefore be prior to the concept of potency, and the knowledge of actuality prior to the knowledge of potency. Hence Aristotle explained above what potency is by defining it in reference to actuality" (Aquinas, IX *Metaphys.*, lect. 7 [1846]).

[42] "Gravitational potential energy is associated with gravitational interactions. There are corresponding types of potential energy associated with other interactions" (Atkins, *Physics,* 130).

work the kinetic energy does.[43] Kinetic energy also has its own universal formula, but potential energy as such has no universal formula.[44] Consequently, potential energy, since it is understood with respect to some correlative force and is formulated mathematically according to the relevant form of energy, is reasonably considered an instance of Aristotelian potentiality, which is intelligible with respect to actuality.

In yet another way, the fact that there are different kinds of potential energy indicates that potential energy is an instance of Aristotelian potentiality. Potentiality is a limiting principle. It is a capacity for certain kinds of actualities and excludes becoming other kinds of actualities. Likewise, the different kinds of potential energy as such limit what can be done to a body and what it can become. In virtue of its strictly gravitational potential energy, work cannot be done to a body by an electromagnetic force and the body cannot acquire electromagnetic energy. For certain kinds of potential energy, a body as such can only have work done on it by the relevant kind of force, which indicates that potential energy is a passive potentiality.

V. Potential Energy and Actual Rest Energy

Another way of viewing potential energy may suggest that it is stored or latent energy or stored or accumulated work. Consider a rock at rest on the Earth's surface. Work must be done on the rock in order to raise it to some height above the Earth. The work that must be done to raise the rock a certain height above the ground equals the amount of potential energy that the rock has at that height with respect to the ground:

> You will undoubtedly be familiar with another way of interpreting a potential energy such as *U(h)* in the last equation. It represents exactly the amount of work

[43] "Of course, the fact that motion has energy has nothing to do with the fact that we are in a gravitational field. It makes no difference where the motion came from" (Feynman, *Feynman Lectures on Physics,* vol. 1, ch. 4, p. 6.

[44] "We express the kinetic energy by the formula $K = \frac{1}{2}mv^2$. We cannot give a similar universal formula by which potential energy can be expressed" (Halliday and Resnick, *Fundamentals of Physics,* 117).

that *we* would have to do in order to raise an object through a distance *h,* against the gravitational pull, without giving it any kinetic energy.[45]

The work done in raising the rock above the ground might be thought of as building work or energy into the rock at its position, and, thus, the rock would have accumulated work or stored energy at that position. Since the two quantities, the amount of work required to raise the rock a height *h* and the potential energy of the rock at height *h,* are equal and have a certain symmetry, those who are especially concerned with the quanti-tative consideration of things and are pragmatic in their general orientation may easily view the potential energy of a system as identical to the work accumulated or built into the system by raising the rock. Once identified with the actual work required to put a body in a certain position, potential energy could easily be viewed as something actual, actual accumulated work or actual stored energy that is now built into the rock-Earth system.

It is true that accumulated work or actual stored energy is built into the rock by raising it to some height *h*. I will call this accumulated work or actual stored energy "classical rest energy" in order to distinguish it from potential energy. By "classical rest energy" I mean the actual energy that a system or a body possesses in virtue of the actual configuration that the system has or the actual position that the body occupies when at rest in a gravitational field or considered with respect to a gravitational force. What I am calling classical rest energy is an instance of the Aristotelian principle of actuality or act. It is the act or activity of rest, but it is not potential energy. Quantitative equality is not necessarily identity in nature, being, and intelligibility. The rock at some height *h* above the Earth's surface has both classical rest energy and potential energy, but the two are distinct. The work done in raising a rock above the ground builds an actuality as well as a potentiality into the system made up of the rock and the Earth so that the rock is both in act and in potency but in different respects. One respect pertains to the actual configuration of the Earth and the rock and the other refers to the potential

[45] French, *Newtonian Mechanics,* 378.

configuration in which the rock can be on the ground or in some intermediate position. The distinction is evident inasmuch as the rock possesses classical rest energy in the place it occupies and after being moved by a force and after having work done on it. By contrast, the rock has potential energy with respect to a position that it does not occupy and with respect to a force that can move it but has not and by virtue of work that can be done on it but has not been done. The classical rest energy and the past work done do not depend upon the potential energy, but the opposite cannot be said. The potential energy does depend, in part, upon the actual location and the previous work done.

Indeed, the potential energy present in a system depends upon the actual order of its parts, the actual location of a body, for the potential energy is different for a body depending upon whether it is one, ten, a hundred, or a thousand feet above the ground. This dependency is to be expected, for any potentiality depends upon some actuality. The potentiality of bronze to be a statue depends upon its actually being bronze. Thus, the dependency of the potential energy of a body or a system upon the actual order of the system's parts or upon a body's actual position is unsurprising and unproblematic and is what one would expect on Aristotelian grounds. Though we may easily conflate the sense in which a body has classical rest energy with the sense in which it has potential energy, we must distinguish the sense in which something is from the sense in which it can be, for the same body can be both in potency and in act but in different respects.[46] A block of bronze is not a stored, accumulated, or latent statue.

A rock suspended above the ground has stored energy or accumulated work, what I have called classical rest energy. But what is this classical rest energy if it is not doing any work and it is neither potential energy nor kinetic energy? We might be tempted to say that classical rest energy, when it is not doing work, is not doing anything, that it is just sitting there and is

[46] "And although the same thing exists both in potency and in act, to be in potency and to be in act are not the same according to nature. Thus, bronze is in potency to statue and is bronze in act, yet the nature of bronze insofar as it is bronze and insofar as it is a potency for statue is not the same" (Aquinas, III *Phys.,* lect. 2 [289-90]).

inactive. However, classical rest energy is better understood as what Aristotle and Aquinas call an unchanging act or a motionless activity. Motion, according to Aquinas, is the kind of act that is best known and is the most evident to us because we most readily perceive it as such through our senses.[47] However, motion is an incomplete act because it possesses its parts successively.[48] A complete act is unchanging. To understand a complete act or a motionless activity, we begin with the activity of motion in order to arrive at a conception of an activity free from becoming.[49] For example, a calm sea and a still air are unmoving activities.[50] In English, "activity" is nearly synonymous with change, and though "act" conveys the sense of something done, it also readily evokes motion, so the notion of an unchanging activity seems odd. "Actuality" better captures the sense of a constant, ongoing act, but in ordinary English it lacks the dynamic sense of "activity."[51] Seeing and contemplation better illustrate the notion of act as an ongoing, unchanging actuality. In this sense, "act" means completion, fulfillment, or form.[52]

Perhaps the most remarkable and best instance of a motionless act in the sciences is mass. Mass is a measure of a body's inertia. It is also a measure of how strongly a body acts and is acted upon gravitationally. Prior to Albert Einstein, mass and energy were viewed as separate and independent principles. However, since the formulation of special relativity, mass is treated as a form of energy as expressed by the famous equation $E=mc^2$. According to Einstein,

[47] Aquinas, IX *Metaphys.,* lect. 3 (1805).

[48] Aquinas, *STh* I, q. 7, a. 3, ad 4.

[49] Yves Simon, *An Introduction to the Metaphysics of Knowledge,* trans. Vukan Kuic and Richard J. Thompson (New York: Fordham University Press, 1990), 42. "[T]here is not only an activity of movement but an activity of immobility" (Aristotle, *Nicomachean Ethics* 7.14.1154b26-27, in *The Basic Works of Aristotle,* trans. W. D. Ross [New York: Random House, 1941], 1058.

[50] Aristotle, *Metaphys*. 8.2.1043a22-26.

[51] Owens, "Aristotle—Motion as Actuality of the Imperfect," 121.

[52] The "term actuality is derived from activity, as has been stated above [lect. 3 (1805)]; and from this it was extended to form, which is called completeness or perfection" (Aquinas, IX *Metaphys.,* lect. 8 [1861]).

> The energy that belongs to the mass m is equal to this mass, multiplied by the square of the enormous speed of light—which is to say, a vast amount of energy for every unit of mass. But if every gram of material contains this tremendous energy, why did it go so long unnoticed? The answer is simple enough: so long as none of the energy is given off externally, it cannot be observed. It is as though a man who is fabulously rich should never spend or give away a cent; no one could tell how rich he was.[53]

When Einstein speaks of the energy of mass as being like the unspent wealth of a rich man, he is speaking, however unintentionally, of something very much like Aristotle and Aquinas's notion of unchanging activity or of a motionless act, for mass is tremendously energetic but unchanging. Physics followed a line of development parallel to that in philosophy. Physicists began with kinetic energy, the first form of energy to be discovered and the most obviously energetic, and then arrived at a conception of an energy free from becoming, namely, mass.

Classical rest energy is not the same as mass, but it is similar in the sense that, like the unspent wealth of a rich man, it is a motionless actuality that corresponds to and is the actualization and fulfillment of the potency of potential energy. The potential energy of an apple hanging on a tree relative to the ground is actualized when the apple is on the ground. The actual stored energy the apple has on the ground, what I have called classical rest energy, is the correlative act of that potency.

The tendency of many physicists to regard potential energy as something actual is similar to the error of the pre-Socratics with regard to coming to be. The ancients, according to Aquinas, "said that nothing is either generated or corrupted."[54] They denied that anything genuinely comes to be or ceases to be and held that whatever came into being in some way already actually preexisted. According to Aquinas, the pre-Socratics' error about coming into being was due to a failure to grasp a principle of potency:

> All of these philosophers were deceived because they did not know how to distinguish between potency and act. For being in potency is, as it were, a mean

[53] Albert Einstein, "E=MC^2" [1946], in idem, *Out of My Later Years,* rev. ed. (Secaucus, N.J.: The Citadel Press, 1956), 51-52.

[54] Aquinas, I *Phys.,* lect. 14 (121).

between pure non-being and being in act. Therefore, those things which come to be naturally do not come to be from non-being simply, but from being in potency, and not, indeed, from being in act, as they thought. Hence things which come to be did not necessarily pre-exist in act, as they said, but only in potency.[55]

The view that potential energy is some kind of stored, inoperative, preexistent actuality is the kind of misunderstanding one might expect if potential energy were an instance of Aristotelian potentiality. It is a common error with a very long history.[56]

VI. Energy and Motion

I turn now to local motion. A consideration of local motion further shows that energy is a specific instance of act and potency. According to Aquinas, motion is "the act of what exists potentially insofar as it exists potentially."[57] This definition signifies that a body's motion is stretched out, as it were, in a continuously differentiated process such that each part of the process is related to a prior part as act to potency and is related to a posterior part as potency to act. A body's motion is twofaced. It has a twofold ordination with respect to the same potentiality. One ordination is with respect to a prior place from which the body has moved. With respect to the potency the body possessed in this prior place, the body's motion is an act. The other ordination of potency is with respect to the posterior place to which the body is moved. With respect to the place to which the body is moved, the body is in potency.[58]

Many features of the Aristotelian definition of motion are instantiated in the relations between work, kinetic energy, and gravitational potential energy especially as considered according to the Law of the Conservation of Mechanical Energy. Ohanian describes this law as follows:

[55] Aquinas, I *Phys.,* lect. 9 (60).

[56] See also Simon, *Great Dialogue,* 60-63.

[57] Aquinas, III *Phys.,* lect. 2 (285). Aristotle, *Phys.* 3.1.201a10.

[58] Aquinas, III *Phys.,* lect. 2 (285), lect. 4 (297-307).

> The sum of the kinetic and potential energies is called the mechanical energy of the particle. . . . This energy represents the total capacity of the particle to do work by virtue of both its velocity and its position. . . . if the only force acting on the particle is gravity, then the mechanical energy remains constant. . . . This is the law of conservation of mechanical energy. . . . Since the sum of the kinetic and potential energies must remain constant during the motion, an increase in one must be compensated by a decrease in the other; this means that during the motion, kinetic energy is converted into potential energy and vice versa.[59]

In the case in which gravity is the only force acting on a falling body, the work done by gravity equals the body's increase in kinetic energy and equals its decrease in potential energy. Since the quantity of kinetic and the quantity of potential energy vary from point to point throughout the fall, the body's motion is a continuously differentiated process. At any point in the motion, the same potential energy has become partly kinetic energy and remains partly potential energy. It has kinetic energy with respect to the point from which it has moved, and so with respect to a prior potential energy. Insofar as the body continues to have potential energy it can have more kinetic energy as it attains further positions. Consequently, each part of the body's motion is related to a prior part as kinetic energy to potential energy and is related to a posterior part as potential energy to kinetic. Motion, Aquinas maintains, is a "mixture of act and potency."[60] Likewise, a mix of potential and kinetic energy characterizes the motion of a falling body.

In Aristotelian terms, the body's potency to be on the ground is actualized through its motion. The body loses the act of location it had in the place from which it fell, moves through a continuum of places with respect to which its motion is determined and to which it is in potency and is then brought to another complete or motionless act in the place in which it is stopped. With respect to energy, as gravity makes the body fall and its potential energy become kinetic energy, the body moves through lower and lower levels of energy and attains cor-respondingly lower energy states until impact with the ground brings it to rest and results in the loss

[59] Ohanian, *Physics,* 1:165.

[60] Aquinas, III *Phys.,* lect. 3 (296).

of its kinetic energy. It moves from one state of classical rest energy to another with respect to which it had potential energy. Since the work done by gravity makes the potential energy become kinetic energy and changes the energy level or energy state of the body, potential energy, like Aristotelian potentiality, is a principle by which something can be made other than it is.

Motion, for Aquinas, is produced by the operation of a mover, for that is part of what is meant by the principle "whatever is moved is moved by another." A mover actualizes the potency of the moved. Likewise, kinetic energy is produced by work, and work is the continuous operation of a force on a body through some distance. As in the example above, the work done by the force brings kinetic energy out of potential energy. This is not to say that motion requires a continuously acting conjoined cause in order to sustain it, as if a moving body would suddenly stop if it did not have such a mover or as if kinetic energy would suddenly disappear without such a continuously acting force. The point is that if work is continually done on a body or if potential energy is becoming kinetic energy, then there is a force operating, and this fits with the requirements of Aquinas's principle inasmuch an agency is required for any reduction from potency to act and a force must be exerted by something.[61]

Further, gravitational motion as treated by the Law of the Conservation of Mechanical Energy exemplifies the antithesis of potency and act. Potency and act are opposed such that something

[61] If we consider the hypothetical and counterfactual case of a body moving in purely inertial force free motion, it follows that the body's kinetic energy remains constant and that no work is being done on the body. Further, in the absence of a force, the body has no potential energy, no energy dependency upon position. This implies that in the abstract case of a body in force free uniform rectilinear motion no potency is being actualized and that purely inertial motion is an unchanging actuality, a motionless motion. These conclusions, drawn from considerations of energy, are the same as conclusions drawn elsewhere by a different approach and by different arguments. See Thomas J. McLaughlin, "Aristotelian Mover-Causality and the Principle of Inertia," *International Philosophical Quarterly* 38 (1998): 137-51; and idem, "Local Motion and the Principle of Inertia: Aquinas, Newtonian Physics, and Relativity," *International Philosophical Quarterly* 44 (2004): 239-64. "In the special case in which the work is *zero*, the kinetic energy remains *constant*" (James A. Richards, Francis Weston Sears, M. Russell Wehr, and Mark M. Zemansky, *Modern University Physics* [Reading, Mass: Addison-Wesley, 1960], 135).

cannot be in potency and act at the same time in the same respect.[62] Similarly, something cannot have potential and kinetic energy at the same time and in the same respect. A decrease in one is compensated by an increase in the other. This antithesis of potential energy and kinetic energy reinforces the idea that they are related as potency to act.[63]

VII. THE ARISTOTELIAN PRINCIPLE OF POTENCY AND POTENTIAL ENERGY: ORIGIN AND REALITY

Another argument that energy is a specific instance of the Thomistic principles of act and potency may now be given. Potential energy was discovered in a way that is similar to the way in which Aristotelian potentiality was discovered. Aristotle discovered the principle of potentiality through explaining how something can come to be or pass away, either accidentally or substantially. Specifically, the principle of potency solves a dilemma concerning change that was posed by the pre-Socratics. Aquinas, commenting on Aristotle, describes this dilemma as follows:

> [T]hey did not know how to resolve the following argument, according to which it seemed to be proven that being is not generated. If being comes to be, it comes either from being or from non-being. And each of these seems impossible, i.e., that being comes to be from being or that it comes to be from non-being. It is clearly impossible for being to come to be from being, because that which is does not come to be, for nothing is before it comes to be. And being already is, hence it does not come to be. It is also clearly impossible for something to come to be from non-being. For it is always necessary that there be a subject for that which comes to be, as was shown above. From nothing, nothing comes to be. And from this it was concluded that there is neither generation nor corruption of being.[64]

The solution of this dilemma requires two things, the principle of potency and a distinction between coming to be from something

[62] Aquinas, *STh* I, q. 75, a. 5, obj. 1.

[63] Edward M. O'Connor, *Potentiality and Energy* (Washington, D.C,: The Catholic University of America Press, 1939), 12-13.

[64] Aquinas, I *Phys.,* lect. 14 (121).

per se and *per accidens*. Aristotle uses the example of a doctor to illustrate the distinction between *per se* and *per accidens*.[65] A doctor heals a sick person *per se,* for the doctor heals as a doctor. However, a doctor may build a house, and then the doctor builds *per accidens,* for the doctor does not build as a doctor. Construction is accidental to doctoring. Similarly, a patient whose profession is carpentry is healed *per se* as a sick person and *per accidens* as a carpenter.

According to Aristotle and Aquinas, nothing comes to be *per se* from either being or nonbeing. However, *per accidens* something does come to be from being and nonbeing. For example, a block of bronze is made into a statue. Something new that previously was not comes to be, the statue shape. The block of bronze acquires a shape that it did not have, and so the statue shape comes to be from its nonbeing. However, the statue's shape comes to be from nonbeing *per accidens* because it is accidental to the one definite shape that the block of bronze has that it lacks all other shapes, including the statue shape. Similarly, the statue comes to be from the block shape of the bronze, and so comes to be from being, the being that is the block shape. However, the statue shape is different from the block shape so that what comes to be is not the same as what was. Thus, the statue's shape comes to be from being *per accidens* because it is accidental to the statue shape that it came to be from a block shape. The statue shape could have come to be from a variety of different previous shapes. Only accidentally does it come to be from a particular block shape.

The statue's shape comes to be *per se* from the potentiality of the bronze to be a statue. The bronze is the subject of the change, but the statue comes to be *per se* from the bronze considered in a certain respect, the respect in which the bronze is open and able to have the shape of a statue. The bronze, insofar as it open to having different shapes, exists in potency to those shapes. The statue can not come to be from the bronze as actual bronze because that would be to come from being as being. The bronze is

[65] Aristotle, *Phys*. 1.8.191a23-b34; Aquinas, I *Phys.,* lect. 14 (120-28); Glen Coughlin, *Aristotle's Physics, or Natural Hearing* (South Bend, Ind.: St. Augustine's Press, 2005), 223-29.

already bronze, and so it cannot come to be bronze. Thus, the statue's shape comes to be *per se* from being in potency.

What are the parallel but more specific origins of potential energy? In a quite remarkable article published in the journal *The Physics Teacher* and entitled "An Historico-Critical Account of Potential Energy: Is *PE* Really Real?", the physicist Eugene Hecht raises and addresses problems concerning the origin and reality of potential energy.[66] In his paper, he reviews the historical development of the notion of energy and argues that the notion of potential energy was originally introduced to account for the coming to be and passing away of kinetic energy in accordance with a conservation law. Christiaan Huygens, Newton's great contemporary, discovered what we now call kinetic energy in the course of doing collision experiments. He discovered that in elastic collisions between two cannonballs the sum of their quantities mv^2 was the same before and after the collision even though the individual velocities of the cannonballs had changed.[67] In such interactions, kinetic energy is conserved.[68] The Conservation of Kinetic Energy is an important principle and is now used extensively in particle physics.

In other interactions kinetic energy is not conserved. Consider a ball thrown upwards which then falls back downward. In leaving the hand that threw it, the ball's kinetic energy is at a maximum. As the ball goes upward, it slows down and its kinetic energy decreases until, at the highpoint of its motion, the ball has no kinetic energy. As the ball begins to fall, its kinetic energy increases until it reaches a maximum again. Where does the ball's kinetic energy go as it rises, and as the ball falls, from where does

[66] Eugene Hecht, "An Historico-Critical Account of Potential Energy: Is PE Really Real?" *The Physics Teacher* 41 (Nov. 2003): 486-93.

[67] Qualitatively, elasticity describes the degree of 'bounciness' in a collision. A completely elastic collision is characterized by perfect rebound of the colliding bodies. None of the kinetic energy is lost through breaking up or deforming the colliding bodies, or through noise, heat, friction and other such things. Automobile accidents, for example, are not elastic. See French, *Newtonian Mechanics,* 309.

[68] Hecht, "Historico-Critical Account of Potential Energy," 487. Richard J. Blackwell, trans., "Christiaan Huygens' The Motion of Colliding Bodies," *Isis* vol. 68, no. 4 (Dec. 1977): 574-97.

its kinetic energy come? It seems to come from and go into nothing.

Repetitive phenomena, such as a swinging pendulum or a roller coaster, especially emphasize the problem. Consider an idealized pendulum, one unaffected by friction or air resistance. The heavy bob at one end of the pendulum arm is initially held at an angle to the vertical. The bob is not moving and has no kinetic energy. The bob is then released and under the force of gravity swings downward toward the vertical. As the bob swings downward, its velocity and kinetic energy increase from zero to a maximum at the vertical position of the pendulum. As the bob swings upward, its velocity and kinetic energy decrease until it arrives at an angle to the vertical equal to that from which its motion began. At this point the velocity of the bob is zero, and the bob has no kinetic energy. As the pendulum swings back and forth, its kinetic energy starts from zero, increases to a maximum, and then decreases to zero. The pattern repeats over and over. Something seems to be conserved. But again as the bob swings back and forth, from where does the kinetic energy come and to where does it go? The kinetic energy seemingly appears, disappears, and reappears out of and into nothing. Gravitational potential energy accounts for the coming to be and passing away of kinetic energy and yields a new conservation law, the conservation of mechanical energy discussed earlier in which the sum of the kinetic and potential energy remains constant. Hecht summarizes as follows:

> Historically, the concept of kinetic energy (*vis viva*) drew its significance from the fact that it was conserved. Because motion was observable, it was reasonable enough to say that *KE* was real. The idea of potential energy was subsequently conceived to account for the disappearance and reappearance of *KE* (as for example, in the case of a swinging pendulum). The problem with *PE* (in the minds of some) was that it was not directly observable, and therefore arguably not real.[69]

This passage contains two closely related points that are important for the argument of this paper. The first is that potential energy was discovered to "explain how *KE* can go in and out of

[69] Hecht, "Historico-Critical Account of Potential Energy," 491.

existence."[70] The kinetic energy of the falling body comes to be from its potential energy, and the kinetic energy of a rising body passes away into the energy of its position, from which the body has a new potential energy. Potential energy explains how kinetic energy can come to be, increase, decrease, and pass away while some quantity, the net mechanical energy, is conserved throughout. Kinetic energy does not appear out of nothing and disappear into nothing.

With respect to a broad range of phenomena, potential energy explains the coming to be and passing away of kinetic energy and the attainment of new positions of differing energy levels. It avoids treating kinetic energy as coming to be out of nothing or as something preexisting in act, though various thinkers try to conceive of potential energy as some kind of preexisting actuality. The kinetic energy of a falling body comes to be *per se* from its potential energy and *per accidens* from its classical rest energy, which it loses as the body falls, much like a block of bronze loses its block shape as it is made into a statue. Consequently, "Potential energy is real for the same reasons that potentiality is real."[71] It is a necessary principle of change. This implies that potential energy is a specific instance of Aristotelian potentiality.

The second important point is suggested by the last sentence of the quotation from Hecht, in which he notes that some thinkers doubt that potential energy is real. According to Hecht,

> The case against the reality of *PE* is basically that *KE* (the energy of an object in motion) seems, by virtue of that motion, to be directly observable, whereas *PE* (the energy of an object at rest) appears to be quite unobservable. The object itself appears completely unaffected by its acquisition of *PE*.[72]

Hecht quotes several physicists, mathematicians, philosophers, and historians of science who make this claim. For example, the mathematician John W. N. Sullivan raised doubts about the reality of potentiality energy:

[70] Ibid., 489.

[71] O'Connor, *Potentiality and Energy*, 75.

[72] Hecht, "Historico-Critical Account of Potential Energy," 489. See also O'Connor, *Potentiality and Energy*, 37-75.

> Potential Energy, it must be admitted, is a somewhat mysterious notion. Other forms of energy, such as the energy of motion and heat energy, are obviously "energetic." But potential energy is undetectable until it is transformed. . . . Thus the notion of potential energy explains away apparent violations of the principle of the conservation of energy. But is this not the very reason for the importation of the notion of potential energy? Is it not a mathematical fiction brought in for convenience?[73]

If potential energy were an instance of Aristotelian potentiality, the difficulties Sullivan and others mention are just what one would expect. A potentiality is not as such observable, "energetic," or directly measurable, and it will not do something to the object that acquires it. Something done or doing is an act.

Hecht further quotes the philosopher W. T. Stace as one who does not think that potentialities are real:

> Either the energy exists or it does not exist. There is no realm of the "potential" half-way between existence and non-existence. And the existence of energy can only consist in its being exerted. If the energy is not being exerted, then it is not energy and does not exist. Energy can no more exist without energizing than heat can exist without being hot.[74]

Stace begs the question of what is precisely the issue. An Aristotelian or a Thomist would maintain that "being in potency is, as it were, a mean between pure non-being and being in act."[75] The position taken by Stace and others implies that something can come to be from nothing, that kinetic energy just appears from nothing at all.[76] By contrast, once the reality of the Aristotelian principle of potency is accepted, and allowing for the positivism,

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[73] J. W. N. Sullivan, *The Limitations of Science* (New York: Mentor Books, 1949), 155; quoted in Hecht, "Historico-Critical Account of Potential Energy," 489.

[74] W. T. Stace, "Sir Arthur Eddington and the Physical World," *Philosophy* 9, no.33 (Jan. 1934): 48-49; quoted in Hecht, "Historico-Critical Account of Potential Energy," 489. See also W. T. Stace, "The Present Dilemma in Philosophy," *Journal of Philosophy* 31, no. 14 (July 1934): 372.

[75] Aquinas, I *Phys.,* lect. 9 (60).

[76] O'Connor, *Potentiality and Energy,* 70-72.

the problems about the reality of potential energy are solved, or rather, they are seen not to be problems at all.[77]

A typical response to the Aristotelian principle of potency, when it is not (mis)understood as a hidden or inoperative actuality, is to deny that it is real, usually by regarding it as a mere idea in the mind and not as a principle in things.[78] Denying the reality of potential energy is opposed to treating potential energy as a stored or inoperative actuality. Both errors involve the assumption that only actualities are real. Given the assumption that only actualities are real, it follows that if potentiality is not actual, then it is not real. Potentiality, on this view, is not a principle in things themselves existing outside of and independently of the mind. Thus, the same errors are found concerning potential energy and Aristotelian potentiality. The frequent occurrence of opposed errors about both potential energy and Aristotelian potentiality further supports the claim that potential energy is an instance of the Aristotelian principle of potentiality.

Hecht's own solution is to argue that potential energy is real by drawing upon the Special Theory of Relativity. Using the mass-to-energy relation $E=mc^2$, Hecht notes that "The mass of a composite object as a whole changes with its energy content."[79] Thus, all other things being equal, the more energy a body has, the greater is its mass. For example, "an apple pie sitting on a table has more mass when it's hot than when it's cold."[80] With regard to gravitational potential energy, a change in the gravitational potential energy of a system is always accompanied by a change in the mass of the system. For example, in a system consisting of the Earth and a ball of mass m, an external force that does work on the system and raises the ball a height h above the Earth's surface increases the gravitational potential energy of the Earth-ball system by an amount equal to mgh. According to special relativity,

[77] See also E. B. Moore, "Positivism and Potentiality," *Journal of Philosophy* 48 (1951): 472-79.

[78] Grace A. De Laguna, "Existence and Potentiality," *The Philosophical Review* 60 (1951): 155-76.

[79] Hecht, "Historico-Critical Account of Potential Energy," 490.

[80] Ibid.

the mass of the Earth-ball system increases by an amount equal to mgh/c^2.[81] Though the change in mass is very small, the mass of a body or system is an actual, measurable quantity. Hecht concludes that

> [A] change in the *PE* of a system of interacting objects is real in that it is always accompanied by a change in mass which is, in principle, measurable. The scientists and philosophers who were disturbed because conservation of energy was predicated on unobservable quantities (i.e., all the various forms of *PE*) can now put their doubts aside—*PE* is real.[82]

Having thus argued that potential energy is real, Hecht goes on to claim that since the concept of potential energy can be replaced by that of mass, the notion of potential energy is redundant and superfluous: "By equating *PE* with mass, the concept of *PE* becomes as real as mass is real, but at the same time it becomes redundant and perhaps even superfluous."[83]

One may readily grant that raising a ball a height *h* above the surface of the Earth increases the energy and mass of the Earth-ball system. Previously, I argued that raising an object above the Earth's surface built both a motionless actuality, what I have called classical rest energy, and potential energy into the system. Hecht's argument supports this claim by showing that raising the ball not only increases the potential energy of the Earth-ball system but also increases the relativistic rest energy. The increase of the relativistic energy is proportional (by $1/c^2$) to the system's increase in mass, and the mass is directly measurable. However, as with classical rest energy, the potential energy of a system is distinct from its relativistic rest energy and mass. It is the actual position of the ball above the Earth's surface, and not its relation to a future possible position, that is measured and shows an increase in mass. The future, like a potentiality, cannot be measured. Though the change in potential energy is accompanied by a corresponding

[81] Ibid., 491.

[82] Ibid., 490.

[83] Ibid. "[I]nsofar as the words *potential energy* can efficaciously be replaced by the word *mass,* the notion of *PE,* in all its various incarnations, is superfluous. There is *KE* and there is mass" (ibid., 492).

change in mass, it would be fallacious to claim that potential energy and mass are identical or that they have the same referent. Thus, strictly speaking, potential energy cannot be redundant because it does not refer to an actual property of a body, which is what mass is. Perhaps, for certain utilitarian purposes, potential energy may be regarded as redundant and superfluous, just as it has been frequently regarded as a stored actuality. However, setting aside these purposes, potential energy is not superfluous or redundant insofar as it explains the *per se* coming to be of kinetic energy in the kind of phenomena noted in Hecht's article. Since mass and potential energy are distinct, the kinetic energy of a falling body can only come from its mass *per accidens*. Without potential energy, the coming to be of kinetic energy remains unexplained.

The argument that has been made in this paper can, I suggest, be generalized. For any kind of fundamental force, gravitational, nuclear, or electromagnetic, there corresponds some kind of potential energy.[84] These kinds of potential energy are also arguably instances of Aristotelian potentiality and correspond to actual forms of gravitational, nuclear, or electromagnetic energy that are instances of the Aristotelian notion of act or activity. If this is indeed the case, then the Aristotelian principles of act and potency are widely and deeply present in modern physics and its understanding of nature.

CONCLUSION

The principles of act and potency are used to define motion and the soul, to explain change and characterize the relation of matter and form, the relation of substance and accident, the relation of essence to existence, and the relation of finite to infinite being. The notions of act and potency are fundamental to an analysis of participation and operation, to the study of being, and to thinking about God. This paper has argued for a further application of these principles, that through the notion of energy

[84] "Since there are four fundamental interactions (strong, weak, electromagnetic, and gravitational), there can be four basic forms of *PE*" (ibid., 491).

the principles of act and potency are present in the modern scientific understanding of nature. After briefly addressing some initial objections, it focused on work, kinetic energy, and gravitational potential energy in Newtonian physics. The treatment of gravitational potential energy required a distinction between the actual energy of a system and the potential energy of the system with respect to a different configuration. The argument was then developed for local motion. It was further argued that, in various phenomena, kinetic energy and gravitational rest energy come to be from potential energy. Potential energy is also often misunderstood in the same ways in which the Aristotelian principle of potency has been misunderstood or rejected. The notion of energy is a very rich one both scientifically and philosophically, especially for an Aristotelian or a Thomist. The subject deserves further investigation not only with regard to Newtonian mechanics and gravity but also with respect to the other fundamental forces of nature, with respect to quantum mechanics and special and general relativity, and with respect to other disciplines that make use of the notion of energy.[85]

[85] An early version of this paper was read to the Society for Thomistic Natural Philosophy at the November 2003 Meeting of the American Catholic Philosophical Association. I am grateful to those present for their comments and criticisms, and especially to Dr. Greg Townsend.