The Physics of Impetus and the Impetus of the Koran

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IN TWO SHORT years from now we shall be at the threshold of 1987, a year which undoubtedly will have as one of its chief events the celebration of the 300th anniversary of Newton's *Principia*. Three hundred years after its publication the *Principia* is still the most important scientific book ever published. In fact, in a sense it marked the beginning of exact science on a grand scale. There was, of course, plenty of science before Newton. Of the three laws of motion, which support the vast edifice of the *Principia*, Newton could claim only one, the third, as his own, and even that only in part. He would have credited Galileo with the law of acceleration and, had he not been ill-disposed toward Descartes, he might have referred to him as the author of the first and second laws. Newton deserved all the credit for putting the three laws in the order in which we find them on the very first page of the *Principia*. The force law is the third, because as an equation it is an action-reaction statement and therefore presupposes the second law. As to the notion of acceleration in that same third law, it presupposes the notion of inertial rectilinear motion, which is what the first law is about.

In a sense, therefore, the whole edifice of physics and of exact science rests on the first law. By ascribing it to Descartes, Newton would not have been entirely wrong. Descartes spoke indeed of linear inertial motion. He even assumed that, hypothetically speaking, such a movement would continue into infinity. But such a movement was impossible in the universe of Descartes. There the major motions were all circular and were confined to within one stellar domain or solar system. For Galileo, too, the inertial motion was circular when it came to the celestial regions, that is, to the moon and the planets. Galileo did not speak of the motion of stars, nor did Newton for that matter. Contrary to countless statements to be found everywhere in the literature, technical and popular, for Newton the material universe was finite. Although that universe was floating in an infinite space, its material particles, stars or atoms, were not supposed to stray into infinity. In other words, when Newton said that a body would indefinitely continue its inertial motion along a straight line, he did not mean actual infinity. It was only in the nineteenth century that the inertial motion as an infinite straight line was taken in a realist sense, but not for long. All permissible paths of motion are more or less curved in the universe as interpreted in Einstein's general theory of relativity.

In view of this the inertial motion as formulated by Buridan and Oresme in the fourteenth century appears more modern than it would at first sight. Buridan and Oresme explicitly spoke of the inertial motion of the sphere of stars and of the planets, circular as that motion was. For both, the diurnal steady motion of the fixed stars was obvious evidence of a motion which, when once started, would go on forever if friction and resistance did not intervene. The manner in which Buridan, and later Oresme, described the beginning of motion, of any motion in the universe, is therefore of enormous importance for an understanding of the ultimate source of the physics of impetus without which there would be no Galilean physics, no Newtonian physics, not even Einsteinian physics.

Buridan's most specific statement occurs in the context of his commentary on Aristotle's cosmological work, *On the Heavens*. Aristotle, of course, insisted on the eternity of motion that was unacceptable to a Christian like Buridan. According to the Christian Creed the world was created in the beginning, or in time, which means that the past history of the universe is finite. The same creed also states that the future history of the universe is also finite. Eternity begins when an end has come to this world. It should also be noted that in 1215, or a hundred years before Buridan, the Fourth Lateran Council made it a dogma that the world was created in time and out of nothing.

All this was in Buridan's mind—and therefore we ought to keep it in mind in order to grasp the full meaning of the statement by which he separated himself from Aristotle on the eternity of the motion of stars:

> God, when He created the world, moved each of the celestial orbs as He pleased, and in moving them He impressed in them impetuses which moved them without His having to move them any more except by the method of general influence whereby He concurs as an agent in all things which take place. . . . And these impetuses which He impressed in the celestial bodies were not decreased nor corrupted afterwards, because there was no inclination of the celestial bodies for other movements. Nor was there resistance which would be corruptive or repressive of that impetus.

Buridan, who had already talked of the throw of the flight of a javelin in terms of an impetus impressed on it by the arm, added in the same breath that in explaining motion, both celestial and terrestrial, in that fashion, he was seeking "from theological masters" as to "what they might teach me in the matter of how these things take place."

Those masters taught him indeed something of extraordinary importance for the future of science. The whole future of physics depended on making a start with the physics of impetus, given in a nutshell in the foregoing statement of Buridan, a statement repeated almost verbatim by Oresme and reproduced all over Europe in countless manuscripts and lecture notes throughout the fifteenth century and reprinted again on a number of occasions during the sixteenth century. Rarely before or after did a statement form a more lasting and coherent tradition in matters scientific.

Buridan's impetus theory differs from Aristotle's theory of motion not only in that the eternity of motion is rejected by it. It also differs from Aristotle's theory concerning the source of motion. For Aristotle the source of all motion is the Prime Mover, who is not really different from the sphere of the fixed stars. In other words, Aristotle's theory implies a cosmic *perpetuum mobile* not only in the sense that in the absence of friction the motion of the fixed stars would last forever. Aristotle's universe is a *perpetuum mobile* also in the sense that it cannot be not moving; in fact it cannot be non-existing. The necessary existence of the cosmos is a basic tenet in Aristotle's thinking. His Prime Mover is not a Creator, and if it were a Creator he could not fail to create. Whatever the role of the Prime Mover in the motion of the heavens, it is a necessary and eternal role. If that role is, as Aristotle would have it, the inspiring of the motion of stars through the Prime Mover's eliciting in them a desire to move, it is still an eternal and necessary role. Unlike the Christian God, or the Jewish God, or the Muslim God, who creates but is not forced to create, the God or Prime Mover of Aristotle is neither a Creator nor is He free not to play his role, let alone to play any other role.

As for any medieval Christian, for Buridan, too, the Christian God is free to create. The freedom of the Creator to create was powerfully reasserted in 1277 by the bishop of Paris in a decree concerning a long series of cosmological questions. The decree, which exerted great intellectual influence, was well known to Buridan, who in line with Christian theology saw the basis of God's freedom to create in His absolute transcendence over anything He might create. If, however, God is fully transcendent to His creation, that is, to the entire universe, there is no need for Him, unlike for Aristotle's Prime Mover, to remain in "physical" contact, however sublimated, with the universe so that its motion might go on.

This difference between Aristotle's and Buridan's concept of the beginning and continuation of cosmic motion bears heavily on their respective dicta on any motion, small and ordinary, such as the throw of a stone or of a javelin. According to Aristotle any motion on earth is accomplished in the same way in which this happens to the sphere of the fixed stars. Just as the Prime Mover must remain in contact all the time with the sphere of the fixed stars, be it by inspiring in it a desire to move so that its motion may continue, the source of the continued motion of any thing is that its mover remains in continuous contact with it. This is why Aristotle supports the theory of *peristasis* or a sort of self-perpetuating vortex mechanism in order to explain for instance the flight of a projectile, say of a javelin. Once the javelin leaves the hand it makes, according to Aristotle, the air in front of it separate around it and then close behind it as a moving force. Quite different is the case with Buridan's theory of the flight of a javelin or of any other projectile. According to Buridan the arm imparts a certain amount of motion or impetus to the javelin that keeps flying until it loses its entire quantity of motion, or impetus, or momentum if you wish, to the resistance of the air. In other words, just as in the case of Aristotle, where a theology (pagan, pantheist, and non-creationist) determines the physics of motion on earth, in Buridan's case theology (Christian or strictly creationist) determines physics, but with a result as different as the two theologies are different. In the case of Aristotle theology stifled physics; in the case of Buridan theology laid the possibility for physics by inspiring the formulation of the physics of impetus.

Between Aristotle, or the Greeks of old, and Buridan, or the Latin medievals, there were, of course, the Muslims not only historically but also scientifically. Much of the Greek scientific and philosophical corpus reached the Latin West through Muslim mediation. By the time this happened, the Muslim world had for almost half a thousand years been in the possession of almost all the extant scientific and philosophical works of the ancient Greeks. In fact, the translation of those works into Arabic was done with an impetuous hunger for learning. It matched the territorial expansiveness of Muslim religion behind which stood the impetus of the Koran as its chief propellant. The ensuing process, which has been amply researched and discussed in a vast literature, has some salient characteristics. First, the acquisition of Greek learning was followed by a considerable elaboration of several of its aspects. Medicine in general and ophthalmology in particular come first to mind. Ophthalmology in turn required intensive study of optics. There and also in algebra and trigonometry Muslim scholars did original work. With the optical work of Ibn al-Haitham (Alhazen) there is on hand a promising balance between experimentation and theory. In addition to talent there was also a vast social matrix, the

Muslim world, making possible easy communication over a land mass stretching from Cordoba to Baghdad with the help of a highly developed language, the Arabic, a language kept alive and spread in a great measure by the daily recitation of the Koran. There were also lively exchanges with neighboring and distant cultures. The Chinese art of paper-making was quickly learned and perfected by Muslims who also noted the great usefulness for commercial purposes of the Hindu decimal system. There were, of course, some setbacks, such as the destruction of Baghdad by the Mongols in the early thirteenth century and, about the same time, the fall of Cordoba. The times of the Crusades were also not helpful for a peaceful cultivation of the arts and sciences.

Such and similar trials and setbacks have often been taken for the cause of a tantalizing aspect of the first 600 years of Muslim history. While in the West the acquisition of Greek scientific knowledge in the late thirteenth century led within 150 years to Copernicus, within 300 years to Kepler and Galileo, and within 350 years to Newton, in the Muslim world the situation was quite different. There, after 300 years of meditation on Greek science, which takes us to the time of Avicenna (Ibn Sina), and even after twice that many years, which take us to Ibn Khaldoun, there were no signs whatever that a Copernicus, a Galileo, let alone a Newton would arise within a reasonable time. Such is a tantalizing situation not only because there was plenty of intellectual excellence as well as technical skill in the Muslim world. The situation is also tantalizing with respect to a possibility which did not materialize. What, one may ask, would have been the course of world history if a Galileo and a Newton had been Arabs, say living in Cairo, between 1000 and 1200, or even as late as 1300 or 1400? Since Newtonian science was quickly followed up by a vast technological development, the same would likely have been the impact of a Muslim Newton. This is all the more a likely conjecture because the energies of the Muslim world became activated and united by the Turks. The empire of Suleiman the Magnificent was much admired in the West for its organization, crafts, and security. It was only 200 years later that the Muslim world, insofar as it was largely a Turkish empire, became in the eyes of Western travelers the paragon of backwardness, intellectual and industrial. It is easy to guess the course of world history if at the time of the battle of Lepanto the Turkish navy had been propelled by steam engines. Two hundred years later, the Muslim world was hopelessly behind the West and still another hundred years later it lay wide open to Western colonial expansion. Such was the case to a large extent because the West had an indisputable technological superiority.

Western technology, at least in the form which gave in the eighteenth and nineteenth centuries a distinct advantage over the rest of the world, was not a fruit of manual dexterity or a result of socio-economic pressures. The transportational, electrical, and chemical industry as it developed in the West was mostly the work of engineers well trained in the Newtonian science of motion or mechanics. It was a science because every step in it was in strict order so that the third step or law was inconceivable without the second and the second without the first. The question of why science—a robust, modern science in which one step is not only preceded by another step, but in which one step generates another in a sequence that cannot be stopped—did not arise in the Muslim world, is therefore the question of why the first law of Newton, the law of momentum or impetus, was not formulated in the Muslim world. In still other words, the foregoing question is a question about the history of the theory of impetus in the Muslim world.

That history is very late and very short. Ibn Sina (Avicenna), who died in 1037, is the only Muslim scholar who speculated about inertial motion in a way that might have issued in the formulation of the theory of impetus. What he said about a hypothetical inertial motion in a hypothetical void has been repeatedly discussed during the past fifty or so years. It is clear from those discussions that even if Buridan had been familiar with Avicenna's views on inertial motion, they would not have helped him at all. For the crucial insight in Buridan's discussion of impetus is a theological point which is completely alien to Avicenna's thinking. This is an all-important point, because, being a Muslim, Avicenna could not be expected to have Buridan's view on creation, which provided the latter's crucial insight. Not only is there no evidence that Avicenna believed in creation, but also there is a vast evidence that he believed in Plotinian emanationism. It is a form of pantheism, the very opposite of creationism. According to Avicenna, God necessarily and eternally produces the world, but such a God is not a Creator.

Avicenna was not alone among Muslim thinkers to hold pantheistic emanationism. He is in fact a chief figure in the camp of those great Muslim scholars who put Aristotle's pantheistic philosophy above the Koran. The story is too well known to be reviewed here, however briefly, but it is a story which is the most decisive story for the fate and fortunes of science in the Muslim world. Equally decisive for that story is the basic attitude of the opposite camp, best represented by al-Ashari and al-Ghazzali and their occasionalism. They represented a Muslim orthodoxy which rejected the notion of scientific law in fear that it would impose constraints on the infinite power of Allah, the Creator.

A Muslim orthodoxy is not necessarily the Muslim orthodoxy, that is, the true teaching of the Koran and in particular of the Koran's true teaching on Creator and creation. Yet, can one, for instance, confidently say that the teaching of the Koran on creation would inspire a world view germane to science? The question is all the more important because a law of science is never about a particular phenomenon, about a single occasion, but about the universal relevance of that law for all such phenomena all across the universe. In other words, all science is about the cosmos, but not about any kind of cosmos. A cosmos, a universe, is useful for science only if it is the totality of consistently interacting things. The laws of that universe are consistently valid everywhere in it and all the time. A second characteristic is that such a universe is not necessary. If the universe were necessary, be it in the form of a necessary emanationism from God, who can generate only one kind of universe, the empirical investigation of such a universe becomes meaningless. The laws of such a universe could conceivably be fathomed on an *a priori* basis, through sheer mental introspection. This is in fact what Aristotle tried to do in his *On the Heavens* and after him all the major Muslim representatives of scientific thinking.

Revealingly, that list includes even an al-Farabi, who is well known in the history of philosophy as the one who first formulated the notion of the contingency of any being other than the Creator with respect to existence. Furthermore, he did so with an explicit view to the Koran's doctrine of creation, that is, with a view to Allah's absolute power and sovereignty over all beings. Yet, that doctrine was not such as to prevent al-Farabi from saying that the starry heavens were divine and existed necessarily, which is the very opposite to being contingent with respect to existence. If, however, the heavens existed necessarily, they had to be eternal and their motion, together with all motion anywhere else in the universe, had to be eternal. In such an outlook it was impossible to do what Buridan did. Buridan, who found in the Christian dogma of creation in time and out of nothing a crucial insight for a concept of cosmic motion with an absolute beginning, could also consider any lesser motion, such as the flight of a javelin, as a motion in which the mover was so superior to the moved thing that it did not have to remain in actual contact with the moved thing.

Was it impossible to do the same for an

al-Farabi or an Avicenna, or in general for Muslim thinkers, because perhaps of an ambiguity or a lack of sufficient explicitness in the Koran about creation in time and out of nothing? If such is the case then the question of the failure of Muslim scholars to formulate the proper impetus theory becomes the question of the true nature of the intellectual impetus provided by the Koran. It is a question which underlies the great ferment that has increasingly engulfed the Muslim world for the past thirty years. Those years are also the first and full exposure of the Muslim world on all levels to Western technology, which brings along an exposure to Western scientific thinking.

Not all fruits of that exposure are of course beneficial. Undue preoccupation with the quantitative, let it be scientific or technological, may atrophy man's sensitivity for qualities and values. This indeed took place in the West. The Muslim world is fully justified both in deploring the abuses of science and in trying to apply science in a humane way. But before that humane application takes place, there has to be science, that is, there have to be minds fully familiar with science. This, however, demands that there be minds fully imbued with the thinking underlying science especially if they wish to be creative in science.

The question is then whether the present-day Muslim reawakening, which is a reassertion of the role of the Koran in every facet of life, can be reconciled with the thinking demanded by science. Modern Muslim thinkers should be well aware that the problem of science versus faith or theology had once before been the crucial issue in Muslim culture. In that first confrontation, the confrontation between the Mutazalites and the Mutakallimum, no middle road was found for doing justice both to the Koran and to a science heavily conditioned by Aristotelian necessitarianism to which no Muslim corrective was forthcoming. Instead of a middle road there came extremist positions whose representatives charged one another with incoherence. Both sides seemed to have, however, one thing in common, a kind of schizophrenia. Thus the orthodox al-Ghazzali denounced the notion of scientific laws, while he also looked for them in his scientific work, whereas Averroes, who mainly cultivated science, paid plenty of lip service to orthodoxy.

Whether we shall see a repetition in the Muslim world today of what happened a thousand years ago, that is, whether in the Muslim world theologians and scientists go separate ways, remains to be seen. Certainly in today's Muslim world the chances are nil for a solution which 600 years ago was set forth by Ibn Khaldoun, whose philosophy of history, the *Muqaddimah*, is today the most widely read Arabic work in the Western world. That solution was in substance a pragmatic avoidance of the problem. Such had to be the case with an interpretation of the history of civilization based on the claim that whenever enough people leave behind the nomadic and agricultural life and gather into cities, they will develop the crafts and the sciences. This is, of course, true only if sciences are taken essentially as practical skills, however refined and useful. Whatever ancient civilization we consider, we find in its great cities a variety of practical skills, but never science properly so called. And as long as, for instance, the art of measurement remained a practical skill, it was not science.

Tellingly, Ibn Khaldoun did not take geometry, helpful as it can be in measurements, for science, that is, for an intellectual enterprise cultivated for its own intrinsic beauty and merit. Instead he praised its practical usefulness, lofty as that usefulness could be, such as the moulding of the intellect along rigorous reasoning. It was such a usefulness that in Ibn Khaldoun's estimate was the purpose of the study of geometry, which in his words does for the mind what soap does for the body. Ibn Khaldoun was not sympathetic toward a cultivation of geometry for its own sake. His diffidence of pure theories, and all theorems of Euclid are pure theories, comes through not only as he discusses theology (he obviously does not want to become involved in the age-old dispute between Mutazalites and Mutakallimum). He frowns also on speculations about general classes in the physical world, that is, what he calls secondary intelligibilia (the primary intelligibilia being purely logical definitions such as that the whole is greater than any of its parts and the like). Ibn Khaldoun, an outstanding representative of what I would call the fourteenth-century Muslim managerial upper class, is doubtful about the mind's ability to find with some certainty some such general classes, that is, as one would say today, for instance, classes of chemical elements, or classes of fundamental particles, or classes of galaxies and stars. As a top-level manager setting the course of the Muslim future, Ibn Khaldoun is a thoroughgoing pragmatist who invokes Muslim religion on behalf of his program for Muslim culture: "We must refrain from studying these things [general classes] since such restraint falls under the duty of the Muslim not to do what does not concern him. The problems of physics are of no importance for us in our religious affairs or our livelihoods. Therefore we must leave them alone." This is a tragic program indeed as far as the fate and fortunes of science in the Muslim world were concerned.

It is in connection with what became the science of science, physics, that Ibn Khaldoun's stifling pragmatism comes through most revealingly. To begin with, he is rather short on the subject with about 200 hundred words on it. His second hundred words refer to Avicenna and Averroes as the authorities to be consulted on physics. Prior to that he gives a brief account of the topics studied in physics. The last of those topics is "the beginning of the motion of bodies — that is, the soul in the different forms in which it appears in human beings, animals and plants."

Ibn Khaldoun wrote these fateful words in 1383, in full awareness that at that time all the crafts were on a higher level in the Christian West than in the Muslim East. Nicole Oresme had just died, but his and his master's, Buridan's, epoch-making words on the beginning of motion had already begun to be copied and carried from Paris to an ever larger number of European universities. Both Buridan and Oresme introduced their discussion of the beginning of motion with a reference to souls, that is, to intelligences which in Aristotle's theory were the instrumental causes of the motion of stars and planets. To be sure, as Christians, Buridan and Oresme could have retained those intelligences as identical with angels. But they refused to make room for angels in natural science. If there was to be a science of nature, then nature had to be liberated from all remnants of animism and for a simple reason. An anima or soul was not such if it did not have some measure of freedom of action. Now if a star or a stone had a soul, each could conceivably deviate from its predetermined path at any given moment and most unpredictably. If, however, this was possible, there could be no science which is strictly predictive about motion, or about any physical motion be it that of a plant or even of an animal.

In other words, if science was to be born, nature had to be de-animized. Animism, which was always an essential feature of pantheism, had to retreat in the measure in which the monotheistic doctrine of creation was gaining ground. Animism was no match, in the long run at least, for the impetus of the doctrine of creation when the doctrine was taken in terms of the New Testament. Its doctrine on Christ as the "only begotten Son," in whom the Father created everything, put a damper on any flirtation with the idea that any other being might be a divine begetting in terms of an emanationism which always carries an animist touch. Animism — the entire history of philosophical learnedness in the Muslim world is a witness — held its own when confronted with the impetus with which the Koran carried the doctrine of creation. In sum, the whole question of why science was not born within the Muslim milieu, or the question of why the physics of impetus was not formulated there, is in ultimate analysis a theological question, which can only be answered in terms of theology, such as the true nature of the Koran's impetus. The significance of this result will not seem minor at a time when religious revival is at work in the Muslim world with a greater impetus than perhaps ever before in its history.[1]

[1]For the quotations from Ibn Khaldoun's *The Muqaddimah* (that is, the preface and book I of his universal *History*), see ch. 6, available almost in full in the one-volume abridgment published by N.J. Dawood (Princeton, N.J., 1969) from F. Rosenthal's three-volume translation. For the context of Buridan's statement, see ch. 10, "The Sighting of New Horizons," in my *Science and Creation: From Eternal Cycles to an Oscillating Universe* (Edinburgh and New York, 1974); ch. 9, "Delay in Detour," is entirely devoted to the theological roots of the stillbirth of science within the medieval Muslim milieu. Further material on the same can be found in ch. 1 of my Gifford Lectures (Edinburgh, 1975 and 1976), published as *The Road of Science and the Ways of God* (Chicago and Edinburgh, 1978). For references to major studies on the early history of impetus theory see notes to ch. 9 and 10 in my *Science and Creation*. For the crucial support given by the dogma of Incarnation to the dogma of creation out of nothing within the Christian milieu, see ch. 3 of my *Cosmos and Creator* (Edinburgh, 1980; Chicago, 1981).