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Islamic Contributions to Modern Scientific Methods

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The author suggests that the rise of modern science was not a revolutionary development confined to modern Europe, but an evolutionary process that began in the Islamic civilization. He reviews those elements of the Islamic religious outlook that appear to have transformed science from the deductive methodology of the ancient Greeks to the inductive approach of modernity. Finally, he suggests that the supposed inherent tension between religion and science is a consequence of the sudden exposure of medieval European culture to the "new" scientific paradigm that had evolved in the Muslim World.

The idea of a dialog between faith and science is viewed somewhat differently in the Islamic world than it is in the modern West. For Islamic society, especially during the classical Islamic era about which I shall primarily speak, the same word, *'ilm*, was used for both religious and scientific knowledge. Indeed the pre-Islamic era was called the *jâhiliyya*, or "Age of Ignorance." In my book, *Signs in the Heavens: A Muslim Astronomer's Perspective on Religion and Science*, the main theme is that the presumed tension between religion and science is a modern Western phenomenon, an anomaly in the history of the world, definitely not part of Islamic thought.

I wish to address the Islamic contributions to the modern methods of science. Note that I will concentrate on the "methods" and not on the body of knowledge, although I will make some reference to that. Most people are aware that there is a distinction between modern science and ancient science, but I doubt that most understand the precise nature of that distinction. I wish to identify those differences because it is my contention that it is the Islamic civilization that developed the elements that are the key positive differences between ancient science and modern science.

There is no doubt that there was an ancient science. Anyone can look back in history at the names of the great Greek and Roman scientists. While many of their ideas have been discredited and much of their data has been superseded, that isn't a criticism of what they did, because modern science supersedes its own theories and data on a regular basis. Yet there is a fundamental difference between what they did and what is considered to be modern science. In particular, I think that the most important difference is one of epistemology. Epistemology is the theory of knowledge, the answer to the question, "How do you know what you know?" The stereotypical ancient scientist is Aristotle. Aristotle identified the essence of doing science as understanding why everything is as it is on the principle that it could be no other way. This concept is a reflection of an epistemology that I call rationalism. "Rationalism" is a word that gets used with many different meanings to different people. I want it to be very clear, therefore, that when I use the term "rationalistic science" I mean neither science that employs reason nor science that insists upon an adherence to reason. I mean a science in which reason is considered to be the dominant means for the ac-

quisition of knowledge, in which reason overshadows—if not completely replaces—any other means of the acquisition of knowledge. What this meant to the ancient Greeks was that if one began with the correct axioms, the correct premises, the correct starting points, that, by reason alone, one could completely deduce the nature of the universe. Modern science doesn't work that way.

Modern science works by what some call "the scientific method" and others say should be called "the scientific methods." Some call it "inductive science" or "inductive reasoning." Any really intelligent high school student could explain that modern science involves not only reason, but also observations of experiments. The idea is that reason must match observation, and theories must be tested by experiments, and that there is a great cycle in which theories inspired by observations are tested by experiments that lead to refined theories to be further refined or overthrown by yet more experimentation or observation.

Yet, this is only two-thirds of the story. There is another element of modern science that never gets mentioned. Since the existence of this third element as a method of modern science is undeniable, I can't help but think that the reason that it never gets mentioned is that people want to contrast modern science against the way of thinking that dominated the Middle Ages—and here I mean the Western European Middle Ages—that was more authoritarian. What Western European moderns viewed Medieval thinking to be was parodied by Molière in his play, *La Malade Imaginaire* (*The Hypochondriac*). The character of the doctor still had a medieval way of looking at things, and the doctor would begin every analysis with the introduction: "Aristotle dit..." ("Aristotle says..."), as if the fact that Aristotle said something constitutes a proof. Yet, referral to authority is an important element of the acquisition of scientific knowledge for all modern scientists. Most of what any scientist knows about a discipline, he or she has read in the scientific literature. Scientists do not check every detail of every theory upon which their own work is based. Scientists do not attempt to reproduce every experiment on which their data is based, nor do they duplicate every observation upon which their work is based. Scientists resort to the scientific literature and they incorporate, adopt, and build upon what they find there. Yet there are two important differences between the way the modern scientist uses the scientific literature and the way in which the medieval scientist approached the sacred or ancient scientific texts, the "ancient wisdom." Above all, modern scientists approach the literature *critically*; they do not assume that it is beyond question. And secondly, they require proper citation.

Even in ancient times, individual scientists can be found who seem very modern in their approach. Archimedes, for example, has always impressed me in this way. Nonetheless, the first civilization to nurture and produce a modern approach to science in which all three of these elements (reason, experiment or observation, and critically approached and properly cited authority) was the classical Islamic civilization. It was there developed in a gradual way. Westerners tend to look at it as a "scientific revolution" that took place in Western Europe: it was very abrupt, and very shocking in its effects on the culture. My understanding is that the West discovered it through their contact with Islam, and because it was thrust upon them so suddenly, it did indeed have a shocking effect on Western society.

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Let me return to Islamic science. The popular view in the West is that there was an ancient science that got lost and was then rediscovered and transformed into modern science by the West. The most one can hope to find in an American high school textbook is a statement along the lines of "The Arabs preserved the ancient science." It is as if Muslims had done the West a favor to serve as curators of their science until they could get back to developing it.

In the intellectual community, the historians of science are more sophisticated. They understand that there was scientific research done during the Muslim era; but even on this, they are divided on its significance. Some think that it was little more than caretaking. They know that knowledge was not simply preserved; but some intellectuals think that what was added was not anything of great importance, just details and flourishes, a few data points and minor refinements to the theories of the ancients. There are others who will admit that there was some important major new work, even whole new sciences, such as spherical geometry, and significant improvements to the old sciences. For example, consider the use of "zero." The Hindus had the concept of zero, but it was the Muslims who developed its use as a placeholder and, thus, made possible the powerful digital system upon which modern civilization is built. This computer in front of me has a memory filled with nothing but zeroes and ones. Were there no zero, its memory would consist only of ones and would be utterly useless. There are a few scholars who believe that what happened during the Islamic era was not just an increase in the sciences, however dynamic: it was, rather, a qualitative change in the way sciences were done, initiating or even completing the process of moving from the ancient way of doing science to the modern way of doing science. I have said that this was an epistemological transformation, going from a pure rationalism, as I defined the term, into a complex epistemology in which reason, observation and experiment, and authority play an interactive role, each one checking on the other.

Before I go into the details of how this was done, I want to justify my statement by pointing to the work of al-Ghazzali. Al-Ghazzali is a key figure. There are many who try to blame him for the downfall of the classical Islamic civilization, and there are others who think that he is the example *par excellence* of an important Islamic thinker. To me the important thing about al-Ghazzali is what he said about epistemology. It is important to consider how much of his view of the theory of knowledge in general matches the modern scientific approach to knowledge of the natural sciences. To understand al-Ghazzali, one must first understand that in the Islamic civilization there was an important school of scholars deeply impressed by the Greek philosophers. In fact, they were themselves called "the philosophers," the *falâsifa*. They were so heavily influenced by the Greeks that some scholars have tried to claim that they fell outside the mainstream of Islam, which is not true. They represented one side of Islamic thought. They were rationalistic in their approach, not as much as the ancient Greeks, for they were influenced by their own culture; but they did lean toward a worldview that came out of ancient Greece and conflicted with the Islamic view—not in the sciences, but in philosophy. For example, they believed that matter is eternal, not an Islamic concept. They thought the physical universe has always been here, always will be here, and has never changed in any fundamental way. Al-Ghazzali criticized this viewpoint. He attacked this view fundamentally, on epistemological grounds. He said that one could not learn about the reality of the universe by reason alone. He insisted that one also needs experience and the transmission of information from reliable sources.

Modern philosophers understand that logic is nothing more than a means of manipulating symbols. There can be no meaning assigned to the symbols by logic. The only reason a person can make meaningful statements about the world using logic is that experience allows the association of meanings with the symbols. If one looks around,

one discovers that much is known that is not reasoned from first principles. There are things one can know only by transmission. For example, I know that Thule, Greenland, exists. I do not know this by experience, for I have never been there, and I certainly could not derive its existence from first principles. No simple set of self-evident axioms will allow me to prove the existence of Thule, Greenland, by some complex but rigorous chain of reason. What has happened is that honest and sane people who have been there have told me of their experiences, and I have no reason to doubt them. In addition, maps by reliable mapmakers confirm their claims.

Similarly, one has to rely on reason as well as experience. Walking through the desert I may perceive a lake in front of me, but if the circumstances are those under which reason dictates that a mirage is possible, I am justified in doubting the evidence of my own eyes. Add to this the evidence of transmission from a reliable source—say, a map that shows there is no lake in this place. Then I may rely on that map to correct my erroneous sensory experience. When I become skilled at testing these three sources of knowledge against one another, then I know that I am getting close to the truth and I may rely upon it. This is the epistemology of al-Ghazzali, and its parallels can be seen with the methods of modern science.

Did this come about during the Islamic era, and if so, why? I wish to look at how Islam, in contrast with the Greek model, treats each of these elements. The Qur'an offers high praise for all three of these sources of knowledge. The Qur'an praises reason and repeatedly condemns the polytheists for their adherence to ideas that contradict their intellectual sense. At the same time it urges humankind to "look at God's signs in the heavens and in the earth." In contrast to Plato's view, for example, that the material world is a poor reflection of the true world of ideas, the Qur'an insists:

> Do they not look at the sky above them?—How We have made it and adorned it, and there are no flaws in it? (50:6)

> ...No want of proportion wilt thou see in the creation of [God] Most Gracious. So turn thy vision again: Seest thou any flaw? (67:3)

Unlike the Platonic and Neoplatonic disdain for the material world, the Qur'an says that the material world is as much as sign of God as the verses of the Qur'an. In fact, the same word (*ayat*) is used to mean both the verses of the Qur'an and the phenomena of the natural world. The implication is that if someone sees what appears to be a flaw in God's creation, he or she should go back and look again. The flaw is not in God's creation, but in either the theory or the observation. Creation is always in perfect accord with the natural laws by which God governs it.

Finally, the Qur'an speaks of the reliable sources, usually in terms of the prophets who have brought God's message to humankind. The development of the concept of care in the proper citation of sources seems to have taken place in Islamic scholarship. I do not find it earlier. The Islamic law is based not only on the Qur'an, but also on the practice of the Prophet Muhammad (peace be upon him). But what was the practice of the Prophet? In the early days of Islam, people would always say, "Prophet did this" or "Prophet said that." But how would it be known whether it was true or not? To avoid accepting unfounded rumors, Muslim scholars were confronted with the challenge of evaluating the reliability of these traditions, called *hadîth*. Early scholars, notably Imam Bukhari and Imam Muslim, compilers of the most highly respected collections of prophetic traditions, set out to develop a scientific means of historical analysis to determine the accuracy of these traditions. They invented a discipline of proper citation. They would demand to know every link in the chain of transmission from the Prophet's lips to their own ears. Then they would develop biographies of those transmitters to determine their reliability. Did they have good memories? Were they honest? Did contiguous links in the chains of transmission actually ever meet one another? This is the precedent for modern standards of citation. I cannot publish a scientific paper containing the assertion,

"Einstein says such and such," unless I give the publication in which he said it, or else plainly and plausibly claim that he said it to me directly, for example, in an unpublished lecture or private communication. This is the modern scientific approach to the argument from authority.

Unlike the commands of the capricious gods of polytheism, God's commands are fixed and eternal, reflecting Divine Unity in the unity of creation. The universe's conformity to divine law is a sign of the Creator's Unity. That the universe conforms to some objective law is an assumption that scientists must necessarily make in attempting to do their work. I must acknowledge that today there is a school of thought that denies the existence of an ontological objective reality. For the purpose of creating scientific models, however, even positivists must postulate operational principles as if such principles correspond to some hypothetical real world. Even positivists act as though there is a rule-based reality, even if they do not believe in it.

> When the night covered him over he saw a star: he said: "this is my Lord." But when it set he said: "I love not those that set."
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> When he saw the moon rising in splendor he said: "This is my Lord." But when the moon set he said: "Unless my Lord guide me I shall surely be among those who go astray."
>
> When he saw the sun rising in splendor he said: "This is my Lord: this is the greatest (of all)." But when the sun set he said: "O my people! I am (now) free from your (guilt) of giving partners to God.
>
> "For me I have set my face firmly and truly toward the One Who created the heavens and the earth, and never shall I give partners to God."
>
> (6:75-79)

The apparent motions of the stars and planets make a good place to look at the differences between the modern and ancient methods of analyzing the natural world. I start with the concept of precession. In watching a spinning top closely, anyone will notice not only that the top spins about its axis, but also that the axis itself moves in a slow circular motion. This circular motion of the axis is called precession. Like a top, the earth's axis precesses slowly and points at different places on the sky as the centuries pass. The North Pole of the earth's axis now points in the general vicinity of the North Star; but it is moving slowly away in a wide circle that will bring it back again to the North Star in about 26,000 years.

There are two important differences between the way the modern scientist uses the scientific literature and the way in which the medieval scientist approached the ancient scientific texts, the "ancient wisdom." Above all, modern scientists approach the literature critically; they do not assume that it is beyond question. And secondly, they require proper citation.

The Qur'an says that the prophet Abraham (peace be upon him) came to the conclusion that there must be only one God by looking objectively at the motions of the planets:

> So also did We show Abraham the power and the laws of the heavens and the earth that he might (with understanding) have certitude.

This apparent "wandering" of the place where the North Pole points was known to the ancient Greeks. Hipparchus, in compiling his catalog of the positions of the stars in 179 B.C.E., noticed how much the stellar positions had changed from the time of the Babylonians' star catalogs and gave a value for the

rate of precession. Three centuries later, Ptolemy, considered to be the greatest astronomer of antiquity, knew that the stars were no longer in the same place in the sky as they had been in Hipparchus' day. Ptolemy knew about precession and realized that a new star atlas was needed. What Ptolemy claimed to have done is to measure anew the positions of the stars in Hipparchus' catalog; and he issued a new catalog with revised positions. In fact, he did not measure their positions at all. What I'm going to say now will seem shocking, for I am speaking about the greatest astronomer of the ancient world. What Ptolemy did so shocked the historian of science Robert Newton that, in his book, *The Crime of Claudius Ptolemy*, he labeled Ptolemy a criminal for what he did. I claim that Ptolemy was not a criminal, but that he was working in that ancient Greek rationalistic paradigm in which what he did was not a crime, but was the obvious thing to do.

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Ptolemy took Hipparchus' catalog and, using Hipparchus's rate of precession, he calculated mathematically the corrections necessary to update the catalog (putting in some additional stars, as well) and published it, saying he had observed the positions. Hipparchus' value for the rate of precession, however, was slightly off. Had Ptolemy actually observed the stars from Hipparchus' catalog, he would have seen that the value of precession was off and could have made a correction to it, giving the world an improved value for the rate of precession. He did not.

Then came the days of the Muslims. They too knew that the star positions had changed and that new catalogs were necessary. What did they do? They measured the positions of the stars, they found that they did not match the theory, they scratched their heads and asked, "What's going on here?" Not understanding that Ptolemy and the ancients did their science differently, they incorrectly concluded that the rate of precession had changed since Ptolemy's day. They thought that the rate of precession must not be constant, that it must vary. So, they invented a complex theory to account for the variation. Later, they found that the rate of precession *is* constant, and they dropped the earlier value inherited from the ancients and replaced it with a completely new one.

For the Muslims, obviously, this rule, "If you see any flaw, look again," was taken very seriously, while for Ptolemy there was no such rule at all. Either that, or Robert Newton is right and Ptolemy *was* a criminal, which I do not believe. Like Aristotle, Ptolemy believed that everything is the way it is because it *must* be that way and *can* be no other way.

Another example relates to the detailed motions of the planets in the model known as the Ptolemaic system. The essence of the Ptolemaic system is not just the belief that the earth is at the center of the universe, although that is an important element. In Ptolemy's system, an ingenious and complex system of cycles, epicycles, and offset centers of velocity account for the motions of the planets. The details need not be given here, but the point is that it was very complex. This system was criticized by the Muslims on a variety of grounds, the significance of which has not been fully appreciated by modern Westerners who are obsessed simply with the question of whether the sun or the earth is at the center of the planetary system. The Muslim objections have nothing to do with whether the sun or

the earth is at the center. To make this clear, I shall concentrate on the orbit of the moon, because everyone agrees and always has agreed that the moon goes around the earth. In the 13th century, there was a great Muslim scholar named Nasir ad-Din at-Tusi, who was the director of the marvelous observatory at Maragha. The equipment at Maragha was so precise that it was unmatched in Europe until Tycho Brahe's famous observatory in the 16th century. At-Tusi was an excellent observer, as Tycho was. In addition, he was an innovative theoretician and a wonderful observatory director. The Maragha observatory was not just an observatory; it was scientific research institution with a library of 400,000 books. At-Tusi attracted scientists from around the world to work with him, even including a Chinese scientist. He devised a new theory to substitute for Ptolemy's. This new system replaced Ptolemy's complicated model with the ingenious devise of picturing the planets as rolling within a series of concentric cylinders (or spheres). This powerful mathematical model (which scientists will readily see is equivalent to a series of linked vectors) is not only easier to understand, but is easier to adapt to the actual observations, whatever they may be.

At-Tusi himself only sought to show that his model could account for the same motions as Ptolemy's, but his student Ibn ash-Shatir used at-Tusi's powerful model to try to resolve observational problems with Ptolemy's system. Most Westerners have not appreciated the degree to which Muslims were concerned with observational issues. They object that it wasn't until Johannes Kepler's day that the minute differences between planetary positions in Kepler's models and Ptolemy's could be discerned. They miss the whole point: a correct theory must account for all the observations of objects the sky, not just the planetary positions. In the 14th century, Ibn ash-Shatir realized that something was wrong with Ptolemy's theory of the moon. If the moon really moved in the big epicycle in Ptolemy's model, then it would move huge distances out and in, out and in from the earth. Every time it moved in closer to the earth, and it should appear huge—twice the size of what is observed. He used at-Tusi's powerful theory to account for the moon's size as well as its position. Hundreds of years later Copernicus published his theory of the moon moving in circles on circles. He mentioned at-Tusi, but he never mentioned Ibn ash-Shatir, even though the so-called Copernican system is just Ibn ash-Shatir's system with the order of the circles changed. Despite this overwhelming circumstantial evidence, some Westerners refuse to admit of a link. They protest that Copernicus could not read Arabic and Ibn ash-Shatir was never translated into Latin. They forget that Copernicus learned astronomy at the University of Padua. Even though he spoke no Arabic, others on the faculty there knew of the work of Ibn ash-Shatir and, it would be expected, would have mentioned it to the promising young student.

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This brings me to the question of why this process of change from ancient to modern methods in science, which was evolutionary in the Muslim world, was a "revolution" in Europe. Why did it cause such a crisis that,

to this day, people say that there is a conflict between religion and science? Most people point to the dispute as to whether the earth or the sun is at the center of the universe. Although all the classical Muslim scholars thought that the earth was at the center of the universe, they discussed the possibility that the earth might move, and they never found it to a theologically threatening concept. Al-Biruni dealt with the matter in the eleventh century, and although his principle monograph on the matter is now lost, in another book he says that this question must be answered purely on grounds of physics. It is neither a question of theology nor astronomy. Why is it not a question of astronomy? Because in Ibn ash-Shatir's theory, if the positions of the earth and the sun are switched, it makes no difference to the astronomical observations, which are absolutely identical.

To Muslims it makes no difference whether the earth is at the center or the sun is at the center; while in Europe, to claim that the sun is at the center was branded heresy. But why should the Europeans care? The reason is that the Ptolemaic system had become married to a theological structure of the European church, a structure known as "The Great Chain of Being." The Great Chain of Being goes back to the influence of Platonic, or Neoplatonic, philosophy on Church theology. This philosophy held God to be infinitely removed from humankind; the connection between them is not direct, but through this Great Chain of Being. Everything in the Chain has its place. God the Father is at the top, and beneath Him God the Son, the Spirit and the angels, and the Church, the Pope, the archbishops and so on down to the parish priest and the ordinary person, and so on. A person might believe this theological concept without identifying it with Ptolemy's science; but by this time in history, the identification had been made and, thus, the new science challenged the theology. To say that the earth is just circling about in space was to remove it from its place in the sacred Chain. It was a provocative thing to say. If the earth's place can be questioned, could not the Church's place be questioned, as well?

Galileo's case was a unique problem of his culture, with its marriage of theology and physics, confronted by a tide of new scientific ideas from another culture with another religion, and the Church's view that this science and this religion must be kept out of Europe.

Galileo Galilei always tried to separate the theology from the science; but unfortunately for him, he had a predecessor who did not. Giordano Bruno was an avid student of Islamic science and philosophy. Bruno argued not only that Copernicus is right—the earth goes around the sun—but that there are many other planetary systems like ours. Infinite numbers of them in universes, all equally under the God, removing the Church completely from the cosmological system.Unsurprisingly, Bruno was driven from Italy. He went to England, and then Germany, and then was invited back to Italy, where was called up before the Inquisition. He was found guilty of heresy and burned at the stake. So when Galileo was pressed on the point of his support for Copernicus, he recalled what happened to Bruno and he recanted. Ask anyone who writes on the tension between religion and science—regardless of whether they call for a reconciliation between them or deny its possibility—and they will all point to "the Galileo affair" as the stereotypical example of the problem. But Galileo's case was a unique problem of his culture, with its marriage of theology and physics, confronted by a tide of new scientific ideas from another

culture with another religion, and the Church's view that this science and this religion must be kept out of Europe. Such an overreaction had a negative effect on Western science.

This accident of history provoked a crisis in Western Europe and people were forced to take sides. The question of whether to side with the new science or with the old science somehow became whether to side with science or with religion. There were three different responses to the question, the same three that can still be heard to this day. First of all, there is what I call the "fundamentalist" reaction, to take a word out of its contemporary context; this reaction is to side with religion and against science. Then there is the secularist response: siding with science against religion. And thirdly, there's the reconciliatory response, which says, "Let's see if we can bring religion and science into some sort of agreement." This leads to the Catholic Renewal, the Protestant Reformation, and to all the discussions found today about reconciling religion and science. This last group believes there need not be a conflict, but that some effort is required to effect a reconciliation.

So far, I have spoken about the positive contributions of Islamic science that Western science has adopted; but there is one element of Islamic science which Western science has not adopted, and that is the spiritual dimension of scientific study. The mainstream Muslim scientists, including even the Greek-inspired *falâsafa*, insist that their science leads them to faith. Throughout history, I think that science and monotheism, as a rule, go side by side fighting against paganism and superstition. In the modern West, there is an exception, with some tension between spirituality and science. I think that it has been to the detriment of Western science that this spiritual attitude toward science was not accepted. My view is that the recovery of spirituality does not require accepting an outdated cosmology. In order to reconcile faith and science, if reconciliation is necessary, there is no need to return to the Great Chain of Being. On the contrary, the Qur'anic cosmology is precisely what is needed to have comfort both with modern science and with religious faith—at least faith in the one God. The idea is that the universe is an egalitarian universe with an infinite numbers of suns and planets—possibly even infinite systems of life. There may be life on other worlds. Why not? All equally under the one God.

I am not urging that modern physics be married to theology in the systematic way that the Church once did—and that some try to do today. Instead, the understanding of physics should be added to the lexicon of symbols that aid in understanding the Divine Power. This is not something new, neither within nor outside of Islamic thought. Isaac Newton is blamed for being the initiator of the mechanistic, materialistic view of science so prominent in the West. It is said that he conceived of a "clockwork universe" that, even if created by the Divine Hand, no longer required God for its operation. Here is what Isaac Newton wrote in the closing of his magnum opus, *Principia Mathematica*:

> This most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful Being. And if the fixed stars are the centers of other like systems, these, being formed by the like wise counsel, must all be subject to the dominion of One....[1]
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> This Being governs all things, not as the soul of the world, but as Lord over all; and on account of his dominion he is wont to be called Lord God...and Deity is dominion of God not over his own body, as those who fancy God to be the soul of the world, but over servants. The Supreme God is a Being eternal, infinite, absolutely perfect.... He is eternal and infinite, omnipotent and omniscient; that is his duration reaches from eternity to eternity; his presence from infinity to infinity; he governs all things, and knows all things that are or can be done.... We adore him as his servants....[2]

To the Muslim hearing these words, Newton sounds as if he were paraphrasing the Qur'an. There is no evidence that Newton ever read the Qur'an, but he did read the Book of

Nature, God's other book; and so no one should be surprised that these are the conclusions he draws. I think that what is needed today is to engage in more critical thinking, to eschew blind imitation. Critical thinking, I believe, is the road not simply to reconciling faith and science, but to eliminating the myth that there should be in any conflict or tension between them.

I say the words I have said, and I ask for God's forgiveness.

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Endnotes:

1. Isaac Newton, p. 369.
2. Ibid., p. 370.

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