2. Short Review about Achievements of Muslim Scholars

According to Ihsan Faruqi (2006), the immensity of the Muslims‟ contributions can best be realized by remembering their significant achievements, while European Emirates were struggling in the cult of barbarism, during the Dark Ages of Europe.

The contribution of Muslims in Medicine, Pharmacology, Alchemy, Physics, Astronomy, Algebra and Math sciences is indeed immense. Drawing on the medical lore of the Greeks, Persians and Egyptians, the Muslim world eagerly adapted all the available knowledge in these fields. The Muslim scientists made significant advances in the art of healing, especially in the use of curative drugs. The world‟s pharmacopoeia is rich with these discoveries. They established hospitals far and wide and provided medical care to prisoners. They carried out careful clinical observations of diseases. The greatest contributions of Islamic medical scientists to Europe in the Middle Ages were carried out by Al-**Razi** (Rhazes in Europe, 865-925), who wrote an important encyclopedia of medicine, Al Havi (Continens). It sums up the knowledge of medicine possessed by the Scientists in the 10th century and was translated and published in Sicily in 1279 [9]. He also wrote on physics, mathematics, astronomy and optics, but these writings could not be preserved. Also, Abu Al-Nasr Al-**Farabi** (870-950). Al-Farabi contributed considerably to science, philosophy, logic, sociology, medicine, mathematics and music. His major contributions seem to be in philosophy, logic, sociology music and, medicine of course, stands out as an Encyclopedist.

Also, Abul Qasim **al-Zahrawi** (known in the west as Abulcasis - father of surgery) was born in 936 in Zahra beside Cordova (Spain). He became one of the most renowned surgeons of the Muslim era and was physician to King Al-Hakam-II of Spain. It is clear from El Zahrawi's history that he devoted his life to the study of medicine and surgery in particular. El Zahrawi wrote a 30-volumes medical encyclopaedia, which included chapters on surgery, orthopaedics, ophthalmology, pharmacology, and nutrition. This book was known as *At-Tasrif* and contained his experience during almost 50 years of teaching and practice. Amazingly, he fully described many operations, such as the extraction of eye cataracts, tonsillectomy, tracheotomy, using a metallic bladder syringe and speculum to extract bladder stones, as well as healing injuries to bones, reducing a dislocated shoulder (called today, '*Kocher's method'*), and was the first to describe the so-called *"Walcher position"* in obstetrics; the first to depict dental arches, tongue depressors and lead catheters and the first to describe clearly the hereditary circumstances surrounding haemophilia. He also described ligaturing of blood vessels long before Ambroise Pare. He insisted on compliance with ethical norms and warned against dubious practices adopted by some physicians for purposes of material gain. Once *At-Tasrif* was translated into Latin in the 12th century, he was known as the chief of surger. For instance, Jaques Delechamps (1513-1588), a French surgeon, made extensive use of At-

Tasrif in his elaborate commentary, confirming the great prestige of El Zahrawi throughout the Middle Ages and up to the Renaissance [7].

Ibn Sina, also known in the West as **Avicenna** (980 – 1037) was also one of the most significant physicians, polymath and astronomers Muslim scientists[4], who wrote the features of the Islamic Golden Age. Out of his 450 works he is believed to have written, only 240 (on philosophy and medicine) have been found and the rest disappeared!

His most famous works are ***The Book of Healing*** and ***The Canon of Medicine***, which became a standard medical text at many universities.

Fig. 1. The Canons of medicine book by Avicenna, Latin translation found at the University of Texas Health in San Antonio, USA.

3. Short Review of Achievements of Muslim Scholars in Physics

The classical (Newtonian) mechanics have indeed benefitted from the original contribution of the Islamic era scientists in math, astronomy and Physics. For instance, in 1000-1030, Abul Rayhan **al-Biruni** introduces experimental scientific methods in **statics** and **dynamics**, and unified them into the science of **mechanics**; he also combined the fields of hydrostatics with dynamics to create the field of **hydro-dynamics**, which he helped to mathematize and realize that **acceleration** ($a=F/m$) is connected with non-uniform (variable speed) motion.

In 1000-1030, Ibn **al-Haytham (**Latinized as: Alhazen) and **Ibn Sina** (Latinized as: Avicenna) developed the concept of **inertia** (known as Newton‟s 1st law) and the concept of momentum ($p=m.v$).

In 1100-1138, Abū-Bakr ibn Yahya **ibn al-Sāyigh (**Avempace**)** developed the concept of a **reaction force** (known as Newton‟s 3rd law).

In 1130-1165, Hibat Allah Abu'l-Barakat **al-Baghdaadi** discovered that force is proportional to acceleration rather than speed, a fundamental law in classical mechanics (known as Newton‟s 2nd law).

In 1121, **Al-Khazini** published *The Book of the Balance of*

Wisdom, in which he developed the concepts of **gravitational potential energy** and gravity at-a-distance (known as Newton gravity law).

Also, the reflecting telescope, he invented, was strongly dependent on the discoveries of Al-**Kindi** (801-871) about the diffraction of light. In fact, al-Kindi developed a theory "that everything in the world emits rays in every direction. This theory had an influence on later scholars such as Ibn al-**Haytham**, Isaac Newton and Roger Bacon

Actually, a typical debate of ancient Greece scientists was about light which is necessary for vision; when we see an object, is it because light goes from the object to our eyes, or from our eyes to the object? Euclid, Ptolemy, and Aristotle didn‟t know, and their starting point was always axioms and theoretical arguments, not physical experimentation. On the other hand, the mathematician Ibn **al-Haytham** did a whole series of experiments, with darkrooms with pinholes (like camera) and other devices, to prove that light rays enter the eye from the outside. And he founded the theory of light refraction and reflection. This work of Ibn al-Haytham, based on experimental observation in the year 100, represents the birth of scientific experimental method. His approach was then translated into Latin and taken up centuries later by Roger Bacon, Francis Bacon, and Galileo.

In 1687, Isaac **Newton** published his *Philosophiae Naturalis Principia Mathematica* [1], in which he formulated Newton's laws of motion and Newton's law of gravity, after centuries of their discovery and publishing, by Islamic era scientists!

This is not an accusation for Isaac Newton, who was the president of the Royal Society of London, who also said after his discovery of the clear man-made changes of the Bible: “Who says the truth will be killed”. Therefore, he burned so many of his papers and books, before his death[5].

4. Short Review of Achievements of Muslim Scholars in Mathematics

The study of astronomy, mathematics and other sciences in the Islamic world during the middle Ages was triggered by their belief in God and the Qur‟an calls to investigate through the Earth and heavens. It was also encouraged by strong intellectual policies implemented by specific caliphs and rulers that allowed scientific knowledge to develop in many areas during their reign, and it turned out that certain scholars became received further support for continuing to develop certain sciences. As these sciences received wider attention from the elite, more scholars were invited and funded to study particular sciences. For example, Muhammad ibn Mussa Al-**Khawarizmi** (780-850), who codified the secret Indian numerals and developed mathematics to new horizons. In particular, Al-**Khawarizmi** invented the “0” digit, which facilitated the decimal computing and has been the basis of binary systems in modern digital computers and coding (ciphering) in modern information theory. In fact, the word “cipher” is an Arabic word, which means nothing or zero “0”. Also, the logarithms (log) hold this name after its inventor name “Al-khwrism”.

Al-**Khwarizmi**'s treatise on algebra (*The Compendious Book on Calculation by Completion and Balancing*, 813–833) presented the first systematic solution of linear and quadratic equations [13]. Because he was the first scientist to treat algebra as an independent science and introduced the methods of "reduction" and "balancing" (the transposition of subtracted terms to the other side of an equation, that is, the cancellation of like terms on opposite sides of the equation), he has been described as the father or founder of algebra. The term *algebra* itself comes from the title of his book (the Arabic word *al-jabr* or algabr meaning "completion" or "rejoining"). His name gave rise to the terms *algorism* and *algorithm.* The translation of his textbook on arithmetic (*Algorithmo de Numero Indorum*) introduced the decimal positional number system to the Western world.

Also the origins of the principles of calculus mathematics were established by Thabet **ibn Qurra** (836-901), about 800 year before Newton [14].

Fig. 2. The Compendious Book on Calculation by Completion and Balancing () by Muhammad ibn Musa Al-Khwarizmi (780-850).

It is also worth noting that the general binomial expansion theory in Algebra was already developed by **Al-Samaw'al** (1130-1180). The first formulation of the binomial theorem and the table of binomial coefficients can be found in a work by **Al-Karaji** (953-1023), quoted by Al-Samaw'al in his "al-Bahir" book. Al-Karaji described the triangular pattern of binomial coefficients and provided a mathematical proof of both the binomial theorem, using an early form of mathematical induction.

The Persian poet and mathematician Omar **Khayyam** (1048-1131) was probably familiar with the binomial expansion formula to higher orders, although many of his mathematical works are lost[6]. Actually, Al-Khayyam was the first to consider the three distinct cases of acute,

obtuse, and right angle for the summit angles of a Khayyam-Saccheri quadrilateral. His elaboration to prove the parallel postulate was significant for the further development of geometry, as it clearly shows the possibility of non-Euclidean geometries.

Al-**Kāshī** (1380 –1429) was born in Persia (Iran) and died in Samarkand (Uzbekistan), . At this period, this region was reined by Shah Rokh and his Turkish wife, Goharshad, who were very interested in all sciences like older Caliphates. They encouraged their people to study various sciences and incubated many mathematicians and scientists into their Ughlu University. Al-**Kashi** produced sine tables to eight decimal digits of accuracy for each degree. He also produced tables dealing with transformations between coordinate systems on the celestial sphere, like the transformation from ecliptic system to the equatorial system. He also wrote the book Sullam al-Sama on the determination of distances and sizes of heavenly bodies, such as the Earth, the Moon, the Sun, and Stars. Al-Kashi also invented the *Plate of Conjunctions*, an analog computer instrument used to determine the time of day at which planetary conjuncttions will occur and perform linear interpolation. Also, al-Kashi invented this algorithm for extracting the square root of any number. Until the advent of electronic calculators in 1970s, this method was still taught to pupils in the United States and Europe. As Al-Kashi was the first to provide an explicit law of cosines for triangulation, the law of cosines is named in French "*Théorème d'Al-Kashi"*.

Many fair researchers call al-Kashi "the first modern mathematician" because he was the first to optimize solutions to, by inventing iterative algorithms. Certain types of equations, such as cubic polynomials and trigonometric equations, were too difficult to solve exactly, but he figured out how to solve them by a method of approximation now known as ***fixed-point iteration***, which is attributed to Isaac Newton today!

The 14th-Century historian **Ibn Khaldūn** summed up the Islamic view of geometry by writing, "It should be known that geometry enlightens the intellect and sets one‟s mind right.

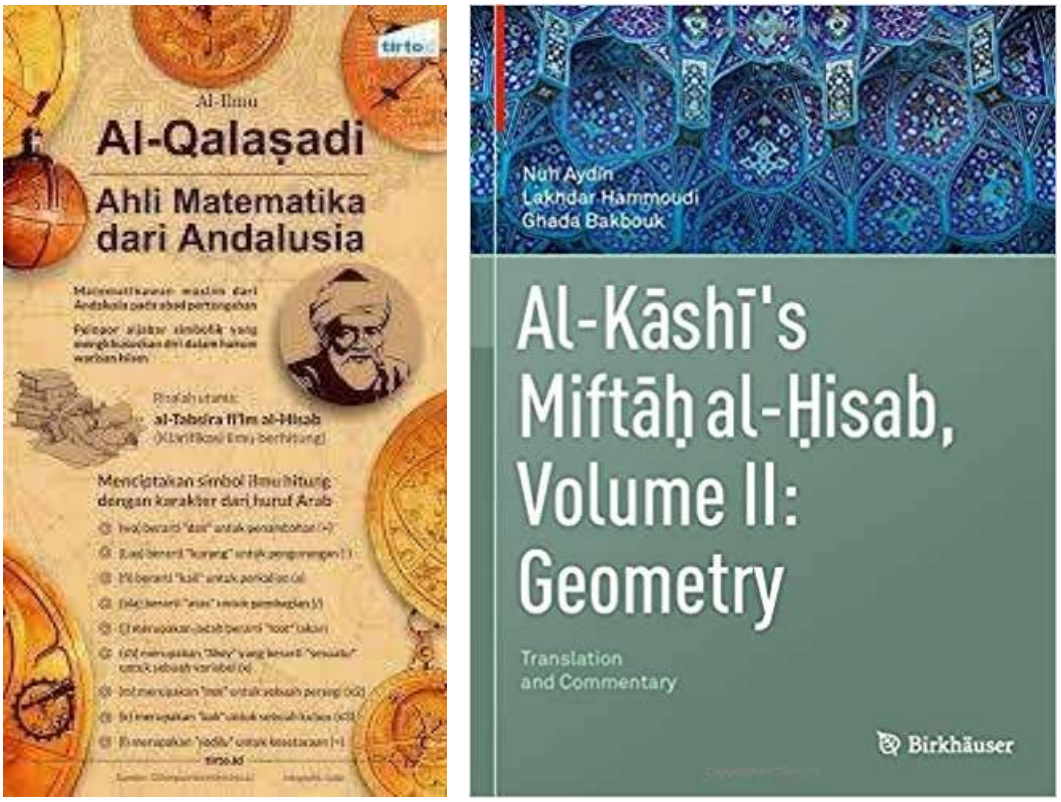

Fig. 3. Cover of one of Al-Kashi books and English translation of another one [22]. Miftāḥ al-Ḥisab (Key to Arithmetic) was unknown to researchers until the mid-20th

Al-Qalasadi or **al-Kalasadi** (1412-1486**)** was a Spanish Muslim mathematician who took the first steps toward the introduction of algebraic symbolism by using letters in place of numbers. Al-Qalasadi was brought up in Bastah (now Baza) which is north-east of Granada city in Spain. He moved south, away from the war zone, to Granada where he continued his studies, and to North Africa and Egypt. The last remaining parts of the Muslim state were under severe attack from Aragon and Castile Christians. However, al-Qalasadi taught and wrote some of his major works during this period. His contributions to algebraic symbolism were in using short Arabic words, or just their initial letters, as mathematical symbols. In particular he introduced the following symbols:

wa meaning "and" for +
illa meaning "less" for –
fi meaning "times" for ×
ala meaning "over" for ÷
j from jadah meaning "root"
sh from shay meaning "thing" (*x, the unknown*)
m from mal for x^2
k form ka'b or cubic for x^3
l from equal for =

Al-Qalasadi wrote several books on arithmetic and one on algebra. Certainly al-Qalasadi wrote original works. His major treatise was *al-*

Tabsira fi'lm al-hisab (Clarification of the science of arithmetic), which was a difficult and therefore he followed up it by simpler versions such as *Unveiling the science of arithmetic*.

5- Astronomy, Geography and Navigation

When we talk about astronomy, we"d remember the Islamic Era scientists and Muslims" contributions, which are clearly reflected in the Arabic names of many stars [18]. When the head of NASA, Charles Bolden, was visiting Cairo, and he mentioned that President Obama told him that NASA needs to get more scientific contributions from a broader range of nations , including the Muslim nations, who have made "historic contribution to science, math, and engineering."

In fact, Muslims absorbed all the astronomical, geographical and navigational science of the ancient world and added their own contributions. For this purpose, they invented the astronomical observatories as we know them today, and applied mathematics to study the motion of the moon, stars, to tell time during the day and night, to predict the times of sunrise, sunset, and to determine the directions, altitudes and azimuths for travelling and navigation purposes.

For instance, ibn Kathir al-**Farghani**, born in Transoxiana, was one of the most distinguished astronomers in the time of Al-Mamun and Al-Mutawakkil Caliphs (800-). He wrote *"Elements of Astronomy"* (*Kitab fi al-Harakat al-Samawiya wa Jawami Ilm al-Nujum* i.e. the book on celestial motion and thorough science of the stars), which was translated into Latin in the 12th century. He determined the diameter of the earth to be 6,500 miles, and found the diameters of the planets. The *book'Elements'* of Al-Farghani has been used, and Sacrobosco's *Sphere* was evidently indebted to it. It was from *'The Elements'* that Dante derived the astronomical knowledge displayed in the *'Vita nuova'* and in the *'Convivio'*. The figure 4 shows model for the motion of the planet Mercury as depicted by Ibn **al-Shatir** (1304–1375), who was a mathematical astronomer in Damascus, Syria in 1350.

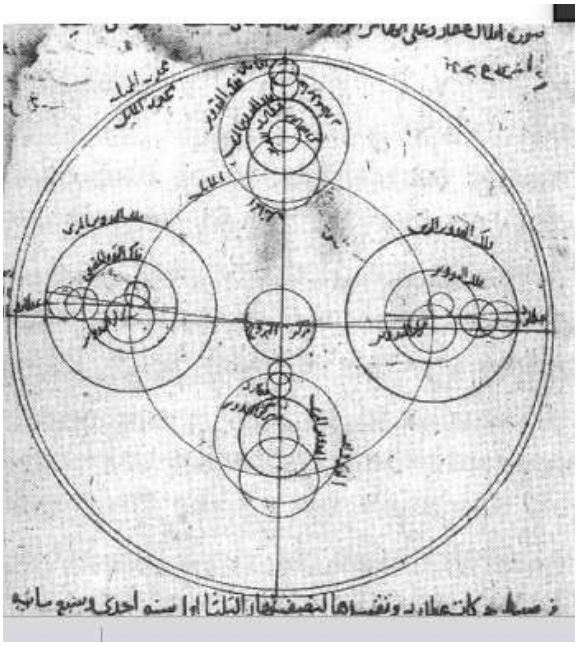

Fig. 4. Model for the motion of the planet Mercury as depicted by Ibn al-Shatir

Another distinct example of early investigations about cosmology, can be found in the work of Fakhru-Din **al-Razi** (1149–1209), in dealing with his conception of physics in his Book Matalib [19]. He criticized the idea of the Earth's centrality (Geocentrism) within the universe, and explores "the notion of multiverse in the context of his commentary" on the Qur'anic verse, "All praise belongs to God, Lord of the Worlds." He raises the question of whether the term "worlds" in this verse refers to "multiple worlds within this single universe or cosmos, or to many other universes or a multiverse beyond this known universe." He rejects the Aristotelian view of a single world or universe in favor of the existence of multiple worlds and universes, a view that he believed to be supported by the Qur'an.

In contrast to ancient Greek philosophers who believed that the universe had an infinite past with no beginning, Islamic Era philosophers developed the concept of the universe having a finite past with a beginning, on the basis of Qur'an verses. The Qur'an says "the heavens and the earth were joined together as one unit, before We clove them asunder" (21:30). This was 1400y later considered in the the so-called Big-bang theory [20].

Muslims were also expert navigators. For millennia, they had boldly traversed the Indian Ocean in quest of trade with India and with the east coast of Africa. They dominated the Mediterranean Sea for about five centuries. They had anticipated Columbus in venturing into the Atlantic, as far perhaps as the Azores, and probably reached America before him [21]. It is safe to say that Columbus would never have ventured forth over the Atlantic or even have conceived the idea of such a voyage without these Muslim skills, which they bequeathed him, and without the concept of a round earth.

Ibn **Battutah** (1304-1369) was the greatest Muslim traveler who traversed around 120,000 kilometers from Morocco to North Africa, Egypt, Arabia, Yeman, Asia Minor, Central Asia, Byzantium, Bulgaria, Persia, to India, China, Ceylon and Sumarta back to Spain via Syria and Morroco in 1349 [24]. In his book: *Rihla*, he mentioned his arrival to Constantinople at the end of 1332, were he met the Byzantine emperor Andronikos-III. From there, he journeyed south to Afghanistan, and then crossed into India. From there, he made his way to Delhi and became acquainted with the sultan, Muhammad bin Tughluq.

Fig. 5. Ibn Battuta (1304-1369) and his known Travels of (Source: http://tarihvemedeniyet.org/2010/01/haritalarda-uc-ortacag-gezgini.html, 2018)

6-Conclusions

The Islamic Era extended about 10 centuries (620-1640), up to the present civilization (usually considered after Isaac Newton, 1642 – 1726).

Islamic Era scientists took things far beyond Greek science and mathematics. Unlike Greeks, sciences were pushed in the realm of experiment and the interplay between theory and practice, well before Roger Beacon, Francis Beacon, Gallilio and Isaac Newton.

Prof. Dr. Muhammad EL-SABA

In particular, between the 8th and 15th centuries, scholars and researchers working from the great Caliphate state from Cordoba in Spain extending to Asia, India, and Uzbekistan have advanced our knowledge of astronomy, chemistry, mathematics, medicine and philosophy to new horizons. It was al-Khwarizmi, for instance, who developed algebra in 9th century, drawing on work by mathematicians in India; al-Jazari, a Turkish engineer of the 13th century whose achievements include the crank, the camshaft, and the reciprocating piston; Ibn Sina (Avecena), whose textbook Canon of Medicine wasa a standard work in Europe's universities until the 1600s. These scientists were part of a sophisticated culture and civilization that was based on belief in God - a picture which helps to scotch the myth of the 'Dark Ages' in which scientific advance faltered (Ehsan Masood, 2009). According to Sally Ragep, a historian of science in Islam, estimated in 2019 that "tens of thousands" of Islamic Era manuscripts (in Arabic language) in mathematical sciences remain unread (or intentionally hidden by pretenders of originality of their research), which "reflect individual biases and a limited focus on a relatively few texts and scholars". We try to shed some light about some scientists of this epoch, taking the reader on a journey through the Islamic empires of the middle ages, the cultural and religious circumstances that made this revolution possible, and its contribution to science in Western Europe.

Extension of Islamic Califates and States in the Golden Era.

1-Period of Righteous Caliphs (630-60)

The first four Caliphs, who truly followed the Quran and the Prophet Muhammad tradition (Sunnah), are known as the „Rightly Guided Caliphs". They are Abu Bakr, Omar, Uthman and Ali. Main characteristics of their rule are:

- assumed office only with the nomination and consent of the people and never imposed themselves through force,
- governed the people through „Shura" (consultation system, from which democracy was derived) and were not inclined toward tyranny, oppression and dictatorship,
- state and its functionaries were committed to the establishment of a just moral order.

2-The Umayyad Dynasty (661-1750)

The Umayyad Caliphate, established in 661 A.D., was to last for about a century. Damascus (the capital of Syria now) became capital of the Islamic world, which stretched from the western borders of China to southern France. Not only did the Islamic conquests continue during this period through North Africa to Spain and France in the West and to India and China in the east.

3-The Abbasids Dynasty (750-1258)

The Abbasids, who succeeded the Umayyads, shifted capital to Baghdad

(Capital of Iraq now). Baghdad soon developed into an incomparable centre of lore and learning. It contained two of the world‟s oldest and greatest universities. While the Abbasids ruled in Baghdad, a number of powerful dynasties, such as the Fatimids, Ayyubids and Mamluks, held power in Egypt, Syria and Palestine. Abbasids ruled for over 500 years. Their power waned gradually. At the end, they became symbolic rulers bestowing legitimacy upon various kings and princes, who wielded actual military power. When Holagu (Halaku Khan), the Mongol ruler, captured Baghdad, in 1258, Abbasid Caliphate ended. His armies destroyed the metropolitan city, including the big libraries.

4- Crusades (-1187),

The most important event of the era as far as the relation between Islam and the west is concerned were the Crusades, declared by the Pope and some European kings. The declared purpose of these Crusades was torecapture the „Holy Land‟, especially Jerusalem. After initial success, as tiny European governments were established in parts of Syria and Palestine, Muslims finally prevailed. In 1187, Saladin (Salahuddin Al- Ayubi), the Muslim leader, recaptured Jerusalem and defeated the Crusaders.

5- Umayyad State in Spain (750-1492)

When the Abbasids captured Damascus, one of the Umayyad princes escaped into Spain, where he established an Umayyad princedom, starting the golden age of Islam in Spain. Cordoba became the capital and Europe‟s greatest city, in terms of culture. In the mean time, various local dynasties were held in North Africa until two powerful Berber dynasties succeeded to uniting the North Africa with Spain in 12th and 13th centuries. The Sharifids of Morocco succeeded Berbers, who still rule the country. Whatever, Muslims‟ power waned in Spain with the epochal defeat of the last Muslim dynasty in Granada in 1492, ending nearly 800 years of Muslim rule in Spain to an end.

Il- Khanids & Timuraids State in Asia (1369-1500)

After The Mongoloid Invasion of the eastern lands of Islamic States, they ruled from the Sinai to India for a century. They soon converted to Islam and were called the Il-Khanids, a Central Asian dynasty. The Timuraids replaced the Il-Khanids and ruled the area from Samarqand as capital from 1369 to 1500 A.D., delaying expansion of the Ottoman Empire.

6-The Ottoman State (1453-1924)

The Ottoman State of Turks rose to political prominence and prevailed over the whole of Anatolia and parts of Europe. In 1453, Muhammad, „the Opener‟, captured Constantinople, putting an end to the Byzantine Empire. The Ottomans conquered much of Eastern Europe and nearly the whole the Arab world. Their power reached its zenith with Suleyman, „the Canonic‟, whose armies reached as far as Hungary and Austria[7]. From the 17th century onward with the rise of Western European powers and later Russia, the power of the Ottomans began to wane. Nevertheless they remained a force to be reckoned with until the First World War,

7-Islamic States in Persia (1502-1736):

Islamic Era Scientists

While the Ottomans were concerned mostly with the western front of their empire, in Persia to the east a new the Safavid dynasty ceased power in 1502. The Safavids state flourished and spanned over two centuries. Arts and literature flowered during this period. Isfahan, the capital, became one of the most beautiful cities with its blue tiled mosques and exquisite houses. The Afghan invasion of 1736 put an end to Safavid rule and prepared the independence of Afghanistan. The Zand dynasty soon took over, but ended by the Qajars in 1779. Qajars ruled from Tehran (the Capital of Iran now) until 1921 when the Pahlavis overrun their state.

8- Islamic States in India

As for India, Islam entered into the east of the Indus River peacefully, since Umayyads. Gradually, Muslims gained political power beginning in the early 13th century. But this period, which marked the expansion of both Islam and Islamic culture, came to an end with the conquest of much of India in 1526 by Babur, one of the Timurid princes. He established a powerful empire, which provided rulers like Akbar, Jahangir and Shah Jahan. It finished with the the British invasion in India, in 1857.

9-Malaysia And Indonesia Farther East (1100-)

In the Malay world, Islam began to spread in the 12th century in northern Sumatra. Muslim kingdoms were established in **Java**, Sumatra and the mainland Malaysia. Despite the later colonisation of the Malay lands, Islam spread in the area covering present day Indonesia, Malaysia, the southern Philippines and southern Thailand. It is still a dominating force in islands in the Farther East.

10- Africa (630-now)

Islam entered in East Africa, at the very beginning of Righteous Caliphs‟, when Egypt was opened by

However, the expansion of Islam remained confined to the north and only Sudan and Somalia. West Africa felt the presence of Islam through North African traders who traveled south of the Sahara. By the 14th century, there were already Muslim princedoms in such areas as Mali, Nigeria and Timbuktu in West Africa. Harare in East Africa had become seats of Islamic learning. Gradually, Islam penetrated both inland and southward, down to South Africa and Cape town.

Reference: Prof. Dr. Muhammad EL-SABA