Scientific Contributions of the Islamic Medieval Period to the West:
Ibn Al-Haytham’s Legacy of Optics

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of
Master of Arts in Anglo-American Studies

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Declaration:

I, Zaidi Khadidja, A candidate of Master at the Department of English, Larbi Ben M'hidi University, I do hereby declare that the substance of the dissertation entitled “Scientific Contributions of the Islamic Medieval Period to the West: Ibn Al-Haytham’s Legacy of Optics” in partial fulfillment of Master of Arts Degree in Anglo-American Studies is my own original work, and it has not previously, in its entirety or in part, been submitted at any university.

Date: .... / .... / 2018

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Signature of the candidate

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Dedication:

To the source of my inspiration and strength: my mother and my sister

To my nephews Akram, Abd Arrahman, Rania, and Israa. I hope that you will make the quest for knowledge a supreme goal in your lives.
Acknowledgments:

Praise be to God who illuminated for me the way of science, helped me, and guarded me until I reached this level. I would like to express the deepest appreciation to my supervisor Mrs. Boudjelit Amina, whose guidance and persistent help made this dissertation possible. I am very thankful to Mrs Ghennam Fatima who honored me by being my examiner and for her efforts to assess this work. I cannot find words to express my gratitude to my mother, my sister, my brothers Mohamad and Salah for their support and encouragement, and I am indebted to my colleagues and friends especially Romaisa and Miada for their help and great advices. Lastly, I offer my regards and blessings to all of those who supported me even with a word during the completion of the project.
Abstract:

During the Medieval period, Muslims established one of the most impressive civilizations in the history of mankind. The Islamic civilization’s development was garlanded with the quest for knowledge and sciences, which was upheld by the principals of Islam and Hadith along with the Arabic language. Muslim scientists and thinkers made pioneering contributions to sciences, which touched all aspects of their lives and resulted social, cultural, and intellectual prosperity and urbanization. Thereby spreading their beam of culture, ideas, thoughts, and sciences that influenced the whole world especially Europe. Abu Ali Al-Hasan Ibn Al-Hasan Ibn Al-Haytham was one of the most prominent Muslim physicists, whose theories and experiments revolutionized this field and brought out the science of optics to light. Not to mention his notable works in different scientific fields, which laid the groundwork and formed several famous modern theories. The aim of this dissertation is to recall the scientific contributions of Ibn Al-Haytham and other Muslim scientists, and to prove the great effect it had on the rise and advance of the Western modern civilization. Despite that this fact has been subjected to various attempts of distortion by many Western scholars, who tried to hide the Islamic scientific victories behind the guise of the Western domination and spotting the lights on the Greek works as the first source of all sciences. But history was keen to keep all evidences that disapproved all the Western libeling and allegations.

Key words: the Islamic Medieval period, Civilizations, scientific contributions, optics, influence, the West.
Résumé :

Pendant la période Médiévale, les Musulmans ont établi l'une des civilisations les plus impressionnantes dans l'histoire de l'humanité. Le développement de la civilisation Islamique était guidé par la quête de la connaissance et des sciences, qui était soutenue par les principes de l'Islam et de le Hadith avec la langue Arabe. Les scientifiques et les penseurs Musulmans ont apporté une contribution pionnière aux sciences, qui ont touché tous les aspects de leur vie et ont abouti à la prospérité et à l'urbanisation sociales, culturelles et intellectuelles. Diffusant ainsi leur faisceau de culture, d'idées, de pensées et de sciences qui ont influencé le monde entier, en particulier l'Europe. Abu Ali Al-Hasan Ibn Al-Hasan Ibn Al-Haytham était l'un des physiciens Musulmans les plus éminents, dont les théories et les expériences ont révolutionné ce domaine et mis en lumière la science de l'optique. Sans parler de ses travaux remarquables dans différents domaines scientifiques, qui ont jeté les bases et formé plusieurs célèbres théories modernes. Le but de cette thèse est de rappeler les contributions scientifiques d'Ibn Al-Haytham et d'autres scientifiques Musulmans, et de prouver le grand effet qu'elle a eu sur la montée et la progression de la civilisation moderne Occidentale. Malgré le fait que ce fait a été soumis à diverses tentatives de distorsion par de nombreux savants Occidentaux, qui ont essayé de cacher les victoires scientifiques Islamiques derrière l'apparence de la domination Occidentale et de repérer les lumières sur les œuvres Grecques comme la première source de toutes les sciences. Mais l'histoire tenait à garder toutes les preuves qui désapprouvaient toutes les libations et allégations Occidental.

Mots clés : la période Médiévale Islamique, la civilisation, l'optique, l'influence, les contributions scientifiques, l'Occident.
ملخص:

خلال فترة العصور الوسطى، أسس المسلمون واحدة من أكثر الحضارات إثارة للإعجاب في تاريخ البشرية.

تطور الحضارة الإسلامية ككل بالبحث عن المعرفة والعلوم، التي أدتها تعاليم الإسلام والحديث الشريف إلى جانب اللغة العربية. قدم العلماء والمفكرون المسلمين مساهمات رائدة في العلوم، والتي تطرقت إلى جميع جوانب حياتهم وأدت إلى تحقيق الرخاء الحضري، الاجتماعي، الثقافي والفكري. وبالتالي نشر شعاع الثقافة، الأفكار، الآراء، والعلوم التي أثرت على العالم بأسره وخاصة أوروبا. كان أبو علي الحسن بن الحسن بن الهيثم واحداً من أبرز علماء الفيزياء المسلمين، حيث أحدث نظرياته وتجاربه ثورة في هذا المجال وأخرجت علم البصريات إلى الضوء. ناهيك عن أعماله الجيدة بالذكر في مختلف المجالات العلمية، والتي وضعت الأسس وشكلت العديد من النظريات الحديثة الشهرة.

الهدف من هذه المذكرة هو التذكير بالمساهمات العلمية لابن الهيثم وغيره من العلماء المسلمين. واثبات أثرها الكبير على نهضة الحضارة العربية الحديثة وتقدمها. على الرغم من أن هذه الحقيقة قد تعرضت لمحاولات مختلفة للتشويه من قبل العديد من العلماء الغربيين الذين حاولوا إخفاء الانتصارات العلمية الإسلامية خلف ستار الهميشه الغربية وتحديد الأضواء على الأعمال اليونانية باعتبارها المصدر الأول لجميع العلوم. لكن التاريخ كان حريصا على الاحتفاظ بجميع الأدلة التي رفضت التشهير الغربي والاعتداءات.

الكلمات المفتاحية: العصور الوسطى الإسلامية، الحضارات، العلوم، علم البصريات، التأثير، المساهمات العلمية، الغرب
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General Introduction:

The Islamic Medieval period witnessed the rule of the Abbasid dynasty, during which the Islamic civilization reached an unprecedented social, scientific, cultural, and economic development, through preserving and building upon previous contributions, and by adding a countless number of their inventions and innovations. Muslims built an intellectual society, based on their appreciation of the value of sciences and knowledge pursuit. Islam and the Arabic language were two edges of the Islamic knowledge sword, for the great role they played in encouraging and patronizing scientific research. During the same period, Europe was intellectually and scientifically paralyzed because of the ignorant and brutal domination of the Catholic church, which deprived all kinds of scientific research and considered knowledge pursuit a heresy; it compelled Europeans to live in darkness and barbarism for about eight hundred years.

Muslims made unparalleled contributions in almost all sciences especially in alchemy, chemistry, medicine, mathematics, and astronomy. Their scientific accomplishments were transmitted to Europe due to different means such as: crusades, trade relations between the Muslims and Europeans, the translation of Arabic scientific works to Latin and other European vernacular languages, the migration of the Westerners to the Islamic world, and the role played by paper-making technology. Thereby, Europeans were amazed by the massive development of the Islamic world, and their constant interaction with this great civilization influenced them and effected their society, culture, and thought. The Islamic scientific productions exceedingly influenced the West and formed the infrastructure and the foundations for the Western Civilization.
Abu Ali Al-Hasan Ibn Al-Hasan Ibn Al-Haytham was one of the Muslim scientists that astounded the whole world with his scientific discoveries and innovations particularly in optics. His noteworthy masterpiece *Kitab Al-Manazir* was considered as the first book written on optics, and the most reliable source for both Muslim and Western scientists for centuries. But the works of Ibn Al-Haytham and of various Muslim scientists were almost erased from the Western memory, because Western scholars throughout ages endeavored to bury the Islamic scientific heritage and the great role it played in the development of the West, by defaming the Islamic civilization and denying all what Muslims achieved in this period, claiming that the Islamic world invented nothing, it was just a path that transmitted Greek and Roman works to the West, and alleging that the source of all modern sciences is purely Greek.

Despite the desperate attempts of some western scholars to repudiate the influence Medieval Islamic scientific heritage had on the rise of the West and the evolution of its civilization, there are many historical, scientific, and cultural evidences that proved the validity of this influence. Spotting the lights on the Works of Ibn Al-Haytham in the field of optics, as an example that reflected the huge impact Muslims’ scientific legacies had on the West. The overall aim of this study is to examine the scientific contributions of the Islamic Medieval civilization particularly the works of Ibn Al-Haytham in optics and prove how it influenced the Western civilization.

This dissertation seeks to answer many questions including: What led to the evolve of the Islamic medieval period? What were the most important sciences that flourished during this period? How were the Islamic scientific contributions transmitted to the west? To what extent can the West be considered the heir of the Islamic civilization sciences? Who was Al-Hasan Ibn Al-Haytham and what are his main works and contributions? To
what extent the scientific legacy of Ibn Al-Haytham influenced the western scientists and modern sciences?

This issue echoed a global reaction whether in Western, Eastern, or Arab scholars’ writings. In his published audio book *Islam and the West*, Seyyed Hossein Nasr conceived to reveal the interaction of Islam, Christianity, and the civilizations they created throughout their histories from the 6th to the 20th century, uncovered the great influence the first had on the second in terms of arts, sciences, technology, culture, and medicine, highlighted their similarities and differences and finally showed that Muslim’s and Christians share much common ground, especially of morality, life issues and family. Equally important, Ahmad Yahia Al-Hassan in his book *Transfer of Islamic Sciences to the West* analysed the means and places that facilitated the transmission of the Islamic scientific and technological contributions to the West, as well as mentioning the essential Medieval Islamic chemical, engineering, and technological inventions that were conveyed to and used by the Westerners. About Ibn Al-Haytham, Charles G. Gross discussed in his article “Ibn Al-Haytham on Eye and Brain, Vision and Perception” the significant stops in the life of Al-Hasan Ibn Al-Haytham, his important theories on visual and psychological perception, and his influence on the Western scientists that came after him and on the modern science of optics. Likewise, Rosanna Gorini in “Ibn Al-Haytham the Man of Experience: The First steps in the Science of Vision” examined the biography of Ibn Al-Haytham and his masterpiece *Kitab Al-Manazir*, she provided a historical background for the classical theories in optics and compared them to Ibn Al-Haytham’s theories, and underscored the influence of his discoveries, inventions, and his scientific method on the modern scientific research.

The strategy which is being followed is the “qualitative research” method, which is used to gain an understanding of underlying reasons, opinions, and motivations; it provides
insights into the problem and helps to develop ideas or hypotheses. It is also used to uncover tendencies in thought and opinions, and dive deeper into the problem. In this regard, using the historical method along with documentary analysis to obtain data about this subject and to bring to light what this dissertation stands for, that is to say, studying the famous Islamic works and contributions of some Muslim scientists in different fields of science and how it influenced the West. In citation style, the dissertation uses the 7th edition of the Modern Language Association (MLA) format (2009).

This dissertation will be divided in two chapters: the first chapter entitled Scientific Contributions of the Islamic Medieval Civilization to the West will include a historical background of The Islamic Medieval Age, the role played by the Arabic language and Islam in the development of the Islamic intellectual life as well as a comparison between the Muslim and the European view to knowledge, thereafter mentioning some of the most famous Islamic contributions to different scientific fields, how these contributions were transmitted to Europe, and the impact they had on the west. Whereas The second chapter entitled Ibn Al-Haytham’s Legacy of Optics will hold in its pages a biography of Ibn Al-Haytham, a review of his famous works focusing more on his book Kitab Al-Manazir, after that an examination of his main scientific contributions in the fields of optics and physics, mathematics, astronomy, philosophy, and an explicit description of his scientific method, and finally proving how his works influenced many Western scholars.
Chapter One

Scientific Contributions of the Islamic Medieval Civilization to the West

Introduction:

During the Islamic Medieval period, the Abbasids led one of the greatest civilizations in the history of mankind for up to 500 years. The capital Baghdad embodied the cradle where knowledge grew. Their astonishing achievements and contributions in every life facet, led to the Islamic “Golden Age” that signified 300 years of scientific progress and cultural evolution. The teachings of the Quran and the Arabic language were the main factors that helped the expansion of the Islamic civilization during the Medieval ages, whereas the role they played in encouraging the pursuit of knowledge and in overemphasizing the value of learning is of a great importance. Muslims in this period, sanctified sciences and considered seeking knowledge a sacred duty and a human trait, whereas middle Ages Europeans were steeped in ignorance and barbarism. The Christian church banned scientific research and regarded it as a blasphemy; Europeans were allowed only to study Christianity and make religious researches.

Under the ensign of knowledge, Muslims formulated theories, practices, and inventions in different scientific fields like alchemy, chemistry, medicine, astronomy, and mathematics, which led their civilization to prosper and thrive. The Islamic scientific feats were transmitted to Europe due to many avenues such as: crusades, trade relations, translation of Arabic scientific works to Latin, the migration of Europeans to the Islamic world, and paper making, which all played a significant role in introducing the Islamic cultures and sciences to the West. Today, many European scholars claimed that Europe was born from the womb of Greek and Roman scientific heritage, but there are plenty
testimonies, facts, and evidences that proves the role of the Islamic scientific legacy on the growth of the Western civilization.

This chapter is willing to answer these questions: What are the reasons behind the rise and fall of the Abbasid rule? To what extant the teachings of Islam and the Arabic language supported the pursuit of knowledge? How can the relationship of Westerners and Muslims to scientific research be assessed? What are the most important sciences in which Muslims excelled? How were these sciences transmitted to Europe? To what extant the Islamic sciences influenced the Western world?

1. **The Islamic Medieval Civilization:**

   At a time when major civilizations like Greek, and Roman were fading, and the western world was struggling with an overwhelming scientific stagnation, the Abbasid Dynasty on the other side, during the Islamic Medieval period, was building a civilization based on the foundations of Islam, scientific research, and Arabic language. It witnessed unprecedented scientific and cognitive development, which made history record it as one of the most influential civilizations in the world.

1.1. **Rise and Decline of the Abbasid Caliphate:**

   After the end of the Rashidun era, the Umayyad Dynasty were heirs of the reins of power. Centered in Damascus, the Umayyad Caliphate (646-749 A.D) confronted inner pressure and opposition (“The Golden Age”). They became more and more unpopular, particularly in the eastern regions of the Caliphate, due to two reasons: firstly, because they preferred Syrian Arabs over other Muslims, and treated Mawali (Newly converted Muslims) as second-rate citizens, and secondly because other Muslims could not accept the idea of turning the Umayyad Caliphate into a hereditary throne. This was the best
opportunity for the Sunni-Arab Abu Al-Abbas Al-Saffah (721-754 A.D) founder of the Abbasid Caliphate to make a move. He waged a war in 750 A.D against the Umayyads at the battle of the Zab close to the Tigris River, where he seized Damascus, killed the Umayyad Caliph Marwan II, and executed all members of the ruling family but Abd Al-Rahman, who escaped to Spain, where he continued ruling under the Umayyad name.

Right after that, Al-Saffah established the Abbasid Caliphate (750-1258) and declared himself as the first Abbasid Caliph in 748 A.D (“The Abbasid Dynasty” 1).

The Abbasid Caliphate covered a large geographical area, spanned from south and southeast Asia, to include the whole Arabian Peninsula, Persia, Southern Europe, north Africa, and stopped at the gates of the Iberian Peninsula, its strategic location created a link between the classical world and the European Renaissance (see Appendix 1, Fig. 1.) (Ali, Essa 1). The Abbasids were the longest reigning Dynasty in Islamic history, they took over the throne with the principal that power should be shared among Muslims, not just Arabs. But with the ascension of the second Caliph Al-Mansur (754-775 A.D) to rule, it became clear that the Abbasid Dynasty followed the Umayyads’ system of ruling and continued the policy of hereditary governance (“The Abbasid Dynasty” 1). However, the early Abbasids sustained after the Umayyads the political and administrative missions in reinforcing the Islamic empire, maintaining its unity, spreading the Islamic touch and style in different areas and institutions, and extending further the use of Arabic language to become a universal lingua-franca (Islam 120).

Perhaps one of the most important changes the Abbasids made, was to shift the capital of the Islamic Empire from the old Umayyad headquarter-Damascus-to a new city: Baghdad, the capital of modern day Iraq, which is located nigh the Tigris and the Euphrates rivers. The Abbasids built their capital not distant from the old Persian capital Ctesiphon, for their increasing desire to bind themselves to Persian Culture; through this
connection, the Persian culture that the Umayyads endeavored to put down, was now permitted to expand (“The Abbasid Dynasty” 2). The Abbasids constructed their capital form nothing, but they kept the network of roads and trade routes that Persians established before the Umayyad dynasty controlled the reins of power (“The Golden Age”). Baghdad was soon the greatest cultural, and intellectual center of the Islamic civilization, perhaps of the whole world. In addition to its unique situation between Europe and Asia that made it an ideal spot for trade, and for exchanging cultures and ideas.

Before the Islamic civilization become influential, it was influenced by many ancient civilizations such as: Persian, Egyptian, Graco-Alexandrian, Jewish, Eastern-Christian, and Indian; this intermingle of civilizations into one, transformed the Islamic civilization to a melting pot of different cultures and ethnic groups: Arabic, Persian, Turkic, Indian, Black-African, Malay, and Chinese cultures existed together under the umbrella of the Islamic rule. This made the Arab world acquire a diverse population, which included: Arabs who are Semites, Persians who belong to the Indo-Iranian group, Turks who are Altaic, Black-Africans, and different South and South-East Asian groups (Islam and the West 6, 17). This mixture of cultures, and ethnic groups managed to live together in harmony, and by this, Islam attempted to create unity while preserving diversity, in order to form a unique civilization.

“The Caliphate became the symbol of unity of the Islamic world, and the rule of the Shariah, as well as the source of legitimacy for various Kings and Sultans” (Islam 122). One of those Caliphs is the fifth Caliph of the Abbasid Dynasty, Harun Al-Rashid (786-809 A.D) who is remembered as one of the history’s greatest patrons of arts and sciences. During his rule, both Islamic philosophy, and science began to flourish. Al-Rashid’s scion and heir Al-Mamun (813-833) shined in law, literature, philosophy, rhetoric, and in different fields of sciences (Ali, Essa 11).
When he became Caliph, Al-Mamun continued his policies of sponsoring artists, scientists, and scholars, and with his Father, they established and founded ‘Bayt Al-Hikma’ or ‘The House of Wisdom’ in Baghdad, which was “a library, an institute for translators and in many ways, an early form of university”. Al-Mamun made a great exertion to attract famous scholars to the House of Wisdom; Muslims, Christians, Jews, all worked together peacefully there (“The Golden Age”). The scholars in the House of Wisdom endeavored to interpret and collect various kinds of knowledge of human history, for one purpose, in one place, using one language -Arabic- (“The Abbasid Dynasty” 2).

Islamic sciences dominated the world for centuries and flowered mostly during this epoch. The pursuit of knowledge spirit emerged among Muslims for two reasons: first, the Quran’s assurance on learning as a sacred duty (“The Golden Age”), and the translation movement that most of the Abbasid Caliphs encouraged and supported, specially Al-Rashid and Al-Mamun. “Many of the ancient works were destroyed after the fall of the Roman empire; because of these translations, the great works of Plato, Aristotle, and Socrates were saved” (Aldrich 1). They translated works in diverse disciplines such as: philosophic, scientific, medical, and legal texts…etc. from Latin and other vernacular languages to Arabic, in order to make these works available to the Arab World. Muslim scholars reproduced and developed inherited Greek knowledge using experimental studies (Thawaqib 129), i.e. Muslims found the works they translated just theories on paper; they sought to develop them, to make those theories tangible, and to create new advances in different fields of knowledge. And perhaps the most important thing that needs to be noted is that Muslim scholars were never very concerned with the Roman thought (Islam and the West 17).

During the Islamic Medieval period, Baghdad was not the only center of intellectual flourishing, Muslim cities such as Constantinople, Persia, Andalusia, Egypt, and Damascus
were knowledge centers, in which scholars, scientists, artists, writers, philosophers, theologians, mathematicians, and others, followed the doctrine of discovery, scientific research, and experimentation (Aldrich 1), which led to the establishment of many knowledge and learning centers like: Al-Azhar in Cairo, The Zaytuna in Tunis, The Qarawiyyn in Fez, The Coteries of Cordoba in Andalusia, the schools of Najaf and Karbala in Iraq, and those of Qumm and Mashhad in Iran (Persia) (Nanji, Ruthven 38). This made these cities become culturally and economically independent, ruled by sub-Caliphs who follow the Abbasid Caliph in Baghdad.

The increased want for knowledge, and the scientific expansion, led to the spread of libraries as one of the essential needs of daily life. Each one of the Caliphs, Viziers, and other high-level Muslims had a private library, there were numerous public and private libraries in the Islamic world; Mosques and hospitals had libraries of their own as well (Thawaqib 133, 134). According to Thawaqib: “in 1000 A.D, hundreds of librarians worked in two libraries of the Caliph, which included 2.200.000 books combined. These books were twenty times as many as the rolled-up books in the unique library of Alexandria at the peak of its boom” (132).

This era of political, economic, cultural, and particularly scholarship thriving, from the 7th century to the 13th century is referred to as ‘The Golden Age of Islam’ (“The Golden Age”). The Abbasid Caliphate prosperousness was due to the adequacy and efficiency of many Caliphs and their advisors, despite the major challenge of ruling a massive multi-ethnic and multi-cultural empire. Yet, the Abbasid authority began to deteriorate significantly after the end of Al-Mamun’s Caliphate. While the Islamic sciences began to decline in the 11th century, by the 12th century onward, there was a decline everywhere and little was left by the 15th century (“The Abbasid Dynasty” 3).
With the massive growth of the empire, it became more and more difficult to control, and the Caliphate could no longer gather parts of the Islamic Empire. In the 10th century, the Ismaili Fatimids began a series of occupations for most of North Africa, starting from Afriqiyyah (present-day Tunisia), then Egypt (969 A.D), and further dominated Jerusalem, Mecca, Medina, and Damascus, where they defeated the Hamdhanids and even threatened Baghdad. The Fatimid Caliphate was the opponent of the Abbasid Caliphate and its rival, which can be seen clearly through their competition in the artistic and scientific fields. The Fatimids were threatened by the Seljuques and later by the Crusaders; the only one who was able to defeat them was Saladin (Salah Al-din Al-Ayyubi) (Islam124-125). Meanwhile in Baghdad, the Caliph Al-Nasir (1180-1225 A.D) struggled to maintain the Abbasid Power in Iraq, his chief rival was the Sultanate of Khwarezm, who ruled Persia.

Apparently, Al Nasir requested for the help of the Mongols: an expanding Central-Asian nomad empire, against Khwarezm. This decision resulted fatal consequences particularly with the coming of Al-Nasir’s less competent successor Al-Mutasim. The Mongols invaded all of Khwarezm, and then aimed their arrows at Baghdad. Baghdad fell in the hands of the Mongols in 1258 A.D, they destroyed the city, and killed Al-Mutasim (1242-1258 A.D). They killed approximately between 100.000 and a million people, burned the books of ‘The House of Wisdom’ and other libraries, ruined all the great monuments of the city, and left Baghdad soaked in its ashes (“The Abbasid Dynasty” 3, 5).

For the Iberian Peninsula; the last piece of the Islamic empire, the marriage of Ferdinand of Aragon and Isabella of Castilian Spanish, led to a great political and territorial unity. Muslim inept Caliphs lost their hegemony over the Iberian Peninsula, which made the two Cristian kings recover those lands. This unity put an end to the Islamic rule in the Iberia with the fall of Granada (1492 A.D) the last Islamic base in Europe (Thawaqib 140). However, the fall of Baghdad was officially the end of the Abbasid rule,
and the fall of the Iberian Peninsula was considered as the decline of the Islamic
civilization, which led to the decline of sciences as well. Thus, the Islamic empire never
recovered from this painful fall, through which the Arab world entered a new phase of its
history and paved the way for the emergence of the next dominant civilization: the west.

1.2. The Role of the Quran and the Arabic Language in the Development of the
Islamic Sciences:

The Quran and the Arabic language are two of the highly important foundations of
Islam, and two of the most substantial characteristics that distinguished Muslims from
other peoples. Both the Quran and the Arabic language acted as a floor for spreading the
Islamic civilization during the Medieval ages, whereas the role they played in encouraging
the pursuit of knowledge and in overemphasizing the value of learning is of a great
significance.

The Quran is more than just a sacred book that was revealed to guide Muslims
religiously, it’s a political, economic, cultural, and social constitution, in which the
scientific research spirit is deeply rooted. The first words that were revealed to the Prophet
Muhammad (PBUH) were: “Read! In the name of your Lord, who has created” (The
Quran, Al-Alaq 96. 1). On this basis, Muslims considered the quest for knowledge as a
religious duty, this latter includes seeking knowledge about the natural world,
contemplating and enjoying the beauty of God’s creations, and working in harmony with
nature, within moral and ethical boundaries. The scientific ingenuity of Muslims was the
result of the intellectual motivation, which is rooted in the sacred challenge to find the
divine miracles by meditating the creations of God (Khoshul 60), as God said in the holy
Quran:
“Indeed, in the creation of the heavens and earth, and the alternation of the night and the day, and the [great] ships which sail through the sea with that which benefits people, and what Allah has sent down from the heavens of rain, giving life thereby to the earth after its lifelessness and dispersing therein every [kind of] moving creature, and [His] directing of the winds and the clouds controlled between the heaven and the earth are signs for a people who use reason.” (The Quran, Al-Baqarah 2. 164).

The Quran evidently differentiates between the sons of Adam and all other creatures by their sanity; the Quranic language is opulent with countless explanation of areas of knowledge including different scientific disciplines (Ali, Essa 3). Concerning the Quran’s important stimulation to learning, the term “Ilm”¹ (knowledge) is considered as one of highest word counts in the Quran; it is mentioned in the Quran about 750 times, and also rated as one of the most repeated terms in the prophet Muhammad’s “Hadiths”² (Ali, Essa 3). In addition to the Quran’s emphasis on seeking knowledge, the teachings of prophet Muhammad (PBUH) and his immediate successors also stresses on the importance of knowledge, as the following Hadith shows: “Allah makes the way to Jannah easy for him who treads the path in search of knowledge” (Omara 52).

About the impact of the Quran on the Islamic society, and its positive influence specially on the cultural and scientific side, the European historian Will Durant wrote that Muslims’ manners and culture evolved because of the Quran, which rescued them from social ills and superstitions. It conferred for those of the lower classes respect and dignity, and made community full of justice and equality, that cannot be found anywhere else. These Quranic principals pushed Muslims to make such an exceptional progress in history (Thawaqib 125,126).
Being the language of the Quran, classical Arabic Language, was the basis of Islam and its civilization. Arabic is not just the sacred language of Islam, it was also adopted as the scientific and liturgical language. The uniqueness of Arabic was obvious in all domains of science and culture; from religious, legal, official, intellectual, to literary vernaculars (Nanji, Ruthven 38). Arabic dominated the Muslim world, and spread its wings in the Western world as well; it was utilized in European universities until Latin substituted it (Ali, Essa 4), i.e. A unified Arabic language was developed during the Golden Age of Islam, and it gradually became the universal language of scholarship.

Scholars claimed that Arabic was the most important scholarly and scientific language in the world along with Persian (the other Islamic language) from the 8th the 15th century (Islam and the West 7). Likewise, The influence of Arabic was not only related to the Arab world, it was extended to affect other foreign dialects and vernacular languages like: Urdu, Persian, Turkish, and even Spanish, as it is stated in the Historical Atlas of Islam that in the western Asian Islamic provinces, the Arabic language overshadowed the local dialects, whereas the Persian language persisted in use eastward; this led to a literary revitalization in the tenth century A.D, and the birth of an Arabo-Persian dialects, which became widespread in Iran as well as Transoxiana and Northern India (Nanji, Ruthven 38). In Addition to that, about ten percent of the Spanish vocabulary is still based on Arabic (Islam and the west 24).

1.3. Science in Middle Ages Europe and Medieval Islam:

During the Medieval Ages, Christians treated Muslims as their enemies, because they viewed Islam as a great danger, and considered it is a heresy. In the territories ruled by Muslims, Minorities of Christians and Jews lived there peacefully, but in the lands of Christian domination, Muslims were completely expelled. Christians assaulted the Prophet
Muhammad and thought that as Christianity is based on the Messiah, Islam is based on Muhammad rather than God (Islam and the West 9, 13). Middle Ages Christians and Medieval age Muslims regarded the idea of knowledge pursuit and scientific research from different and contradictory angles.

At that time, the common idea shared among Westerners was that seeking knowledge in the natural world, exploring and experimenting, and the adoption of scientific research meant nothing but wasting time, and misusing the rational abilities. In this context, Laktantius (317 A.D), a western teacher in a church school said that: “As nobody has reached the truth yet and a lot of efforts and time might have been wasted in search for it, obviously knowledge cannot be found where science and scientific research is sought” (Thawaqib 132). A similar opinion given by another teacher; Tertolian, in which he assumed that: “On Jesus Christ’s orders, after the descent of the Bible, it is not our duty to be inquisitive and acquire knowledge further than what is in the holy book” (Thawaqib 133).

In contrast, the Islamic science was the most active and developed science in the whole world, mostly from the 8th to the 15th century. Muslims glorified the pursuit of knowledge and scientific research, which was obvious from the amounts of scientific experiments they made, books they wrote, and libraries they built. Books of history hold in their pages many stories of Muslims who made great initiatives for the sake of sciences. Perhaps the best example for that is the story of Harun Al-Rashid, after winning the battle of Amuriyyah with Byzantium (839 A.D), he agreed to make peace with the Byzantine ruler Michael III, only after handing over the classical Greek works, and all philosophical contributions to Muslims as war tribute, even if they were not translated to Arabic yet (Thawaqib 133). Moreover, Caliphs used to send rich and educated emissaries from Baghdad to other countries like: Persia, India, Byzantium to collect relevant works, and to ask scientists for help in some scientific issues.
2. Islamic Medieval Period Scientific Contributions:

From the eighth to the fifteenth century, Islamic sciences were the most developed and advanced form of science in the world. At the beginning, Muslims were influenced by sciences of previous civilizations, they sought out the secrets of alchemy in Alexandrian and Chinese sciences, botany of Persian sciences, astronomy and mathematics of Greek and Indian science, and learned much from Mesopotamian and Byzantium sciences (*Islam and the West* 22).

The Islamic science had special characteristics that differentiated it from other sciences and made it timeless. It was characterized by its universal spirit, which was shaped by its openness and acceptance of the scientific contributions of others. It was the first to include reason, experimentation, and observation in its approaches. Most importantly, its reliance on contemplating the sacred nature, and the doctrine of monotheism, made it very tied to the Islamic religion (*Islam and the West* 22). That is why Muslims established, developed, and excelled in many scientific fields, most importantly:

2.1. Alchemy and Chemistry:

Islamic alchemy inherited the early heritage of Alexandrian and Chinese alchemy in the 8th century, which inspired Muslims to make major contributions to the field by then. The word Alchemy was derived from “Egyptian word Khemi with Arabic Al made Alchemia” (Saeed 262), and it can be defined as a science of materials and a complement to certain branches of traditional medicine; it is a mixture of both the cosmos and the soul, in which nature was regarded as a sacred milieu, where they can seek knowledge, it is the integration of both the spiritual and material aspects with the cosmos, based on the methods of experiment and experience (Nast, *Islamic Alchemy* 41).
Alchemy paved the way for the birth of chemistry, and Muslims were credited for being the first to establish the science of chemistry. The two most famous figures, and celebrated masters in the field are “Jabir Ibn Haiyyan, the Latin Geber (776-815 A.D)” (Nasr, _Islamic Alchemy_ 41), and “Abu Bakr Muhammad Zakaria Al-Razi, the Latin Rhazes (923/24 A.D)” (Saeed 266). Yet a study was made of the writings of both men, obviously discloses that although Al-Razi studied the languages of Jabirian alchemy, he was not going on the footsteps of alchemy, but he was walking in the path of chemistry (Nasr, _Islamic Alchemy_ 41). Al-Razi extracted chemistry from alchemy, and this latter by no means became an independent field of science. Al-Razi’s works were believed to be the first books of chemistry in the history of science (Saeed 277).

During the Islamic medieval period, Muslim alchemists made great contributions through their works and experiments such as: Jabir Ibn Haiyyan, who was a great alchemist credited for discovering the process of distillation, sublimation, transmutation, in addition to spirit wines, mercuric chloride, and mineral acids. It is recounted that Ibn Haiyyan saved the life of a slave girl of Yahia Ibn Khalid Barmaki by dint of an elixir. In his book _Kitab Al-Mawazin or Book of wisdom_, he stated that metals are composed of four elements (fire, air, earth, and water), and the relations between those elements are extracted in arithmetic terms (the principal of balances). According to him, the basic qualities of metals are Sulphur and mercury, and they are mixed naturally in different proportions. (Saeed 263, 266). In another book, _Summa Perfectionis Magisterii_, Ibn Haiyyan described metals and made distinctions between them on the basis of their melting point, color, luster, and ductility, he also mentioned methods of refinement of metals, preparation of steel, dyeing of cloth and leather, preparation of varnishes to water-proof the cloth and leather and protect iron, use of manganese dioxide in glass making, use of iron pyrites for writing in gold, and distillation of vinegar to concentrate acetic acid, etc. (Saeed 264).
Ibn Al-Wahshiya (870 A.D) is another alchemist that left his mark in the world of alchemy, in which he was more interested in the secrets of planets, alchemy, and sorcery. His most famous books are: *Falaha Al-Nabatia* and *Kanz Al-Hikma/Kanz Al-Asrar* or *Treasury of Wisdom*, in which he dealt with the system of alchemy. Moreover, the many-sided genius Abu Al-Nasr Al Farabi (870-950 A.D), is the only Arabic philosopher involved in alchemy. In his book of alchemy *On the Art of Arts*, he made the study of logic much easier, by dividing it into categories of Takhayyul (Imagining), and Thubut (Proof) (Saeed 266, 269). However, alchemy later begin to vanish because it encouraged imposters who claimed that they can make people rich by the transmutation of base metals into gold.

The first seeds of chemistry were planted during the Islamic Medieval period. Chemistry grew out of alchemy and gradually formed an important part of other industries such as: distillation, metal-working, ceramic manufacture, pharmacy, and dyeing. The physician, the student of alchemy, and the founder of chemistry Abu Bakr Muhammad Zakariyya Al-Razi (‘Rhazes’ in Latin), wrote some of the most important books in the history of chemistry including: *Kitab Ithbat Al-Kimya* (*The Establishment of Chemistry*) and *Liber Secretorum*. In this latter, he did many experiments for the first time, he classified chemical compounds into inorganic (minerals and derivatives), and organic (animal and vegetable), and divided the former into six subgroups: spirits, bodies, stones, vitriols, borates, salts (Saeed 266-267).

Al-Razi differentiated between calcium and potassium carbonates, the process for the preparation of white arsenous oxide, silica compounds from bamboo, the treatment of Sulphur, arsenic and organic compound and preparation of salmoniac, he is also credited for the use of gypsum mixed with egg white as a plaster for broken bones. “His writings established the foundation for empirical Arabic chemistry, experimental chemotherapy, and objective alchemical procedures today being practiced on a large scale” (Saeed 267).
Abu Yousuf Yakoub Ibn Ishaq Al-Kindi (800-873 A.D) was another brilliant chemist, who contributed to the Islamic chemistry account with his almost 36 works on chemistry and technology. Extraction of perfumes and the distillation equipment used by Al-Kindi, is described in his book *Kitab Kimya Al-Itr Wa Al-Tas’idat* (*Book of Perfume Chemistry, and Distillation*) (Saeed 271).

All those Muslim scientists left their fingerprints in history and revolutionized the world of alchemy and chemistry with their discoveries and innovations. Muslim works added a great deal of new knowledge resources to both sciences, in which these resources are considered as indispensable and still used today in chemistry. They also developed the field of medicine and made many contributions to it.

### 2.2. Medicine:

Islam -as a religion- has a considerable role in the foundation of the Islamic medicine during the Medieval period. For instance, Allah in the Quran emphasized on the importance of health, and considered protecting it as a sacred duty, as he said in the Holy Quran: “And do not with your own hands cast yourselves into destruction” (*The Quran*, Al-Baqarah 2.195). Prophet Muhammad (PBUH) also gave directions and instructions concerning eating habits, hygiene, preventing illness, and healthy conducts that Muslims should follow, as he said: “Two most significant blessings of Allah that most of the people are careless about are health and opportunity” (Islam 47), he also said: “Make use of medical treatment, for God has not made a disease without appointing a remedy for it, with the exception of one disease -old age” (Masood 95). The Quranic emphasis, teachings of the prophet Muhammad, and the Abbasid Caliphs encouragement, inspired Muslim scholars to seek medical knowledge. During the Abbasid epoch, most scholars acquired
medical knowledge, and most of them became polymaths, especially that the atmosphere encouraged to learning, and scientists had a high rank in society (Ali, Essa 14).

“The Islamic medical Knowledge enriched by the translations of previous works and mainly of Greeks, medical texts were rendered into Arabic, as the works of Aristotle, Dioscorides, Galen, Oribasuis, Hippocrates, Paul of Aegina” (Islam 47), and the one who represented the best example for that is Hunayn Ibn Ishaq, a practiced physician who become the greatest translator of his days. He translated Greek works into Arabic, wrote hundreds of medical works, and taught future influential physicians (Ali, Essa 14). But this does not mean that Islamic medicine inherited the Greek legacy of medicine, because the Islamic medical theories and practices, hospitals, pharmacies, and even medications were genuine according to Edward Brown: “both the Arab and non-Arab Muslims made the largest contribution to the body of scientific doctrine that they inherited from the Greeks, regarding chemistry and medicine” (Ali, Essa 14).

Baghdad had 860 licensed physicians during the early 9th century (Ali, Essa 14), and one of the greatest names was Abu Ali Al-Husayn Ibn Sina (Avicenna in Latin), who was the most recognized doctor, mathematician, and philosopher, and due to his works Muslim medicine reached its climax. Ibn Sina’s fame in medical history lies in his masterpiece Al-Qanun Fi Al-Tibb, known in the west as the five volumes Canon in Medicine (Ali, Essa 14). Ibn Sina is credited for discovering many contagious ailments like tuberculosis, which he found that it could be transmitted through soil, water, and air, and introduced the quarantine as means of preventing the spread of transferrable infections (Aldrich 3). He was also the first one to identify dangerous diseases such as cancer (“The Golden Age”).

One cannot deal with Islamic medicine without mentioning the father of modern surgery, Abu Al-Qasim Al-Zahrawi (Abulcasis in Latin) (936-1013 A.D), who achieved
numerous advances in surgery and anatomy. He brought to surgery about 200 surgical instruments, ranging from a tongue depressor, a tooth extractor, to a catheter. In his famous book *Al-Tasrif Li Man Ajiza A’n T’arif*, he explained tonsillectomy (the removal of the tonsils), tracheotomy (creating a breathing hole in the throat), and craniotomy (brain surgery), in addition to writing about injuries of joints, and bones fractures, from nasal bones fractures to those of the vertebrae, and in fact the modern method used to fix the dislocated shoulder, was Al-Zahrawi’s idea and creation. He pioneered the use of anesthesia in operations, also the use of animal guts for internal and external operations (stitching wounds), which he experimented on corpses (dead bodies) (Aldrich 3).

In addition to Ibn Sina and Al-Zahrawi; Abu Bakr Muhammad Ibn Zakariyya Al-Razi (Rhazes in Latin) (856-925 A.D), was the genius who excelled in both alchemy and medicine. He wrote over 200 books half of them on medicine, including a 10-volume treatise on Greek medicine (Ali, Essa 14), including his masterpiece *Al-Hawi Fi Tibb*. His writings contributed to the maturity of Arabian medicine, and perhaps one of his important works was to distinguish smallpox from measles in his book *Kitab Fi Al-Jadari Wa Al-Hasbah*, or *Book on Measles and Smallpox* (Ali, Essa 14). Furthermore, he was credited for using opium as an anesthetic (pain killer), he made as well important explanations about hay fever, and kidney stones (Aldrich 3).

The world’s first medical schools and hospitals were established during the Islamic Medieval period, they were places for treating people, teaching, as well as study. There was a big difference between the European Middle Ages hospitals and the Islamic Medieval hospitals: in Europe, monasteries were used as hospitals, and patients were told that they will live or die according to God’s will not human interference; whereas Muslim hospitals founded the practices of diagnosis, treatment, and future prevention.
Islamic hospitals were the perfect model for today’s European hospitals. The first hospital in the Islamic world was built during the Umayyad rule in Damascus in 707 A.D, and soon most Islamic main cities had hospitals in which hygiene was guaranteed and treating patients was a priority, but after the coming of the Abbasid Dynasty, a major hospital was built in Baghdad, which paved the way for another thirty-four hospitals throughout the Muslim world. Hospitals were open 24/7, many of them with special wards for women, and most doctors worked for free, in addition to travelling clinics with appropriate medication supplies toured the countryside, isolated areas, and others paid regular visit to jails (Aldrich 5).

Besides, Muslims also made great achievements in the field of pharmacology. “Islamic civilization produced pharmaceutical terminology and practices that transferred to European medicine, such as methods of medication preparation” (Ali, Essa 14.15), in which this latter integrated the use of traditional herbal sciences with alchemy. “Like alchemy, medical theory was based on the Greek concept of the four elements (earth, air, fire, and water). The elements were related to the four “humours”, and disease was supposed to be caused by an imbalance in the humours” (Nasr, *Islamic Alchemy* 42). The world’s first pharmacy was established in Baghdad in the 8th century, and after the spread of this science, Baghdad had at one time eight hundred and sixty-two (862) registered pharmacies all of whom had passed formal examination (Aldrich 5). Despite their massive achievements in alchemy, chemistry, and medicine, Muslims’ scientific machine did not stop only at that limit, it continued making great contributions also to astronomy.

**2.3. Astronomy:**

For Medieval period Muslims, astronomy was a sacred science, in addition to its practical reasons, it was strongly tied to religion. Allah stressed the importance and
benefits of astronomy in the Quran, as he said in the Quran: “It is he who placed for you the stars that you may be guided by them through the darkness of the land and see. Who have detailed the signs for people who know” (The Quran, Al-Ana’am 6.97), and also said: “It is he who made the sun a shining light and the moon a derived light and determined for it phases. That you may know the number of years and account [of time]. Allah has not created this except in truth. He details the signs for a people who know” (The Quran, Yunus 10. 5).

Improvements in astronomy greatly aided travelers to be acquainted with the positions of constellations and movements of stars, in order to calculate time and find their directions; it guided sailors and aided navigation in seas, especially for purposes of trade and travel, and it was important in determining accurate lunar calendar. The moon was very important for the Islamic astronomy, which distinguished 28 sequential groups of stars known as ‘lunar stages’, and location of the moon against these stages detected the seasons of the year (Ali, Essa 13). Indeed, astronomy’s benefits are countless, and perhaps the most important one is the discovery of horology: the science of measuring time, and for the religious side, it provided an accurate guidance for Muslims to determine prayer times, the direction of Al-Qibla, and important religious festivals and events such as: Aid Al-Fitr and Ramadan.

Muslims added a countless number of originally Islamic theories and practices to the field of astronomy, they did not just synthesis Greek, Indian, and Persian astronomy, they translated the best parts of the most rational works, corrected and developed them to suit the scientifically advanced Islamic civilization. Muslim scholars deduced that the earth was round, based on Quranic interpretations and descriptions, at times when Europeans believed that the earth was flat, in addition to Spanish Muslim and Jewish astronomers absolute refusal to Ptolemy’s theories in favor of Aristotle’s ones, which led them to
corrected Ptolemy’s planetary model to adjust to Islamic almanac tables, and discovered the being of other planetary system (Ali, Essa 12).

Important Islamic observatories were established in many cities across the Islamic world as scientific institutions. The 9th century witnessed the establishment of Al-Mamun observatory in Baghdad, then the Maragha school in the 13th century, and later the Ulugh Beg at Samarkand in the 15th century. “Observatories were used to advance astronomy, astrology, and geography on both the practical and theoretical levels” (“Sciences”), but for astronomy, observatories were used to study the sun, the moon, the movements of the stars and other heavenly bodies (Aldrich 6).

Further, Muslims also developed many astronomical tools and instruments such as the Zij and the astrolabe. The first Zij was developed by Muhammad Ibn Al-Batani, “it is a set of astronomical and astrological tables, along with instructions for their use, and occasionally account of their construction. We know over 200 zijes in Arabic, Pahlavi, and Syriac” (“Sciences”). Through using the position of the stars, the astrolabe allowed people to find the exact latitude. The astrolabe is of a Greek origin, Muslims such as Merriam Al-Astrolabi, one of the many brilliant women of her time, developed the Greek astrolabe and made more practical and sophisticated astrolabes. The astrolabes were developed each time to suit the people’s needs, like when the astrolabe was later modified to be used on ships. Through this innovation, Europeans found faster trade routes to Asia by sea, and Christopher Columbus made his journey to discover the new world (Aldrich 6).

Islamic astronomy was developed due to the genius works and contributions of many Muslim astronomers and astrologists like: Muhammad Ibn Ibrahim Ibn Fazari, Yakub Ibn Tarek Abu Al-Mash’ar Al-Balkhi and his famous book *Al-Madkhal-ul-Kabir*, Abu Reihan
Al-Bairuni and his masterpiece *Al Tafhim Li Awa’il Sanat Al-Tanjim*, and the most famous astronomer of the House of Wisdom Khajeh Nasir Al-Tusi (Thawaqib 130).

**2.4. Mathematics:**

Islamic mathematics is a term used to refer to the mathematical theories and practices applied by Muslims in the Islamic world between the 8th and the 13th A.D (Rogers 1). Medieval Muslims viewed mathematics as having a sacred importance, symbolizing the interior nucleus of all things Allah created. There is nothing in the whole world does not contain mathematics within it, especially sciences, that is why it is called “the mother of sciences”. Islamic mathematicians developed the work of earlier Greek, Indian, Persian, and Chinese mathematicians and made important advances.

The most significant contribution maybe the creation of Algebra, which originated in The House of Wisdom or Bayt Al-Hikma in Baghdad. One of the most famous mathematicians and pioneers of algebra is Muhammad Ibn Musa Al-Khawarizmi (800-847 A.D). He popularized a number of mathematical concepts, including the use of geometry to demonstrate and prove algebraic results, he also wrote about the Jewish calendar, arithmetics, and algebra (Rogers 1). one of the greatest works of Al-Khawarizmi in this domain was the introduction of “Arabic numerals”; he wrote a very significant treatise on Hindu-Arabic numerals, which made the application of those numbers widespread (Rogers 2). Influenced by Indian numeral structure, Al-Khawarizmi created Arabic numerals with a unique system based on value and a decimal system of tens, which made it easy and possible for these numbers to be used for calculation, simple fractions, addition, subtraction, multiplication, and division, unlike the roman classic system (see Appendix 2, Table. 1) (Aldrich 2).
Moreover, he introduced the number Zero (0), which was used in the Islamic world for about 250 years before it reached Europe, he also familiarized to both Arab and European worlds the Hindu notion of decimal positioning notation, which is still used today (Rogers 2). In his book *Hisab Al-Jabr Wa l’-Muqabala*, which was translated to Latin as *Liber Algorismi*, he included elaborated clarifications, and suggested geometrical solutions with statistics of quadric equations, for example: $X^2+10X=39$ (Islam 43). In fact, the longest chapter of this book was written for practical reasons, and it aimed to explain to people how to apply algebra to Islamic inheritance laws (Rogers 2).

Ibrahim Ibn Sinan (d. 946) was another famous medieval Muslim mathematician. He was the grandson of Thabit Ibn Qurra, the famous mathematician and translator of Archimedes. Ibn Sinan was famous for dealing with the area of the segment of a parabola, using very simple methods. In his mathematical studies, he was more interested with common methods and theories, than with particular new problems. This method revealed the skills of Ibn Sinan and other Muslim mathematicians to create Greek style proofs, in addition to contributing to geometry by giving briefer geometrical constructions and proofs (Rogers 6, 8).

Islamic mathematics was developed mostly for two practical applications: physical such as art, and social such as inheritance laws. One of those who exploited geometry for art is Abu Al-Nasr Al-Farabi (d. 950). His work *Book of Spiritual Crafts and Natural Secrets in Details of Geometrical Figures* helped artists to create endless patterns in their designs, and to fit these patterns into different scientific areas. Islamic geometrical forms are totally based on geometry, algebra, and arithmetics; and their value is not just limited to the artistic aspects, but also includes mathematical and religious sides.
The development of geometrical proofs and constructions was mostly due to the Islamic art of geometrical designs expansion (Rogers 9, 15). Moreover, before Muslims knew of Greeks geometry, they calculated circumstances using $\pi$ properly (Ali, Essa 12), and they also did extremely well in trigonometry and trigonometric tables, degree measurements, as well as algorithm (Ali, Essa 13). Muslims contributions to mathematics extend much beyond works mentioned above, it was an everyday science that Muslims used in every facet of their lives; new theories and works were born every day, and mathematics became the science acquired by almost every Medieval Muslim.

3. The transmission of Islamic Scientific Contributions to the West:

The Islamic Civilization during the Medieval period reached the highest extent of development in every aspect of life, that no other civilization did before. From the 12th century onwards, the Islamic civilization moved towards deterioration, and the Muslim scientific enthusiasm began to fade. On the other side, the Western civilization started to originate, and opened its arms to embrace the scientific development.

It is well known that when two civilizations share the same geographical area, in spite of the religious, social, and scientific differences, this geographical nearness will encourage the cultural interaction, which will cause one civilization to influence the other, and that was exactly what happened between the Islamic and the Western Civilizations (Koshul 39). The Islamic civilization was waning, while the European civilization was growing, this led the latter to be built upon the former’s ruins. “As a result of creating the really stunning and brilliant culture and civilization, the Muslim world could penetrate into the Christian world and influence it” (Thawaqib 135). This influence occurred in many places like: Italy, Sicily, and The Iberian Peninsula (present-day Spain), but there were
various conditions that served as means of transmission, according to the European Scholar Will Durant:

The Islamic civilization penetrated into Europe through trade, Crusades, translation of hundreds of Arabic books into Latin and the journey of such scholars as Gerbert, Michael Scott, Adelard of Bath, etc. to the Islamic Andalucía as well as by young Christians who were sent by their fathers to the Muslim countries in order to acquire knowledge and etiquette and become civilized. (qtd.in Thawaqib 135)

In other words, the Europeans conveyed the Islamic civilization’s cultural and scientific contributions via crusades, trade relations, translation of Arabic scientific works to Latin, migration, and paper making. Although the Crusades were fierce religious wars between the two civilizations, but it was one of the ways that introduce the Islamic social and cultural development to the backward West.

3.1. The Crusades:

From the 11th to the 13th century, crusades lasted for about 200 years. In order to strengthen their insecure domination over the Syrian and the Palestinian coasts, Crusaders continued moving towards the east in order to conquer Jerusalem (Thawaqib 136). “It was a short, rapid; powerful period of contact between the two (Europe and the Arab world), but the crusades did not have the lasting effect on Dar-Al-Islam that they had on Western Christian lands” (Islam and the West 10). The long-lasting wars, either with non-Christians or between Christian princes, led to horrendous massacres by Christian crusaders (Thawaqib 136), though the crusades caused bloody wars between the two civilizations, trade routes were founded, and that helped to calm down the disputes to some extant (Islam and the West 10). The first-time Western crusaders set foot in the Islamic world, they were
greatly surprised, because they confronted a civilization superior to theirs in these lands (Thawaqib 136).

Although the role played by the crusades to convey the Islamic sciences to Europe was small, but the crusaders during their visit to the Arab world experienced the appealing characteristics of Islamic life and endeavored to imitate these in their lands. Christians heard of the Islamic world’s development, but seeing and testing this development astonished them, to the extent that many of them decided to settle in the conquered Islamic lands. Those crusaders who were exposed to the Islamic progress, helped to convey this latter to Europe. This resulted in the adoption of Europe to many of the great achievements of the Arabic civilization, as an example: the Islamic luxury products were introduced to the Western nobility by the crusaders, and this was contributory in the rise of manufactures in Europe to produce comparable goods (Al-Hassan 5). From this example, the Arabic products were to have a great impact on the growth of industrial Europe in the renaissance.

The crusades against the Muslims in the Iberian Peninsula resulted the various kinds of sciences transfer, such as the use of gunpowder and cannon. Also, the Islamic technology of sugar processing and refining was passed on to Europe via crusades. Crusaders returning home described this ‘new spice’ and how pleasant it was, it became a luxury product in high demand, and it was firstly tried in England in 1099 (Al-Hassan 5, 27). In Addition to crusades, trade relations were a major factor in the process of Muslim scientific and cultural advancement transfer to Europe.

3.2. Trade Relations:

As civilizations and societies came in contact through trade networks and commercial exchange, they shared knowledge and technologies across cultural barriers. As a result to crusades and scientific interaction, trade routes between the West and the
Islamic World were established. Weather during warfare or peace, there were active commercial relations between the Europe and the Islamic world most of the time (Douglass 4, 11). And as an effect, European mercantile communities were created in various Muslim cities such as the republics of Venice, Genova, as well as Barcelona in Spain (Skeen 3). In addition to groups of Muslim merchants that resided in Byzantium, where they made connections with Swedish traders traveling down the Dnieper (Al-Hassan 5).

There are many examples of the merchandises that Europe imported from the Islamic world such as: varieties of hard soaps in the thirteenth century that were imported from lands of the Mediterranean and were shipped across the Alps to Northern Europe via Italy, in addition to transferring methods of soap making mostly from Syria and North Africa to Italy and Southern France during the renaissance (Al-Hassan 6). Moreover, throughout the twelfth century, the trade in silk, tin-glazed wares, and porcelain started to brisk because of the increasing demand of the European wealthy classes for these luxury products (Skeen 2). Oriental luxury goods were necessary to the lifestyle of the European nobility, this made the foreign trade that provided these lavishly items an economic enterprise on a grand scale. Trading these goods was very significant for both Islamic and European civilizations: for improving the European culture, and for expanding the Medieval Islamic economy. Islamic luxury goods and paper were shipped from Egypt and Syria via Venice, which became a main transfer point in Europe, and the most prominent among the Italian cities in its trade relations with the Arab world (Al-Hassan 6).

Because of trade, books could move quickly across the Islamic world to the West. The revolution in European intellectual history was shaped by the importation of Greek and Arabic scientific works, depended for most part on books that were written or translated in Persia and Baghdad, which were readily available in Spain because of the
thriving book trade there (Skeen 1). Thousands of Islamic goods were exported to the West to fulfil the increasing needs of its peoples. Such goods opened the European’s eyes to sophistication and civilized them especially from the cultural and scientific side. Trade relations (books trade in particular) helped to spread the use of the Arabic Language, and played a great role in the thriving of the 12th century European translations of Arabic works to Latin and other vernacular languages.

3.3. Translation:

The Western translation movement in the twelfth century had a deep impact on conveying Arabic science to Europe. “The translation of Arabic works into Latin and vernacular languages such as Spanish, Catalan, Provençal, and French helped to expose Medieval Europe to Islamic thought” (Islam and the West 10). The interpretation of famous Muslim works in different scientific disciplines from Arabic to Latin by Sicilian translators, opened the gates for an active translation trend (Thawaqib 137). This translation movement flourished in the 12th century, and included various sciences such as: alchemy, chemistry, mathematics, medicine, in addition to religious and philosophical texts. The best example for that, was Robert Chester’s translation of the Arabic work Book of the Composition of Alchemy in February 1144, which was regarded as the first work that introduced alchemy to Europe (Holmyard 105, 106).

In addition to treatises on medicine and pharmacology that contained various directions on material processing, mathematical treatises which introduced the Islamic science of surveying to the West, and different works of astronomy. The court of Alfonso X knew an active translation movement from Arabic to Latin, were the work Libros Del Saber De Astronomia was collected, which included a section on timekeeping that
comprised a weight-driven clock with mercury escapement, like the one that Muslims in Spain constructed 250 years before (Al-Hassan 6).

In Spain, some researchers acquired both Arabic and Latin languages, showed passionate interest for Islamic sciences, and competed to collect and interpret those works to meet the increasing demand of the European nobility; Jews were most active in this quest. The most famous translated works of that time were Adelard of Bath’s new version of *Mappae Calviculta*, and the *Liber Ignium* of Marcus Graecus. Several other Latin works like those of Albertus Magnus and Roger Bacon in the thirteenth century, Kyeser and Leonardo da Vinci in the Fifteenth, contain formulae of Arabic origin (Al-Hassan 7-8).

New sciences prospered from the 12th to the 14th century as a result of the access of Islamic Sciences into the Christian world, due to the numerous works of Western translators (Thawaqib 137), these interpretations gave birth to new European sciences with an Islamic spirit and impression. Translation of Medieval Islamic scientific works was the way that allowed the Western civilization to cross the threshold of ignorance, and enter to a new era of its history, the era of scientific development, industrial revolutions, and imperialism. The scientific and intellectual progress the Islamic civilization witnessed, made many Western artisans, clergy, converts, scholars, students, commercial agents, and even spies to escape to the Islamic world, which was a very effective and useful way to transmit knowledge to the West.

3.4. The Migration of Westerners to the Islamic World:

The migration of westerners to the Islamic world, was the most effective method for conveying and transferring the Islamic scientific works to the west. Europeans fled their difficult circumstances running from church oppression, wars and persecution, to the Islamic world to seek better opportunities (Al-Hassan 8). However, there was a movement
in the opposite direction due to particular conditions; Muslims migrated to the western lands and spread their innovations and creative scientific methods there.

Muslim craftsmen migrated to Christian Spain throughout the crusades with the fall of Muslim cities; Al-Andalus was the center where Christians imported Muslim made products they did not produce themselves, for example: in the 13\textsuperscript{th} and the 14\textsuperscript{th} centuries, the economy of Provence in Southern France was shaped by contact with both the Muslim west and east. In the case of migration of Western converts and clergy to the Islamic world, many names were registered in history such as: Gerbert or became pope Sylvester II. A French educator and mathematician, who spent three years (967-970) in a monastery in Northern Spain studying Arabic sciences, which gained him later the title of ‘the first ambassador who carried the new Arabic sciences across the Pyrenees’. Another one is Constantinus Africanus (1010-1087), who was the first to introduce Arabic medicine to Europe and herald the start of a proper medical education in the West; it is said that during the three years that he spent in Tunisia studying medicine, he collected several Arabic medical works and then took them to Italy (Al-Hassan 8-9).

The first well-known Western scholars to travel to the Arab lands were: Adelard of Bath (active between 1116-1142), and Gregory of Cremona (1114-1187) (Koshul 47). Adelard of Bath traveled widely in the Muslim world, first in Syria, then in Sicily, and later in Spain; through his travels in this latter, he collected many books and doctrines, which he spread actively in France and England (Koshul 47). He published a reviewed version of \textit{Mappae Clavicula}, a valuable collection of formulas on the making of colors and other chemical products (Al-Hassan 9-10). He also translated many Greek mathematic treatises that were available only in Arabic at that time, “It was from his rendition of Euclid’s works that all subsequent editions were to appear in Latin until the sixteenth century”.
Gregory of Cremona was identified by Westerners as “the leading scholar of his time”, because he spent fifty years in Cordova basically learning Arabic, and after that he preoccupied himself by translating Arabic books of scientists like: Al-Khawarizmi, Euclid, Archime des, Ptolemy, and Al-Razi to Latin, and among the works he translated eighty-five were ascribed to him. Further, Leonardo Fibonacci was another important scholar from the same period. Fibonacci acquired mathematics during his travels in Algeria and Muslim Spain, and after returning to Italy, he wrote his revolutionary work *Liber Abaci* in 1228 (Koshul 45-47). He also made commercial travels to the ports of the Mediterranean, where he visited Syria and Egypt, and had the chance to access to Arabic manuscripts and increase his experience in Arabic commercial mathematics (Al-Hassan 10).

From the Renaissance period, was the French scholar Guillaume Postel (1510-1581), who was well competent in Arabic and other languages, which enabled him to go through two trips one to Istanbul and the other to Palestine and Syria to collect a large number of Arabic manuscripts on behalf of the king of France; two Arabic astronomical manuscripts from his gatherings that covered Al-Tusi theorems, can be found now in the Biblioteque Nationale of Paris and the Vatican. From the same era, Jacob Golius (1590-1667) was an Arabist as well as a scientist, and it is informed that he translated some works of Ibn Haiyyan into Latin and had them published, and he also spent four years in the Islamic world, were he reaped 300 Arabic, Persian, and Turkish manuscripts (Al-Hassan 10).

The Muslim Caliphs character of clemency and moderation when dealing with adherents to other religions especially the Cristian and Jewish scientists, made various Western students to migrate to the Islamic world (Thawaqib 137). With the rise of the scientific consciousness in the West, many wealthy people, and nobility in Europe sent their sons to the Islamic world, to acquire disciplines, sciences, and etiquette on the hands of special Muslim tutors. As an example: Levinus Warner (1619-1665), who settled in
Istanbul in 1644, and during his stay he collected a great library of about 1000 manuscripts, which he donated to the University Library of Leiden (Al-Hassan 10).

Western kings sent many spies to snoop on Muslims’ political and economic conditions, their lifestyle, and to track their weaknesses. In this context, only one unique traveler as well as spy should be mentioned. Bertrandon de la Broquière was a French traveler, who was an extremely skilled spy and a very sharp-eyed tourist; he was curious to understand everything that comes in his way. In 1432, La Broquière was sent on a spying mission to Syria and the Anatolian Turkish state to assess the probability of launching another crusade. In the course of this mission he carried with him the secret of fireworks to France, which were introduced to him for the first time in Beirut, where he found people celebrating the “Eid”; that made him realize their massive abilities in war, and with just a bribe, he managed to get the method of fireworks making (Al-Hassan 11).

From what is said before, the migration of Western artisans, clergy, converts, scholars, commercial agents, students, and spies to the Islamic World, was extremely important to the development of Europe in many sides. Those immigrants took all what their hands and minds can reach of the Islamic legacies, not just the scientific contributions, but all what was beneficial and constructive to grew their civilization from ashes. Using paper as means, made all their plans to loot Islamic scientific wealth successful.

3.5. Paper Making:

The technology of paper-making had a valuable role in sharing and promoting knowledge during the Islamic Medieval period; paper was the means that rescued their scientific, technological, agricultural, literary, architectural, and artistic contributions from loss, and saved-not only their works-but also rare translated Greek works in the immortal
pages of history. Paper as well helped to spread Muslims books, treatises, and manuscripts to the whole world.

Just around the time the House of Wisdom was founded in Baghdad, the new technology of paper-making gave boost to the spread of Arabic, Greek, and Persian knowledge (Douglass 9). During the Abbasid rule, there was a rapid increase of written knowledge, due to their improvements on printing technology, which they obtained from the Chinese (Khan Academy). Paper mills were launched in Baghdad, and then were expanded to Syria, Egypt, North Africa, and finally it reached Muslim Sicily and Spain, later this technology was transferred form Jativa in Muslim Spain to Fabriano in Italy, were the first mill in Europe was established in 1267; it took five centuries for this industry to reach Europe. The Muslims revolutionized the industry of paper-making, and its basic manufacture method remained almost the same until modern times, the only changes made were the use modern machinery and new methods of production (Al-Hassan 26).

Whether in China, in the Arab world, or in Europe, paper-making was a practice limited only to the elite and wealthy patrons. As a result, making books became cheaper and easier, especially in the major Islamic cities where people collected, wrote, and manufactured books (Douglass 9). Paper-making was one of the greatest innovations in the history of mankind. The production of paper facilitated the making of books on an unparalleled scale, and its development and spread revolutionized printing; these two important achievements caused a true cultural transformation in human civilization (Al-Hasan 26).

Paper was not just a way of spreading knowledge throughout the Islamic empire and make it available for every Muslim, but it was also a means of universalizing this knowledge via transmitting it to the rest of the world. Many famous Muslim researchers,
scholars, and scientists still remembered today because of their surviving legacies of written works, especially in times when the Western hegemony is trying to bury all what is non-Western.

4. The Impact of the Islamic Sciences on the Development of the Western Civilization:

Undoubtedly, the fact that the Greek and Roman scientific legacy had affected the Western civilization is undisputed, but the impact of the Islamic civilization on the Western one is more inclusive and stronger than both of the previous civilizations. The exceptional scientific maturity that the Islamic civilization reached was extraordinary, and no other civilization before it got close to that astonishing accomplishment. Ironically, Europe received most of the Greek scientific works from the Islamic civilization, which Muslims collected and translated to Arabic, and in this context, George Sarton confessed that “when the West sufficiently matured to feel the need for deeper knowledge, when it finally wanted to renew its contact with ancient thought, it turned its attention first of all not to Greek sources, but to the Arabic ones” (qtd.in Koshul 46).

The scholar Charles Homer Haskins believed that the first and most impressive scientific and intellectual contributions of the Medieval ages, from medicine and mathematics to astronomy and alchemy originated where the prophet Muhammad ruled (Thawaqib 134), and about the Same issue, Seyyed Hossein Nasr believed that: “Islamic science was the basis for medieval and Renaissance sciences in the west”. The Islamic world offered the West several theories and practices like: Arabic numerals and algebra, planetary theory and star names, criticism of Ptolemaic astronomy, new astronomical tables and instruments (Islam and the West 23). Besides, Medical practice in Europe was essentially centered on Islamic medicine and using expertise of Jewish and Muslim
doctors, which made the Western medicine for many centuries an extension of the Islamic medicine (Ali, Essa 28). Further, Muslims offered to the West criticism of Aristotelian theory of motion, adjusted the concept of momentum, discovered the basic doctrines of chemistry, and invented many chemical instruments still in use today (Islam and the West 23).

The Islamic civilization also taught Europe ideas methods, and practices such as: Industrial, commercial tools and traditions, rules and customs of seafaring, coats of arms, weapons, medications, dishes, syrup, and artistic flair (Thawaqib 135-136). Moreover, Europeans were accustomed to live in filthiness, and were drowning in the Dark ages mud, until Muslims introduced to them methods of personal hygiene from showers, to swimming pools, and hammams⁵. Muslims in major cities like Baghdad, Cairo, Toledo, Granada, Istanbul, and Damascus benefited from the many public Baths that were built by both, the government and private citizens. These baths were supplied by aqueduct systems, which even the Greeks and the Romans never experienced before (Koshul 39).

Arabic language is another proof that the Islamic Medieval period sciences greatly influenced the Western civilization. During the Renaissance and the Reformation, the scientific fields and institutions were still dominated by the Arabic language, it was - without rivals- the most translated language in the world. concerning this, Haskins stated that the Latin world could have benefited greatly from the Graeco-Latin versions of the works of Aristotle, Galen, Ptolemy, and Euclid, it could have got much Greek science that way, but in fact these works were available only in Arabic translations at that time. That is because Arabic was the language of sciences during Medieval ages, and the whole scientific movement from Spain and Provence to Southern Italy was Arabic in its origin (Koshul 47).
Since the Arabic language was the most consumed language in the world, it invaded even other languages such as Latin, English, and other vernacular European languages. Some of the inherited Arabic vocabulary (especially scientific terms) still used till today (see Appendix 3, Table. 1). “Attempts to purge western languages of inherited Arabic vocabulary during the Renaissance, especially the fields of sciences and technology were not completely successful” (*Islam and the West* 24). To be exact, the strong impact of Arabic language on the Western civilization cannot be concealed, because most modern sciences particularly medicine and chemistry, were in fact based on discoveries and works made by Muslim scientists.

The impact of the Islamic civilization is reflected clearly in the influence of the Islamic sciences and culture on the works, attitudes, and behavior of some Western figures of that period. Thomas Aquinas is considered as one of the prominent Christian theologians of Medieval period. He expressed a great admiration for both Arabic language and the Islamic civilization, to the extent that he admitted in the introduction of his *Philosophiae* that: “without Arabic, Greek knowledge would never have reached the Europeans. Knowledge of Arabic was essential not only for access to classical Greek sources but also for access to the work of leading Muslim Scholars” (Koshul 47).

Roger Bacon is another European scholar that showed an immense interest for the Islamic civilization. He studied many works of Muslim scholars like Al-Razi, Al-Kindi, and his famous work *Magnus Opus* was merely a plagiarized version of Ibn Al-Haytham’s *Opticae Thesaurus*, and speaking of Bacon’s fascination with the Islamic world, Wieruszowski wrote: “Bacon worshiped the Arabs for their works in all fields of science and in the ‘Pseudosciences’ astrology, and alchemy, and for their method of experiment and observation” (qtd.in Koshul 47). The Islamic civilization development also inspired the king Charlemagne, who traveled to the Arab world, and spent many years in Spain
studying in the Islamic universities and technical institutions (Ali, Essa 28). Several non-Muslims adopted Islamic names clothes, and customs, and used Arabic language in public and private life, which was very evident on king Fredrich II. Because of his court’s oriental character and his Arabic-like habits, he was known as the “Baptized Sultan”\(^6\), he mostly dressed Islamic clothes, wore a turban, and had Harem\(^7\), his castle Del Monte Palace in Sicily was designed on Dome of the Rock mosque in Jerusalem; he was very eloquent in Arabic language, and he keenly supported and sponsored Arab scholars, philosophers, and artists (Koshul 45).

The issue of the influence of Islamic civilization on the Western one is very controversial. The views of Western scholars who are interested in this era of the Islamic history, varied between those who repudiated the influence of the Islamic Medieval period sciences on the shaping of the western civilization, and those who acknowledged the undeniable role of the Islamic civilization on the development and prosperity of the West. M. André Sevier rejected the idea that the Islamic civilization encouraged the pursuit of knowledge, to the extent that he denied even the existence such a civilization:

> What is called ‘Arab civilization’, in so far as any manifestation of Arab genius is concerned, has never had any real existence. The civilization that passes under that name is due to the labor of other peoples who, subjected to Islam by force, continued to develop their aptitudes in spite of the persecution of their conquerors. (qtd.in Koshul 38)

But many other European researchers -after making deep historical studies- recognized the countless graces of the Islamic golden age on the Western civilization, and as a response to those who repudiated that, R. Briffault stated that there cannot be an impressive and vibrant civilization alongside a people steeped in savagery without leaving
a profound impact upon their development, because that would be an anomaly or non-existent state. This case or law of nature applies significantly to the relationship between the Islamic world and Europe, despite the conspiring of every condition to repress, distort, and eradicate the truth about this relation (Koshul 39). Indeed, the Islamic civilization inspired the whole world, and without a doubt, it found the understructure of the western civilization we know today, as R. Briiffault admitted that it is very possible to say that if it were not for the Arabs, modern European civilization would not have been able to rise, and certainly if it were not for the Arabs, it would not have been able to build a character that enabled it to exceed all the preceding stages of growth. Although there is no aspect of Europe's development devoid of Islamic influence, it is necessary and important to recognize the rewards of the Islamic power that built the modern world’s core by its absolute source of natural sciences and the scientific spirit (qtd.in Koshul 37).

However, historical, scientific, cultural, social, and even natural evidences, testifies that Muslims founded a civilization 1500 years ago, and their advanced works and contributions in every aspect of life, changed the history course, and cultivated in other communities the most transcendent characteristics of humanity: the search for truth and the pursuit of knowledge.

Conclusion:

It is crystal clear that the Islamic civilization, through its expansion managed to illuminate the darkness of Europe and the world at large, due to the great scientific progress reached in all fields. Muslims were influenced by the scientific works of preceding civilizations. Nonetheless, they did not rely entirely on these work, and used them only as a base to start their own sciences. The principals of both the Quran and Al-Hadith, combined with the universality of the Arabic language, provided a suitable
environment for different aspects of thought to thrive. Muslims pioneered various sciences, they are credited for creating the science of chemistry, and most of their theories and practices in medicine, pharmacology, and anatomy still used today, as well as numerous mathematical concepts, and astronomical instruments.

As the Arab world was struggling to survive at the late 12th century. It was the perfect time for Europe to rise and gather itself on the ruins of a declining civilization. With the availability of the appropriate factors, a variety of Islamic scientific works were transferred to Europe. These works awakened the West from a lethargy that lasted for eight centuries.

The subject of the contributions of Islamic Medieval sciences to the West have always been contentious. History remains a testimony to the enormous role played by Muslims and their revolutionary scientific achievements in building the foundations of the early and modern Western civilization, no matter how radical European scholars try to distort the truth. Perhaps, one of the Islamic scientific legacies that constructed modern Western optics and affected some of the most famous Western scientists are the works of Abu Ali Al-Hassan Ibn Al-Hassan Ibn Al-Haytham, who dazzled the world with his ahead-of-time genius theories and practical inventions in the field of optics that are still used till today.
**Endnotes:**

1 **Ilm:** it is the Arabic translation of the word knowledge, which means according to Oxford dictionary information understanding, and skills gained through education or experience.

2 **Hadiths:** a recount of sayings, habits, and customs of prophet Muhammad (PBUH) and his companions.

3 **Catheter:** The catheter is a thin flexible tube used to get fluids in or out of the human body for medical purposes (Aldrich 3).

4 **Eid:** Muslims’ religious holidays that they celebrate every year. Muslims have two official holidays: Eid Al-Fitr and Eid Al-Adha.

5 **Hammam:** a public bathhouse which combines between cleansing, sauna, and relaxation.

6 **Sultan:** a Persian word which means according to the Oxford dictionary a ruler of certain Muslim countries.

7 **Harem:** an Arabic word which means according to the Oxford dictionary women living in, or separate women’s part of a Muslim house.
Chapter Two

Ibn Al-Haytham’s Legacy of Optics

Introduction:

Light and vision have always been a source of interest for scientists, philosophers, and thinkers throughout ages. First ancient Egyptians, then Greeks, and after them the Romans sought to work out how humans see and perceive light, and investigated kinds, structure, and sources of light, but their theories were traditional and were not based on pure scientific evidences. Through the increasing development of the Islamic civilization, scientists like Ibn Ishaq, Al-Kindi, Ibn Sahl, Al-Quhi were able to come up with some theories concerning the field of optics, but with the brightness of Ibn Al-Haytham’s star, most of the secrets of light were revealed and nearly all enigmas of vision were solved.

Al-Hasan Ibn Al-Haytham was the most brilliant physicist in the Islamic Medieval period, he excelled in mathematics and astronomy as well, and was very interested in philosophy. His fascination with optics made him write his pioneering book *Kitab Al-Manazir*, which was one of the first books written on the matter light, natural phenomena related to light, celestial physics, visual and psychological perception. His innovative theories in different scientific disciplines eliminated all the traditional, backward, and irrational theories that existed before especially in optics. Moreover, he was the first to develop the concept of the scientific method and the first to use it as a basic and crucial stage, through which all his theories must pass on.

His works were introduced to the West after they were translated to Latin; whether in physics, mathematics, astronomy, or even philosophy, his theories deeply influenced the
European scientists generation after generation. But the impact of his accomplishments in the field of optics was exclusive, for the reason that most of his theories were present in the works of his Western contemporaries and the works of those who came after them, and his legacy in optics continued to survive to this day.

This chapter is willing to answer these questions: who was Ibn Al-Haytham? What are the known works of Ibn Al-Haytham? What are his contributions to different scientific disciplines? To what extent the works of Ibn al-Haitham influenced Western scholars? The aim behind all these questions is to investigate the works of Ibn Al-Haytham in order to reveal the truth, which is the emergence and growth of the Western civilization on the shoulders of Muslims’ scientific legacies.

1. Biography of Al-Hasan Ibn Al-Haytham:

The Arab Muslim scientist and polymath Abu Ali Al-Hasan Ibn Al-Hasan Ibn Al-Haytham was born in 965 A.D in the city of Basra in Southern Iraq (Amr, Tbakhi 464). Arabs occasionally referred to Ibn Al-Haytham as “Al-Basri” (from the city of Basra, his birthplace), or “Al-Misri” (since he spent most of his life in Egypt), whereas Westerners called him Alhacen or Alhazen (the Latinization of Al-Hasan), and some Western Medieval works and writings used Avenetan or Avenatan as a Latinization of Ibn Al-Haytham (Gorini 53). The life of Ibn Al-Haytham is insufficiently known; many fine points of his life were missed over time, and most of the records on of Ibn Al-Haytham’s life story came from the writings of the 13th century Muslim historian Ibn Al-Qifti (1172-1248) (Amr, Tbakhi 464).

Ibn Al-Haytham received his formal education in Basra and Baghdad, where he studied mathematics, astronomy, physics, and philosophy (Elicioglu, Unal 325). These two cities were the most appropriate, intellectual, and enlightened milieu for a future scientist
like Ibn Al-Haytham to grow. He started his carrier as a civil servant and was appointed as a judge for Basra (Amr, Tbahi 464). After serving for a period of time, Ibn Al-Haytham decided to quit his work, this way, he freed himself from the restrictions of civil service and embraced the world of scientific research and experimentation (Shuja 324).

Because of the existence of several religious movements, conflicts and different views at that time, he became passionate about religious studies, and decided to devote his time and effort for the study of theology, philosophy, and other sciences. He discovered in the works of ancient thinkers a solid floor to stand on, like those of Aristotle; some mathematical achievements of Greeks, especially Euclid, Archimedes, Apollonius; and the writings of Ptolemy of Alexandria on astronomy and optics (Smith 190). He quickly built an astonishing reputation as a scientist in physics and mathematics, which made him eminent and very famous in Iraq, Syria, Andalucía, and Egypt (Amr, Tbahi 464).

Perhaps one of the most prominent incidents recorded by history in the life of Ibn Al-Haytham is the Aswan Dam incident. It was recounted by Al-Qifti that Al-Haytham said:

“If I were in Egypt, I would have done a work that would benefit in every case of its increase and decrease” (“Ibn Al-Haytham”), which made Al-Hakim invite him to Egypt to help regulating the flow of the Nile river during the floods, by constructing a dam (the same location where Aswan dam stands today) (Amr, Tbahi 464). Al-Hakim was a patron of sciences, and he was known for surrounding himself always with scholars, and especially famous astrologers (Haidar 30), but he was also known to be eccentric Caliph who issued many despotic verdicts, for instance prohibiting the consuming of certain foods, banning women from leaving houses, slaughtering all the dogs, and compelling people to work during night and rest by day; he was quite brutal and had murdered his guards and ministers on a vagary (Amr, Tbahi 464).
After Al-Haytham presented to Al-Hakim a hydraulic scheme to control the spate of the Nile (Gorini 53). Later, his field work made him realize the impracticability of his plan (Shuja 324), in other words, building a dam over the river may not prevent the water overflow (“Ibn Al-Haytham Biography” 3). To prevent the Caliphs wrath and punishment, Al-Haytham pretended to be insane (“Ibn Al-Haitham" 3). This trick saved his life but unfortunately, he was stripped off his possessions, and was forced to house arrest for 10 years from 1011 until Al-Hakim’s death in 1021, who was assassinated in mysterious circumstances (Amr, Tbakhi 464). During his period of incarceration, he wrote his groundbreaking masterpiece *Kitab Al-Manazir* or *The Book of Optics*, in addition to a range of other works in mathematics, physics, philosophy, and astronomy (Haidar 31).

After his discharge from house arrest, Ibn Al-Haytham settled in a domed Building (Qubbah) close to the Azhar mosque in Cairo, where he taught mathematics and physics, and earned his living by duplicating texts (Amr, Tbakhi 464). This stage of his life provided him with ample time to travel to many Islamic cities and other parts of the world for his academic scientific pursuits and allowed him to develop the concept of the scientific method (Shuja 324). He continued his quest for knowledge and his faithful dedication for scientific research until he passed away in Cairo in 1040 A.D (Haidar 31).

Ibn Al-Haitham works included his contributions to different scientific disciplines, but his most significant studies were inclined to optic matter, and his influence on the western thought is mainly due to his works in the field of optics (Gorini 53). And through this, Haidar believed that Al-Hassan Ibn Al-Haytham is considered the first modern physicist, and he is with the Greek scientist Claudius Ptolemy, the founding fathers of optics (30). Ibn Al-Haytham is a scientific miracle in itself, he was a man of sciences; excelling one science did not satisfy his passion, he chose to shine in various disciplines such as physics, optics, mathematics, astronomy, biology, anatomy, philosophy, and
theology. He put his extraordinary life in the right direction despite the difficulties, and with his skills and intelligence, he was able to achieve a great fame in the Islamic world as well as the Western world, thanks to his ahead of time revolutionary works, optics in particular.

2. His Works:

Ibn Al-Haytham wrote more than two-hundred works on a large collection of specialties; about ninety-six of his scientific works are known, and the rest were lost, but more than fifty of them had survived to date and have influenced many scientists for almost a millennium (see Appendix 4, Table. 1) (Shuja 324). About half of his writings are in the field of mathematics, fourteen on optics, including his authoritative and multi-volume work Kitab al-Manazir or book of optics, twenty-three on astronomy, two on astrology, two in the field of philosophy (one on the place and the other on the invisible part), three on statics and hydrostatics, and four were dedicated to various other topics (Rashed, “Ibn Al-Haytham” 1089). Not all his surviving works were studied, but here are some titles of his studied books: in physics and optics Kitab Al-Manazir (Book of Optics) and Mizan Al-Hikmah (The Balance of Wisdom), in mathematics Al-Kutaibat (Opuscula) and Fi A-Tarkib wa A-tahlil (Synthesis and analysis), In astronomy Takwin Al-Alam (On the Configuration of the World) and Taswibat Ala Al-Mijastyi (Correction of Almagest), in addition to his famous treatise in philosophy Maqala fil Makan (Ttreatise on Place) (Rashed “The Celestial” 8-9).

All his works added many contributions to a variety of sciences, and perhaps the most impressive characteristics that attracted attention to his writings, is that all his works are connected together despite the subjects’ variance, and also his method of including different scientific fields when tackling one problem or phenomena. The best example concerning this is Kitab Al-Manazir, in which Ibn Al-Haytham included anatomy,
mathematics, physics, celestial physics, mathematical astronomy, philosophy, and even psychology to make researches and studies in optics. A fleeting look at the works of Ibn Al-Haytham on optics uncovers not only its innovative nature but also its inclusiveness; laying his hands on all the known branches of optics: optics in its proper sense in his *Kitab Al-Manazir (Book of Optics)* and his *Risala Fi A-Daw’ (Discourse on Light)*; catoptrics, particularly on the burning mirrors (parabolic and spherical burning mirrors); dioptrics, in *al-Kura al-Muhriqa (The Burning Sphere)*; and meteorological optics in *Daw al-qamar (The Light of the Moon)*, *Aḏwā al-kawākib (The Light of the Stars)*, *Fī Ṣūrat al-kusūf (On the Shape of the Eclipse)* and *Al-Hāla wa-Qaws Quzah (The Halo and the Rainbow)* (Rashed, “Ibn Al-Haytham” 1091).

*Kitab Al-Manazir or Book of Optics* is Ibn Al-Haytham’s most famous work in optics (Unal, Elcioglu 326). This masterpiece changed the scientific approaches about optics and other fields forever, which made its effect last till today (Shuja 325). This book was composed of seven-volumes, and it was written between 1011 and 1021 (Gorini 54). Because it was written in Arabic, *Kitab Al-Manazir* influenced the Islamic world for about 100 years (Shuja 325), but its availability in the Arabic language made it reachable only for the European scholars who spoke Arabic, until the 13th century when it was translated to Latin by an unknown scholar in 1270 (Gorini 54). However, it grew more popular in Europe after being published by Fredrick Risner at Basel in 1572 under the title of *Opticae Thesaurus: Alhazeni Arabis Libri Septum* (see Appendix 5. Fig. 1.) (Shuja 325). In this Edition, Risner also included the Gerard of Cremona’s Latin translation *Liber De Crepusculis et Nubium Ascensionibus*, and the translation of Witelio as well (Gorini 54).

*Kitab Al-Manazir* constituted of 7 books. In Book one, Ibn Al-Haiitham investigates the light, vision, camera obscura and discusses the structure of the eye, while the Book two is devoted to the visual perception, and Book three examines the conditions necessary for
good vision and the causes of errors in vision. Books four and five focuses on the theory of reflection, and then Book six examines error in vision due to reflection, whereas book seven discusses refraction (Abdullah, Ali, Musa 12). Ibn Al-Haytham also researched optical illusions, binocular vision, perspective atmospheric refraction, comets, shadows, eclipse, rainbow, mirages, and the atmospheric density (Gorini 55).

The first part of this *Kitab* outlined eight subtitles which studied the formation of eyesight, the approaches followed by the former optics scientists, the characteristics of sight and the properties of light and its spread, the effect of light and color on the eye, the perception of the vision process, the function of each visual organ in sight, and the preconditions of sight (Unal, Elicioglu 326). The Concept of observation and experimentation of Ibn Al-Haytham was very evident in his works, especially in *Kitab Al-Manazir*. The Latin translation of this book contained expressions like: “Experimentum”, “Experimentare”, and “Experimentator” that corresponds to the Arabic translation “Itibar”, “Itibare”, “Mutabir” which suggests the use of experimental method for defining the proof (Unal, Elcioglu 326).

Ibn Al-Haytham’s *Book of Optics* was written as a critical response to Ptolemy’s optics, that preceded it by nearly 9 centuries (Smith 181). According to Charles G. Gross, *the Book of Optics* represented the first main improvements in optics after Euclid and Ptolemy of Alexandria, and in visual psychology after Galen (309). About Ibn Al-Haytham’s contributions to optics, professor Robert S. Eliot wrote: “Alhazen was one of the ablest students of optics of all times. His seven-volume treatise published on this subject had strongly influenced Western thought notably that of Roger Bacon and Kepler” (qtd. in Abdullah, Ali, Musa 12). Through *Kitab Al-Manazir*, Ibn Al-Haytham established the science of optics on new grounds in the 9th century, and his superiority in this science gained him the title of “Father of Optics” (Unal, Elcioglu 325).
The advantages of Ibn Al-Haytham’s works on the development of different sciences, and on the transcendence of the human thought are countless. His contributions to various sciences such as: optics, physics, mathematics, astronomy, and philosophy are appreciated, and have always been regarded as the beginning of a new era in theoretical and practical research.

3. His Contributions:

Al-Hasan Ibn Al-Haytham was one of the brilliant polymaths of the Medieval Islamic period, he contributed to a variety of sciences including: physics in general and optics in particular, mathematics, astronomy, and philosophy. In his works, Al-Haytham exceeded classical Greek works, to establish his own methods and concepts, that added the feature of originality and authenticity to his theories. His works were characterized by the strength of emphasis on wisely designed experiments to test theories and hypotheses (“Ibn Al-Haytham and the Legacy”). His writings were marked by the transparency of exposition and the inventiveness of approach, wherein he critically assessed the issues and offered the solutions (Langermann 556). In that regard, he was following a technique somewhat analogous to the modern method that scientists adhere in their fact-finding researches (“Ibn Al-Haytham and the Legacy”).

3.1. Optics and Physics:

Ibn Al-Haytham’s ground-breaking discoveries and innovations in physics in general and optics in particular were regarded as the first valid theories that laid the foundations for the contemporary physics. Ibn Al-Haytham’s theories in optics were neither identical with, nor directly descendant from any one of the theories known to have existed in the ancient times or in Islam (Amr, Tbakhi 465).
Perhaps one of the immortal theories that changed the science of optics for forever was Ibn Al-Haytham’s theory of visual perception. The first hypothesis of vision was dated back to the times of Leucippus of Miletus (490/80-420 B.C.) and Democritus of Abdera (460-370 B.C.), who together founded the theory of “atomistic intromission” which stated that atoms spreading in different directions from an object, to create visual sensations by entering the eyes of the observer, while the founders of the “extramission theory” like Empedocle of Acragas (495/90-435), believed that the eyes emit rays of light to see the objects. Subsequently, Plato and his pupil Aristotle came up with a “mediumistic theory”, by which the eye receives rays rather than direct them outwards, and the object being looked at somehow changes the atoms between the object itself and viewer’s eye, so it was possible see the object because the atoms’ alternation was transmitted to the eye. Later, Euclid and Ptolemy improved and reconsidered the “extramission theory” to be the theory that scientists used for centuries (Gorini 54). Among its many flaws, the extramission theory cannot explain how the information retrieves to the eye since it is based on rays leaving the eyes (Curtotti). The creation of ibn Al-Haytham’s theory overthrew all the prevailing theories at that time, as he said explaining the visual perception in Kitab Al-Manazir:

The act of vision is not accomplished by means of rays emitted from the visual organ…., vision is accomplished by rays coming from external objects and entering the visual organ, from each point of every colored body, illuminated by any light, issue light and color along straight lines that can be drawn from that point. (qtd.in Gross 309-310)

In other words, luminous bodies (sun, moon, fire…etc.) send out light rays directly and in straight lines into the observer’s eyes, and also covers objects which are illuminated themselves in various degrees, and whose light we receive in similar way (Smith 190). He
believed that the eye realizes things like the light and colors, but the evaluation of the size, the distance, and the shape of the viewed objects stems from more complicated rational judgements (Gorini 54). Ibn Al-Haytham conducted several experimentations that proved the invalidity of the extramission theory, and the best proof was that humans cannot see in the dark, besides gazing at a light resource directly may injure the eyes, adding to that when light rays enters from a whole on the wall of a dark room, we can just see the illuminated zone, not to mention that when looking at the stars, we see them at that very moment (Elcioglu, Unal 326). Further, he was credited for being the first one to discover the substantial role of eye movements for visual perception (Shuja 325). He believed that there is no perception without eye movements, because this latter is very essential to building up human’s consciousness of the visual world (Gross 310).

Ibn Al-Haytham is considered as the founder of ophthalmology and visual psychology (Abdullah, Ali, Musa 12). He was able to identify eye components (see Fig. 1.1. And Fig. 1. 2.), and all names of eye layers were ascribed to him such as: conjunctiva, cornea, pupil, albugenious humor, crystalline humor, vitreous humor, and iris, in addition to the neutral components of the visual system including: retina, optic nerve, and optic chiasm1 (Ben lakhder et al.).

His description of the structure of the eye brought countless advantages and improvements to the field of anatomy and surgery of the eye (Abdullah; Ali, Musa 12). Ibn Al-Haytham psychophysics developed a clear understanding of the optic systems of the convex and concave lenses of the eye, visual angle, and the reversal of the visual image (Bn Lakhder et al.). Through his genius observations and experiments, he answered the most important question in visual psychology: how can our brain form the image of an object? From knowledge of the eye’s interior, he concluded that rays entering the eye are
refracted by the crystalline humor (lens) (Smith 190), assuming that only light rays orthogonal to the surface of the crystalline humor passed through it; the others were refracted which makes them too weak for the eye to perceive.

After that he believed that a topographically ordered point-to-point representation of the visual world entered the crystalline humour (Gross 310), stressing that this latter is the organ which is sensitive to light rays and the information it acquires is transmitted to the brain via the optic nerve (Smith 190). Above all, his most exceptionally amazing theory was his belief that before sensation can be transformed by the brain into perception, a series of logical inferences must happen, emphasizing that the speed of perception requires that these inferences themselves be imperceptible i.e., must be unconscious to the observer (Gross 311). The importance of Ibn Al-Haytham’s theories of eye description, point-to-point projection, transmission of visual information to the brain, forms the visual psychology the world knows today (Ben Lakhder et al.).

To explain the nature of light, the function of the eye, and the process of vision, Ibn Al-Haytham invented Al-Beit Al-Muzlim, that was translated to Latin as camera obscura and it is considered as the device that forms the basis of photography (“Ibn Al-Haytham and the Legacy”). The camera obscura is “a shuttered dark room with just a small aperture that admits light inside it” (Curtotti). Although Aristotle, Thenon of Alexandria, Al-Kindi, and the Chinese philosopher Mozzi introduced its idea, but Ibn Al-Haytham was the first one to succeed in revealing its physical concepts and mathematical interpretations (“Ibn Al-Haytham”), as Wade and Finger in their book *The Eye as an Optical Instrument* acknowledged that: “the principals of the camera obscura first began to be correctly analyzed in the eleventh century, when they were obtained by Ibn Al-Haytham” (qtd.in Abdullah, Ali, Musa 12). The camera obscura allowed Ibn Al-Haytham to prove the validity of many of his theories. He compared it to the human eye to prove that the light
rays orthogonal to the curved surface of the crystalline lens, would project an inverted image on the back of the eye (as illustrated in Fig. 2.) (Gross 310). Moreover, he used it for his theory of propagation, and to defend the hypothesis of straight-lined spread of light (Ben Lakhder et al.), he even used it for the observation of solar eclipses (Gorini 55).

**Fig. 2.** Drawing which illustrates the function of Ibn Al-Haytham’s camera obscura as the human eye. Source: “Brief History of Photography Part I.” *So Very Tired.* N. p, n. d. Web. 09 Apr. 2018.

The first genuine breakthroughs of the work of a lens, in particular the ability of a convex and concave lenses to produce a magnified image of an object was attributed to Ibn Al-Haytham (Amr, Tbakhki 465). He argued that magnification was due to refraction, which led him to explain the connection between the glass curvature and magnification (Abdullah, Ali, Musa 12). He made clear that magnification was due to the bending of light rays at the glass to air boundary (refraction), and not due to something inside the glass as many scientists before him believed, which made him the first to discover that the magnifying effect happens at the surface of the optical element rather than within it (Ben Lakhder et al.). Furthermore, he was credited with inventing the spectacles, which he
found out through his experiments on concave and convex lenses (Abdullah, Ali, Musa 12), as the Islamic Medieval history revealed that when he became old, he designed two convex lenses with different powers to be able to continue reading scientific treatises; that allowed him to come up with the theory of binocular vision, which stated that the degree of visual impairment does not necessarily have to be equal in both eyes, and that each eye requires a specific correction (Ben Lakhder et al.).

He was the first physicist to detect the bending of light rays when entering from one medium to another such as water and air, as well as explaining that a ray of light arriving vertically from air to water cannot be bent at all (Abdullah, Ali, Musa 12). His investigations in the subject of reflection and refraction in *Kitab Al-Manazir*, resulted his most famous fourth degree equation, which was called after his name “Alhazen’s Problem” (see fig. 8.). This Problem included studies in catoptrics, the experimentations of the spherical lens and the spherical diopter, not only as burning means, but also as optical instruments in dioptrics (Rashed, “Ibn Al-Haytham” 1092). About one of his hypotheses on Alhazen’s Problem, he said in book V of Kitab Al-Manazir: “An object and an observer are at given positions in a plane; how do we locate the point or points on a circular mirror, at which a ray is reflected from the object to the observer?” (qtd.in Smith 192). He presented solutions for Alhazen’s Problem relying on Apollonian methods of conic sections, as well as solving the three-dimensional problem for a cylindrical mirror, and the similar problem for a cone (Smith 192).

In his *Risala fi Daw’* (Treatise on Light), Ibn Al-Haytham discussed and made advanced investigations about the properties of luminance and its radiant dispersion through various transparent and translucent media (Amr, Tbakhi 466). He included this focus in *Kitab Al-Manazir*, where he performed the first experiments on the dispersion of light into its constituent colors (Ben Lakhder et al.), via exposing water-filled glass spheres
to sunrays; he was able to remark that the beams of light were refracted at measurable angles (Abdullah, Ali, Musa 12). In Medieval Islam, in the thirteenth and the fourteenth centuries, there was a great interest in rainbow to the extent that a special science on it was established, named “Ilm Qaws Quzah” (Gorini 55). Ibn Al-Haytham was one of the scientists that followed the line of investigation on the rainbow, and based on his light dispersion experiments, he discovered that rainbows are due to the refraction of sunlight by rain dews, not reflection as Aristotle assumed (Abdullah, Ali, Musa 12).

Ibn Al-Haytham’s understanding of the role played by the brain in interpreting what the eyes observe, allowed him to explain optical illusions such as “the moon illusion” (Gorini 54), which means “the apparent increase in size of the sun and the moon when near the horizon” (Amr, Tbakhi 465). Ptolemy in his well-known masterpiece Almagest, assumed that the causes of this enlargement was the refraction of light (sun or moon light) through the earth’s vapors (atmosphere), just like when bodies become magnified after being immersed in water (Langermann 557).

Ibn Al-Haytham disagreed with Ptolemy’s theory, through giving the correct explanation of this phenomena in his Kitab Al-Manazir. He emphasized that our brain is misled by objects like trees, houses, or hills on the horizon, into thinking that the moon or sun is becoming bigger, that is because when the moon is high in the sky, there are no references in the sky with whom the brain can compare and thus it looked smaller (Gorini 54), although he believed that the atmospheric effect could sometimes be a second way reason (Langermann 557). For that, Ibn Al-Haytham was probably the first to explain this phenomenon from a psychological perception angle, and to examine it from the size-distance invariance concept (Gorini 54).
Another celestial phenomenon that attracted the attention of Ibn Al-Haytham was the link between the atmospheric density and the twilight. In his treatise *Mizan Al-Hikma* (Balance of Wisdom), he investigated the density of the atmosphere, and related it to the altitude (Amr, Tbakh 466). From his studies of the atmospheric refraction, he discovered that the twilight begins only when the sun is 19° below the horizon, on this basis he attempted to measure the height of the atmosphere (Ben Lakhder et al.).

Perhaps the most famous discoveries of Ibn Al-Haytham in the field of physics was his theories of attraction, motion, and gravity. In the treatise of *Mizan Al-Hikma*, he discussed the theory of attraction between masses, as well as the studying the concept of the magnitude of acceleration, through analyzing the action of the force of gravity from a distance (Abdullah, Ali, Musa 12). In his treaties *Maqala fi L-Makan* (Treatise on Place), he criticized the Aristotelian theory of motion and developed the concept of momentum (*Islam and the West* 23). Aristotle believed that motion requires a force to maintain, whereas Ibn Al-Haytham explained that a body moves constantly, unless an external force stops it or changes its directions of motion. This statement was an outline to Newton’s first law of motion, also known as “the law of inertia” (Abdullah, Ali, Musa 12).

Therefore, Al-Hasan Ibn Al-Haytham was no ordinary scientist, which was very apparent in his achievements in optics and physics. His theories put both fields in the right path and his works were believed to be the accurate beginning. His extraordinary research in physics and optics refuted the classical theories that prevailed for a long time, adding to that his ahead of time researches that invaded the works of both the Arabs and the Westerners and lasted till today. His scientific achievements did not stop at that limit, but he went beyond optics and physics to excel in Mathematics.
3.2. Mathematics:

Ibn Al-Haytham built his mathematical background from the works of Euclid and Thabit Ibn Qurra, and continued on developing infinitesimal calculus, conic sections, number theory, and analytical geometry (Amr, Tbakhi 466). His mathematical researches were mostly in the field of geometry, and according to some ancient bibliographers, he wrote a book that was dedicated specially to algebra but unfortunately it did not survive (Rashed, “Ibn Al-Haytham” 1090). However, in the field of geometry, he developed analytical geometry, by establishing the linkage between algebra and geometry (Amr, Tbakhi 466); one of his most famous theories in analytical geometry was his Alhazen's geometrically summation formula (as illustrated in Fig. 3.).

\[ n=2: n(n+1) = (1+2)+(1+2) = 2(1+2) \]
\[ n=3: n(n+1) = (1+2+3)+(1+2+3) = 2(1+2+3) \]
\[ ... \]
\[ n(n+1) = 2(1+2+3+...+n) \]
\[ 1+2+3+...+n = \frac{n(n+1)}{2} \]

In his treatise *Maqala fi A-tahlil Wa A-tarkib (On Analysis and Synthesis)*, he discussed several problems about the creation of mathematics and its different methods. He dealt particularly with the establishment of a new discipline, a kind of proto topology, adding to that the theory of the demonstration, within difficulties raised by the fifth postulate of Euclid or with the theory of parallels (Rashed, “Ibn Al-Haytham” 1090). He wrote several commentaries on the postulates of Euclid, and his brilliant proof was very similar to Lambert's quadrilateral and Playfair's axiom in the eighteenth century (Smith 189). In the same treatise, he founded the formula for adding the first 100 natural numbers. His works on number theory included his theories concerning perfect numbers; he was the first to figure out that every even perfect number is of the form $2^n - 1(2^n - 1)$ where $2^n - 1$ is prime, but he could not find a successful solution, until the eighteenth century when it was proved by Euler (Amr, Tbakhi 466).

Furthermore, Ibn Al-Haytham was also very interested in investigating the theories of conic sections. He applied the theory of intersection of conics to resolve problems that cannot be formed with a compass or a ruler, which made this kind of problems either passed down, for example the solution of a solid arithmetic problem. Ibn Al-Haytham was one of the first mathematicians who emphasized on showing the existence of the point of intersection of two conics as it is shown in this example: $(n - 1)! - 1 \pmod{n}$ (Rashed, “Ibn Al-Haytham” 1091).

Ibn Al-Haytham believed that physics and mathematics are inseparable, which made this characteristic very evident in his works. The best example about this is “Alhazen’s problem”, which is-from a mathematical view-drawing of two lines from two points in the plane of a circle, meeting at a point on the circumference and making equal angles with the normal at that point (as illustrated in Fig. 4.), which leads to a fourth-degree equation (Amr, Tbakhi 466). In figure. 8, a circle has center O and any radius or ray passes from A
to B after reflection at P. A, B, and P are represented by the complex numbers a, b and z. The angles of reflection A P R and RPB are equal to \( \arg \left( \frac{(a - z)}{z} \right) \) and \(-\arg \left( \frac{(b - z)}{z} \right)\) respectively, and by equating them we obtain: \( \arg \left( \frac{(a-z)(b-z)}{z^2} \right) = 0 \). (Smith 193). By using this solution, Ibn Al-Haytham adopted from a classic formula for the sum of fourth powers, and by using an ancient proof by mathematical induction, he advanced a method for resolving the general formula for the sum of any integral powers (Amr, Tbakhi 466).

![Fig. 4. An illustration of Alhazen’s Problem. Source: Smith, John D. “The Remarkable Ibn Al-Haytham.” The Mathematical Gazette 76. 475 (1992): 189-198. Print.](image)

Alhazen’s Problem was essential to the improvement of infinitesimal and integral calculus (Amr, Tbakhi 466). Ibn Al-Haytham calculated the volume of paraboloid, which was studied before by Thabit Ibn Qurra and Al-Quhi, after that he took the next step to his own brainchild through calculating the volume of a paraboloid taken from the relation from a parabola around its ordinate. He explained that this volume is 8/15 of the circumscribed cylinder. His calculation was equal to that of the integral:
\[
\pi \int_{a}^{b} R^2 \left( b^2 - 2b^2y^2 + y^4 \right) dy = \frac{8}{15} \pi k^2 b^5 = \frac{8}{15} v
\]

with \( v \) being the circumscribed cylinder (Rashed, “Ibn Al-Haytham” 1090-1091).

Ibn Al-Haytham was very passionate about mathematics, and the evidence was the 14 books he wrote about different mathematical subjects. The theories mentioned above are just a drop of water from his infinite sea of mathematical theories, problem solutions, geometry, infinitesimal mathematics, and new concepts that he came up with. His incredible attachment to mathematics allowed him to use it as a proof tool for his experiments and link it to all his works especially physics and astronomy.

3.3. Astronomy:

It is known that Ibn Al-Haytham was very fascinated with the astronomical works of classical Greek scientists especially Aristotle and Ptolemy. Studying the astronomical works of Ptolemy constructed his astronomy background, which made him follow his own pace and master the techniques of this science. He wrote many works in astronomy only 23 of them survived, and most of them have not been studied yet (Rashed, “Ibn Al-Haytham” 1093).

In his ground-breaking work *Al-Shukuk Ala Batlamyus* (*Doubts Concerning Ptolemy*), Ibn Al-Haytham provided a detailed critique of Ptolemy’s *Almagest*, *Planetary Hypotheses*, and *Optics*, he also explained where and how Ptolemy had violated the Principals of natural philosophy (Langermann 556). He believed that some of the mathematical devices Ptolemy introduced to astronomy especially the Equant, failed to satisfy the physical requirements of uniform circular motion (Amr, Tbakh 466). Speaking of which, the theory of motion or “Ilrifaf” that was explained by Ptolemy in his studies of the motion in latitude of the planets; Ibn Al-Haytham was the first to correct and set up the perfect physical solution for this theory (Langermann 556), which led to the replacement of
the classical Ptolemaic theories by ibn Al-Haytham’s solutions in the 13th century Maragha and 14th century Damascus astronomy school (Amr, Tbakhi 466). Ibn Al-Haytham’s criticism and corrections of Ptolemaic theories, made many later European scholars and historians call him “Ptolemaeus Secundus” (Ptolemy the second) (Abdullah, Ali, Musa 12).

His treatise *Fi Hay’at Al-Alam (On the Configuration of the World)*, was his most ambitious effort in the field of astronomy, in which he offered a comprehensive account of the earth’s physical structure and composition (“Ibn Al-Haytham Biography” 4), along with linking the geometry of mathematical astronomy to the three-dimensional picture, endorsed by natural philosophy (Langermann 556). Out of this, he continued to accept the physical structure of the celestial spheres, as he affirmed: “The earth a whole is a round sphere, whose center is the center of the world. It is stationary in its [the world’s] middle, fixed in it and not moving in any direction nor moving with any of the varieties of motion, but always at rest” (Amr, Tbakhi 466).

Further, he explained basic astronomical concepts like longitude, latitude, and altitude, from which he was able to enter to the world of mathematical geography (Langermann 556). In addition to that, he portrayed the natural philosophy through describing the three-dimensional orbs, moving inward from the planet the earth center, and he identified the geometrical constructs of the astronomers through showing how these orbs set up the intersection of the three-dimensional bodies with the flat surfaces of the circles produced by either the planet or devices such as the center of the epicycle (Langermann 557).

Ibn Al-Haytham’s *Namuzaj Harakat Al-Kawakib A-Saba’a (On the Model of the Motion of the Seven Planets)* was one of the most significant astronomical works in The
Islamic Medieval period. This treatise included subjects such as the theory of planetary motion, a systematic study of celestial kinematics that was completely geometric, astronomical calculus, and different astronomical instruments (Amr, Tbakhi 466). Over and above, his monograph *Fi Kayfiyat Al-Arsad (On the Method of Astronomical Observations)*, offered one of the best historical explanation in the Medieval period on how astronomical theory was built on observation. Along with other treatise that contributed to some of the subjects that were popular among Muslim astronomers in the Islamic Medieval period such as: *Al-Mazhar Al-Mar’i Li Sath Al-Qamar* (The Visible Appearance of the Lunar Surface), *Tahdid Al-Qiblah* (The Determination of Al-Qiblah), as well as *Tahdid A-Zawal* (The Determination of the Meridian), and *A-Sa’a A-Shamsia* (sundials) (Langermann 557).

Ibn Al-Haytham was an astronomer by nature, his works in optics and mathematics drove him towards the world of astronomy. He did not study the works of his predecessors, but rather criticized, corrected, and provided them alternatives and solutions. His works were regarded as the most trusted resources for the astronomers that came after him, whether for Westerners or Muslims. He proved himself as an eminent scientist in physics, optics, mathematics, and astronomy, but astonishingly Ibn Al-Haytham was also a philosopher.

3.4. Philosophy:

When he was young, Ibn Al-Haytham studied philosophy and theology under the hands of the most eminent Muslim tutors, adding to that the interest that he showed for the Platonian and the Aristotelian philosophies. These factors shaped his philosophical character, and gave depth to his works, where he mixed the precision of science with the insights of philosophy.
In this discipline, Ibn Al-Haytham is considered an innovator of phenomenology, and this latter was not further developed until the 20th century. By means of his phenomenological thought, he created a relationship between the physical and observable world, intuition, the psychology, and mental functions. His theories about knowledge and perception that linked the domains of science to religion, led to a philosophy of existence based on the direct observation (Abdullah, Ali, Musa 12). However, he was credited for articulating a comprehensive theory of knowledge, and in this context, he said: “I constantly sought knowledge and truth, and it became my belief that for gaining access to the effulgence and closeness to God, there is no better way than that of searching for truth and knowledge” (Plott 465).

It is said that Ibn Al-Haytham was a follower of the Ash’ari² school of Islamic theology, and opposed to the teachings of the Mu’tazila school, but it was doubted that he could possibly be a Mu’tazila³ supporter himself at some point in his life (Abdullah, Ali, Musa 12). Another famous theory of Ibn Al-Haytham in the domain of philosophy is his theories of pain and feeling, which some scholars believe that this theory was influenced by Buddhist philosophy. About this theory he assured that every sense is a form of suffering, and that what people call pain is just an exaggeration of imagination; there is no qualitative difference but only quantitative difference between pain and ordinary sensation (Plott 462).

His philosophical theories were the best evidence on his mental and intellectual maturity, and his notions showed the depth of his scientific insights. Despite that Ibn Al-Haytham’s philosophical aspects remained modest and his name was rarely discussed in the philosophical stage, his philosophy was the light from which the scientific method rays were derived.
3.5. Scientific Method:

Rudiments of modern scientific method originated in the in Medieval Islamic philosophy, particularly the use of experiments to differentiate the validity of rival scientific theories, and to pursue the belief that knowledge reveals nature’s reality (Amr, Tbakhi 465). According to most of historians, Al-Hasan Ibn Al-Haytham was the developer and the forerunner of modern scientific method (Shuja 325), since he advanced accurate experimental approaches of regulated scientific examination in order to confirm theoretical hypotheses, and validate inductive conjunctures (Amr, Tbakhi 465). His investigations were not based on abstract theories, but on systematic empirical evidences (Gorini 55), that typified his method as consisting of a repeating cycle of observation hypotheses, experimentation, and the need for independent verification, which made his method very similar to the modern scientific method (Amr, Tbakhi 465), and in this regard he stated:

Therefore, the seeker after truth is not one who studies the writings of the ancients and following his natural dispositions, put his trust in them, but rather the one who suspect his faith in them and questions what he gathers from the one who submits to argument and demonstration, and not to the sayings of a human being whose nature is fraught with all kinds of imperfection and deficiency. (Shuja 327)

Ibn Al-Haytham's works were remarkable for their emphasis on testimony and proof. He is recognized to have said: “If learning the truth is the scientist’s goal… then he must make himself the enemy of all that he reads.”, and by this he meant that it was very crucial to conduct experiments to test what is written rather than blindly consenting it as true (“Ibn Al-Haytham and the Legacy”). All his works clearly indicated the use of a scientific method, including the systematic observation of physical phenomena, and their involving
together into a scientific theory (Ben Lakhder et al.). *Kitab Al-Manazir (Book of Optics)* was the best example, it included a range of his most famous experiments, like those on rectilinear properties of light using a dark room with a narrow opening in an intermediate wall, the illustration of the laws of reflection of light by a precise experimental technique, and structuring equipment gear to research similar laws for refraction of light (Smith 190). With this book, he changed the meaning of the term optics and founded experiments as the standard of proof in the field (Gorini 55). Further, the German scholar Matthias Schram said in his famous book *Ibn Al-Haythams Weg Zur Physik* describing one of Ibn Al-Haytham’s experiments:

[Ibn Al-Haytham] was the first to make a systematic use of the method of varying the experimental conditions in uniform manner in an experiment showing that the intensity of the light-spot formed by the projection of the moonlight through two small apertures onto a screen diminishes constantly as one of the apertures is gradually blocked up. (Abdullah, Ali, Musa 12)

And about the importance of Ibn Al-Haytham’s scientific method, the scholar Rosemordue asserted:

Al-Haytham insists on the importance of investigating by inducting existing phenomena, and in this way distinguishing the properties of individual things. From here, we may turn to research and comparison in a gradual and orderly way, criticizing premises and being careful about results. (Shuja 325)

Ibn Al-Haytham created his scientific method more than 200 years before the European scientists adopted it. For this reason, he was called “The First scientist” (Abdullah, Ali, Musa 12). This approach made his name immortal, and made his scientific style, the path that every scientist should follow. Through this method, he proved that
science is more than just abstract theories, it is practical and empirical, and theories are supposed to be the results of both observation and experimentation.

4. Legacy and influence:

Al-Hasan Ibn Al-Haytham left for the world one of the most precious scientific and intellectual legacies. Scientists from both the Islamic and the Western worlds find in his works a priceless, unique, cutting-edge theories and applications in different scientific fields. Some of them plagiarized many theories, some borrowed from his works and acknowledged his eminence, whereas others took his theories and developed them in line with the scientific development.

*Kitab Al-Manazir* played a central role as a reference for many Muslim scientists to develop and put together their optic theories, and this was noticeable in Ibn Rushd’s works in this field, adding to him Kamal Al-Din Al-Farisi (1260-1320), who developed the optic theories of Ibn Al-Haytham in his detailed commentary *Taqiqh Kitab Al-Manazir* or *Revision of Ibn Al-Haytham’s Book of Optics* (“Ibn Al-Haytham”), also Qutb Al-Din Al-Shirazi (1236-1311), who pursued the path of Ibn Al-Haytham’s studies and sought to extend them (Gorini 55). Later, Taqi Al-Din Al-Shami, the encyclopedic scientist, based his book *Nur Hadaqatul Ibsar Wa Nur Haqiqatu Nazir* on the theories of both Ibn Al-Haytham And Kamal Al-Din Al-Farisi in 1574 (“Ibn Al-Haytham”). The influence of Ibn Al-Haytham was not restricted to optics, but also included mathematics and astronomy. In Mathematics, his influence can be seen in the works of Ibn Hud, Omar Al-Khayyam, Sharaf Al-Din Al-Tusi, and Al-Samaw’al (Rashed, “Ibn Al-Haytham” 1093), whereas in the field of astronomy, Taqi Al-Din Ibn Ma’aruf, a well-known Turkish astronomer in the 16th century, was a great admirer of Ibn Al-Haytham’s concepts and notions in this field (Unal, Elcioglu 326). The impact of Ibn Al-Haytham on those Muslim scientists helped to
promote his works and spread his scientific reputation across the Islamic world (Gorini 55).

The translation of *Kitab Al-Manazir* and many other treatises in physics and optics to Latin such as: *Maqala fi A-Daw'* (*Treatise on light*), *Al-Maraya Al-Muharaqa Bil-Maqtu’a* (*On the Burning Mirrors*), and *Maqala fi Qarastun* (*Treatise on the Center of Gravity*), provided a valuable source and a solid ground for making researches for scholars like: John Peckham, Roger Bacon, Johannes Kepler, Erasmus Witelo, Willebrord Snell, Theodoric of Freiberg, Descartes, Galileo, Fermat, Newton, Grosseteste and many others… (Roshdi, “Ibn Al-Haytham” 1093). When Ibn Al-Haytham’s writings became well-known in the West, the value of his contributions to optics was extensively recognized, and his works were studied by many Medieval, Renaissance, and Enlightenment European scholars (Smith 192), while and the major physical and optical knowledge that Ibn Al-Haytham founded was transformed into scientific laws (Unal, Elcioglu 325), for example the seventeenth century Occam’s Razor (a philosophical law that Ibn Al-Haytham referred to in *Kitab Al-Manazir*), Snell’s Law (or Snell-Descartes Law), and the Inertia Law (Newton’s first law in physics) (“Ibn Al-Haytham”).

The European scholar Erazmus Ciolek Witelo took the initiative to write the first product of optical efforts in Europe, which was an analytical commentary on Ibn Al-Haytham’s works entitled *Perspectiva* (Unal, Elcioglu 327), where he emphasized that all what he wrote in this commentary owes to Ptolemy and Ibn Al-Haytham, and he confessed that the law of optics is wrongly associated with Leonardo da Vinci (Shuja 325). Later, Witelo was called “Alhazen’s Ape”, when scholars realized that his work was almost the exact copy of *Kitab Al-Manazir* (“Ibn Al-Haytham and the Legacy”). However, the translation of the works of Ibn Al-Haytham in optics and the publication of Witelo’s commentary, paved the way for the beginning of a long series of works that treated
different subjects in optics; the first and the most popular ones were written by Roger Bacon (1217-1297) and John Pecham (1235-1292), the archbishop of Canterbury (Unal, Elcioglu 327), as professor Roshdi Rashed stressed in his article “A Polymath in the 10th Century”:

Ibn al-Haytham, therefore, started not only the traditional theme of optical research but also others, new ones, to cover finally the following areas: optics, meteorological optics, catoptrics, burning mirrors, dioptrics, the burning sphere and physical optics. (qtd. in “Ibn Al-Haytham and the Legacy”)

Further, Polyak was the first European scholar that used the eye diagrams of Ibn Al-Haytham in his monograph *Arab Diagrams of the Eye and their influence in Europe Upon the anatomy and physiology of the visual organs*, through which he made a link between the works of Ibn Sina and Ibn Al-Haytham, and believed the latter was the most important representative of physiological optics (Unal, Elcioglu 327).

The emergence of the discipline of visual theory in Europe, and the evolution this discipline made in the age of Kepler and Descartes, was mainly due to their studies and researches into Ibn Al-Haytham’s theories and approaches (Belting 43). Ibn Al-Haytham’s theory of psychological perception, particularly the transformation of sensation to perception by the brain, was exactly what Helmholtz mentioned in his theory of unconscious influence, that played a major role in the 19th century and still used in the modern study of vision (Gross 311), and about this subject, Matthias Schram stated in his *Ibn Al-Haytham Weg Zur Physik*:

Through a closer examination of Ibn Al-Haytham’s conceptions of mathematical models and of the role they play in his theory of sense perception, it becomes evident that he was the true founder of physics in the
modern sense of the word; in fact, he anticipated by six centuries the fertile ideas that were to mark the beginning of this new branch of science. (qtd. in Abdullah, Ali, Musa 12)

Scientists like Roger Bacon, John Peckham, and Witelo based their theories of “moon illusion” on the explanation of Ibn Al-Haytham; since this, the explanation of the moon illusion as psychological phenomena began gradually to be accepted in the 17th century, with the rejection of Ptolemy’s theory. Besides, Theodoric of Freiberg studied the phenomena of the rainbow in the 14th century relying on Kitab Al-Manazir (“Ibn Al-Haytham”). Moreover, Florence’s celebrated creation of pictorial perspective in the 15th century, was in fact a copied version of both the term and the original mathematical theory of vision from the 11th century Kitab Al-Manazir (Belting 43). Additionally, Robert Grosseteste (1168-1253) the prominent physicist and mathematician of the 13th century began his experimental physics studies with his research on lenses, relying on the discoveries of Ibn Al-Haytham in this field as the most trusted and valid source (Unal, Elcioglu 327). It was the same case for his student Roger bacon, who plagiarized Ibn Al-Haytham’s concept of the scientific method, that was ascribed to him later by European scholars, not to mention the 16th century Johannes Kepler, who carried out revolutionary achievements specially in optics, mathematics, and astronomy, thanks to the scientific legacy of Ibn Al-Haytham (Unal, Elcioglu 325).

Further, Ibn Al-Haytham’s investigations on gravity, his number theory, analytical geometry, and the link between algebra and geometry inspired the English physicist Isaac Newton to present gravity as a force, and to come up with his method of calculus. To put it in another way, it is said that Newton wrote in a letter to his competitor Robert Hooke: “If I have seen further it is by standing on the shoulders of giants”, and Ibn Al-Haitham was
indeed one of the giants Newton had in mind when he wrote this comment (Abdullah, Ali, Musa 12).

Not to forget the Italian astronomer and physicist Galileo in his law of falling bodies, was also one of the scientists who benefited from the scientific heritage Ibn Al-Haytham (see Appendix 6, Fig. 1.) (Unal, Elcioglu 325). Ibn Al-Haytham is mostly remembered in the West for his game changer theory “Alhazen’s Problem” on the reflection of light from a spherical mirror, which he solved using geometric and conic sections; many endeavored to find algebraic solutions for this problem such as: Huygens, Gregory, L’hospital, Barrow and others (Smith 189), but the solution was reached only in 1997 by Oxford University mathematician Peter Newman (“Ibn Al-Haytham”).

In philosophy, traces of Ibn Al-Haytham’s philosophy can be found in the works of both works of the German philosophers Immanuel Kant (1724-1840), and Gottfried Wilhelm Leibniz (1654-1716), as well as the French mathematician and philosopher Rene Descartes (1596-1650) (Unal, Elcioglu 327). Likewise, the translated version of Kitab Al-Manazir to Latin made a huge fame in the Latin speaking world, when scholastic philosophy acquired it and discussed it in the circle of the so called “Perspectivists”, namely: Erazmus Witelo, Roger Bacon, and John Peckham; Renaissance artists like Filippo Brunelleschi, and the humanist Leon Battista Alberti. Their aim in line with the Renaissance ideology of revival, was to erase the Arab Contributions and to marginalize them in favor of Greek and Roman contributions (Belting 43).

To honor his name and to appreciate his contributions to science, an impact crater on the moon near the east mare cranium was named Alhazen, also one of the newly discovered asteroids was called by the name “59239 Alhazen” in February 7th, 1999 (Shuja 326). In Pakistan, the University of Aga Khan paid tribute to Ibn Al-Haytham by naming
its ophthalmology brilliant chair as “The Ibn Al-Haytham Associate Professor and Chief of Ophthalmology”. Whereas in Iraq, His portrait was featured on the 10 dinars banknote since 1980, and on the 10.000 dinars banknote in 2003 (see Appendix 7, Fig. 1.). In addition, one of the research facilities inspected by UN inspectors seeking chemical and biological weapons in Iraq during the American-Iraqi war was named after Ibn Al-Haytham (“Ibn Al-Haytham”). Further, in January 2015, the UNESCO declared 2015 as the international year of light; along with the British based organization “1001 Inventions”, they launched a global campaign to celebrate the international year of light and light-based technologies, as well as the scientific legacy of the remarkable 11th century scientist Al-Hasan Ibn Al-Haytham and his noteworthy work Kitab Al-Manazir, on top of that they produced a short film about his contributions to science entitled: “1001 Inventions and the World of Ibn Al-Haytham” (“Ibn Al-Haytham and the Legacy”).

With increasing scientific awareness and technological advance in the late 20th century and with the turn of the 21st century, many Arab and Western scholars recognized the credit of Ibn Al-Haytham’s works on the development of modern sciences, especially optics and physics. Among those scholars: professor Richard Lorch, professor Abdelhamid Sabra, Professor of Electron Optics and Nanotechnology Mohamed El-Gomati, professor Charles Falco, and professor Mark A. Smith (“Ibn Al-Haytham and the Legacy”), Nobel Prize winning physicist Abdus Salam, Belgian chemist and the father of the history of science George Sarton, The notable scholar Professor Robert S. Elliot, The science historian David Linderberg (Abdullah, Ali, Musa 12). Professor George Saliba of Columbia University, New York City, USA believed that it is universally agreed that Ibn Al-Haytham was one of the most creative scientist the Islamic civilization had ever known.

Through his critique of the inherited Greek theories of light and vision in Book of Optics, and his refute to the Greek cosmological doctrines in his Doubts Concerning
Ptolemy, he created his own experimentally tested theories to replace them, thereby erection the first building blocks for the modern understanding of vision, overthrowing the Aristotelian universe, and bringing out to light the modern astronomy of the European Renaissance (qtd. in “Ibn Al-Haytham and the Legacy”). By the same token, in the medieval French poem Roman de la Rose (Romance of the Rose), Guillaume de Lorris and Jean de Meun said about Ibn Al-Haytham and the worth of Kitab Al-Manazir:

Alhazen, the nephew of Hunain, was neither a fool nor a simpleton, and he wrote the book of “Optics”, which anyone who want to know about the rainbow should know about. The student and observer of nature must know it and he must know geometry, the mastery of which is necessary for the proofs in the book of Optics. (qtd. in Abdullah, Ali, Musa 12)

In the Same context, Professor Glen M. Cooper, historian of Science in Claremont McKenna College, Claremont, confessed about the importance of Ibn Al-Haytham’s contributions to science:

It is both through his clever use of thought experiments and in his emphasis on performing actual and careful experiments that Ibn Al-Haytham must be considered as one of a handful of scientists whose contributions were pivotal to the development of the modern world…However, it was through his research in optics that he made an even greater impact. Ibn Al-Haytham and his followers in the West laid the groundwork for the Renaissance rediscovery…, without which the Scientific Revolution might not have been possible. (qtd. in “Ibn Al-Haytham and the Legacy”)

Ibn Al-Haytham’s contributions to sciences particularly optics, spoke on behalf of him and told the whole world about what Muslims gave to science in a period were the West was
living in darkness. Ibn Al-Haytham was the king who stood on the throne of optics for over 1000 years; no one of the Western scientists that came after him overthrew his crown, and his important position in the history of sciences silenced all Western skeptics.

**Conclusion:**

The subject of optics and physics cannot be discussed without mentioning Ibn Al-Haytham, because he is the celebrated symbol and the founder of modern optics. His theories upgraded this science to a more advanced level, and his discoveries and inventions made this discipline reach the development we know today. His book *Kitab Al-Manazir* was like a sacred book for the European scientists, and because of its accurate experiments, valid theories, and exact solutions, it was the most scientifically trusted source for about 600 years.

Ibn Al-Haytham improved various traditional theories in arithmetics, geometry, conic sections, and infinitesimal mathematics to create mathematical solutions that competed modern approaches. Besides, he criticized most of the astronomical obsolete beliefs that prevailed at that time and replaced them with accurate and correct theories. He introduced experimentation and proof to astronomy and reconstructed this latter on a scientific ground instead of relying on fables and observation to build up hypotheses. In addition, most of the physical theories that he discovered were transformed by famous Western physicists to laws, which nowadays became indispensable in this field of science. Not to mention the effect that his philosophical theories had on the European Enlightenment age and the 19th century philosophy. Through his works, he managed to create an inseparable link between optics, physics, and mathematics, and founded an intimate relation between astronomy, physics, and mathematics; all his theories were somehow linked to different scientific disciplines.
The rays of the Ibn Al-Haytham’s contributions were reflected on Europe to illuminate the darkness of the Middle Ages, and to light the whole world for more than a millennial. His works especially in optics influenced European scientists elite like: Bacon, Kepler, Galileo, Newton, Witelo, Descartes… and still influencing modern sciences hitherto after 1000 years. His theories of reflection, refraction, diffraction, dispersion, Alhazen’s problem, moon illusion, eye anatomy, visual and psychological perception were the theories that formed the modern science of optics, proved his genius and the extent of the scientific development Muslims reached during the Medieval ages. On this basis, Ibn Al-Haytham is still living between us because of his impressive contributions to different sciences, which in turn made his name and his scientific soul immortal.
Endnotes:

1 **Chiasm:** part of the brain were the optic nerves partially cross (Ben Lakhder et al.).

2 **Ash’ari:** according to the Free Dictionary, the classical synthesis in the Islamic philosophical theology known as Ash’arism was formulated by Abu al-Hasan al-Ash'ari (873-936 AD).

3 **Mu’tazila:** according to Wiktionary, the Mu’tazila are members of a denomination in Islam that valued reason over hadith interpretation
General Conclusion:

This research examined the scientific contributions of Muslims during the Islamic Medieval period from the 9th to the 12th century, and investigated the immense impact they had on the booming of the Western Civilization and on the advance of modern sciences. In this regard examining the works of Ibn Al-Haytham as the best representative of this impact. In addition to disproving the Western scholars’ views who abjured and repudiated the idea that the Medieval Islamic scientific accomplishments built the Western civilization the World knows today. To demonstrate that the Western modern civilization came to exist mostly because of the Islamic scientific legacies, it is highly imperative to go back to the Islamic Medieval age and dig in its history from the 9th to the 15th century. shedding some light on several celebrated Muslim scientists, their scientific contributions, and how their achievements influenced the coming Western generations. Particularly, focusing on the works of Al-Hasan Ibn Al-Haytham as the best example that clearly signifies this influence.

The Abbasid Dynasty showed a great respect for knowledge and for everyone who followed its path. Adhering to the teachings of Islam that glorified knowledge and the role played by the Arabic as both sacred and scientific language, the Abbasids constructed the Islamic civilization on an intellectual entity. Unlike Europeans, Muslims during this period regarded knowledge pursuit as a vital human need to achieve mental, intellectual, and spiritual transcendence, as well as including this knowledge in their daily method of life and conduct. The genius contributions of Muslims in various sciences like alchemy and chemistry, medicine, astronomy, and mathematics changed the domain of science, nations, people, and built great civilizations. Their scientific outcome from theories and
discoveries, to practices and inventions are still universally used as pillars for modern science; their works amazed the whole world to the extent that many scholars and scientists today dedicated their life just to study and understand Muslims scientific heritage.

The scientific contributions of the Islamic Medieval period invaded the European world during the Middle and the Medieval ages. The crusades, trade relations, the 12th century translation movement, the migration of the westerners to the Islamic world, and paper-making served all as an effective transmission means for those scientific treasures to Europe, which pulled out this latter from the darkness of ignorance to the light of science and opened the doors of cultivation and urbanization for the West.

The key role played by Muslims’ scientific contributions to the rise and advance of the Western civilization was an important matter that made controversial disputes between different Western as well as Muslim scholars. Throughout ages, the majority of Western scholars did their best just to obliterate the Islamic Medieval period and its victories from the history’s memory, endeavored to deform everything that had to do with Muslims during that period, and ascribed many Medieval Islamic theories and writings to Western scientists, with their absolute belief that the origin of all sciences is Greek. However, whatever allegations the Western scholars spread, the Impact of the Medieval Islamic scientific works on the West can be evident in the countless theories and practices the Western science used for 1200 years, also in the limitless use of Arabic scientific expressions that integrated themselves in Latin and become used in most of the European languages today. Furthermore, this impact is reflected clearly in the lifestyle, attitudes, and behavior of some Western figures of the Medieval and renaissance Europe, and most importantly on the works of many Western scientists that stashed in its pages Islamic concepts, notions, and theories. Yet, all the Islamic scientific accomplishments and
achievements mentioned in this dissertation are just a small galaxy in the wide space of their contributions.

Abu Ali Al-Hasan Ibn Al-Hasan Ibn Al-Haytham was one of the Muslim scientists that devoted themselves to the quest for knowledge, and dedicated their lives for the sake of sciences and the search for truth. It was not enough for him to be just a physicist, he was also a mathematician, an astronomer, as well as a philosopher, and his works varied between all those disciplines. The most famous work among all his writings is Kitab Al-Manazir or Book of Optics, which distinguished him from other Muslim scientists and showed his great abilities as a physicist.

Western scholars found in the pages of his noteworthy works scientific treasures, the numerous theories and practices he brought to light in different scientific fields draw the start line for many Western scientists, provided others with an accurate background for their works, while others stole some of his ideas and just renamed them. His accomplishments in the field of optics dazzled the world with their creativity, originality, and validity, and his works in this field preserved the proof of his genius and scientific talent as the first optician who set the rules for modern optics.
Appendices
Appendix 1

Appendix 2

Table. 1

Comparing the Arabic numeral system with the Hindu and Roman numerals. It is clear that the Roman numeral system is the less appropriate one for mathematical use because it not based on a decimal system, it does not contain the zero which is indispensable for arithmetics, and it does not cover practical mathematics (odd and even numbers, fractions...).

<table>
<thead>
<tr>
<th>Arabic Numerals</th>
<th>Hindu Numerals</th>
<th>Roman Numerals</th>
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</thead>
<tbody>
<tr>
<td>0</td>
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<tr>
<td>1</td>
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<td>I</td>
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<td>2</td>
<td>٢</td>
<td>II</td>
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<td>3</td>
<td>٣</td>
<td>III</td>
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<td>4</td>
<td>٤</td>
<td>IV</td>
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<td>5</td>
<td>٥</td>
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<td>٨</td>
<td>VIII</td>
</tr>
<tr>
<td>9</td>
<td>٩</td>
<td>IX</td>
</tr>
<tr>
<td>10</td>
<td>١٠</td>
<td>X</td>
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<tr>
<td>100</td>
<td>١٠٠</td>
<td>C</td>
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<tr>
<td>1000</td>
<td>١٠٠٠</td>
<td>M</td>
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</tbody>
</table>
Appendix 3

Table. 1

Famous Latin and English words of an Arabic origin.

<table>
<thead>
<tr>
<th>Arabic Origin</th>
<th>Latin</th>
<th>English</th>
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<td>Admīrālis</td>
<td>Admiral</td>
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<td>Alchymia</td>
<td>Alchemy</td>
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<tr>
<td>Al-Kuhul</td>
<td>Alcohol</td>
<td>Alcohol</td>
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<td>Alembicus</td>
<td>Alembic</td>
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<tr>
<td>Al-qalawiy</td>
<td>Alkali</td>
<td>Alkaline</td>
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<td>Alghebrae</td>
<td>Algebra</td>
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<tr>
<td>Al-Khawarizmiyat</td>
<td>Algorismus</td>
<td>Algorithm</td>
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<tr>
<td>Al-Manakh</td>
<td>Almanach</td>
<td>Almanac</td>
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<tr>
<td>Awrati</td>
<td>Arteriae</td>
<td>Aorta</td>
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<tr>
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<td>Ātlās</td>
<td>Atlas</td>
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<tr>
<td>Qandiyy</td>
<td>Dulcis</td>
<td>Candi</td>
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<tr>
<td>Al-kīmiyā</td>
<td>Alchimista</td>
<td>Chemistry</td>
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<td>Sifr</td>
<td>Cifra</td>
<td>Cipher</td>
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<tr>
<td>Qulun</td>
<td>Kόlon</td>
<td>Colon</td>
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<td>Qutun</td>
<td>Cotho</td>
<td>Cotton</td>
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<tr>
<td>Al-Qaraniya</td>
<td>Cornea Tela</td>
<td>Cornea</td>
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<td>Terra</td>
<td>Earth</td>
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<td>Mattress</td>
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<td>Etiesia</td>
<td>Monsoon</td>
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<td>Natrium</td>
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<td>Pankreas</td>
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<td>Sabun</td>
<td>Sēbum</td>
<td>Soap</td>
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<tr>
<td>Sukkar</td>
<td>Zuccarum,</td>
<td>Sugar</td>
</tr>
<tr>
<td>Zarqun</td>
<td>Zircōnium</td>
<td>Zircon</td>
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</table>
Appendix 4

Table. 1

known books titles and works of Al-Hasan Ibn Al-Haytham in different scientific fields

<table>
<thead>
<tr>
<th>Disciplines</th>
<th>Title of the Book</th>
<th>Original Title</th>
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<tbody>
<tr>
<td>Optics</td>
<td>Book of Optics</td>
<td>Kitab Al-Manazir</td>
</tr>
<tr>
<td></td>
<td>On the Burning Sphere</td>
<td>Al-Maraya Al-Muharraqa Bi-dawa’ir</td>
</tr>
<tr>
<td></td>
<td>Treatise on Light</td>
<td>Al-Maraya Al-Muharraqa Bi-lqutua</td>
</tr>
<tr>
<td></td>
<td>The Burning Mirrors of the Rainbow</td>
<td>Maqala fi Daw Al-Qamar</td>
</tr>
<tr>
<td></td>
<td>On the Light of the Moon</td>
<td>Kayfiyat Al-Idal</td>
</tr>
<tr>
<td></td>
<td>On the Nature of Shadows</td>
<td>Maqala fi Qaws Quzah Wa-lhala</td>
</tr>
<tr>
<td></td>
<td>On the Rainbow and Halo</td>
<td>Maqala fi Surat Al-Kusuf</td>
</tr>
<tr>
<td></td>
<td>On the Form of Eclipse</td>
<td>Maqala fi Surat Al-Kusuf</td>
</tr>
<tr>
<td>Physics</td>
<td>The Balance of Wisdom</td>
<td>Mizan Al-Hikma</td>
</tr>
<tr>
<td></td>
<td>Treatise on the Center of Gravity</td>
<td>Maqala fi Qarastun</td>
</tr>
<tr>
<td></td>
<td>Resolution of Doubts Concerning the Winding Motion</td>
<td>Hulul Al-shukuk Hawla Al-Haraka Al-Mutaarija</td>
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<tr>
<td></td>
<td>The Winding Motion</td>
<td>Al-Haraka Al-Mutaarija</td>
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<tr>
<td>Astronomy</td>
<td>- Doubts Concerning Ptolemy</td>
<td>- Al-Shukuk Ala Batlamyus</td>
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<tr>
<td></td>
<td>- Exact Determination of the Pole</td>
<td>- A-tahdid A-daqiq Lil Qutb</td>
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<td>- Exact Determination of the Meridian</td>
<td>- A-tahdid Al-Daqiq Li Khat Al-Toul</td>
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<td>- Finding the Direction of Al-Qibla by Calculation</td>
<td>- Kayfiyat hisab Itijah Al-Qibla</td>
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<tr>
<td></td>
<td>- On Seeing the Stars</td>
<td>- Fi Ru’yatb Al-Kawakib</td>
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<td>- On the Configuration of the World</td>
<td>- Takwin Al-Alam</td>
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<td>- On the Milky Way</td>
<td>- Maqala fi Darb Al-Tabana</td>
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<td>- The Correction of the Operations in Astronomy</td>
<td>- Tashih Al-Amaliyat fi Iml Al-Falak</td>
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<td>- The Direction of Mecca</td>
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<td>- The Model of the Universe</td>
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<td>- Khutut Sa’a</td>
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<td>- Horizontal sundials</td>
<td>- Sa’at Shamsiya Al-Ufouqiya</td>
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<td>- Taswibat Ala Al-Mijastiya</td>
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<td>- Hal Al-Shukuk Hawl Al-Mijastiya</td>
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<td>- The Model of the Motions of Each of the Seven Planets</td>
<td>- Namathij Harakat Al-Kawakib Al-Saba’a</td>
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<td>Mathematics</td>
<td>Philosophy</td>
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<td></td>
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<tr>
<td>- <strong>The Ratios of Hourly Arcs</strong> to their Heights</td>
<td>- <strong>Treatise on Place</strong></td>
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<td>- Nisab Aqwas A-Sa’a Ila Murtyafa’atiha</td>
<td>- Maqala fil Makan</td>
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<tr>
<td>- <strong>Opuscula</strong></td>
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Appendix 6

Appendix 7

Works Cited
Works Cited:


