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An Introduction to Ibn al-Haytham's Contributions to the Field of Optics

MENGENAL KARYA IBNU HAITSAM BIDANG OPTIKA

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Abstract

The work of Muslim scientists has always attracted attention. Uniquely, the work became widespread and known through its critics, the majority of whom were orientalists. Here are the historians in the field of science. One of the favorite Muslim scientists to study his work is Ibn al-Haitsam. This study with this model of literature seeks to specifically reveal some aspects of optics developed by Ibn Haitsam after the introduction of Islam with previous civilizations. The data revealed focuses on Ibn Haitsam's literature obtained from oriental studies; which specifically discusses optics. This study finds that various works of Ibn Haitsam that have been edited, commented on, and translated by orientalists have a high level of complexity. Therefore, it is necessary to be given a structured advance in understanding it. Moreover, with a concise purpose; namely to know the role of Ibn Haitsam from one of the branches of his various works, namely Optics. The results of the critical analysis say, that Ibn Haitsam's scientific ethos is so high. Because, he honestly acknowledges that his knowledge can evolve through the contributions of previous scientists. Even further, he reached a critical level of study and revised his previous views on the concept of human vision.

Keywords Muslim Scientist, Optics, Ibn al-Haytham, Islamic Science

Abstract

Karya saintis muslim selalu menarik perhatian. Uniknya, karya tersebut menjadi tersebar dan dikenal melalui pengkajinya yang mayoritas adalah orientalis. Berikut pula para sejarawan dalam bidang sains. Salah satu saintis muslim yang digemari untuk dikaji karyanya adalah Ibnu al-Haitsam. Kajian dengan model pustaka ini berusaha mengungkap secara khusus beberapa aspek dari ilmu optika yang dikembangkan oleh Ibnu Haitsam setelah perkenalan Islam dengan peradaban sebelumnya. Data yang diungkap berfokus pada literature Ibnu Haitsam yang didapat dari kajian orientalis; yang secara spesifik membahas tentang optika. Kajian ini menemukan bahwa berbagai karya Ibnu Haitsam yang telah diedit, dikomentari, dan diterjemahkan oleh orientalis memiliki tingkat kerumitan yang tinggi. Sehingga, perlu diberikan pendahuluan yang terstruktur dalam memahaminya. Apalagi, dengan tujuan yang ringkas; yakni mengenal peran Ibnu Haitsam dari salah satu cabang dari berbagai karyanya, yakni Optika. Hasil analisa kritis menyebutkan, bahwa etos ilmiah Ibnu Haitsam begitu tinggi. Karena, ia mengakui secara jujur bahwa ilmunya dapat berkembang melalui kontribusi saintis sebelumnya. Bahkan lebih jauh lagi, ia sampai pada tingkat studi kritis dan merevisi pandangan terdahulu tentang konsep penglihatan manusia..

Keywords Saintis Muslim, Optika, Ibnu Haitsam, Sains Islam

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Introduction

It is not a novel observation that during the golden age of Islamic civilisation, a remarkable array of intellectual achievements flourished, particularly in the realms of science and technology. Indeed, many of the preeminent scientists of that era drew profound inspiration from the Qur'an and Hadith. Among the diverse fields they explored were the natural sciences, encompassing disciplines such as arithmetic, geometry, navigation, meteorology, and numerous others. This intellectual efflorescence reflects a synthesis of spiritual guidance and empirical inquiry, emblematic of an age where the pursuit of knowledge was both a sacred duty and a testament to human ingenuity..[1]

The era of the Umayyad Caliphate is primarily remembered for its efforts to expand the reach of Islamic da'wah, whereas the Abbasid period is celebrated as a time of profound cultural and civilisational development. While the Umayyads were largely "Arab-oriented" in character, the Abbasids embraced a more "international" outlook, marked by the assimilation of intellectual and cultural influences from great civilisations such as Persia, the Byzantine Empire, Egypt, and others..[2] This period witnessed the emergence of a vibrant intellectual movement, characterised by the translation of seminal works from Persian, Sanskrit, Syriac, and Greek into Arabic. Furthermore, it was distinguished by the establishment of centres of learning and vast libraries, fostering the growth of diverse schools of thought and disciplines, which laid the foundations for a flourishing Islamic intellectual tradition..[3]

One of the most intriguing branches of physics worthy of scholarly reflection is the study of optics. It is undeniable that modern human life is deeply reliant on optical instruments, ranging from their use in everyday activities such as vision correction, to healthcare with eyeglasses, communication through fibre optics, and scientific inquiry via microscopes and telescopes. Naturally, the evolution of optical science is intertwined with rich historical narratives and profound intellectual legacies. Yet, it is striking that many Muslims today seldom explore or celebrate these contributions. More astonishingly, the works of early Muslim scholars in this field have been

[1] Abdul Syukur Al-Azizi, "Kitab Sejarah Peradaban Islam Terlengkap," *Jogjakarta: Saufa*, 2014, hlm. 17.
[2] Harun Nasution, "Islam Ditinjau Dari Berbagai Aspeknya," 2019, hlm. 71.
[3] Dudung Abdurrahman, *Sejarah Peradaban Islam: Dari Masa Klasik Hingga Modern* (LESFI, 2012), hlm. 116.

revisited and republished, often gaining recognition and acclaim among European historians of science, particularly orientalist scholars.[4]

profoundly integrative vision held by early Muslim scientists, embodying a harmonious synthesis between religion and knowledge. Their intellectual framework was shaped by a worldview that resisted dichotomies, uniting the spiritual and the empirical into a cohesive pursuit of truth. History attests to the achievements of numerous distinguished scholars and polymaths excelling in fields as diverse as philosophy, science, politics, sociology, theology, medicine, and beyond. Among these luminaries stands Ibn al-Haytham (Arabic: ابن الهيثم, Latinised as Alhazen or Ibn al-Haytham), celebrated as the "Father of Optics." His pioneering discoveries in the field of optics not only revolutionised contemporary understanding but also profoundly influenced the trajectory of scientific progress in subsequent generations..[5] In the modern era, the field of optics has evolved into a highly intricate discipline, its principles and applications permeating nearly every facet of human life. From the realms of technology and communication to healthcare and scientific exploration, the advancements in optics reflect the relentless pursuit of knowledge and innovation. This progression underscores not only the depth of its theoretical foundations but also its enduring relevance, bridging the past and present in a continuum of intellectual achievement..

The contributions of Ibn al-Haytham in the field of optics have been widely acknowledged in the Western world, particularly in Europe. His works held such significance that numerous scholars of the early modern period undertook the task of translating his writings into Latin, as well as other European languages. Among them was Friedrich Risner, who, in Basel in 1572, produced one of the notable Latin translations of Ibn al-Haytham's works during the medieval period. This act of translation not only preserved his legacy but also facilitated the diffusion of his ideas, profoundly shaping the intellectual landscape of early modern Europe..[6]

Even in the present era, the study of Ibn al-Haytham remains a subject of considerable interest. Noteworthy are several works that involve editions and commentaries on his manuscripts, many of which have been published in esteemed journals. Among the prominent contributors to this scholarship are Abdelhamid Ibrahim Sabra (A.I. Sabra),[7], Mark Smith[8], and Jan (Pieter)

[4] Abdelghani Tbakhi and Samir S Amr, "Ibn Al-Haytham: Father of Modern Optics," *Annals of Saudi Medicine* 27, no. 6 (2007): 464–67.

[5] Tbakhi and Amr.

[6] Rosanna Gorini, "Al-Haytham the Man of Experience. First Steps in the Science of Vision," *Journal of the International Society for the History of Islamic Medicine* 2, no. 4 (2003): 53–55.

[7] A. I Sabra, "Ibn Al-Haytham's Criticisms of Ptolemy's Optics," *Journal of the History of Philosophy*, 1966, https://doi.org/10.1353/hph.2008.1150; A I Sabra, "Optics, Astronomy, and Logic: Studies in Arabic Science and Philosophy," *ANNALS OF SCIENCE*, 1994.

[8] A. Mark Smith, "Alhacen on Image-Formation and Distortion in Mirrors: A Critical Edition, with English Translation and Commentary, of Book 6 of Alhacen's De Aspectibus," *Transactions of the American Philosophical Society*, 2008; A. Mark Smith (book author) and Glen M. Cooper (review

Hogendijk, who has compiled various critical studies on Ibn al-Haytham's legacy.[9] hese scholarly endeavours reflect a profound and serious engagement with his work, highlighting the need for an introductory article to serve as a foundational entry point into this extensive body of research. Furthermore, studies focusing on Ibn al-Haytham within the Indonesian language remain relatively scarce, pointing to a potential area of academic enrichment. Accordingly, this essay aims to narrow its scope to one specific yet essential dimension of Ibn al-Haytham's prolific corpus: his contributions to the field of optics, or ilm al-dhau' (علم الضوء), the "science of light," as it was known during his era. By concentrating on this aspect, the essay seeks to elucidate the depth and enduring influence of his work within this critical domain of knowledge.

Research Methodology

This study adopts a literary review model, focusing on the exploration and analysis of Ibn al-Haytham's works in the field of optics. It emphasises the collection of data from both primary and secondary sources. The secondary sources include commentaries, Latin translations of his works, and prior studies that have examined Ibn al-Haytham's contributions to optics as their central subject. The primary sources, however, consist specifically of Ibn al-Haytham's original writings on optics, which form the core of this investigation.Among the primary texts examined are: 1.Kitāb al-Manāẓir (The Book of Optics), 2.Tanqīḥ al-Manāẓir (The Revision of Optics), 3.Fī al-Dhaw' (On Light), 4.Fī al-Adhwā' al-Kawākib (On the Lights of the Stars), 5. Fī al-Dhaw' al-Qamar (On the Light of the Moon), 6. Fī Māhiyat al-Athr alladhī fī Wajh al-Qamar (On the Nature of the Markings on the Moon's Surface), 7. Fī Shūrat al-Kusuf (On the Form of Eclipses), and 8.Fī al-Kurā al-Mutaharriqa (On the Moving Spheres). These texts not only serve as a testament to Ibn al-Haytham's intellectual legacy but also provide a foundational basis for understanding the evolution of optical science in his era and beyond.
The data is analysed through a critical textual approach, aiming to reveal the scientific and contributory value of Ibn al-Haytham's work. This analysis draws upon commentaries published by historians of science, which highlight Ibn al-Haytham's significant contributions to the field. The objective is to uncover his position as a leading figure in the domain of optics, a stature that is reinforced by the assessments of various experts in the field. Methodologically, this article seeks to provide an introductory framework for understanding Ibn al-Haytham's many contributions to optics, setting the stage for further exploration of his enduring legacy in the history of science

author), "Alhacen's Theory of Visual Perception: A Critical Edition, with English Translation and Commentary, of the First Three Books of Alhacen's De Aspectibus, the Medieval Latin Version of Ibn Al-Haytham's Kitab Al-Manazir," *Aestimatio: Critical Reviews in the History of Science*, 2015, https://doi.org/10.33137/aestimatio.v1i0.25649.

[9] Jan P Hogendijk, "Two Editions of Ibn Al-Haytham's Completion of the Conics," *Historia Mathematica* 29, no. 3 (2002): 247–65.

Finding and Discussion

The full name of Ibn al-Haytham is Abu Ali Muhammad al-Hasan ibn al-Haytham, known in the Western world by his Latinised name, Alhazen. A polymath of extraordinary breadth, he was a Muslim scholar distinguished in the fields of science, astronomy, mathematics, geometry, medicine, and philosophy. Born in Basra in 965 CE, Ibn al-Haytham began his scholarly pursuits in his hometown, where he also served in the government for a period. After some time in public service, he embarked on an intellectual journey (rihlah), traveling first to Ahwaz and then to Baghdad. Driven by an enduring passion for knowledge, he eventually settled in Egypt, where he conducted investigations into the flow and channels of the Nile River. During his time in Egypt, he also dedicated himself to copying and studying manuscripts on mathematics and astronomy, further cementing his reputation as one of the most influential scholars of his era..[10]

During his journey to Al-Azhar in Cairo, Ibn al-Haytham undertook various forms of work solely to secure financial provisions for his livelihood. Through perseverance and diligence, he honed his expertise in science, astronomy, mathematics, geometry, medicine, and philosophy. His writings on the eye became foundational references in the scientific study of vision in the West, with his research on ophthalmology forming the basis for advancements in modern medical practices. Beyond science, Ibn al-Haytham authored extensively on philosophy, logic, metaphysics, and theological questions. He also engaged in the study of earlier scholars' works, producing critical reviews and summaries of their contributions. Ultimately, his intellectual pursuits led him to the field of optics, where his investigations would establish him as a towering figure in this domain, influencing both his contemporaries and future generations..[11]

For Ibn al-Haytham, philosophy could not be separated from mathematics, science, and theology. These three domains of knowledge were interwoven and essential, requiring mastery through the dedicated use of one's youthful years. Ibn al-Haytham produced an impressive body of books and treatises, among which his notable works include: Al-Jāmiʿ fī Uṣūl al-Ḥisāb (The Compendium on the Principles of Mathematics), Al-Taḥlīl wa al-Tarkīb (On Analysis and Synthesis in Geometry), Maqālah fī Mā Tadʿu Ilayhi (The Use of Geometry in Religious Matters), Risālah fī Ṣināʿat al-Shiʿr (A Treatise on the Art of Poetry), and Kitāb al-Manāẓir (The Book of Optics). Many of Ibn al-Haytham's works were translated into Latin, often without acknowledgment of his authorship, becoming integral to European scientific traditions. In recent times, critical studies on the history of science in Europe have emerged, leading to a greater recognition of Ibn al-Haytham's monumental contributions across multiple scientific disciplines. His legacy, spanning

[10] Gorini, "Al-Haytham the Man of Experience. First Steps in the Science of Vision."
[11] Gorini; Asfana Banu and Abdi O Shuriye, "Contributions of Muslim Scholars Attributed to Other Scholars in Optics" 7 (2017): 9–15.

mathematics, geometry, optics, and beyond, continues to be celebrated as a cornerstone of intellectual history.[12]

Ibn al-Haytham was among the pioneers of the experimental method (al-manhaj al-tajrībī), laying the foundation for systematic investigation and empirical inquiry. One of his notable experiments involved burning glass, which led to the formulation of the theory of magnifying lenses. This groundbreaking theory was later adopted by scientists in Italy to produce the world's first magnifying glass, and its principles continued to influence generations of scientists thereafter.

His meticulous observations of light profoundly inspired figures such as Roger Bacon and Johannes Kepler, contributing to the invention of the microscope and telescope. Moreover, his insights paved the way for advancements in optics, including the formulation of Snell's Law. Ibn al-Haytham's contributions thus served as a cornerstone for the evolution of optical science and its practical applications.[13] Ibn al-Haytham was among the first scientists to document the various characteristics and properties of light. His meticulous observations led to the creation of the camera obscura, a darkened chamber that served as the conceptual foundation for the modern camera. By the late 10th century CE, he, along with Kamal al-Din al-Farisi, delved into the fundamental principles underlying the camera obscura, advancing the understanding of optical phenomena. This innovation not only marked a significant milestone in the history of optics but also laid the groundwork for future developments in imaging technology..*[14]*

Historically, Ibn al-Haytham's fascination with the phenomenon of eclipses led him to create a small aperture in a wall, allowing light to project an inverted image of the sun onto the opposite surface within a darkened space. This discovery laid the groundwork for the camera obscura phenomenon, a foundational principle in the science of optics that ultimately inspired the mechanics of modern cameras. In Webster's Dictionary, this phenomenon is literally defined as a "dark room." Following Ibn al-Haytham's groundbreaking work, the camera obscura concept captivated the Western world, culminating in the introduction of the camera during the 16th century CE. Among the Western scientists influenced by Ibn al-Haytham's findings were Cardano Geronimo (1501–1576), who replaced the pinhole aperture with a glass lens; Giovanni Battista della Porta (1535–1615), and Johannes Kepler (1571–1630). Kepler further enhanced the camera's functionality by

[12] Sohrab Ghassemi, "Ibn Al-Haytham and Scientific Method" (Georgetown University, 2020).
[13] Dominique Raynaud, "Ibn Al-Haytham on Binocular Vision," in *Studies on Binocular Vision. Archimedes (New Studies in the History and Philosophy of Science and Technology)* (Springer, 2016), 71–93, https://doi.org/10.1007/978-3-319-42721-8_5; Dominique Raynaud, "The Experimental Study of Binocular Vision by Ibn Al-Haytham and Its Legacy in the West," *Hist* 2 (2018): 127–51.
[14] George Tebogo Mahashe, "Walking towards a Camera Obscura," *Critical African Studies*, 2020, https://doi.org/10.1080/21681392.2020.1750968.

incorporating a negative lens behind a positive one, enabling the projection of magnified images. These developments, rooted in Ibn al-Haytham's initial discoveries, signify a critical evolution in the history of imaging technology..[15]

Ibn al-Haytham passed away in Cairo, Egypt, around 1040 CE. Through his extensive research in the field of optics, he laid the foundational principles that have shaped the science of optics as we know it today. His groundbreaking concepts not only advanced the understanding of light and vision in his time but also served as a catalyst for the remarkable progress achieved in modern optical sciences. For these enduring contributions, Ibn al-Haytham has been rightfully honoured with the title "The Father of Modern Optics," a testament to his profound and lasting influence on the discipline..[16]

Works in the Field of Optics

Ibn al-Haytham was an exceptionally prolific writer, producing works that extended far beyond optics. His essays encompassed subjects as diverse as astronomy, geometry, mathematics, physics, and epistemology. While some of his writings have been lost to history, his surviving contributions can be categorised into several key areas:1.Optics 2.Ligh 3.Light of the Moon 4.The Face of the Moon 5.Light of the Stars 6.Eclipses 7.Celestial Bodies (Burning Spheres) 8.Parabolic Burning Mirrors 9.Circular Burning Mirrors 10. Lunar Haloes and Rainbows 11.Shadows

These works collectively reflect the breadth of his intellectual pursuits and his unwavering dedication to advancing the understanding of natural phenomena. His systematic inquiries laid the groundwork for numerous fields of study, establishing him as one of the most influential figures in the history of science.

Ibn al-Haytham was an exceptionally prolific writer, producing works that extended far beyond optics. His essays encompassed subjects as diverse as astronomy, geometry, mathematics, physics, and epistemology. While some of his writings have been lost to history, his surviving contributions can be categorised into several key areas :

1) *Kitāb al-Manāẓir* yang juga memiliki versi latin dan telah diterjemahkan ke Inggris oleh A.I. Sabra berjudul *The Optics of Ibn al-Haytham: Books I-III On Direct Vision* dan *Kitab al-manaẓir (the Optics) of al-Hasan ibn al-Haytham, Books IV-V: On reflection and image seen by reflection*.
2) *Tanqih al Manadzir* yakni komentar atas karya Ibnu Haitsam oleh Kamal al Din al-Farisi.
3) *Fī al-Dhaw'*
4) *Fī al-Adhwā' al-Kawākib*,
5) *Fī al-Dhaw' al-Qamar*

[15] Banu and Shuriye, "Contributions of Muslim Scholars Attributed to Other Scholars in Optics."
[16] Tbakhi and Amr, "Ibn Al-Haytham: Father of Modern Optics."

6) *Fī Māhiyat al-Athr alladhī fi wajh al-Qamar*, yang diedit dalam *Maj'mū' al-Rasail*.
7) *Fī Shūrat al-Kusuf* yang diedit oleh Dominique Raynaud dan diterbitkan dengan judul *A critical edition of Ibn al-Haytham's On the shape of the eclipse : the first experimental study of the camera obscura*.
8) *Fī al Kurā al Mutaharriqa* telah diedit ke bahasa Inggris oleh R. Rashed berjudul *Geometry and Dioptrics in Classical Islam*.

Beberapa Penjelasan Singkat dalam Karyanya

The Kitab al-Manazir represents a seminal work in the field of optics, drawing inspiration from Aristotelian thought, particularly regarding the concept of vision as the reception of external images. Aristotle postulated that the eye emits light capable of reaching distant stars. However, Ibn al-Haytham offered a critical examination of this Aristotelian explanation. He contended that a more rigorous account was necessary to address how large objects, such as mountains, could be perceived and "enter" the relatively small human eye. This critique marked a pivotal moment in the evolution of optical theory, as it demanded greater precision and empirical grounding in understanding visual perception..[17]

Ibn al-Haytham's explication of the nature of light may rightly be regarded as strikingly modern. Among his assertions is the phenomenon of the refraction and deflection of sunlight as it traverses the Earth's atmosphere. He delved into the inverse processes and provided a meticulous account of the angular configurations involved. Furthermore, he investigated the celestial phenomena wherein stars appear on the horizon before they have physically risen and, conversely, remain visible even after they have set below it. Such observations and analyses reflect a profound engagement with the interplay of light, atmosphere, and perception, underscoring the sophistication of his scientific inquiries..

Ibn al-Haytham's critiques of ancient authorities such as Euclid and Ptolemy heralded a veritable revolution in the understanding of optics during his era. Both Euclid and Ptolemy concurred in their belief that vision occurred because the eye emitted rays toward objects. Ibn al-Haytham, however, overturned this *extramission* theory, offering a profound reformulation. He argued that vision does not arise from rays projected by the eye onto visible objects; rather, it is the eye that receives rays of light emanating from those objects. These rays pass through the transparent structures of the eye, most notably the lens, to enable perception. This reconceptualization underscored a pivotal shift towards a more empirically grounded and logically coherent framework in the study of visual phenomena.[18]

[17] Gorini, "Al-Haytham the Man of Experience. First Steps in the Science of Vision."
[18] Samuel Y Edgerton, *The Mirror, the Window, and the Telescope: How Renaissance Linear Perspective Changed Our Vision of the Universe* (Cornell University Press, 2009), hlm. 22-27.

Contemplating the myriad perspectives on the nature of light, and more specifically the science of optics, Ibn al-Haytham sought to advance a programme of reform that compelled him to grapple with a diverse range of complex problems. The cornerstone of this intellectual reform lay in his determination to elucidate the distinction between the conditions governing the propagation of light and those underlying the perception of objects. This effort not only refined the conceptual foundations of optics but also gave rise to several pioneering scientific theories attributed to Ibn al-Haytham, marking a transformative epoch in the history of the discipline.:

1. The Theory of the Law of Refraction (Atmospheric Phenomena)

   Ibn al-Haytham made profound contributions to the study of reflection and refraction, laying foundational principles in these domains. He concentrated his inquiries on the laws of reflection as they pertain to parabolic and spherical mirrors, delving deeply into their properties and applications. Moreover, he extended his analysis to encompass the phenomenon of optical aberration, revealing a nuanced understanding of the imperfections inherent in reflective systems. These investigations not only advanced theoretical optics but also demonstrated his meticulous approach to reconciling mathematical precision with empirical observation

   A notable case involving spherical mirrors, later known as *Alhazen's Problem*, was solved by Ibn al-Haytham using geometric principles, a challenge that optical scientist Christiaan Huygens would address mathematically centuries later. Within his study of the laws of reflection, Ibn al-Haytham articulated the second law of reflection: that the incident ray, the normal line, and the reflected ray all lie within the same plane. Furthermore, he observed that the red light on the horizon at dawn begins when the Sun is positioned 19 degrees below the horizon, while the red hues of twilight fade when the Sun descends 19 degrees beneath the horizon after sunset. In modern physics, this law, which Ibn al-Haytham explored in relation to refraction, has become known as *Snell's Law*, named after the Dutch physicist Willebrord van Roijen Snell. This attribution, however, obscures the pivotal contributions of earlier scholars like Ibn al-Haytham to the foundational principles of optics..[19]
2. The *Theory of Vision* (Optics)

   Within Ibn al-Haytham's optical theory, two principal dimensions are delineated: the theory of vision, encompassing the physiology of the eye and the psychology of perception, and the theory of light, addressing geometric and physical optics. He further integrated these dimensions into a comprehensive *Theory of Vision*. According to this theory, every point within an illuminated region emits rays of light in all directions. However, only a single ray from each point, entering the eye perpendicularly, is perceived; other rays striking the

[19] Raynaud, "The Experimental Study of Binocular Vision by Ibn Al-Haytham and Its Legacy in the West"; Alistair Kwan, John Dudley, and Eric Lantz, "Who Really Discovered Snell's Law?," *Physics World* 15, no. 4 (2002): 64; Robert MQOD, "Ibn Al-Haytham, the Arab Who Brought Greek Optics into Focus for Latin Europe," *Adv Ophthalmol Vis Syst* 9, no. 2 (2019): 44–51.

eye at oblique angles remain unseen. Ibn al-Haytham illustrated this principle through the use of a pinhole camera, which, he noted, produces the clearest image. He conceptualised light rays as streams of minuscule particles traveling at a defined velocity, a notion that foreshadowed later developments in optical science. Moreover, he advanced Ptolemy's theories on refraction, though his pioneering work remained largely unrecognised in Europe until the 16th century. Through these contributions, Ibn al-Haytham laid the groundwork for a profound rethinking of optics, melding empirical observations with innovative theoretical constructs[20]

Experimentally, Ibn al-Haytham conducted several investigations, including the use of a glass cylinder submerged in water to study refraction and to determine the magnifying power of lenses. He employed a lathe to shape the lenses he utilised in his experiments, showcasing a remarkable integration of craftsmanship with scientific inquiry. These empirical endeavours not only advanced the understanding of light's behaviour but also demonstrated his innovative approach to experimental methodology, setting a precedent for the development of optical instruments and techniques. Through such work, Ibn al-Haytham bridged theoretical knowledge with practical application, exemplifying the fusion of observation and experimentation that would come to define the scientific method

Ibn al-Haytham also employed sound mathematical and physical principles, enabling him to conduct meticulous experiments. In his research, he explored the motion of light, the characteristics of shadows and images, and many other significant optical phenomena. He refuted the theories of Ptolemy and Euclid, which posited that human vision occurs through rays of light emitted from the eye. Contrary to these views, Ibn al-Haytham asserted that it is not the eye that emits light, but rather it is the objects being observed that reflect light into the human eye. This insight marked a fundamental shift in the understanding of vision, laying the groundwork for a more accurate and empirical approach to the study of optics..[21]

In his youth, Ibn al-Haytham studied the works of Aristotle, the Greek philosopher whose contributions spanned various fields, including philosophy, natural science, and politics. Among his works, Aristotle's writings on optics became a significant area of study for subsequent scientists. One of his key theories involved the use of the "pinhole" technology, also known as the pinhole theory. Aristotle posited that light passing through a small hole would form an image or impression. This method, introduced by Aristotle, became the foundational principle for a theory that would persist and influence the development of photographic technology. The pinhole theory was later adopted by various scholars, including Ibn al-Haytham in the medieval period, marking a crucial link in the evolution of optical science.

[20] "The Development of Anatomy of the Eye and Its Optics," *Acta Ophthalmologica*, 2018, https://doi.org/10.1111/aos.13972_364.

[21] Imam Amrusi Jailani, "Kontribusi Ilmuwan Muslim Dalam Perkembangan Sains Modern," *Jurnal Theologia* 29, no. 1 (2018): 165–88.

In addition to Aristotle, Ibn al-Haytham also studied the works of Euclid and Ptolemy. Euclid, the Greek mathematician often regarded as the "father of geometry," produced *Elements*, one of the most influential works in the history of mathematics. Ptolemy, a polymath from Alexandria, was renowned not only for his contributions to mathematics, astronomy, geography, and philosophy but also for his literary and poetic works. Living in the Roman-ruled city of Alexandria, he made significant advances in various fields, including optics. Both Euclid and Ptolemy shared the belief that vision involved rays emanating from the eye towards visible objects, and they explored the relationship between the perceived size of objects and the angles at which they were viewed. Their work laid important foundations in the study of optics, which would later be critically examined and expanded upon by Ibn al-Haytham.

One of Ibn al-Haytham's most renowned works is *Kitab al-Manazir*, the first book to explain the principles of the camera obscura. To substantiate the theories presented in this work, he constructed *Al-Bayt al-Muzlim*, more commonly known as the camera obscura or dark room. *Al-Manazir* became a foundational text for subsequent scholars in the field of optics, offering a detailed explanation of the workings of vision. Ibn al-Haytham also introduced new methods for interpreting visual perception. His extensive work on the eye spans nearly twenty-four separate treatises. In his book, Ibn al-Haytham did not entirely dismiss the theories of Ptolemy; instead, he interpreted and selectively incorporated elements of Ptolemy's ideas, aligning them with his own discoveries. Indeed, he rejected several established theories in light of his new insights into the nature of light, demonstrating both a critical engagement with the past and a profound advancement in the science of optics.

In this work, Ibn al-Haytham corrected the theory previously embraced by Bathlemus, which stated that "vision is perfected through light reflecting from the eye to the visible object." This view was later supported by other scholars. However, Ibn al-Haytham offered a more refined explanation, asserting that vision is perfected when light reflects from the observed object towards the eye. His series of discoveries demonstrated that these rays spread in parallel straight lines, positioned between two distinct types. Through this, Ibn al-Haytham not only refined the prevailing theories of his time but also provided a more accurate understanding of the mechanics of vision, marking a significant advancement in the field of optics

Ibn al-Haytham and His Influence on Modern Optical Theory

Ibn al-Haytham, in his profound inquiry into the nature of light, conducted meticulous observations on its trajectory as it traversed various media. Through these experiments, he elucidated the laws of light refraction, thus becoming the first to uncover principles concerning the properties of light—principles that would, centuries later, be recognised as Snell's Law, discovered some 600 years before Snell himself. Moreover, it was Ibn al-Haytham who pioneered the experimental technique of dispersing light into distinct colours, laying the foundation for further advancements in optical

science. His work, deeply rooted in empirical observation, marked a significant milestone in the history of science, transcending his time and foreshadowing future developments in the study of optics

Further to Ibn al-Haytham's groundbreaking discoveries in optics, which were later developed by modern scientists, his contributions culminated in an invention that has become a cornerstone of historical significance: the camera. The term "camera" itself is derived from the Arabic word qamara, illustrating the deep influence of Arab scholars on the field. Long before the Western world had conceived of the camera, the fundamental principles underlying its construction were already outlined by an Arab scholar approximately a millennium ago. This visionary was none other than the legendary scientist Ibn al-Haytham. At the close of the 10th century, al-Haytham succeeded in devising the camera obscura, a device that would later inspire the development of modern photography and revolutionise the way humans perceive and record the visual world. His work stands as a testament to the intellectual legacy of the Arab world, whose early contributions paved the way for future technological innovations

The inspiring discovery of the camera obscura was achieved by Ibn al-Haytham in collaboration with Kamal al-Din al-Farisi. Together, they meticulously studied and documented the phenomenon. The origins of this groundbreaking work can be traced to their investigation of solar eclipses. In order to better understand the eclipse, al-Haytham created a small hole in a wall, which allowed a semi-real image of the sun to be projected onto a flat surface. This simple yet ingenious experiment laid the foundation for the later development of the camera obscura, a crucial device that would evolve into the modern camera. Their work exemplifies the profound intellectual curiosity and empirical rigor of the era, contributing significantly to the history of optics and vision..[22]

Ibn al-Haytham's contributions to optics profoundly influenced Western scholars, an impact that became more pronounced after his works were translated into Latin. In the 13th century, the English scholar Roger Bacon (1214-1294) wrote extensively about magnifying glasses, elaborating on how objects could be enlarged using a piece of glass. In his writings, Bacon remarked, “For this purpose, these instruments are most useful for those who have weak sight, as they enable one to see small objects when sufficiently magnified.” This acknowledgment of Ibn al-Haytham’s principles illustrates the cross-cultural transmission of knowledge and highlights how the scientific advancements of the Islamic Golden Age shaped the intellectual landscape of medieval Europe

Several historians of science have noted that Bacon drew heavily upon the knowledge of Ibn al-Haytham. Bacon was particularly influenced by the

[22] Kwan, Dudley, and Lantz, “Who Really Discovered Snell’s Law?”; Nader El-Bizri, “Arabic Classical Traditions in the History of the Exact Sciences: The Case of Ibn Al-Haytham?,” *The European Physical Journal Plus* 133, no. 7 (2018): 271.

works of al-Haytham, most notably his Kitab al-Manadhir (Book of Optics). David L. Shenkenberg, in his article "Before Newton, There Was Alhazen", argues that a close reading of the works of both Roger Bacon from the 14th century and Sir Isaac Newton reveals that many concepts attributed to Newton were, in fact, the intellectual property of al-Haytham. The paradigms of these two civilizations, shaped by the political and cultural dynamics of the Crusades, obscured al-Haytham's contributions, which have only been more fully acknowledged in modern scholarship. As Shenkenberg suggests, now is the time to begin a more thorough study of the remarkable works of these two great minds, as their ideas complement one another and offer a more profound understanding of the history of science. This reclaiming of al-Haytham's legacy is crucial for a more accurate representation of scientific history.[23]

Alhazen also elucidated the phenomena of refraction and the dispersion of light into several components of colour—a concept that would later be echoed by Isaac Newton. "Of course, in the field of optics, Newton himself lived 700 years after al-Haytham," remarked Jim al-Khalili, a professor of physics at the University of Surrey in the United Kingdom. This reflects the immense intellectual debt owed to al-Haytham, whose work laid the foundational principles that Newton would later build upon. Dr. Abdus Salam, a Nobel laureate in physics, also acknowledged the significance of al-Haytham's contributions, noting their lasting impact on the development of modern science. Al-Haytham's pioneering work in optics stands as a crucial precursor to later scientific advancements, and these acknowledgments from scholars like al-Khalili and Salam help restore his rightful place in the history of scientific discovery

"Ibn al-Haytham (Alhazen, 965-1039 CE) is regarded as one of the greatest physicists of all time. His contributions to experimental science in the field of optics were of the highest order. He revealed that a beam of light, when passing through a medium, takes the quickest and easiest path—a principle that echoes Fermat's Law of Least Time. He also formulated the law of inertia, which would later become Newton's First Law of Motion."

This statement underscores the profound nature of al-Haytham's work, which prefigured several key developments in physics and optics. By establishing the relationship between light and media, he laid the groundwork for future scientific inquiry. Moreover, his formulation of inertia anticipated Newtonian mechanics, illustrating the depth of al-Haytham's insights that would resonate throughout the centuries, influencing both Islamic and Western scientific thought. His achievements stand as a testament to the intellectual flourishing of the Islamic Golden Age, a period whose contributions have only more recently been fully recognised in the broader history of science.

[23] T V VENKATESWARAN, "INFLUENCE OF IBN AL-HAYTHAM ON VISION, OPTICS, AND EXPERIMENTAL SCIENCES," *SCIENCE AND CULTURE*, 2016.

The study of optics, pioneered by Ibn al-Haytham, was further advanced by the distinguished Muslim scholar Qutb al-Din al-Shirazi (1236-1311), who continued the work on light and vision. Al-Shirazi was a prominent intellectual in fields such as mathematics, astronomy, optics, and philosophy. His primary contribution to physics was his explanation of the rainbow. He demonstrated that the rainbow phenomenon occurs when sunlight strikes small water droplets in the air, as happens during rain. The sunlight then undergoes internal reflection within the droplets, ultimately becoming visible to the human eye. Al-Shirazi was the first scientist to provide a correct explanation for the formation of the rainbow, marking a significant advancement in the understanding of optical phenomena. This work built upon the foundations laid by Ibn al-Haytham, showing the continued development of optical science in the Islamic Golden Age. Al-Shirazi's work is a prime example of the intellectual continuity within Islamic scholarship, where previous discoveries were not merely preserved but actively expanded upon, demonstrating the cumulative nature of scientific progress over the centuries..[24]

Following al-Shirazi, the mantle of furthering optical studies was taken up by his pupil, Kamal al-Din al-Farisi (1267–1319 CE). In addition to studying under al-Shirazi, al-Farisi also learned from the eminent Nasir al-Din al-Tusi (1201–1274 CE). A leading physicist from Persia, al-Farisi was born in the city of Tabriz, in what is now Iran. Renowned for his contributions to optics and number theory, al-Farisi made a significant revision to the theory of light refraction that had been developed by earlier physicists. His teacher, al-Shirazi, encouraged him to re-examine the light refraction theories presented by the legendary Muslim physicist Ibn al-Haytham (965–1039 CE). Deeply engaging with al-Haytham's Kitab al-Manazir (Book of Optics), al-Farisi critically reviewed and revised these foundational ideas. The result of his extensive study was a monumental work: Kitab Tanqih al-Manazir (The Revision of Optics), which became a masterpiece in its own right. This revision, a cornerstone of medieval Islamic science, stands as a testament to the intellectual rigor and continuity of scientific scholarship in the Islamic world. Al-Farisi's work did not merely preserve the achievements of his predecessors but refined and expanded them, reflecting the dynamic nature of knowledge transmission and innovation that characterised the intellectual traditions of the era

The revised work, Kitab Tanqih al-Manazir, represents al-Farisi's critical reflections and perspectives on the seminal writings of Ibn al-Haytham. In this monumental text, al-Farisi presented his own theories on the formation of rainbows and the properties of light refraction. He argued that not all of Ibn al-Haytham's optical theories were entirely correct. Recognising the gaps in Ibn al-Haytham's framework, al-Farisi proposed alternative theories to

[24] Mourad Zghal et al., "The First Steps for Learning Optics: Ibn Sahl﷽s, Al-Haytham﷽s and Young﷽s Works on Refraction as Typical Examples," in *Education and Training in Optics and Photonics*, 2007, ESB2.

address these shortcomings. Through these revisions, al-Farisi sought to perfect and refine the optical principles established by his predecessor, thereby advancing the understanding of light phenomena and bringing further precision to the field of optics.

This process of critique and revision highlights the dynamic nature of scientific inquiry in the Islamic Golden Age, where scholars not only built upon existing knowledge but also engaged in the rigorous task of challenging and improving previous theories. Al-Farisi's work serves as an important link in the development of optical science, ensuring that the contributions of earlier figures like Ibn al-Haytham were not just preserved but evolved in response to new insights.

After completing his revised work Tanqih al-Manazir around 1309 CE, al-Farisi consolidated his ideas into a more concise and systematic form in his final work, Kitab al-Basir fi 'Ilm al-Manazir (The Insight into the Science of Optics). This text served as a textbook aimed at explaining optical theories in a clearer, more accessible manner, summarising his earlier contributions to the field. Kitab al-Basir stands as al-Farisi's magnum opus, representing the culmination of his life's work in optics and marking the conclusion of his scholarly career.This book not only reflects al-Farisi's intellectual maturity but also his effort to make complex scientific ideas more comprehensible, ensuring that the legacy of his and his predecessors' work would be preserved and transmitted more effectively. It encapsulates the scientific spirit of the time—building upon and synthesising earlier knowledge while striving for greater clarity and precision in the explanation of natural phenomena.[25]

Around the late Middle Ages, the advancement of Islamic science and the intellectual contributions of Muslim scholars gave rise to a movement of cultural and intellectual revival in Europe, known as the Renaissance, which blossomed in the 14th century. The rediscovery of Greek thought was facilitated by Arabic translations of ancient Greek texts, which were later translated back into Latin, making these works accessible to European scholars. This process of intellectual transmission played a crucial role in bridging the gap between classical knowledge and Renaissance humanism, sparking a profound shift in European thinking and scientific inquiry. The exchange of knowledge between the Islamic world and Europe thus became a pivotal moment in the history of Western intellectual development.

Many Westerners, particularly European youth, traveled to study at the Islamic universities in Spain, such as those in Cordoba, Sevilla, Malaca, Granada, and Salamanca. Toledo, in particular, served as a hub for translation. While studying at these institutions, they actively participated in translating works by Muslim scholars, including those of Ibn al-Haytham (al-Manazir).

[25] Hüseyin Gazi Topdemir, "Kamal Al-Din Al-Farisi's Explanation of the Rainbow," *Humanity & Social Sciences Journal*, 2007; Babak Daneshfard, Behnam Dalfardi, and Golnoush Sadat Mahmoudi Nezhad, "Ibn Al-Haytham (965--1039 AD), the Original Portrayal of the Modern Theory of Vision," *Journal of Medical Biography* 24, no. 2 (2016): 227–31.

After their studies, they returned to their homelands, where they established universities of their own and began to teach the sciences and knowledge they had acquired from the Islamic universities.This movement of intellectual exchange, particularly through the translation and dissemination of Islamic scholarly works, played a significant role in the transmission of knowledge from the Islamic world to Europe, contributing to the intellectual awakening that would become known as the European Renaissance. It marked a pivotal moment in the history of science, bridging cultures and enriching European thought.

The influence of this intellectual exchange brought significant advancements in experimental methods and had a profound impact on Western scientists. One notable figure was the English scholar Roger Bacon (1214–1292 CE), a follower of Robert Grosseteste at Oxford. Bacon expanded upon the optical work of Grosseteste, particularly in relation to the study of light and vision. In 1268 CE, Bacon simplified the findings of Ibn al-Haytham by applying glass lenses to aid vision, a key development in the history of optics. This contribution reflects the ongoing transmission of knowledge from the Islamic world to the West, where the works of scholars like Ibn al-Haytham were not only preserved but adapted and expanded. Bacon's work stands as a clear example of how medieval scholars in Europe built upon the foundations laid by their Islamic predecessors, advancing the understanding of optics and vision in ways that would later influence the scientific revolution.[26]

Around the 16th century, the concept of the camera obscura, first discovered by Ibn al-Haytham, was introduced to the West—five centuries after its original invention. This shift began with the studies of Geronimo Cardano (1501–1576 CE), who, influenced by Ibn al-Haytham's work, replaced the pinhole of the camera obscura with a lens (camera). Later, Joseph Kepler (1571–1630 CE) enhanced the function of the device by using a negative lens behind a positive one, which allowed for the enlargement of the projected image—a principle that would later be applied in modern telephoto lenses. Kepler's influential work, Dioptrics (1604), which was published in Frankfurt, was entirely based on the foundational concepts put forward by Ibn al-Haytham, solidifying the legacy of his contributions to the field of optics. The progression of the camera obscura into more refined optical devices underscores the enduring impact of Ibn al-Haytham's work on Western science. It exemplifies how knowledge, once transmitted across cultures and centuries, could be expanded and adapted to new technological advancements.[27]

The work of Ibn al-Haytham on the camera obscura significantly altered the course of world civilization. Similarly, his other contributions, particularly his Book of Optics (al-Manazir), especially his theories on refraction, left a

[26] Raynaud, "Ibn Al-Haytham on Binocular Vision."
[27] Ghassemi, "Ibn Al-Haytham and Scientific Method."

lasting impact. These theories were later adopted by Snellius in a more mathematical form, marking a pivotal moment in the history of optics. It is also quite possible that Isaac Newton's theories were influenced by Ibn al-Haytham, as during the European Middle Ages, Ibn al-Haytham's optical theories were already well-known and widely cited by European scholars. From the 16th to the 17th century, both Isaac Newton and Galileo Galilei integrated Ibn al-Haytham's theories with their own discoveries, demonstrating the ongoing intellectual legacy of his work. This process of intellectual inheritance underscores the continuity of scientific progress across cultures and time periods. Ibn al-Haytham's pioneering work in optics served as the foundation for later scientific revolutions, illustrating the critical role of earlier scholars in shaping modern scientific thought. His contributions not only influenced immediate successors but continued to resonate throughout the centuries, from the Middle Ages to the dawn of the Scientific Revolution.[28]

By the 17th century, Ibn al-Haytham had come to be regarded as one of the most pivotal figures in the history of optics. His groundbreaking explanations of optical concepts reshaped earlier views on light, the anatomy and physiology of the eye, and the relationship between the eye and objects. Light had long been a subject of study, but it was Ibn al-Haytham's work that brought a more nuanced understanding of its nature and behavior. His contributions were fundamental in altering perceptions about the way vision operates, providing a more scientific basis for future inquiries into optics. As the 17th century progressed, the relationship between the eye and objects became a key issue, with various existing theories conflicting with one another. This intellectual tension signified the need for a more coherent framework, and it was Ibn al-Haytham's theories that helped resolve these contradictions, offering a clearer path for later scientific developments. His work laid the groundwork for resolving these disputes and advancing the study of light and vision into a more systematic and empirical field of research..[29]

Conclusion

Broadly speaking, the study of Muslim scientists remains an area of great importance. It is crucial to critically explore their works, along with the philosophical aspects that played a role in driving their scientific pursuits. In this regard, Ibn al-Haytham stands out as a particularly prolific Muslim scientist, whose scientific ethos was deeply inspired by various teachings of Islam and supported by the academic climate of his time. Interestingly, his contributions to the field of optics have been extensively commented upon by non-Muslim scientists, as well as by orientalists studying history. This highlights the widespread recognition of his work outside the Muslim world,

[28] "Florence and Baghdad: Renaissance Art and Arab Science," *Choice Reviews Online*, 2011, https://doi.org/10.5860/choice.49-1858.
[29] Tbakhi and Amr, "Ibn Al-Haytham: Father of Modern Optics."

suggesting that such intellectual engagement should inspire today's Muslim generations. One of the objectives of this work is to spark further exploration of the contributions of orientalists in uncovering and appreciating the legacy of Muslim scientists. This reflection on Ibn al-Haytham's influence underscores the enduring relevance of Islamic intellectual traditions in the global history of science and calls for a renewed effort among contemporary Muslim scholars to engage with and build upon this rich heritage.

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